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* via the long-term refinancing operations (LTROs), the European Central Bank (ECB) improved the collateral value of sovereign bonds of peripheral countries. This resulted in an elevated concentration of these bonds in the portfolios of domestic banks, increasing fire-sale risk and making both banks and sovereign bonds riskier. In contrast, the ECB's announcement of being a potential *buyer of last resort* via the Outright Monetary Transaction (OMT) program attracted new investors and reduced fire-sale risk in the sovereign bond market.

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1. Introduction

Since the onset of the financial crisis in 2007, central banks globally have acted in unprecedented ways to combat the negative effects of the financial crisis and restore growth. These interventions have comprised of conventional tools (such as interest rates) as well as unconventional methods (long-term liquidity interventions or asset purchases). The effects of the unconventional policies and their efficacy are not yet fully understood.

In this paper, we investigate the effectiveness of two key central bank interventions in the context of the European sovereign debt crisis, which were both measures intended to enhance liquidity in financial markets, but differed in their design. After investors "ran" from European banks by massively withdrawing short-term funding in the summer of 2011,[1] the European Central Bank (ECB) reacted with a series of non-standard policies. First, the long-term refinancing operations (LTRO) – introduced in two stages in December 2011 and March 2012 – was a classic *lender of last resort* (LOLR) instrument, through which the ECB provided long-term liquidity directly to banks against eligible collateral without imposing any conditionality. Second, the Outright Monetary Transactions Program (OMT) – announced in July 2012 and introduced in September 2012 – was an innovation in the ECB's approach to provide liquidity, in which the central bank promised to buy sovereign bonds in the secondary market (under specific conditions). Under the OMT, the ECB was not designed to be lending directly to banks, but providing liquidity to the market at large by purchasing (or promising to purchase) these assets, effectively becoming a *buyer of last resort* (BOLR).

A key question arising from comparison of these two interventions is: *Should the central bank in a crisis be a lender of last resort or a buyer of last resort?* Specifically, are there unintended consequences of LOLR and BOLR interventions in light of banks' responses to these interventions in the context of a sovereign debt crisis?

[1] In particular, U.S. money market funds massively withdrew funding 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).

Theoretical motivation

Diamond and Rajan (2011) provide an important theoretical foundation for answering this question. They show theoretically that a "fear of fire sales" emerges when risky banks hold assets that would become illiquid in the event of a future liquidity shock. The uncertainty about future liquidity induces risky banks to hold on to illiquid assets due to risk-shifting (gambling for resurrection) incentives. Potential liquid buyers, in turn, require higher expected returns in anticipation of a fire sale.

Consequently, the market for illiquid assets freezes up when the assets are held by those risky banks, which given their fragile (demandable) liability structure, would become insolvent with a future liquidity shock. Worse, insolvent banks would load up even more on the illiquid assets if they had the cash to invest. This in turn, implies that lending by a central bank directly to weak banks (and without imposing any conditionality) could destabilize the financial system and entrench risky assets to the balance sheets of these banks. This would segment the market for risky assets further increasing the fear of fire sales.

Diamond and Rajan (2011) (see also Acharya and Tuckman (2014)) propose that — instead of lending directly to banks — a central bank should purchase assets from the market. Moving risky assets from the balance sheet of insolvent banks unfreezes the market for these assets. The credibility of such an intervention in future periods of stress can even attract other buyers to the market, allowing risky banks to de-lever by selling their risky assets and reducing the risk of fire sales.

This theoretical framework provides a natural setting to analyze the European sovereign debt crisis and the novel instruments introduced by the ECB, in particular, to explore the relative effectiveness of LOLR and BOLR interventions.

Empirical design

Overall, we test the hypothesis related to a novel dimension of the sovereign-bank nexus implied by the theoretical motivation above: *LTRO (lender of last resort) interventions increase the risk of fire sales by distressed banks in the sovereign bond market.*

Our analysis combines several data sources related to European banks and sovereigns as de-

scribed in detail in the data section below. In a first step, we investigate whether and how lending through the LTROs segmented the sovereign bond market. A common approach in the asset pricing literature is to investigate the sensitivity of equity returns to changes in asset prices. Using equity returns of different investors (banks, insurance companies or hedge funds), we investigate how their exposure to sovereign risk changes at different points in time during the sovereign debt crisis, e.g., before and after the LTRO and after the implementation of the OMT (buyer of last resort) program. Our key hypothesis is that (domestic) sovereign bonds accumulated in the portfolios of distressed banks, while other investors reduced exposure after the LTROs, effectively creating a "freeze" in the market for these bonds; this trend should reverse after the OMT program.

In a second step, we use Granger-causality tests on sovereign and bank CDS premiums. If the LOLR interventions increases fire sale risks, we expect to find that bank risk predicts sovereign risk following the LTROs. The theory predicts that a fear of fire sale is more pronounced the more segmented the sovereign bond market is towards banks. Therefore, we need to investigate the sensitivity of our Granger causality estimates to the sovereign bond holdings of banks. That is, bank risk should predict sovereign risk if sovereign bond concentration is high in the portfolios of risky banks.

Finally, to compare the relative effectiveness of LOLR and BOLR interventions, we show that this effect of LTRO reverts after the announcement of the OMT program by the ECB. In particular, we test if when the central bank provides liquidity to the market as a whole rather than just to banks, possibly taking the risky assets off the balance sheets of risky banks in the process, an increase in bank risk does not predict sovereign risk, as the fear of fire sale is attenuated.

Results

Consistent with prior literature, we document that the LOLR policy led to the entrenchment of risky sovereign bonds in the portfolios of banks dependent on public funding. The evolution of eurozone sovereign debt concentration is shown in Figure 1, together with the evolution of eurozone banks' access to unsecured funding from U.S. MMFs.[2] After eurozone banks lost 77% of their

[2]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.

unsecured funding from U.S. MMFs in 2011, the sovereign debt concentration in eurozone domestic banks increased by 3.3 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.

However and in contrast, the BOLR policy reduced concentration of sovereign bonds in domestic banks. After the announcement of the OMT program in July 2012, sovereign debt concentration started to decrease while eurozone banks were recovering access to private funding.

Using data on banks' sovereign bond holdings 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.[3] Sovereign risk in the eurozone thus became more concentrated in the portfolios of peripheral banks.

With the concentration of risky sovereign bonds in the portfolios of banks dependent on public funding, the prediction of a fear of fire sales implies that the riskiness of sovereign bonds rises with the probability of future insolvency of domestic banks. Therefore sovereign bonds become riskier due to their concentration in domestic banks and when the solvency condition of domestic banks deteriorate. We document this prediction using Granger-causality tests on five-year sovereign CDS prices and five-year bank CDS prices.[4] Specifically, Grange-causality tests could in principle reveal that sovereign risk and bank risk predict each other simultaneously, with the same economic and statistical significance. However, we find that domestic bank risk predicts home sovereign risk (but not vice-versa in France, Germany, Italy and the UK) in the period banks relied on LTRO funding

[3] 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.

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

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, i.e., sovereign risk predicts domestic bank risk (but not vice-versa in Italy and Spain).

The statistical relationship between sovereign and bank risk is however not sufficient to establish a connection with the fear of fire sales prediction. The relationship between sovereign risk and bank risk can appear independently from banks' holdings of sovereign bonds. For example, sovereign risk increases with bank risk because of banks benefiting from deposit insurance and implicit government guarantees. We rule out this alternative explanation by showing 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. 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 a fear of fire sales affecting both the riskiness of banks and GIIPS sovereign bonds following the LTRO liquidity injections.

In summary, the increasing concentration of sovereign bonds in the portfolios of domestic banks relying on LTRO liquidity injections contributed to increased fire-sale risk in the sovereign bond market.[5] 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 fire-sale risk and led to a permanent stabilization of bank risk. In further tests, we find that the OMT program attracted new investors (eurozone banks as well as 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. 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

[5]While the ECB's LTROs might have helped banks — that would become insolvent absent central bank 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. This phenomenon has been much documented and studied (see for example, Acharya and Steffen (2015), De Marco and Macchiavelli (2016), Drechsler et al. (2016), Ongena et al., 2019). Instead, we use this increase in sovereign debt concentration in domestic banks to study a fear of fire sales in the sovereign bond market.

bond market and the consequence of LOLR and BOLR interventions regarding this channel.[6]

The rest of the paper proceeds as follows. In Section 2, we describe the institutional background and the conceptual framework. We present Section 3 the data used in our analyses, as well as descriptive statistics. 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. 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 mechanism. 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.

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.*"[7] 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.[8] 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.

[6] 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.

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

[8] In LTRO 1, most banks rolled their existing central bank short-term funding over into the three-year LTRO 1 maturity and, effectively, about € 0.5 trillion of net liquidity was injected into the eurozone banks with the two three-year LTRO liquidity injections.

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*", highlighting 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.[9] 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 that had a major impact on financial markets as our descriptive statistics in Subsection 3.2 suggest.

2.3. Conceptual framework

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 risky banks may even increase if banks can use the public funds to increase their exposure to risky but eligible collateral because of, for example, gambling incentives of under-capitalized banks (Acharya and Tuckman, 2014; Drechsler et al., 2016) or moral suasion (De Marco and Macchiavelli, 2016; Ongena et al., 2019).

In the context of the European sovereign debt crisis, under-capitalized banks would have incentives to increase their holdings of risky domestic sovereign bonds (Crosignani, 2020), especially once they are eligible collateral at the central bank at attractive haircuts (Drechsler et al., 2016; Hoshi and Kashyap, 2015; Nyborg, 2017). Such response could segment the market for eligible collateral

[9]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.

by making domestic banks the dominant holder of these assets, further strengthening the bank-sovereign nexus. While the LOLR intervention might temporarily increase the collateral value of sovereign bonds allowing banks to raise funding against this collateral, a deterioration of sovereign credit quality could negatively impact the balance sheets of banks holding these assets (a "*holdings channel*"). Moreover, 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 delever 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

We collect all asset prices (e.g., bank equity prices and CDS spreads, sovereign bond yields and CDS spreads) from Bloomberg from January 2010 until 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 (out of which 33 banks are publicly listed and 28 banks have liquid CDS spreads).

Finally, we collect monthly information on U.S. MMF investments in 63 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.[10] The 63 banks cover 15 European countries; 10 are countries in the eurozone (including three GIIPS countries). We provide the list of banks with access to U.S. MMFs in Table A.1 and the definitions of variables used in the analysis in Table A.2 in the Appendix. Descriptive statistics of bank characteristics are available in Table A.3.

3.2. Bank and sovereign risk following LOLR and BOLR

In this section, we provide first descriptive evidence as to 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%).[11] 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

[10] 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.

[11] 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.

banks following LTRO 2.[12]

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 spreads 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 spreads decreased about 59% after Mario Draghi's speech during the July 2012 to December 2012 period. Not only the risk of GIIPS countries decreased after the announcement of the ECB acting as a BOLR, the average CDS spreads of non-GIIPS eurozone countries and non-eurozone countries decrease by 64% and 59%, respectively, from July 2012 until December 2012. In contrast, the LTRO liquidity injections are not followed by significant trends in eurozone sovereign yields or CDS spreads. 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.[13] While

[12] 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.

[13] "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.

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).[14] The trend in funding flows is 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 indicated by lower sovereign and bank CDS spread, higher equity prices and increased access to short-term U.S. MMF funding. In Sections 4 and 5, we investigate possible channels explaining this contrasting effect of LOLR and BOLR interventions on bank risk.

[14] 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.

4. Fire-sale risk in the sovereign bond market

The fire-sale risk channel we document in this section arises from a similar mechanism as described in the model of Diamond and Rajan (2011); an increasing concentration of illiquid assets in the hands of insolvent banks conditional on a future liquidity shock, while other financial institutions hoard liquidity on their balance sheets. In the context of the European sovereign debt crisis, this means an increase of concentration of risky GIIPS sovereign bonds in the portfolios of risky domestic banks.

4.1. Sovereign bond holdings of banks

The reallocation of the sovereign bond portfolio among European banks following ECB interventions is shown 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 LTROs.

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 LTROs and OMT program announcements.

We report the same trends for the fraction of a country's sovereign debt held by domestic bank in Panel B of Table 2. 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).[15] After the OMT program announcement, non-GIIPS banks invest again in both short-term and long-term GIIPS sovereign bonds.

[15]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).

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

If sovereign bond markets become less segmented, we also expect other (non-bank) investors to return to GIIPS sovereign bonds and improve liquidity in sovereign bond markets. Unfortunately, micro level data of sovereign bond holdings of banks and non-bank financial institutions is hardly available. 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. 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 bunds, $dy_{GIIPS,t}$ is the daily change on 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 - 12-31-2012), respectively. We construct equity indices for GIIPS, non-GIIPS eurozone, non-eurozone European, and U.S. banks using weights given by the banks' market capitalizations in 2011. We also 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.[16]

We find that eurozone banks and insurance companies had a short exposure in German bunds during our sample period, while hedge funds maintained a long exposure in those bonds. The regression of equation (1) is specified such that the parameter β_{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)

[16]The estimation sample starts with the beginning of the sovereign debt crisis (June 2011) and ends at the end of the post-OMT period (December 2012).

period compared to the sovereign debt crisis period. During the summer of 2011, we find that all European banks (including non-eurozone banks) and insurance companies have a significant long exposure.[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.[18] We also find that GIIPS banks increase their domestic exposure, while non-eurozone European banks reduce their GIIPS exposure following the OMT program announcement.

Following the OMT program announcement (ECB acting as BOLR), all eurozone banks and 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.[19]

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

[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] We find similar results for the domestic exposure of Italian and Spanish banks in Appendix Table B.1. We also find an increase of hedge funds' exposure to Italy and Spain following the OMT program.

[19] 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).

government, (iii) a weaker economy due to impaired lending to firms, and (iv) fire-sale risk when 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. If dominant holders rely on short-term funding, demand for liquidity might lead to fire sales (Diamond and Rajan (2011)).

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. Granger-causality tests help indicating the relative importance of each direction in the nexus (i.e., sovereign risk predicting bank risk vs. bank risk predicting sovereign risk) for 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 maximum likelihood 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 eq. (2) are reported in Panel A of Table 4. In this joint regression, the parameter β_{1j} (resp. β_{2j}) indicate the percentage change in the average domestic bank (resp. sovereign) CDS spread following a one percentage 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 eq. (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. The contrasting Granger-causality test results in the post-LTRO period versus other periods indicate 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.[20]

4.4. Bank contagion and sovereign bond holdings

In order to explain the contagion between bank risk and sovereign risk, we consider Granger-causality regressions at the bank level, controlling for common factors as in Acharya et al. (2014) capturing volatility cycles, credit cycles, and interest rate policy. We collect a cross-section of bank-level β_1 and β_2 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 $\triangle svg_{it}$ is the daily percentage change in the five-year sovereign CDS price of the country where bank i is located. We control for common factors $\mathbf{x}_t$ including the return on the Markit iTraxx Europe Crossover index on the most liquid sub-investment grade 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 panel regressions explaining the influence of sovereign risk on bank risk and the influence of bank risk on sovereign risk. We first

[20]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 as we report in Table B.2 in Appendix B.

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):

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

where λ_τ are period fixed effects (for the crisis, post-LTRO and post-OMT periods), $\hat{\beta}_{2i\tau}$ is the estimate capturing the influence of the risk of bank i on home sovereign risk in period τ, $\frac{Home\,holdings_{i\tau}}{Assets_{i\tau}}$ 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_τ 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 two rightmost columns of Table 5 we report the results of a regression where we impose the restriction $\lambda_{1\tau} = \lambda_{3\tau} = 0$ (no differential effect for GIIPS countries). We do not find a significant effect of domestic banks holdings of sovereign bonds during the post-LTRO period in the restricted regression.[21]

We report the results of the unrestricted regression of eq. (4) in column (3) of Table 5. The parameter capturing the sensitivity of a GIIPS bank's influence on sovereign risk to its home sovereign risk exposure is $\lambda_{1\tau} + \lambda_{2\tau}$. This parameter is close to zero for GIIPS banks during the crisis ($\hat{\lambda}_{1,crisis} + \hat{\lambda}_{2,crisis} \simeq 0$) in column (4). 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 one percentage change in the CDS spread of a domestic bank the previous day is 3.05 percentage points larger when the share of

[21] Home holdings are even negatively associated with the bank influence on sovereign risk in the crisis period (column (1)), and in the post-OMT period when we restrict the sample to the most liquid bank CDS prices of 19 banks (column (2)).

home sovereign bonds in the bank portfolio increases by one percentage point.[22]

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. Banks' influence on sovereign risk to the home sovereign bond holdings of the weak banks is thus limited to the post-LTRO period which is 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. 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 bank realized performance following ECB interventions in Subsection 5.3.

5.1. Holdings channel

While the banking literature has focused on domestic banks motives to hold sovereign bonds in a crisis (Acharya and Steffen, 2015; Drechsler et al., 2016; De Marco and Macchiavelli, 2016; Ongena et al., 2019), this section analyses the consequences of bank sovereign bond holdings on bank risk. To illustrate the holdings channel we 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.

[22]The last column shows that this effect is also positive when we restrict the sample to the most liquid bank CDS prices of 19 banks.

The sovereign contagion parameters $\hat{\beta}_{1i\tau}$ capture the sensitivity of domestic banks' CDS spread returns to a one percent 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 τ, the other elements of the regression are the same as described for eq. (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 their risk is predicted by sovereign risk during the crisis period. This effect is also significant during the post-OMT period when we restrict the sample to banks that have the most liquid CDS in column (2). 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 (columns (3)-(4)).[23] GIIPS banks and other European banks are similarly exposed to the holdings channel. It does not mean there are exposed to the same risk, but they are similarly affected by the holding channel when holding sovereign bonds of their country on their balance sheets. Importantly, 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), as we find for the fire-sale risk channel in Table 5.

We report in Appendix C the results of an event study methodology linking bank sovereign bond

[23] Only for the sample of the most liquid CDS, we find a positive effect for non-GIIPS banks and a slightly negative effect for GIIPS banks, indicating that the holdings channel could be present for non-GIIPS European banks but not for GIIPS banks.

holdings to abnormal stock returns and abnormal CDS changes around the intervention announcement dates. This complementary analysis of the holdings channel highlights the immediate market reaction to banks' sovereign bond holdings around intervention dates. The results of the event study show a reduction in bank risk and an improvement in bank profitability for banks holding short-term GIIPS sovereign bonds (i.e., sovereign bond of maturity between one and three years) around the LTRO announcement. The announcement improved the collateral value of sovereign bonds of maturity between one and three years corresponding to the maturity extension in three-year LTROs compared to previous ECB loans. The announcement reduced the default risk of banks holding these bonds as it reduced bank funding pressure. In contrast, 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 eq. (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 eq. (4).

Third, a riskier domestic banking sector might lead to impaired lending to domestic firms and households. An economic slowdown results 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.

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., 2019). 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 eq. (4) and eq. (5) describing the two directions of contagion in the bank-sovereign nexus, and find in Table B.1 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.[24]

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

Finally, we 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.

The effects of the holdings and fire-sale risk channels for the post-LTRO period, and the post-OMT period are summarized in Table 7. We separate the holdings and fire-sales effects for short-term sovereign bond holdings (maturity between one and three years) vs. long-term sovereign bond holdings (maturity above three years). In the 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 7, we find that, during the post-LTRO period, the average increase in CDS

[24] In Tables B.3 and B.4, we show additional robustness tests for our results of Subsection 4.4, allowing for differential effects of control variables between LTRO and OMT periods.

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 their short-term GIIPS sovereign bond holdings (-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 of short-term bond holdings on bank risk is further decomposed into holdings and fire-sale effects.[25] For eurozone non-GIIPS banks, the effect of holding short-term GIIPS bonds on bank CDS spreads (-47 bps) during the post-LTRO period is dominated by a fire-sale risk effect (+70 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. Bank CDS spreads reduce by 48 bps on average due to banks' long-term GIIPS sovereign bond holdings. 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 reduction is only -68 bps on average from short-term bond holdings.

We report the average channel effects on bank equity returns in Panel B of Table 7. As opposed to 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 is 15% on average during that period. While positive equity returns are associated with short-term bonds in the post-LTRO period, an average reduction in equity prices of -30% is associated with 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 average equity return from holding long-term GIIPS sovereign bond is 16% for GIIPS banks, and 2% for eurozone non-

[25] See methodology described in Appendix D.

GIIPS banks during the post-OMT period. 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., Daetz et al., 2016; Acharya et al., 2019, 2020; Carpinelli and Crosignani, 2020), and the effects of these policies on sovereign risk (e.g., Eser and Schwaab, 2013; Szczerbowicz, 2015; Krishnamurthy et al., 2018). 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., 2020). 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.

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., 2018; Alves et al., 2016; Drechsler et al., 2016; Garcia de Andoain et al., 2016; Crosignani et al., 2020). 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. (2019) 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 borrowing from the LOLR 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 fear of fire sales. Moreover, we highlight the role of central banks as BOLR to 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 ECB's LTROs, the collateral value of short-term GIIPS (i.e. Greece, Irish, Italian, Portuguese and Spanish) sovereign bonds improved. However, 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 an-

nouncement 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 it contributes to increasing 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 5-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 1 and 3-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 3-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). Bank indexes include value-weighted indexes of EBA non-GIIPS eurozone banks (non-GIIPS), of EBA GIIPS banks (GIIPS), of EBA non-eurozone banks (non-Euro), and of U.S. banks (U.S.). Non-bank indexes 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 constants. As for market return, we include the Euro Stoxx 600 for European indexes, the MSCI World for the global index, and the S&P 500 for the U.S. 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

	GIIPS	non-GIIPS	non-Euro	U.S.	Hedge funds	Insurance
GIIPS bond	-0.015***	-0.019***	-0.006***	-0.001	0.043	-0.007***
	(-4.610)	(-3.160)	(-3.010)	(-0.569)	(0.490)	(-3.440)
GIIPS bond post LTRO	-0.006	-0.001	0.002	-0.005	-0.023	0.001
	(-0.658)	(-0.146)	(0.582)	(-1.350)	(-0.142)	(0.181)
GIIPS bond post OMT	-0.061***	-0.018	0.017***	0.008*	-0.756***	0.002
	(-4.940)	(-1.470)	(2.860)	(1.680)	(-2.940)	(0.521)
German bond	0.108***	0.093***	0.001	0.022	-1.328***	0.037***
	(8.000)	(6.860)	(0.079)	(3.090)	(-4.690)	(6.140)
N	465	465	465	520	522	532
R^2 (%)	64.77	75.00	84.75	81.90	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 to 12-07-2011), the post LTRO period (12-09-2011 - 07-25-2012), and the post OMT period (07-27-2012 to 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. Evidence in columns 2 and 4 is based on the 19 banks with the most liquid CDS spreads. 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)	(3)	(4)
Home holdings*GIIPS*crisis			3.25***	-0.05
			(2.84)	(-0.02)
Home holdings*GIIPS*LTRO			3.66***	6.79**
			(3.38)	(2.51)
Home holdings*GIIPS*OMT			-3.12	-5.96
			(-1.66)	(-1.12)
Home holdings*crisis	-2.21***	0.01	-3.33***	-0.35
	(-2.87)	(0.01)	(-6.53)	(-0.10)
Home holdings*LTRO	-0.56	-1.23	0.61	-5.60**
	(-0.98)	(-1.24)	(1.11)	(-2.10)
Home holdings*OMT	-0.97	-3.01***	-0.09	3.62
	(-1.38)	(-3.72)	(-0.15)	(0.70)
R^2 (%)	7.24	8.26	18.56	4.41
N	84	57	84	57
Banks	28	19	28	19

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. Evidence in columns 2 and 4 is based on the 19 banks with the most liquid CDS spreads. 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)	(3)	(4)
Home holdings*GIIPS*crisis			1.14	0.34
			(0.92)	(0.34)
Home holdings*GIIPS*LTRO			-0.47	-3.63**
			(-0.66)	(-1.99)
Home holdings*GIIPS*OMT			0.28	2.14
			(0.38)	(1.25)
Home holdings*crisis	0.61**	0.86***	0.27*	-0.13
	(2.15)	(3.68)	(1.75)	(-0.14)
Home holdings*LTRO	-0.14	-0.15	-0.29	2.39***
	(-0.54)	(-0.28)	(-1.22)	(4.08)
Home holdings*OMT	0.44	2.16***	-0.49***	-1.90
	(0.90)	(6.16)	(-3.30)	(-1.16)
R^2 (%)	13.80	50.35	34.23	60.44
N	84	57	84	57
Banks	28	19	28	19

Table 7: **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 derived according to the regression of eq. (D.1), 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: 5-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.

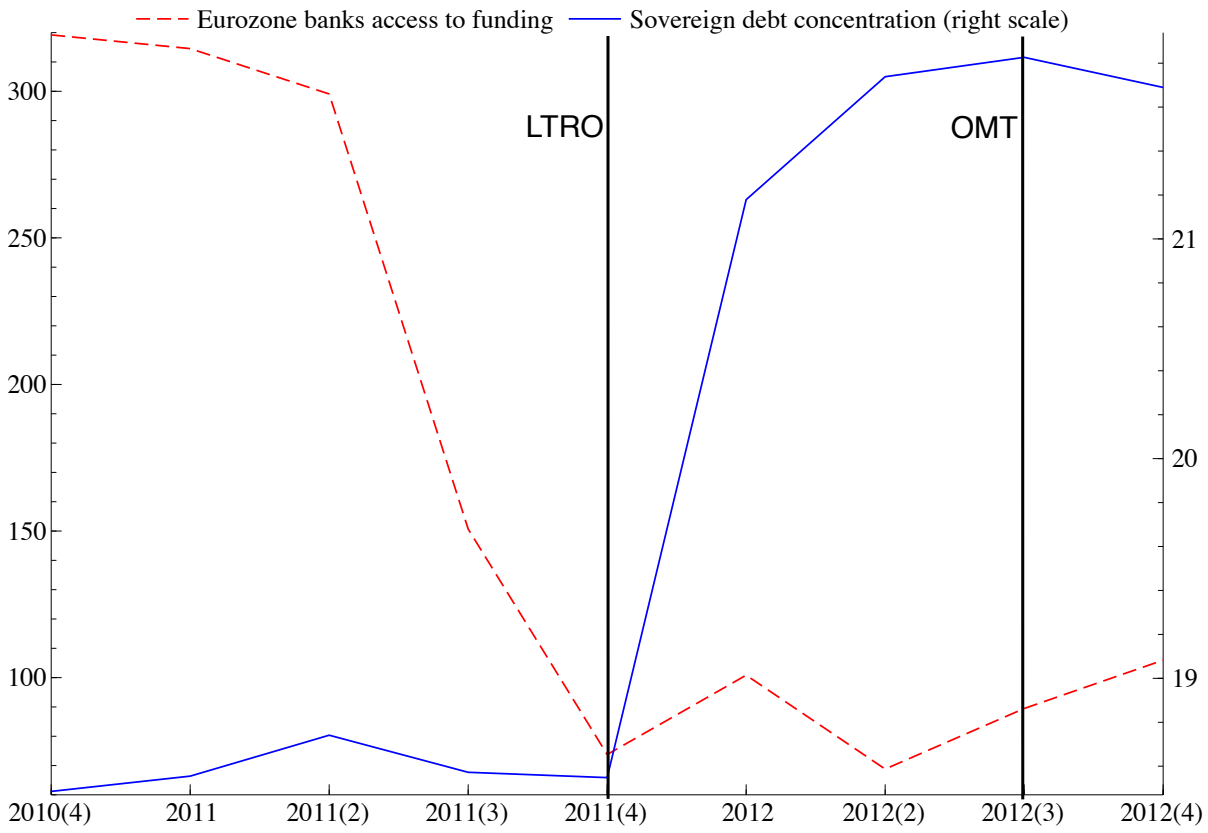
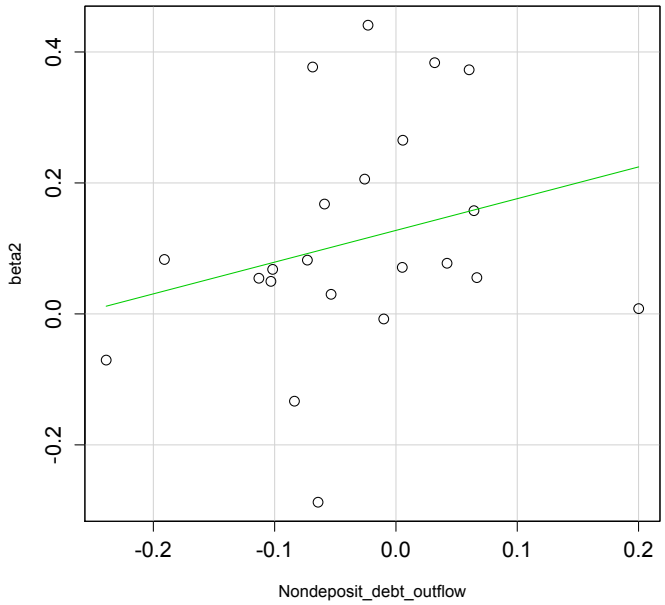


Figure 2: **Crisis funding outflows, bank risk contagion, and sovereign bond holdings**
This figure shows the correlation between the non-deposit liabilities outflows of banks during 2011 and the parameters capturing the influence of bank risk on sovereign risk in the post-LTRO period (12-09-2011 - 7-25-2012) in Panel A, and the correlation between the unsecured non-deposit liabilities outflows of banks during the crisis 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

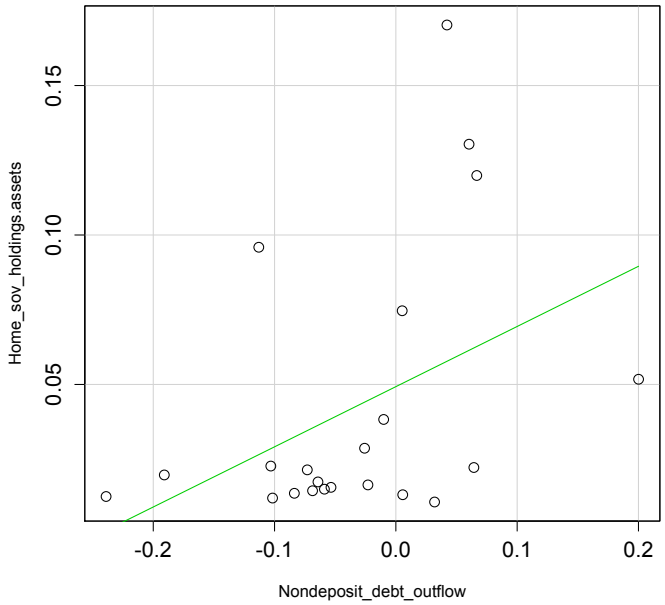
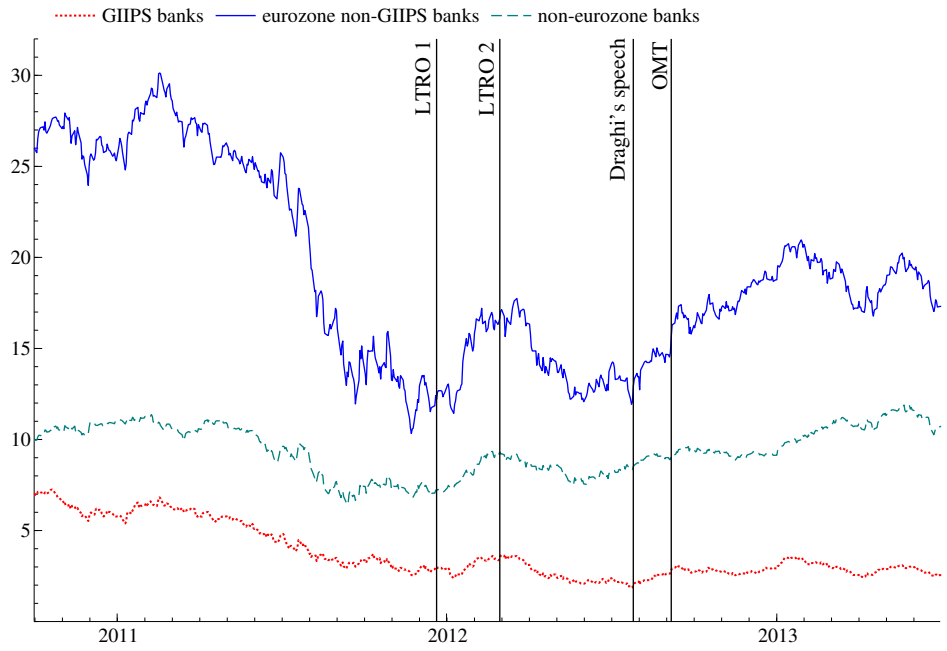


Figure 3: **Bank equity and CDS prices**
This figure shows the average equity prices (Panel A) and average five-year CDS prices (Panel B) of GIIPS banks (excluding Greek banks), non-GIIPS eurozone banks (excluding Dexia), and non-eurozone banks. Vertical bars indicate ECB interventions: LTRO 1 (12-21-2011), 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)

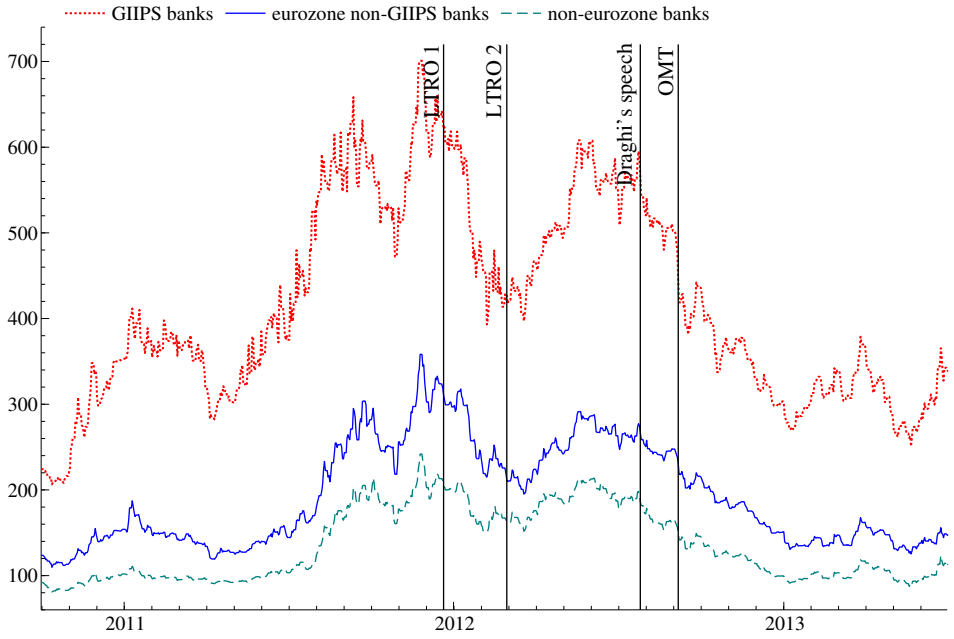


Figure 4: **Sovereign risk**
This figure shows the average five-year sovereign CDS prices of IIPS countries (Ireland, Italy, Portugal, and Spain), non-GIIPS eurozone countries, and non-eurozone countries. Vertical bars indicate ECB interventions: LTRO 1 (12-21-2011), LTRO 2 (2-29-2012), Draghi's speech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

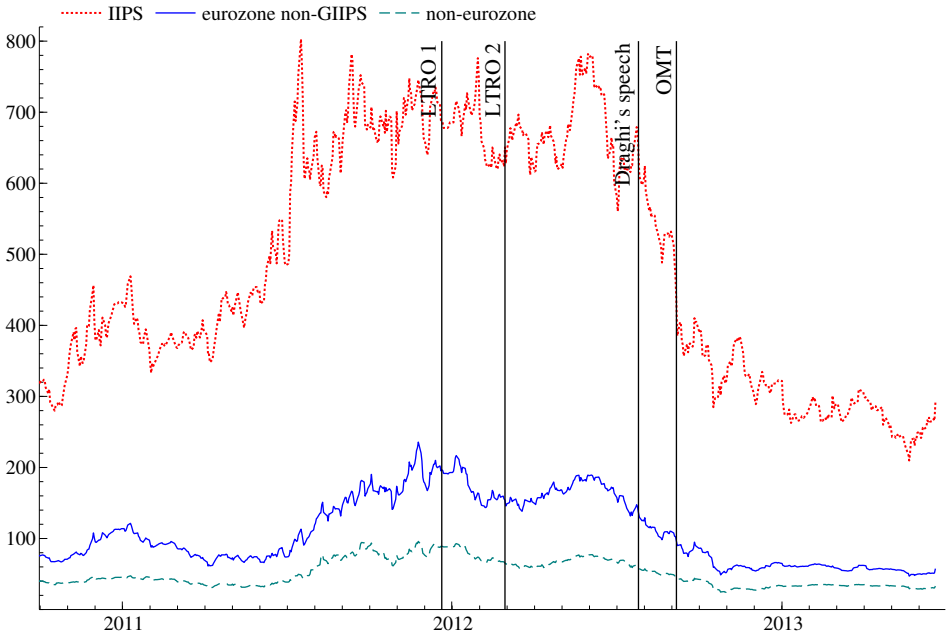


Figure 5: **Bank access to funding**
This figure shows the principal amounts of unsecured funding ($ billion) invested by U.S. money market funds at GIIPS, non-GIIPS eurozone, and non-eurozone banks. Vertical bars indicate ECB interventions: LTRO 1 (Dec 2011), LTRO 2 (Feb 2012), Draghi's speech (Jul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

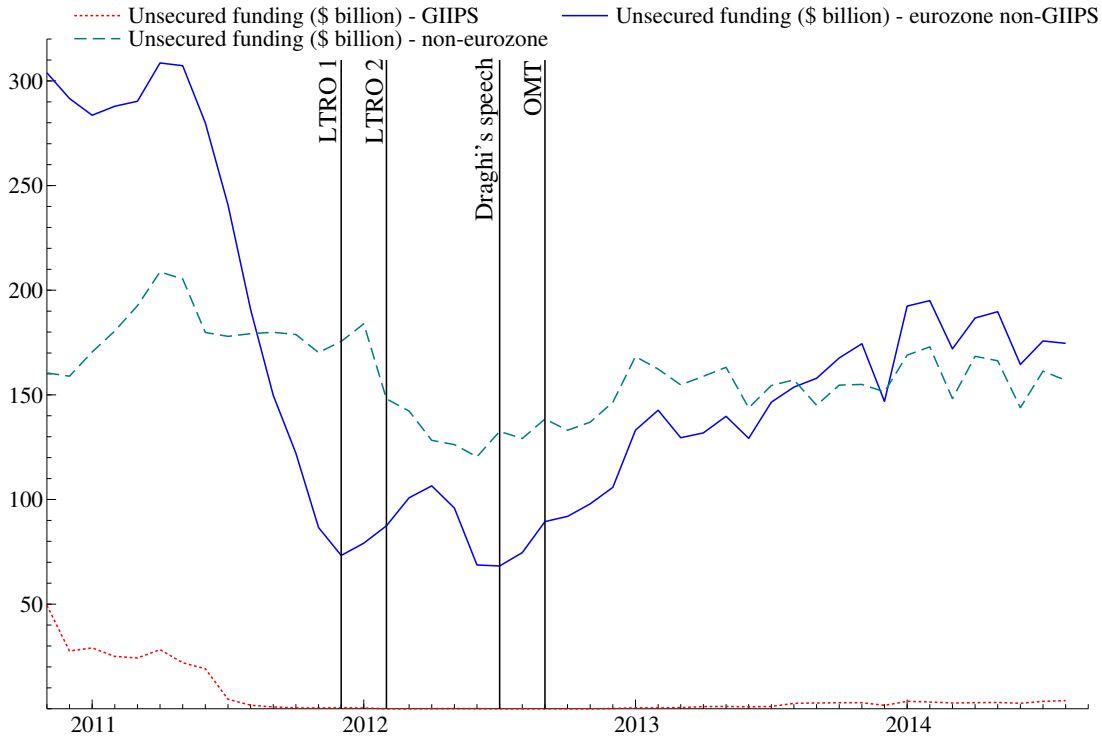
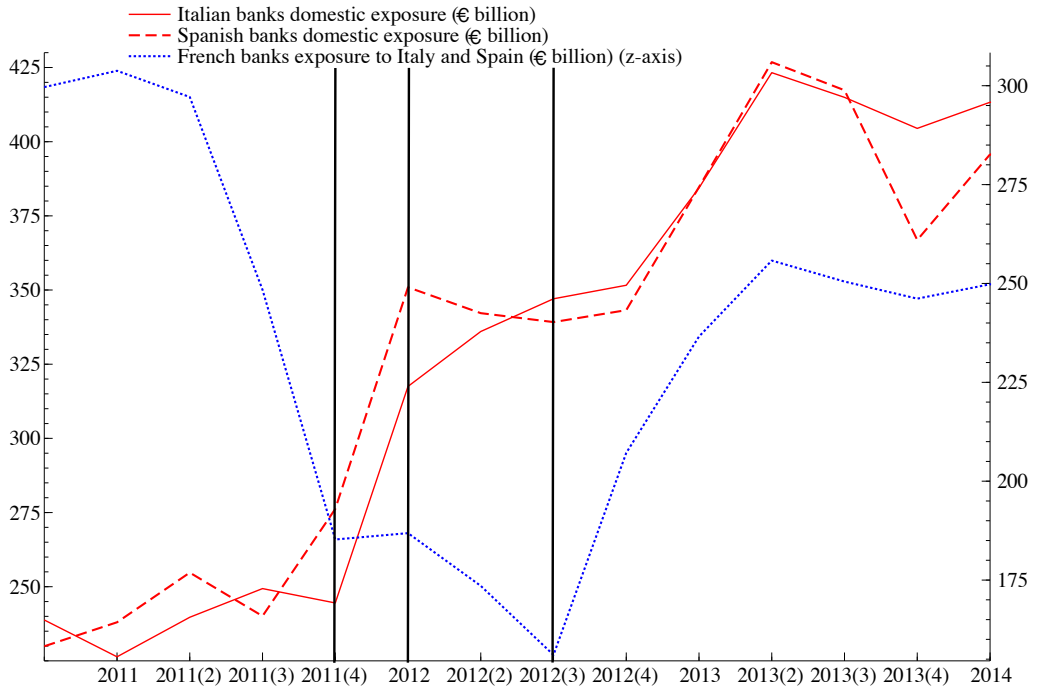


Figure 6: **Italian and Spanish sovereign debt investors**
This figure shows the national banking sectors' exposure (€ billion) to Italian and Spanish official sectors. Sources: BIS Consolidated Banking Statistics and ECB. Vertical bars indicate ECB interventions: LTRO 1 (Q4 2011), LTRO 2 (Q1 2012),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



Lender of Last Resort, Buyer of Last Resort, and a Fear of Fire Sales in the Sovereign Bond Market: Online Appendix

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This Appendix contains four sections: Appendix A describes the sample and variables used in the empirical analyses, and provides additional descriptive statistics. Appendix B presents robustness tests for our Granger-causality results describing the fire-sale and holdings channels. Appendix C presents the results of an event study analysis on bank CDS spreads and bank stock prices around the announcement dates of the LOLR and BOLR interventions we study. Appendix D describes the methodology employed in Section 5.3 of the paper to summarize the effects of the fire-sale and holdings channels on bank realized performance.

Appendix A. Variables description, sample, and descriptive statistics

Table A.1: **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.2: **Variable definitions**

Variable	Definition
MMF investments	Principal amount of unsecured securities invested by U.S. MMFs at European banks in $ billion.
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.
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.
Home holdings/Assets	Ratio of bank's holdings of home country sovereign bonds to its total assets.
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.
GIIPS	Dummy variable equal to one if a bank's headquarter is located in a GIIPS country.

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

Table B.1: **Holdings versus fire-sale risk 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. Evidence in columns 3-4, and 7-8 is based on the 19 banks with the most liquid CDS spreads. 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)	(5)	(6)	(7)	(8)
Home holdings*GIIPS*crisis			3.09**	-1.10			0.60	-0.05
			(2.18)	(-0.28)			(0.64)	(-0.05)
Home holdings*GIIPS*LTRO			3.41***	7.62***			-1.10	-3.51*
			(3.02)	(2.71)			(-1.40)	(-1.79)
Home holdings*GIIPS*OMT			-3.08	-5.80			-0.35	2.33
			(-1.48)	(-1.04)			(-0.44)	(1.49)
Home holdings*crisis	-2.11***	-0.43	-3.24***	0.85	0.46	0.86***	0.39*	0.12
	(-2.68)	(-0.50)	(-5.45)	(0.23)	(1.81)	(3.44)	(1.76)	(0.13)
Home holdings*LTRO	-0.17	-1.91	0.83	-5.88***	-0.01	-0.20	-0.27	2.50***
	(-0.30)	(-1.39)	(1.25)	(-2.30)	(-0.03)	(-0.35)	(-1.32)	(2.70)
Home holdings*OMT	-0.81	-3.61***	-0.03	3.28	0.24	2.14***	-0.40**	-2.05
	(-1.11)	(-3.52)	(-0.05)	(0.63)	(0.50)	(5.85)	(-2.58)	(-1.41)
Controls	Y	Y	Y	Y	Y	Y	Y	Y
R^2 (%)	5.65	8.57	15.89	6.83	24.29	50.33	43.43	59.58
N	84	57	84	57	84	57	84	57
Banks	28	19	28	19	28	19	28	19

Table B.2: **Holdings versus fire-sale risk channel: Granger-causality at the country level (based on optimal lag length)**
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 to 12-07-2011), the post LTRO period (12-09-2011 - 07-25-2012), and the post OMT period (07-27-2012 to 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.3: **Fire-sale risk channel: cross-sectional regressions**
This table presents the results of cross-sectional regressions of the influence of bank risk on sovereign risk ($\hat{\beta}_2$) on bank characteristics for the post LTRO period in Panel A, and for the post-OMT period in Panel B. Home holdings is the fraction of home sovereign bond holdings of a bank to the total assets of the bank in September 2011 (June 2012 for the post-OMT regressions). GIIPS is a dummy variable equal to one if the bank is headquartered in a peripheral eurozone country. Controls include the bank total home exposure divided by bank total assets in December 2010, the logarithm of bank total assets in September 2011 (June 2012 for the post-OMT regressions), the MMF funding flows, and the fraction of bank Tier 1 capital held by government in September 2011 (June 2012 for the post-OMT regressions). 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

	Panel A: post LTRO				Panel B: post OMT			
Home holdings	-1.01	-0.54	-7.97***	-7.36***	-2.87***	-2.96	5.15	10.06
	(-0.90)	(-0.29)	(-5.32)	(-4.17)	(-3.38)	(-1.58)	(0.85)	(1.41)
GIIPS*Home holdings			11.96***	11.39***			-7.75	-11.76
			(4.48)	(3.59)			(-1.25)	(-1.60)
GIIPS			-0.58***	-0.54**			0.10	0.11
			(-4.09)	(-3.00)			(0.47)	(0.47)
Constant		-2.08	0.13*	-0.68	0.23***	2.31*	0.09	3.56***
		(-1.57)	(1.83)	(-0.61)	(2.98)	(2.04)	(0.53)	(3.29)
Controls	N	Y	N	Y	N	Y	N	Y
N	19	19	19	19	19	19	19	19
R^2 (%)	23.98	17.11	74.89	39.71	27.45	18.15	27.39	30.04

Table B.4: **Holdings channel: cross-sectional regressions**
This table presents the results of cross-sectional regressions of the influence of sovereign risk on bank risk ($\hat{\beta}_1$) on bank characteristics for the post LTRO period in Panel A, and for the post-OMT period in Panel B. Home holdings is the fraction of home sovereign bond holdings of a bank to the total assets of the bank in September 2011 (June 2012 for the post-OMT regressions). GIIPS is a dummy variable equal to one if the bank is headquartered in a peripheral eurozone country. Controls include the bank total home exposure divided by bank total assets in December 2010, the logarithm of bank total assets in September 2011 (June 2012 for the post-OMT regressions), the MMF funding flows, and the fraction of bank Tier 1 capital held by government in September 2011 (June 2012 for the post-OMT regressions). 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

	Panel A: post LTRO				Panel B: post OMT			
Home holdings	-0.15	-0.65	2.56***	2.22	2.22***	3.37***	-1.36	-2.42*
	(-0.24)	(-0.91)	(3.07)	(1.51)	(5.85)	(5.65)	(-0.75)	(-2.04)
GIIPS*Home holdings			-4.01	-3.60			1.50	3.19**
			(-1.61)	(-1.31)			(0.78)	(2.47)
GIIPS			0.16	0.11			0.17**	0.15***
			(0.85)	(0.44)			(2.64)	(3.26)
Constant	-0.03	1.331**	-0.07**	0.97	0.01	-0.51	0.06	-1.45***
	(-0.85)	(2.20)	(-2.34)	(1.30)	(0.38)	(-0.87)	(1.36)	(-4.18)
Controls	N	Y	N	Y	N	Y	N	Y
N	19	19	19	19	19	19	19	19
R^2 (%)	-12.02	-18.48	-12.96	-27.70	47.18	47.81	71.60	84.02

Appendix C. Event studies

To quantify the announcement effects of LOLR and BOLR interventions on banks' profitability and risk, 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 of two days, 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.[1]

The reported average cumulative abnormal CDS spread changes and the abnormal cumulative 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.

In Table C.1 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 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).

The results reported in this table show a significant average abnormal reduction of CDS spreads and significant average abnormal positive equity returns for all European banks around December 1, 2011. We also find significant average abnormal negative CDS spread changes around the announcement of the OMT program details for GIIPS banks. The average abnormal performance of banks around other intervention dates does not appear statistically significant in our tests. We however obtain a cross-section of CDS and equity CARs for each intervention announcement, and link the abnormal performance of banks to their sovereign bond holdings in the rest of this section.

CDS CARs . In Panel A of Table C.5, 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 by the banks' total assets:

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

[1] We show the CARs derived over alternative event window lengths in Tables C.2, C.3, and C.4.

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.[2] 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., 2020). This haircut subsidy without additional credit risk extended to sovereign bonds of maturity between one and three years improved the collateral value of these bonds, and reduced the default risk of banks holding them as it reduced 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.

Equity CARs. In Panel B of Table C.5, we show a similar analysis as in Panel A, where we replace the dependent variable (bank CDS CARs) by bank *equity* CARs, and control 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.[3]

[2]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. For example, redenomination risk will affect equivalently all assets of one country denominated in Euros. If we make the assumption that the share of Euro-denominated assets in each asset class is the same, redenomination risk should not be specific to the sovereign bond holdings of the bank.

[3]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

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.[4] Around that date, the two-day equity CAR increase by 2.17% for a bank holding one additional percentage point of its portfolio in short-term GIIPS sovereign bonds.

Around the announcement date of the OMT program details (September 9, 2012), banks holding long-term GIIPS sovereign bonds tend to exhibit higher abnormal profitability. The two-day equity CAR around the OMT program announcement increases by 1.22% when the bank holdings of long-term bonds increases by one percentage point of its assets, holding the other variables (including the bank sensitivity to interest rate policy) in the regression constant. This effect is however only significant at the 10% level.

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.

- 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.

[4]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, 2020).

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 5-year CDS CAR			**Average 3-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: 5-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 5-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: 3-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 3-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)

Table C.5: **Holdings channel: regression analysis of determinants of bank abnormal 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. 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: 5-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

Appendix D. 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 eq. (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, and non-linear function of the bank capitalization ratio (defined by the ratio of bank's Tier 1 common capital to its total assets).

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 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 eq. (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

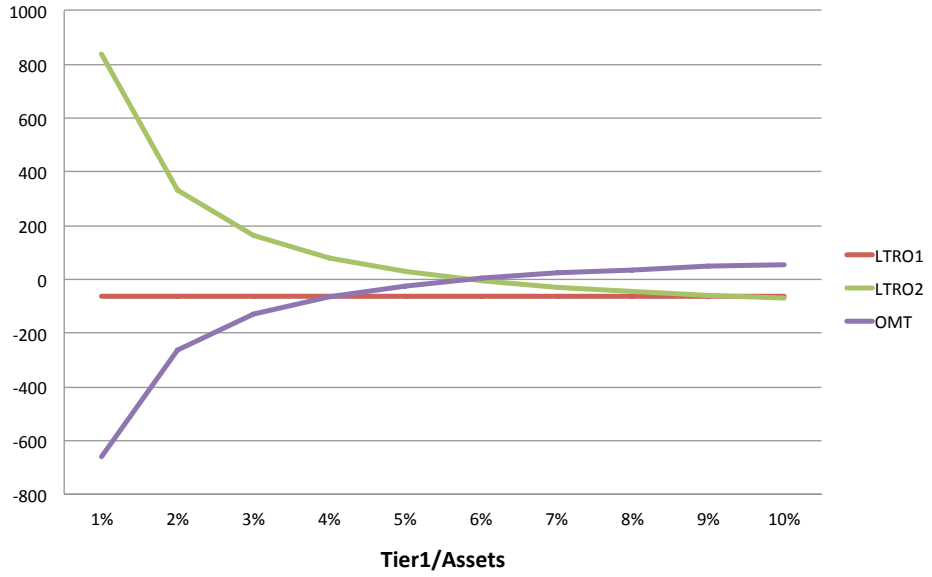
to a reallocation of GIIPS sovereign bonds in the portfolios of GIIPS banks. Figure D.1 (Panel A) shows that the effect of short-term GIIPS holdings on bank risk is greater for banks that do not hold sufficient capital to absorb asset losses. This is consistent with a fire-sale risk effect since the 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)