The (Unintended?) Consequences of the Largest Liquidity Injection Ever*

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Abstract

We show that the design of lender-of-last-resort interventions can exacerbate the bank-sovereign nexus. During sovereign crises, central bank provision of long-term liquidity incentivizes banks to purchase high-yield eligible collateral securities matching the maturity of the central bank loans. Using unique security-level data, we find that the European Central Bank's three-year Long-Term Refinancing Operation caused Portuguese banks to purchase short-term domestic government bonds, equivalent to 10.6% of amounts outstanding, and pledge them to obtain central bank liquidity. The steepening of eurozone peripheral sovereign yield curves right after the policy announcement is consistent with the equilibrium effects of this "collateral trade."

JEL: E58, G21, G28, H63

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1 Introduction

The collapse of the U.S. subprime mortgage market and the subsequent European sovereign debt crisis contributed to long-lasting recessions by impairing financial intermediaries, which then transmitted the shocks to firms and households.[1] In the eurozone periphery, the crisis was also characterized by the "bank-sovereign nexus" as banks increased their holdings of domestic public debt at increasing spreads, triggering a vicious cycle that threatened the stability of both the sovereign and the financial system. As part of their policy response, central banks extended collateralized loans to banks to counter ongoing credit contractions, effectively acting as lenders of last resort (LOLR). While the rationale for this type of intervention is based on a vast body of literature, existing research provides little to no guidance on how central banks should design their liquidity provision, thus leaving policymakers "in largely unchartered waters" during crises.[2]

In this paper, we examine the transmission of LOLR interventions and analyze how their design affects banks' holdings of eligible collateral securities. Our context is the largest LOLR intervention ever conducted: the European Central Bank's (ECB) three-year Long Term Refinancing Operation ("LTRO" hereafter), implemented in December 2011 at the peak of the eurozone crisis.[3] Through this operation, the ECB extended the maturity of its liquidity provision from a few months to three years, with the stated goal to "support bank lending and liquidity in the euro area money market."

Using data on security-level holdings by Portuguese banks from the country's central bank, Banco de Portugal (BdP), we find that the LTRO maturity extension induced banks to purchase

[1] Ivashina and Scharfstein (2010), Chodorow-Reich (2014), Popov and van Horen (2016), and Acharya et al. (forthcoming) present evidence on the negative real effects of these crises.

[2] Mario Draghi, in a speech at the first ECB Annual Research Conference in 2016, said the central bank had to "conduct both policy and research in real time (...) operating in largely unchartered waters (...) based on the best insights that research could provide at the time" and that central bank actions had "inevitably moved ahead of academia during the crisis." Source: https://www.ecb.europa.eu/press/key/date/2016/html/sp160928.en.html.

[3] Garcia-de-Andoain et al. (2016) and Drechsler et al. (2016) discuss the ECB's role as a LOLR during the crisis.

high-yield eligible securities, in the form of domestic government bonds matching the maturity of the central bank loans, and pledge them to obtain central bank liquidity. Using publicly available stress test data, we show that banks in other peripheral countries such as Italy and Spain also expanded their domestic sovereign bond holdings, also driven by securities matching the maturity of ECB liquidity. The observed steepening of peripheral sovereign yield curves right after the LTRO announcement, driven by a collapse of short-term yields, is consistent with the equilibrium effects of this "collateral trade" on sovereign funding costs.

Our contribution is twofold. First, we show that the central bank provision of long-term, but not short-term, liquidity to banks induces them to purchase high-yield securities. In the collateral trade, contrary to a standard carry trade, banks maintain their desired level of reserves and prefer bonds matching the maturity of the central bank loans. Second, we show that, during sovereign crises, central bank liquidity can exacerbate the bank-sovereign nexus by inducing banks to buy domestic government bonds lowering, in turn, sovereign borrowing costs.

The collateral trade works as follows. In an environment with costly external financing, banks hold liquid reserves as insurance against shocks. If the central bank provides liquidity against high-yield government bonds at more favorable terms than the private market, banks can use their reserves to purchase government bonds and pledge them at the central bank to replenish their original reserves. This strategy allows banks to profit if the bonds yield a return higher than the cost of the loan and maintain a desired level of reserves.

Banks can minimize funding liquidity risk by matching the maturity of the bonds they buy with the maturity of central bank liquidity. Bonds maturing after the central bank loans expose banks to the risk that their price may be lower by the time banks need to repay the central bank. Because eligible securities that have both a high yield and a very short maturity are scarce, the collateral trade becomes particularly attractive in the presence of long-term LOLR liquidity. In

equilibrium, by inducing a higher demand for short-term government bonds, the collateral trade causes a drop in short-term sovereign yields, leading to a steepening of the sovereign yield curve.[4]

As formalized in a simple model, the collateral trade generates three predictions: (i) banks "buy and borrow" as they purchase high-yield government bonds to borrow from the LOLR; (ii) the collateral trade is caused by the long maturity of LOLR liquidity; and (iii) the sovereign yield curve steepens, driven by a drop in short-term yields in response to the higher demand for short-term bonds. Starting from the observation that bank holdings of domestic government bonds increase from 16.4% to 20.2% of the amount outstanding during the three months around the LTRO allotment, we test the first two predictions and provide evidence consistent with the third prediction.[5]

First, we show that these purchases, in the cross section of banks, correlate one-to-one with LTRO borrowing and explain a large part of its cross-sectional variation (first prediction). Second, we show that banks purchased government bonds *in response* to the LTRO by comparing, in a differences-in-differences specification, purchases of bonds maturing before the LTRO loans ("short-term" bonds) and bonds maturing after the LTRO loans ("long-term" bonds), while controlling for time-varying bank heterogeneity and bank-bond heterogeneity using fixed effects (second prediction). Our results are economically significant. The LTRO caused a €5.1 billion increase in holdings of short-term bonds, equivalent to 10.6% of the total amount outstanding. Consistent

[4]The meanings of short- and long-term in this paper should be understood in the context of the asset class. Relative to the typical liquidity instruments of central banks, 3-year maturities are considered long-term. For the case of sovereign bonds, where decade-long maturities are common, securities with maturity below 3 years can be considered short term. Thus, when we refer to LTRO, we will adopt the ECB's terminology in describing it as long-term. When we refer to sovereign bonds, we will use short-term to describe bonds with maturity up to 3 years.

[5]Domestic government bonds – as opposed to other high-yield assets – are the most attractive asset for the collateral trade for two reasons. First, euro-denominated government bonds have a capital requirement of zero, making them particularly appealing from a regulatory capital standpoint. Second, banks in countries with high credit risk can use *domestic* government bonds to risk-shift and/or satisfy eventual government moral suasion.

with the preference for short-term securities, the LTRO caused an increase in holdings of long-term bonds of only €2.4 billion, equivalent to 2.6% of the total amount outstanding.

Our causal claim is confirmed by three additional tests: (i) We show that there is no effect in other periods, except for November 2011 when the ECB undertook another (similar but smaller) long-term liquidity injection, (ii) we show that our results do not extend to institutions that have no access to ECB liquidity (e.g., hedge funds, insurance companies), and (iii) we show that more LTRO borrowing is positively correlated with more collateral trade activity. Using publicly available stress test data, we show that our findings extend to the largest peripheral eurozone countries. Large banks in Italy and Spain increased their holdings of sovereign bonds from €209 billion to €240 billion and from €162 billion to €171 billion between December 2011 and June 2012, respectively, with most of the increase being driven by purchases of short-term bonds.

Finally, consistent with an equilibrium effect of the collateral trade, we show that short-term yields dropped right after the LTRO announcement in peripheral – but not in core – eurozone countries, leading to a steepening of their sovereign yield curves (third prediction). Thanks to these price changes, the Italian, Spanish, and Portuguese sovereigns saved €10 billion, €3 billion, and €1 billion in their public debt issuance in the six months after the LTRO (respectively), a possibly unstated objective of the policy.[6] The collateral trade was also ex-post very profitable for banks. Following the drop in peripheral yields in summer 2012, Portuguese banks realized profits on their bond holdings – effectively an indirect recapitalization – of €3.8 billion, or 9% of total book equity.

Our results on the role of the maturity of central bank liquidity fill a gap in the LOLR literature

[6]These findings echo the remarks of former French President Nicolas Sarkozy at a press conference related to the LTRO announcement: "This means that each state can turn to its banks, which will have liquidity at their disposal."

that has mostly focused on the rationale for the LOLR to exist (see Santos, 2006 for a survey) and the effects of LOLR interventions on market liquidity (Garcia-de-Andoain et al., 2016) and bank private credit supply (Carpinelli and Crosignani, 2018; Andrade et al., forthcoming).[7]

We also contribute to the theory literature on the bank-sovereign nexus (Farhi and Tirole, forthcoming; Brunnermeier et al., 2016; Gennaioli et al., forthcoming, 2014; Leonello, forthcoming; Cooper and Nikolov, 2013; Crosignani, 2017; Acharya et al., 2014; Bolton and Jeanne, 2011; Broner et al., 2010). The empirical literature on the eurozone crisis attributes banks' purchases of domestic government bonds during the crisis to moral suasion (Becker and Ivashina, forthcoming; Ongena et al., 2016; Altavilla et al., 2017; Uhlig, 2013; De Marco and Macchiavelli, 2016) or risk-shifting (Drechsler et al., 2016; Acharya and Steffen, 2015). The collateral trade channel we propose is complementary to these explanations and explains banks' preference for short-term high-yield securities.[8]

Two papers are closely related to ours. First, Drechsler et al. (2016) show that, before the LTRO, weakly capitalized banks borrowed more from the ECB and pledged riskier collateral than strongly capitalized ones. They document a reallocation of risky assets, including sovereign bonds, from strongly to weakly capitalized banks consistent with a "risk-taking theory" of the LOLR. Second, Acharya and Steffen (2015) show that banks engaged in a carry trade that involved purchases

[7]The LOLR theory literature has recently suggested that the LOLR should, in some cases, lend against low-quality collateral (Choi et al., 2017; Koulischer and Struyven, 2014). Our findings show that in such an environment the choice of the maturity of LOLR liquidity crucially affects its transmission through banks.

[8]See Krishamurthy et al. (forthcoming) for a comprehensive analysis of ECB policies during the crisis. Our paper also relates to the analysis of the effects of ECB policy on asset prices (Eser and Schwaab, 2016; Trebesch and Zettelmeyer, 2014; Corradin and Rodriguez, 2014), bank credit (van Bekkum et al., forthcoming; Heider et al., 2017; Acharya et al., 2017; Andrade et al., forthcoming; Carpinelli and Crosignani, 2018; Garcia-Posada and Marchetti, 2016), firm financing (Grosse-Rueschkamp et al., 2017), and market liquidity (Garcia-de-Andoain et al., 2016; Pelizzon et al., 2016) and naturally follows the literature on bank credit contraction during the eurozone crisis (Popov and van Horen, 2016; De Marco, forthcoming; Cingano et al., 2016; Bofondi et al., forthcoming; Bocola, 2016; Acharya et al., forthcoming; Bottero et al., 2017). Our findings also relate to the literature on the Federal Reserve's interventions in the U.S. (Di Maggio et al., 2016; Darmouni and Rodnyansky, 2017; Chakraborty et al., 2016; Foley-Fisher et al., 2016).

of peripheral sovereign bonds funded in short-term wholesale markets. They document that the bulk of purchases by peripheral banks happened in the first half of 2012, around the LTRO period. In this paper, we (i) causally link the LTRO with these purchases and identify the collateral trade mechanism that – contrary to a carry trade – allows banks to maintain a desired level of reserves and (ii) show, thanks to our granular data and the LTRO maturity extension, that the long LTRO maturity further induced banks to purchase short-term domestic sovereign bonds, consistent with the stark steepening of sovereign yield curves right after the LTRO announcement.[9]

The rest of the paper proceeds as follows. In Section 2, we illustrate the collateral trade and its empirical predictions. In Section 3, we present the empirical setting and the data. We present our empirical analysis in Section 4 and further discuss our results in Section 5. Section 6 concludes.

2 The Design of LOLR Interventions and the Collateral Trade

The theory of the LOLR is intuitive. Banks hold fewer liquid assets than liquid liabilities and are therefore subject to runs. During a run, the central bank should act as a LOLR, providing liquidity to banks that are illiquid but solvent to prevent socially costly deleveraging and liquidations. According to the classical principle of Bagehot (1873), LOLR liquidity should be granted "early and freely to solvent firms, against good collateral at high rates." High rates – that is, penalty rates compared with the private market – ensure that banks relatively unaffected by the run continue to obtain funding in the private market.

[9]These two papers rely on very limited stress test data: just five Italian, five Spanish, four Portuguese, two Irish, and zero Greek banks participated in all the five stress tests conducted in March 2010, December 2010, September 2011, December 2011, and June 2012. The first paper uses these five dates and the second uses the first three dates. Existing studies that exploit security-level holdings either analyze the role of bank capital for the risk-taking channel of monetary policy (Peydró et al., 2017) or focus on the portfolio choice – not in relation to central bank interventions – of banks in Germany (Abbassi et al., 2016; Buch et al., 2016; Hildebrand et al., 2012; Timmer, forthcoming).

The prescription regarding collateral eligibility is, however, more vague, as the LOLR should accept collateral securities "that are considered safe in normal times" valued at pre-panic prices. Recent research suggests that the LOLR should, in some cases, also accept low-quality securities to preserve the quality of collateral in private markets (Choi et al., 2017) and to grant banks with scarce collateral access to central bank liquidity (Koulischer and Struyven, 2014). Moreover, the existing literature does not specify the maturity at which the LOLR should lend to banks.

In this paper, we argue that collateral eligibility and maturity matter for the transmission of LOLR liquidity. We show that a LOLR that provides *long-term* liquidity accepting high-yield securities as collateral encourages banks to engage in what we call a "collateral trade." We intuitively describe this mechanism next and present a formal model in Appendix A.

2.1 The Collateral Trade

Consider an economy in which external financing is costly and banks hold some liquid reserves for insurance motives. There is a LOLR that provides long-term liquidity to banks collateralized by government bonds, safe securities in normal times and high-yield securities during sovereign crises. During sovereign crises, banks can use their reserves to purchase high-yield government bonds that can then be pledged to borrow at the central bank and therefore replenish their original reserves.

Banks can minimize the risk of this trade by purchasing government bonds that have a maturity equal to or less than the maturity of the LOLR loan. A bank engaging in the collateral trade using collateral with a maturity exceeding that of the LOLR loan is exposed to funding liquidity risk: If the pledged securities drop in price during the LOLR loan, not only may the bank receive a margin call from the central bank, but the bond itself may be worth less by the time the loan expires. These scenarios force the bank to raise funds to either meet the margin call or repay the loan, which may be very costly during crises and increase uncertainty regarding liquidity management.

If collateral securities mature before the loan, the risk associated with the margin call is lower, as the securities mature (become cash) before the loan is due.[10]

Note that the combination of the eligibility of high-yield securities and the long maturity of LOLR loans makes this trade particularly attractive. If the LOLR only accepted low-yield securities, the profit from this trade would be lower. If the LOLR loans were short term, most eligible collateral securities would mature after the LOLR loan, exposing the bank to higher funding liquidity risk.[11] In equilibrium, for a given supply of government bonds, the collateral trade causes the sovereign yield curve to steepen as banks demand more short-term government bonds.[12] In sum, in an environment where the LOLR provides long-term liquidity against high-yield government bonds, the collateral trade generates three predictions.

Prediction 1: Banks buy high-yield government bonds to borrow at the LOLR. Banks engaging in the collateral trade buy €1 of government bonds for every euro borrowed from the LOLR.

Prediction 2: The LOLR causes purchases of high-yield short-term government bonds. More specifically, banks develop a preference for high-yield *short-term* government bonds in order to match the maturity of LOLR loans with the maturity of the asset pledged to secure them.

Prediction 3: The sovereign yield curve steepens. The increased demand for short-term government bonds by investors with access to LOLR liquidity causes a steepening of the sovereign yield curve.

[10] The collateral maturing before the LOLR loan still results in a margin call, which the bank can cover with the newly available funds and so entails much less risk. In the Online Appendix, we present a simple model of margin calls and the collateral trade.

[11] This intuition is clearly illustrated in the 2012 Annual Report of Banco Carregosa (a medium-sized Portuguese bank): "The Bank (...) invested essentially in short-term deposits with other financial institutions and in the Portuguese public debt, in most cases, with maturities up to 2015. (...) transforming the short-term financing with the ECB into 3 years, the Bank not only maintained a very comfortable position regarding permanent liquidity but also guaranteed the same position for the coming 2 years."

[12] LOLR liquidity, even when long-term, does not usually exceed a maturity of a couple of years.

3 Data and Setting

We bring these predictions to the data in the context of the Portuguese financial sector during the largest LOLR intervention ever conducted: the ECB's three-year LTRO announced in December 2011.[13] We now present the empirical setting and describe the data.

3.1 Empirical Setting

The ECB provides liquidity to the financial sector using collateralized loans. Any bank located in the eurozone can obtain a cash loan from the central bank. There is no limit on the amount of funds that a bank can borrow from the ECB, provided that it pledges sufficient collateral ("full allotment" policy). Eligible collateral includes government bonds, asset-backed securities, and bank and corporate bonds. Although every bank can borrow at the same interest rate from the ECB, the haircut depends on the characteristics of the pledged security (residual maturity, rating, coupon structure, and asset class). The maturity of the loan is typically one week or three months.[14]

As the sovereign crisis worsened in the second half of 2011, on December 8, 2011, the ECB announced the provision of two unprecedented three-year maturity loans: the three-year LTRO. The stated goal was to provide long-term funding to banks to "support bank lending and money market activity."[15] Over 800 eurozone banks borrowed €1 trillion at the LTRO, making this the largest

[13] See Reis (2013) for a detailed analysis of the Portuguese economy from 2000 to 2012.

[14] The absence of a limit on how much banks can borrow from the ECB was introduced in October 2008. The ECB offers two types of loans: (i) MRO loans with a maturity of one week and (ii) LTRO loans with a maturity of three months. During the crisis, the ECB strengthened its supply of longer-term funding with extraordinary 6-month and 12-month LTROs. Three 6-month LTROs were allotted in April 2010, May 2010, and August 2011. One 12-month LTRO was allotted in October 2011. We describe the ECB collateral rules in detail in the Online Appendix. In the main text, we use the term "LTRO" to refer to the December 2011 three-year operation.

[15] In the second half of 2011, peripheral eurozone banks experienced funding dry-ups, mainly driven by U.S.-held certificates of deposit and commercial paper (Chernenko and Sunderam, 2014). Sovereign CDS spreads of large countries such as Italy and Spain reached record highs in November 2011 and remained elevated until Draghi's OMT announcement in July 2012. Pelizzon et al. (2016) show that market makers were wary about providing liquidity to the sovereign bond market before the LTRO. The announcement of the LTRO can be found at www.ecb.europa.eu.

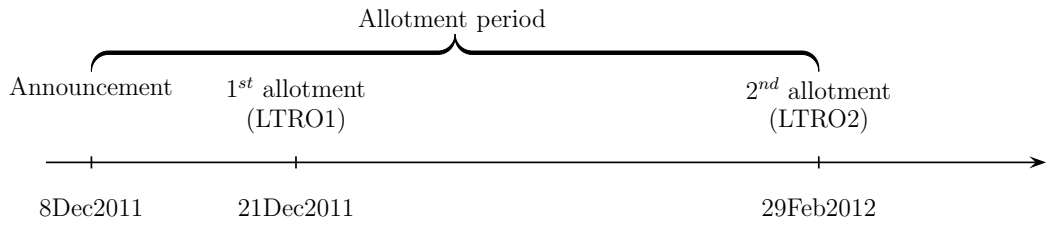

Figure 1: LTRO Timeline. This figure illustrates the timeline of the LTRO intervention.

liquidity injection in the history of central banking. More than two-thirds of ECB liquidity was allotted to banks located in peripheral countries where the LTRO long maturity and below-market haircuts made these loans particularly attractive compared with private funding markets.[16]

Note that the main difference between the LTRO and preexisting facilities was its long maturity. Prior to the LTRO, the ECB was providing liquidity to banks against the same types of collateral but at a much shorter maturity, typically two weeks or three months.[17] In a frictionless world, loan maturity does not matter and the LTRO is redundant, as banks would be indifferent between borrowing from the central bank at a three-year maturity and rolling over shorter-maturity borrowing. These two strategies are not equivalent if there is uncertainty about the ECB's role as a liquidity provider in the next three years, likely the case at the end of 2011, as the continuation of the ECB's full allotment policy and the future of the eurozone were both unclear.

Figure 1 shows the timeline. The announcement is followed by the allotment of the first loan (LTRO1) on December 21 and, two months later, by the second allotment (LTRO2) on February 29. We refer to the period between the announcement and LTRO2 as the "allotment period."

[16]This ECB implicit haircut subsidy is discussed in Drechsler et al. (2016).
[17]The ECB also lowered the rating threshold for asset-backed securities to be eligible.

3.2 Data

Our data set results from the merger of two proprietary data sets from Banco de Portugal (BdP).[18]

The first data set contains monthly bank-level data on the composition of the balance sheets of all Portuguese monetary and financial institutions that have access to ECB liquidity. This unbalanced panel contains information on 81 banks and 10 savings institutions. As a complement, we obtain information on the bank-level ECB collateral pool by type: government debt, marketable assets, additional credit claims, and government-guaranteed bank bonds. Crucially, we observe bank-level uptake of LTRO liquidity.[19]

The second data set contains monthly security-level data of all holdings of Portuguese government debt by domestically regulated institutions. The universe of entities of this second data set is larger than that of the first, as it includes non-bank institutions such as mutual funds, hedge funds, brokerages, and pension funds (among others). For each institution, we have data on book, face, and market value at the security (ISIN) level. We match this data set with bond-level information from Bloomberg such as yield, maturity, and amount issued.[20] Note that we do not have standard balance sheet characteristics (e.g., total assets) for these non-bank institutions.

In the remainder of the paper, we refer to the institutions in the first data set (that have access to ECB liquidity) as "banks" and to the institutions included only in the second data set (that have no access to ECB liquidity) as "non-banks."

[18] A more detailed description of the data set is provided in the Online Appendix.

[19] Given that the bank-level LTRO uptake are not publicly available (Bloomberg publishes self-reported, incomplete, information), the stigma associated with borrowing from the ECB is not a first order concern in our setting (Anbil, forthcoming).

[20] We are able to match more than 98% of the value of holdings in the data set.

4 Empirical Analysis

We now bring the three predictions of the collateral trade to the data. In Section 4.1 and Section 4.2, we test the first two predictions (effect on demand for government bonds). In Section 4.3, we provide evidence consistent with the third prediction (equilibrium effect on prices).

In the collateral trade, banks purchase high-yield collateral in the form of government bonds. In the context of the European sovereign debt crisis, government bonds – particularly domestic ones – were the most attractive type of high-yield security to engage in this trade for several reasons. First, euro-denominated government bonds have a zero regulatory capital risk weight and are therefore cheap from a capital standpoint. Second, in the presence of sovereign-bank linkages and government guarantees, *domestic* government bonds are even more attractive, as banks can use them to satisfy government moral suasion (Becker and Ivashina, forthcoming; De Marco and Macchiavelli, 2016; Ongena et al., 2016) and to risk-shift (Crosignani, 2017; Drechsler et al., 2016).[21]

In Figure 2, we plot government bond holdings at face value of banks (which could access the LTRO) from June 2011 to June 2012. The vertical lines delimit the LTRO allotment period. The figure shows that Portuguese banks increased their holdings from €22.9 billion in November 2011 to €27.8 billion in February 2012, a change equivalent to 0.9% of total assets and 3.5% of total public debt outstanding.[22]

[21] When sovereigns and banks default in the same states of the world, limited liability leads banks to not internalize any losses from sovereign default when choosing their portfolios.

[22] Banks increased their holdings of government bonds from 16.4% in November 2011 to 20.2% in February 2012 as a percentage of amount outstanding and from 4.0% to 4.8% as a percentage of total assets. In the Online Appendix, we show a version of the figure where holdings are normalized by total public debt outstanding and a version where holdings are normalized by total assets. Finally, we also show that, during the same period, holdings of non-banks (which were excluded from the LTRO) were stable.

Figure 2: Holdings of Domestic Government Debt. This figure plots the evolution of domestic government bonds held by banks from June 2011 to June 2012. Quantity is measured as the face value in billions of euro. The two vertical dashed lines delimit the LTRO allotment period. In the Online Appendix, we show that the figure is robust to normalizations by total assets total public debt outstanding.

4.1 Bank Buy-and-Borrow Behavior

We now check whether banks purchased government bonds in the allotment period and used them to borrow at the LTRO (Prediction 1). Based on the short time span between the announcement and the first allotment, we focus on the second allotment.[23]

Given that we do not observe which securities banks pledge at the ECB, our strategy is to analyze the correlation in the cross section of banks between changes in holdings of eligible collateral during the allotment period and LTRO2 borrowing. More formally, we run the following cross-

[23]There are two weeks between the announcement and LTRO1, as opposed to three months before LTRO2. Indeed, most domestic government bond purchases occurred in January and February. Two other reasons may have inhibited banks from using LTRO1 but not LTRO2 for the collateral trade: (i) concerns that tapping LTRO might have sent a bad signal to the market (resolved before LTRO2, as suggested by Andrade et al. (forthcoming)) and (ii) window-dressing to not show increased government bond holdings on the annual report (based on holdings as of December 31). Consistent with these motives, banks used LTRO1 mostly to rollover previous short-term ECB funding, increasing only moderately their total ECB borrowing. Banks do not need to pledge additional collateral when rolling over previous borrowing.

sectional regression in the subsample of banks:

$$\text{LTRO2}_i = \alpha + \beta \Delta \text{EligColl}_{i,\text{Feb12-Nov11}} + \gamma \text{TotalCollateral}_{i,\text{Nov11}} + \epsilon_i \tag{1}$$

where the dependent variable is LTRO2 uptake, $\Delta\text{EligColl}_{\text{Feb12-Nov11}}$ is a vector of changes in holdings of eligible collateral during the allotment period (one change per asset class), and $\text{TotalCollateral}_{\text{Nov11}}$ is the stock of eligible collateral in November 2011, as banks might have used their preexisting collateral holdings to access the LTRO. Changes are measured between November 2011 (last pre-announcement observation) and February 2012 (LTRO2 date).[24] All variables are normalized by bank assets in November 2011 and collateral measures are haircut adjusted.[25]

We observe four asset classes of ECB-eligible collateral in our data: domestic government bonds, additional credit claims, government-guaranteed bank bonds, and other marketable assets (e.g., asset-backed securities, corporate and bank bonds, foreign government bonds). If banks engaged in the collateral trade using one specific asset class, (i) the related changes in holdings should explain a large part of the cross-sectional variation in LTRO2 uptake and (ii) the related β coefficient should be close to one.[26]

We show the estimation results in Table 1, where we measure changes in domestic government bond holdings using either face values (column (1)) or market values (column (2)), as bank borrowing capacity at the ECB depends on the market value of collateral assets, but market values might simply reflect price movements and not changes in actual holdings. Consistent with the

[24] LTRO2 was allotted on February 29, 2012, but settled on March 1, 2012. February observations are therefore the last snapshot of balance sheets before LTRO2, which is observed only in March data.

[25] The collateral variables are net of the haircut imposed by the ECB. If a bank purchased during this period 100 units of a security that is eligible to serve as collateral at a haircut of x%, our measure is $100 \times (1 - x)$.

[26] While banks could borrow at the LTRO using their existing holdings of eligible collateral in November 2011, the collateral trade implies a *buy*-and-borrow behavior by banks and has therefore no prediction for the coefficient γ.

LHS Var.: LTRO2	(1)	(2)	Semi-Partial R^2
ΔGovt (Face Value)	0.933***		
	(0.091)		
ΔGovt (Market Value)		1.034***	30.5%
		(0.098)	
ΔACC	1.196**	1.229**	3.2%
	(0.583)	(0.553)	
ΔGGBB	0.837***	0.838***	0.8%
	(0.031)	(0.030)	
ΔOtherMarketable	0.802***	0.801***	10.0%
	(0.036)	(0.035)	
$\text{TotalCollateral}_{\text{Nov11}}$	0.218*	0.221*	1.9%
	(0.131)	(0.125)	
Observations	68	68	
R-squared	0.960	0.962	

Table 1: Bank Buy-and-Borrow Behavior. This table presents the estimation results for specification (1). The dependent variable is the total uptake at LTRO2 normalized by total assets in November 2011. Independent variables include changes in holdings of central bank eligible collateral between November 2011 and February 2012, and the stock of eligible collateral in November 2011. Eligible collateral includes domestic government bonds, additional credit claims (ACC), government-guaranteed bank bonds (GGBBs), and other marketable securities. All variables are normalized by bank assets in November 2011. All measures of collateral are adjusted for the respective ECB haircuts. Column (1) measures changes in government bond holdings using face values, while column (2) uses market values. Column (3) reports the semi-partial R-squared of the independent variables in column (2). In the Online Appendix, we show a version of this regression with additional controls. Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

buy-and-borrow behavior, all coefficients on changes in holdings are statistically significant and close to one.[27]

The last column reports the semi-partial R-squared that captures how much marginal information each independent variable provides about LTRO2.[28] We find that domestic government bonds have by far the largest marginal contribution with a semi-partial R-squared of 30.5%, compared with 10% for other marketable securities and less than 4% of other asset classes, consistent with

[27] In the Online Appendix, we show that these estimates are robust to controlling for changes in a wide range of balance sheet components during this period.

[28] Given a set of covariates $\{x_n\}_{n=1}^{N}$, the semi-partial R-square of variable x_n captures the information in x_n about the dependent variable that is orthogonal to the other covariates. It is computed as the difference between the R-squared of a regression that includes all covariates and that of a regression that excludes x_n.

government bonds being the most important asset class eligible for collateral at the ECB.[29]

4.2 LTRO Causes the Collateral Trade

We now test whether banks increased their government bond holdings *in response* to the LTRO (Prediction 2). In Section 2, we suggested that banks have an incentive to purchase securities maturing before the second LTRO loan in February 2015. Hereafter, we refer to these securities as "short-term" bonds.

The first step in our empirical test is to properly measure bank-level changes in government bond holdings of different maturities. This variable requires particular care, as one needs to simultaneously take into account that large banks likely buy more bonds (normalize by bank size) and that the amounts of short- and long-term bonds outstanding might change over time as new bonds are issued and existing bonds mature (normalize by amounts outstanding).[30]

We address these concerns by defining the following variable:

$$\widetilde{\text{Holdings}}_{i,m,t} = \frac{\frac{\text{Govt. Bond Holdings}_{i,m,t}}{\text{Amount Outstanding}_{m,t}}}{\frac{\text{Assets}_{i,t}}{\text{Total Assets}_t}}$$

[29] In the euro area, government bonds accounted for 47.3% of total collateral pledged to the ECB in 2011, versus 3.2% of regional government bonds, 14.8% of unconvered bank bonds, 12.1% of covered bank bonds, 9.6% of corporate bonds, 7.7% of asset backed securities, and 5.4% of other marketable assets. In our sample, only six banks held government-guaranteed bank bonds and such holdings were markedly smaller compared with other asset classes. Additional credit claims were introduced at around the same time but only after March 2012 do they become a non-negligible part of the collateral pool of Portuguese banks. We do not have a finer disaggregation of marketable assets other than government bonds.

[30] Consider the following example. Bank A and Bank B buy €50 in short-term and €50 in long-term government bonds. If Bank A is larger than Bank B, we should divide bank holdings by bank assets to take into account that Bank B has a stronger preference relative to its size. Assume also that there are €200 short-term government bonds outstanding and €400 long-term government bonds outstanding in that period. By simply looking at bank holdings, even if normalized by bank size, it would seem that both banks did not favor a specific maturity. However, they are concentrating on shorter maturities relative to other investors as they purchase a greater share of the total short-term public debt outstanding compared with the long-term public debt outstanding. The stock of short-term and long-term public debt outstanding in November 2011 is €50.5 billion and €89.3 billion, respectively.

This variable measures the share of public debt outstanding of maturity m held by bank i in month t, divided by the size of that bank i relative to the size of banking sector.[31] The numerator captures the share of government bonds outstanding with (residual) maturity m held by institution i. The denominator scales the numerator by size. Our measurements are not affected by movements in prices as both holdings and amounts outstanding are measured in face value.

We test Prediction 2 in two steps. First, we run the following specifications in the subsample of banks (which have access to ECB liquidity):

$$\widetilde{\text{Holdings}}_{i,m,t|m\in\text{Short}} = \alpha + \beta_{\text{Short}}\text{Post}_t + \eta_i + \mu_m + \epsilon_{i,m,t} \tag{2a}$$

$$\widetilde{\text{Holdings}}_{i,m,t|m\in\text{Long}} = \alpha + \beta_{\text{Long}}\text{Post}_t + \eta_i + \mu_m + \epsilon_{i,m,t} \tag{2b}$$

where the dependent variable is the normalized holdings of short-term and long-term government bonds in specifications (2a) and (2b), respectively. The sample runs for 12 months, from June 2011 to May 2012; Post_t is a time dummy equal to 1 on and after December 2011; and η_i and μ_m are bank and maturity fixed effects, respectively.[32] With these two regressions, we ask whether banks purchased more short-term and long-term government bonds after the LTRO announcement relative to the pre-announcement period.

Second, we run the following differences-in-differences specification for the same sample period

[31] The banking sector includes all Portuguese monetary and financial institutions that have access to ECB liquidity. We discretize m into six bins based on the bond's residual maturity on February 2012: 0-0.5, 0.5-1, 1-3, 3-5, 5-10, and 10+ years. We label the first three bins as short term and the last three bins as long term.

[32] The sample ends in May 2012, not overlapping with Draghi's July 26, 2012 OMT announcement.

and sample banks:

$$\widetilde{\text{Holdings}}_{i,m,t} = \alpha + \beta \text{Post}_t \times \text{Short}_m + \eta_{i,t} + \xi_{i,m} + \epsilon_{i,m,t} \tag{3}$$

where Short_m is a dummy variable equal to 1 for sovereign bonds maturing on or before February 2015, $\eta_{i,t}$ are bank-time fixed effects, and $\xi_{i,m}$ are bank-maturity fixed effects.

Table 2 shows the estimation results. The first two columns show that banks increased their holdings of both short-term and long-term government bonds after the LTRO announcement. Consistent with Prediction 2, the coefficient is larger for short-term bonds. This difference is confirmed by the estimation results for the differences-in-differences specification in columns (3)-(5), where we progressively saturate the regression with more and more stringent fixed effects.

We find that the coefficient of interest is positive, significant, and stable across specifications.[33] Taken together, our results show that banks purchased domestic government bonds in response to the LTRO, favoring short-term over long-term bonds. Column (5) includes bank-time and bank-maturity fixed effects, therefore ruling out a series of alternative explanations. For example, bank-time fixed effects ensure that our results are not driven by highly leveraged or politically connected banks, and bank-maturity fixed effects ensure that our results are not driven by bank-level preference for specific maturities, such as large banks demanding short-term bonds for regulatory purposes.

Aggregate Effects The LTRO had an economically significant effect on the demand for government debt, especially at shorter maturities. We measure the quantitative importance of our

[33] In the Online Appendix, we estimate (3) using the share of total public debt outstanding of maturity m held by bank i as a dependent variable.

LHS Var.: $\widetilde{\text{Holdings}}_{i,m,t}$	(1)	(2)	(3)	(4)	(5)
Post	0.323**	0.081**			
	(0.118)	(0.032)			
Post × Short			0.245**	0.245**	0.242**
			(0.107)	(0.081)	(0.098)
Bank FE	✓	✓	✓		
Maturity FE	✓	✓	✓	✓	
Time FE			✓		
Bank-Time FE				✓	✓
Bank-Maturity FE					✓
Specification	(2a)	(2b)	(3)	(3)	(3)
Sample Bonds	Short-Term	Long-Term	Full Sample	Full Sample	Full Sample
Observations	2,478	2,478	4,956	4,956	4,950
R-Squared	0.346	0.524	0.258	0.337	0.686

Table 2: LTRO and Government Bond Purchases. This table presents the results of specifications (2a) in column (1), (2b) in column (2), and (3) in columns (3)-(5). The dependent variable is the share of total public debt outstanding of maturity m held by bank i divided by the total assets of bank i relative to the assets of the financial sector. Independent variables include a Post dummy equal to one on and after December 2011 and a Short dummy equal to one if the government bond portfolio matures on or before February 2015 (LTRO maturity). Columns (1) and (2) only include bonds maturing on or before February 2015 and after February 2015, respectively. The sample period includes 12 months and runs at a monthly frequency from June 2011 to May 2012. This regression includes only institutions with access to the LTRO (banks and savings institutions). Standard errors double clustered at the bank-maturity and month levels are in parentheses. In Table C.1, we show estimation results with standard errors double clustered at the bank and month levels. In the Online Appendix, we show estimation results using the share of total public debt outstanding of maturity m held by bank i as a dependent variable. * p<0.10, ** p<0.05, *** p<0.01.

results calculating the aggregate effect of the LTRO on the demand for government bonds using the results of the first two columns of Table 2. For each bank-maturity observation in February 2012, we perform the following calculation:

$$\text{Demand Boost}_{i,m} = \hat{\beta}_m \frac{\text{Assets}_{i,\text{Feb12}}}{\text{Total Assets}_{\text{Feb12}}} \text{Amount Outstanding}_{m,\text{Feb12}}$$

where $\hat{\beta}_{\text{Short}}$ and $\hat{\beta}_{\text{Long}}$ are the estimates in specifications (2a) and (2b). The result is the effect of the announcement on the demand for a given maturity by a given bank, measured in euros. We aggregate these amounts across banks and find that the LTRO boosted demand for short-term bonds by €5.1 billion, or 10.6% of the amount outstanding. For long-term bonds, the demand boost was €2.4 billion, or 2.6% of the amount outstanding, leading to a total boost of €7.5 billion,

or 5.4% of the amount outstanding. Relative to the size of the banking sector, the total increase in holdings amounted to 1.3% of total assets: 0.9% for short-term and 0.4% for long-term bonds.

Placebo Test A potential concern with our differences-in-differences strategy is that the described effect might also be present in periods other than the treatment period, suggesting that our results might not be driven by the long maturity of central bank liquidity provision.

To investigate this possibility, we run placebo regressions simulating the application of the treatment in every month from December 2010 to June 2012. Interestingly, at the end of October 2011 a weaker treatment was actually in place as the ECB adopted a 12-month operation, long enough to allow banks to buy government bonds with matching or lower maturities.[34]

We run the following specification separately for every month between January 2011 and June 2012, indexing the month by τ:

$$\widetilde{\text{Holdings}}_{i,m,t} = \alpha + \beta_\tau \mathbb{I}_{t,\tau} \times \text{Short}_m + \eta_{i,t} + \xi_{i,m} + \epsilon_{i,m,t} \tag{4}$$

where $\mathbb{I}_{t,\tau}$ is an indicator variable equal to 1 if $t = \tau$ and 0 otherwise, $\eta_{i,t}$ are bank-time fixed effects, and $\xi_{i,m}$ are bank-maturity fixed effects. Short_m is a dummy equal to 1 for bonds in the first three maturity categories in February 2012.

In Figure 3, we plot the coefficients of the interaction term for each separate regression. The solid line shows the estimate for the coefficient of interest, and the dashed lines delimit its 95%

[34]The three-year-long maturity of the LTRO expanded the set of securities attractive for the collateral trade. Previous operations were "too short term" given the distribution of residual maturities for government bonds. In particular, three one-year LTRO were allotted in June 2009, December 2009, and October 2011. The first two operations happened during a period of relatively low sovereign stress (Portuguese 10-year sovereign yields below 5%) when the collateral trade was less attractive. Given that we observe holdings at a monthly frequency, we do not have sufficient observations not overlapping the December 2011 3Y-LTRO to re-estimate specifications (2a), (2b), (3) around the October 2011 1Y-LTRO. Finally, we do not observe bank-level 1Y-LTRO uptake and therefore cannot estimate (1) around the October 2011 1Y-LTRO.

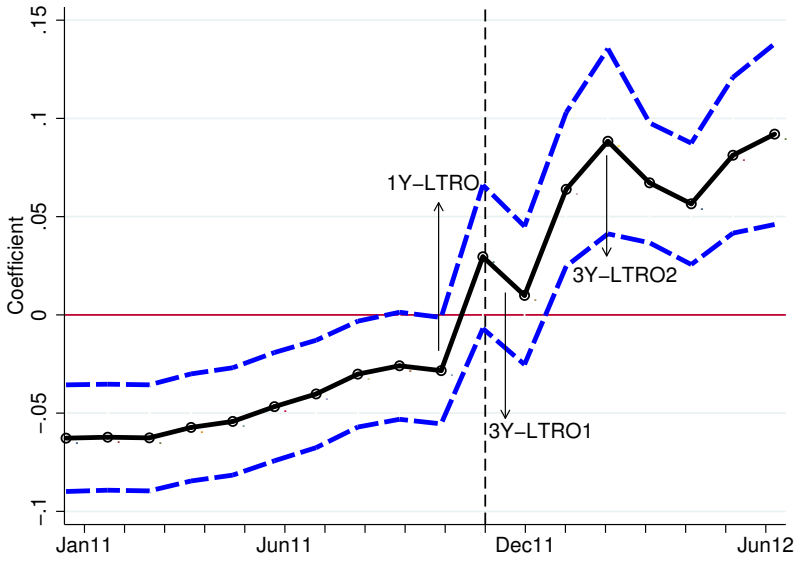

Figure 3: Placebo Test. This figure plots interaction coefficients from specification (4) estimated from January 2011 to June 2012. The dashed lines delimit the 95% confidence interval. Standard errors are double clustered at the bank-maturity and period level. The dashed vertical line indicates the date before of the LTRO announcement.

confidence interval. Before the LTRO, the coefficient is stable, close to zero, or even negative. In November 2011, the coefficient becomes positive, capturing the effect of the 1-year operation settled at the end of October and eventually replaced by the LTRO. The coefficient becomes positive and statistically significant during the allotment period when the collateral trade induced banks to purchase short-term bonds. As banks kept these bonds on their balance sheets, the coefficient remains positive and statistically significant after the allotment period.

Non-Banks as a Control Group Our identification strategy relies on the assumption that in the absence of the LTRO, banks would not have purchased more (short-term) government bonds after the announcement compared with the pre-period. So far, we have analyzed only banks, i.e. the subsample of financial institutions with access to ECB liquidity. We check the plausibility of the identification assumption by analyzing the behavior of non-banks that do not have access to ECB liquidity. We conduct two tests: We re-estimate specification (3) in the subsample of non-banks,

LHS Var.: $\frac{\text{Govt. Bond Holdings}_{i,m,t}}{\text{Amount Outstanding}_{m,t}}$	(1)	(2)	(3)	(4)	(5)	(6)
Post×Short×Access		0.332**	0.332**	0.327**	0.327**	0.104**
		(0.149)	(0.129)	(0.140)	(0.139)	(0.042)
Post×Short	-0.003	-0.003***	-0.003***	-0.003		
	(0.002)	(0.000)	(0.000)	(0.002)		
Short×Access		0.188**	0.188**			
		(0.078)	(0.069)			
Post×Access		0.044***				
		(0.004)				
Entity FE		✓				
Time FE		✓				
Maturity FE		✓	✓			
Entity-Time FE	✓		✓	✓	✓	✓
Entity-Maturity FE	✓			✓	✓	✓
Maturity-Time FE					✓	✓
Specification	(3)	(5)	(5)	(5)	(5)	(5)
Sample Institutions	Non-Banks	Full	Full	Full	Full	Full
Sample Bonds	Full	Full	Full	Full	Full	1-5Y
Observations	27,372	32,376	32,376	32,322	32,322	10,774
R-squared	0.944	0.300	0.386	0.698	0.700	0.964

Table 3: Access to ECB Liquidity and Government Bond Purchases. Column (1) of this table replicates specification (3) for the subsample of non-banks. Columns (2)-(5) present the results of specification (5), estimated in the full sample of banks and non-banks. Column (6) presents the results of specification (5), estimated in the subsample of bonds with residual maturity of 1-5 years. The dependent variable is the share of total public debt outstanding of maturity m held by institution i, not normalized by assets. Independent variables include a Post_t dummy equal to 1 on and after December 2011, a Short_m dummy equal to 1 if the government bond portfolio matures on or before February 2015 (LTRO maturity), and a Access_i dummy equal to 1 for institutions that have access to ECB liquidity (banks). The sample period runs monthly from June 2011 to May 2012. Standard errors double clustered at the bank-maturity and period levels are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

and we estimate the following triple differences-in-differences specification:

$$\frac{\text{Govt. Bond Holdings}_{i,m,t}}{\text{Amount Outstanding}_{m,t}} = \alpha + \beta \text{Post}_t \times \text{Short}_m \times \text{Access}_i + \eta_{i,t} + \xi_{i,m} + \mu_{m,t} + \epsilon_{i,m,t} \tag{5}$$

We run specification (5) in the full sample (banks and non-banks), where Access_i is a dummy equal to 1 if institution i is a bank. We saturate the regression with institution-time, institution-maturity, and time-maturity fixed effects. The dependent variable is no longer normalized by the size of the institution relative to the size of the financial system, as we do not observe assets for non-banks.

In column (1) of Table 3, we estimate specification (3) in the subsample of non-banks only. The estimated coefficient on the interaction term is close to zero and not statistically significant, evidence

that institutions with no access to ECB liquidity did not purchase more short-term bonds after the announcement. In columns (2)-(5), we present results for the triple differences-in-differences specification estimated in the full sample with progressively more stringent fixed effects. In all these specifications the triple interaction coefficient is positive, stable, and statistically significant, suggesting that institutions with access to the LTRO purchased more short-term than long-term bonds after the announcement compared with institutions with no access and relative to the pre-announcement period. In the last column, we estimate the specification in column (5) in the subsample of government bonds maturing in a 2-year narrow window around the LTRO maturity. We find that our results hold in this restricted subsample where short-term and long-term bonds have similar residual maturities.

Intensive Margin The collateral trade also suggests a positive correlation between how much a bank borrowed at the LTRO and its collateral trade activity. To investigate this relationship, we define the following variable:

$$\text{Intensity}_i = \frac{\text{LTRO}_i}{\text{Assets}_i}$$

where the numerator is bank i LTRO borrowing and the denominator is assets of bank i in November 2011. We then adapt specifications (2a), (2b), and (3) to include this new variable:

$$\widetilde{\text{Holdings}}_{i,m,t|m\in\text{Short}} = \alpha + \beta\text{Post}_t \times \text{Intensity}_i + \eta_i + \xi_t + \epsilon_{i,t} \tag{6a}$$

$$\widetilde{\text{Holdings}}_{i,m,t|m\in\text{Long}} = \alpha + \beta\text{Post}_t \times \text{Intensity}_i + \eta_i + \xi_t + \epsilon_{i,t} \tag{6b}$$

$$\widetilde{\text{Holdings}}_{i,m,t} = \alpha + \beta\text{Post}_t \times \text{Short}_m \times \text{Intensity}_i + \eta_{i,t} + \xi_{i,m} + \nu_{t,m} + \epsilon_{i,m,t} \tag{6c}$$

where the last specification includes bank-time, bank-maturity, and maturity-time fixed effects.

We show estimation results in Table 4. In columns (1)-(2) we find that banks that borrowed

LHS Var.: $\widetilde{\text{Holdings}}_{i,m,t}$	(1)	(2)	(3)	(4)	(5)	(6)
Post × Intensity	0.086***	0.019***				
	(0.017)	(0.004)				
Post × Short × Intensity			0.067***	0.067***	0.067***	0.065***
			(0.012)	(0.011)	(0.014)	(0.015)
Institution FE	✓	✓	✓			
Time FE	✓	✓	✓			
Maturity FE	✓	✓	✓	✓		
Institution-Time FE				✓	✓	✓
Institution-Maturity FE					✓	✓
Time-Maturity FE						✓
Specification	(6a)	(6b)	(6c)	(6c)	(6c)	(6c)
Sample Bonds	Short-Term	Long-Term	Full	Full	Full	Full
Observations	2,478	2,478	4,956	4,956	4,950	4,950
R-squared	0.409	0.548	0.361	0.401	0.702	0.702

Table 4: LTRO and Government Bond Purchases: Intensive Margin. This table presents the results of specifications (6a), (6b), and (6c). The dependent variable is the share of total public debt outstanding of maturity m held by bank i divided by the total assets of bank i relative to the assets of the financial sector. Columns (1) and (2) only include bonds maturing on or before February 2015 and after February 2015, respectively. Columns (3)-(6) include all bonds. This regression includes only entities with access to LTRO, i.e., banks. Independent variables include a Post_t dummy equal to one on and after December 2011, a Short_m dummy equal to one if the government bond portfolio matures on or before February 2015 (LTRO maturity), and an Intensity_i continuous variable equal to LTRO borrowing divided by assets in November 2011. The sample is monthly from June 2011 to May 2012. Standard errors double clustered at the bank and period levels are in parentheses. In Table C.2, we show estimation results with standard errors double clustered at the bank-bucket and month levels. * p<0.10, ** p<0.05, *** p<0.01.

more at the LTRO purchased more government bonds – especially short-term – compared with banks that borrowed less at the LTRO. The estimated coefficient on the triple interaction terms in columns (3)-(6) is positive, stable, and significant, confirming that the correlation between LTRO borrowing and purchases of government bonds is stronger for short-term securities.[35]

External Validity Finally, we show that banks in Italy and Spain, the two largest peripheral countries, also likely engaged in the collateral trade.[36] Figure 4 shows holdings of GIIPS (Greece, Ireland, Italy, Portugal, and Spain) and non-GIIPS sovereign bonds held by Italian (left panel) and

[35] In Figure B.1 in the Appendix, we replicate Figure 3 for specification (6c) and confirm that the correlation between LTRO borrowing and purchases of government bonds is positive and significant from November 2011 onward.

[36] Santos (2017) provides an excellent narrative of the Spanish banking crisis between 2008 and 2012. Carpinelli and Crosignani (2018) analyze the effect of the LTRO on bank lending in Italy.

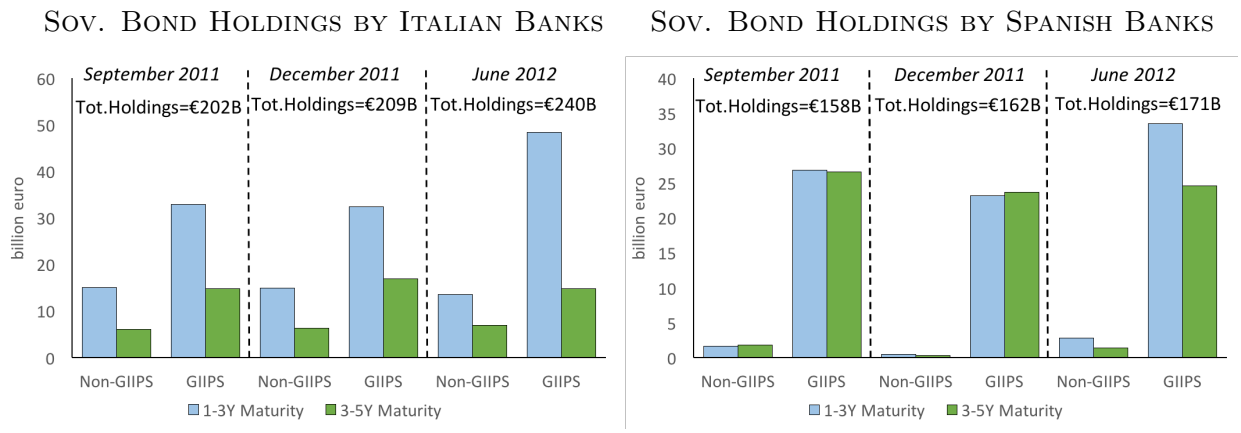

Figure 4: The Collateral Trade in Italy and Spain. This figure shows holdings of sovereign bonds of 1-3Y maturity (blue bars) and 3-5Y maturity (green bars) by Italian banks (left panel) and Spanish banks (right panel) at the time of the three EBA stress tests of September 2011, December 2011, and June 2012. Holdings are measured in billions of euro and disaggregated in holdings of GIIPS sovereign bonds and non-GIIPS sovereign bonds.

Spanish (right panel) banks in September 2011, December 2011, and June 2012 – the three stress test dates around the LTRO for which the European Banking Authority (EBA) has made data publicly available.[37]

Italian and Spanish banks in the EBA sample increased their holdings of sovereign bonds from €209 billion to €240 billion and from €162 billion to €171 billion between December 2011 and June 2012, respectively. The bar charts show holdings of bonds of comparable maturities around the LTRO three-year maturity: 1-3Y maturity holdings (light blue bars) and 3-5Y maturity holdings (dark green bars). Consistent with the collateral trade, we find that the sizable increase in total holdings is driven by GIIPS bonds with 1-3Y maturities, just shorter than the LTRO maturity.[38]

While this evidence is consistent with the collateral trade, the stress test data are too limited to formally test our predictions in countries other than Portugal. First, the EBA sample is limited

[37]The EBA is responsible for conducting stress tests on systemically important financial institutions in the European Union. The data are available on the EBA website.

[38]In Figure B.2 in the Appendix, we show that our findings are mostly driven by domestic bonds. In Figure B.3 in the Appendix, we show that our findings do not extend to core countries like Germany and France, where banks (i) could in general borrow in the private market at more favorable terms compared with the LTRO, (ii) could not use (low-yield) domestic government bonds to risk-shift, and (iii) were likely not subject to government moral suasion.

to a handful of very large banks in each country.[39] Second, the EBA reports holdings on only a few stress test dates, thus preventing us from checking whether the increase in holdings coincides with the LTRO allotment. Finally, the EBA does not report bank-level LTRO uptake.

4.3 Effect on Government Bond Yields

By increasing demand for short-term relative to long-term government bonds, the collateral trade should have resulted, for a given supply of bonds, in a steepening of the sovereign yield curve (Prediction 3).[40] In this section, we analyze government bond yields across eurozone countries and provide evidence consistent with this prediction. Given that the collateral trade is more profitable if banks purchase *high-yield* bonds (especially if domestic, due to underpricing of default risk by domestic banks), we should observe a steepening of the yield curve in risky, but not in safe, countries.

Figure 5 plots the evolution of the slope of the sovereign yield curves – defined as the 10-year minus the 1-year yield – for three peripheral (Italy, Spain, and Portugal) and three core (Germany, France, and the Netherlands) countries between June 2011 and May 2012. We observe a structural break corresponding to the LTRO announcement (dashed vertical line): The slope in Italy and Spain is decreasing before and rises by about 300 basis points after.[41] The opposite is true for Germany and the Netherlands, where the slope declines over this period. France experiences a modest steepening that begins well before the announcement date.

[39] Five Italian banks, four Spanish banks, four Portuguese banks, three Irish banks and no Greek banks participated in the September 2011, December 2011, and June 2012 EBA stress tests.

[40] This prediction is the result of market segmentation in the spirit of Vayanos and Vila (2009), as government bonds of different maturities are imperfect substitutes for banks that have access to LTRO liquidity. Note that we would need a structural model to carefully characterize the equilibrium implications of the collateral trade. Such analysis goes beyond the scope of this paper.

[41] The Portuguese slope is not available for the entire sample, as there are no securities with 1-year residual maturity between October 26, 2011, and February 20, 2012. However, pre- and post-announcement observations are consistent with a steepening during the LTRO period.

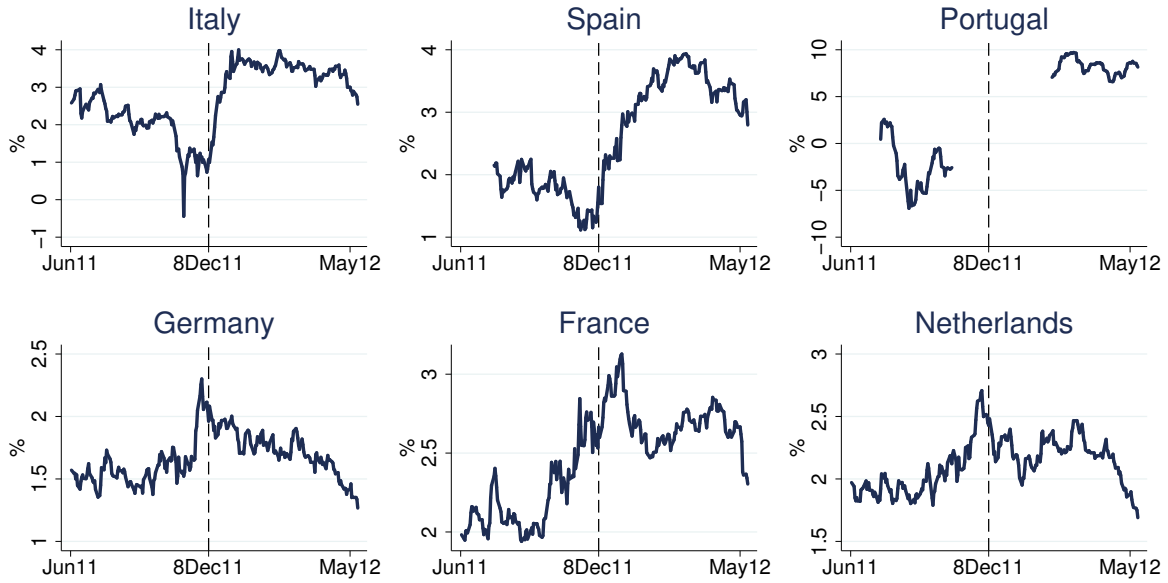

Figure 5: Slope of the Sovereign Yield Curve. This figure plots daily time series for the slope of the sovereign yield curve in three peripheral (Italy, Spain, and Portugal) and three core (Germany, France, and the Netherlands) countries. The slope is defined as the 10-year yield minus the 1-year yield. The dashed vertical line corresponds to the LTRO announcement. Portuguese yield data are not available on Bloomberg for parts of the sample.

We rule out that the observed steepening in peripheral countries is driven by changes in the supply of government bonds. We analyze public debt issuance from June 2011 to May 2012 and find that the supply of sovereign bonds was approximately constant across maturities for Italy and Spain. In Portugal, issuance of short-term public debt increased after the announcement, which would go against our results, as short-term yields should *rise* in response to higher supply of short-term sovereign bonds.[42] The change in slope on the day of the LTRO announcement also rules out that the observed pattern of sovereign yields might be driven by the ongoing ECB purchases of short-term securities in the secondary market under the Securities Markets Programme (SMP).[43]

In a frictionless world, we should observe the steepening of the entire yield curve happening on

[42] In Figure B.4 in the Appendix, we show monthly public debt issuance in Portugal, Italy, and Spain.

[43] Krishamurthy et al. (forthcoming) show that the average remaining maturity of Portuguese bonds in the SMP portfolio was approximately five years during 2011, suggesting that most purchases were made at longer maturities. The contemporaneous SMP effect would therefore flatten, not steepen, the yield curve.

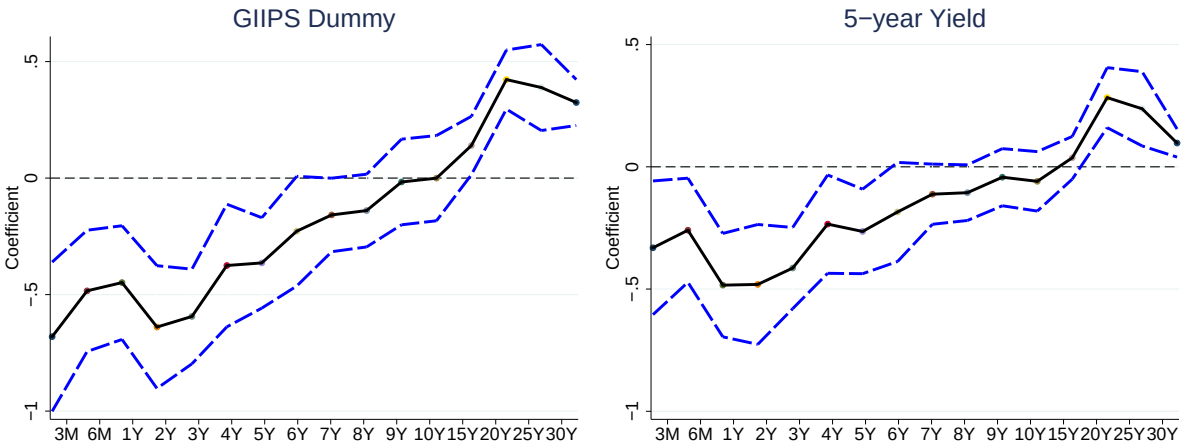

Figure 6: Yield Curve Steepening. This figure plots the $\beta_{(m)}$ estimates of specification (7) as a function of maturity (m). Regressions are estimated separately for each maturity; the sample period is daily from November 29 to December 19; and sample countries are the Netherlands, Portugal, Spain, France, Ireland, Belgium, Germany, Italy, Austria, Finland, Cyprus, Slovakia, and Slovenia. In the left panel, Risk is a dummy equal to 1 for Ireland, Italy, Spain, and Portugal. In the right panel, Risk is the log of the 5-year yield on November 28, 2011. In the Online Appendix, we replicate this figure for the 1-Year LTRO allotted in October 2011. Dashed lines delimit the 99% confidence interval. Standard errors are robust. Source: Bloomberg.

the announcement date rather than gradually over the following few months. The gradual change observed in the data is likely due to the low liquidity in sovereign bond markets during this period and constraints affecting peripheral banks, which are among the most active participants in these markets. In sum, a non-negligible component of prices is likely due to binding constraints, liquidity premia, and other factors beyond the expected present discounted values of these securities' cash flows.

We complement this evidence by analyzing parametrically how yields at different maturities across countries behaved in a narrow window around the LTRO announcement. Our prediction implies that the announcement should cause short-term yields to fall in peripheral countries relative to core countries. We estimate the following specification in the 14 business day window around

the LTRO announcement from November 29 to December 19[44]:

$$y_{i,t}^{(m)} = \alpha + \beta_{(m)}\text{Post}_t \times \text{Risk}_i + \eta_i + \delta_t + \epsilon_{i,t} \tag{7}$$

where $y_{i,t}^{(m)}$ is the sovereign yield for country i at day t and at maturity (m), Post_t is a time dummy that is equal to one on and after the announcement on December 8, Risk_i is a time-invariant measure of sovereign risk, and η_i and δ_t are country fixed effects and day fixed effects, respectively. We use two measures of sovereign risk: a dummy variable equal to one if the country is peripheral (Ireland, Italy, Spain, Portugal), and the log of the 5-year yield on November 28, 2011. We estimate separate regressions for each maturity term (m).[45] Our sample includes all eurozone countries except for Greece, for which government bond yields are unavailable at all maturities.[46]

Figure 6 shows the point estimates for the $\beta_{(m)}$ coefficient as a function of maturity (m) with 99% confidence bands, using the peripheral dummy (left panel) and the log yield (right panel). The figure shows that shorter-term yields in riskier countries significantly fell after the LTRO announcement relative to shorter-term yield in core countries, while longer-term yields increased.[47] Thanks to these price changes, we find that the Italian, Spanish, and Portuguese sovereigns saved €10 billion, €3 billion, and €1 billion in their public debt issuance in the six months after the LTRO (respectively), a possibly unstated objective of the policy.[48]

[44]Our results are robust to changing this window.

[45]In the Online Appendix, we replicate this estimation around the announcement of the October 2011 1Y-LTRO. In that context, we also find a stark reduction of sovereign yields matching the maturity of central bank liquidity.

[46]By focusing on a short window around the LTRO, we can take the government bond supply as given, as bond issuances are pre-determined in publicly available calendars released by public debt management agencies (and bond maturities are known at the time of issuance). We manually check that there were no changes to the issuance calendar between November 29 and December 19, 2011, for Italy, Ireland, Portugal, and Spain.

[47]These results are also consistent with lower sovereign credit risk causing a steepening of the yield curve (Asonuma et al., 2017).

[48]We obtain these numbers using the following back-of-the-envelope calculations. First, we generate a collection of estimates β from (7). Second, for each maturity m, county i, and day t, we compute counterfactual yields

5 Discussion

Having presented supporting evidence for the collateral trade, we now discuss three questions that arise naturally from our analysis. First, how did banks fund the collateral trade? Second, which banks engaged in the collateral trade the most? Third, how much did banks profit from it?

5.1 Funding the Collateral Trade

Banks that wanted to engage in the collateral trade needed to buy the securities *before* pledging them at the central bank. The timing of this strategy is the key difference compared with a standard carry trade in which banks buy high-yield securities after securing funding.

Table 5 aggregates the balance sheets of our sample banks in November 2011 (before the LTRO announcement) and February 2012 (at LTRO2) and shows levels and changes for several balance sheet items. We observe that (i) the aggregate balance sheet size increased from €571 billion to €583 billion; (ii) wholesale funding increased through security issuance; (iii) book equity was mostly stable (leading to a small increase in leverage); and (iv) private credit, particularly for non-financial firms, fell by around €4 billion. Taken together, these findings suggest that the collateral trade was likely funded by an increase in borrowing and a decrease in private credit.

5.2 Bank Heterogeneity

According to the collateral trade, *all* banks should have purchased government bonds during the allotment period. In columns (3) and (4) of Table 6, we divide our sample into banks that engaged

$y_{i,t}^{(m),cf} = y_{i,t}^{(m)} - \hat{\beta}^{(m)} Post_t \times Risk_i$. Third, for each issuance between December 8, 2011 (LTRO announcement) and July 26, 2012 (OMT speech), we compute savings assuming that amounts issued are constant and principal payments change with yields. In particular, we treat bonds as zero coupon securities and discount future savings using Eonia/OIS as of December 8, 2011. Fourth, we sum savings by country.

	Nov11 €M	Feb12 €M	Change €M	Change % Assets
Total Assets	571,235	582,656	11,421	2.0
Cash	1,603	1,477	-126	0.0
Securities	139,879	151,540	11,661	2.0
Equities	24,930	26,864	1,935	0.3
Total Private Credit	292,830	288,814	-4,016	-0.7
Lending to Firms	121,363	117,561	-3,802	-0.7
Lending to Households	143,149	142,422	-728	-0.1
Lending to Banks	69,778	72,227	2,449	0.4
Other Assets	42,216	41,734	-482	-0.1
Total Liabilities	571,235	582,656	11,421	2.0
Equity	42,045	42,587	542	0.1
Securities Issued	90,809	98,103	7,294	1.3
ECB Total	45,724	47,611	1,888	0.3
Borrowing from Banks	164,448	165,349	902	0.2
Deposits	195,481	197,223	1,742	0.3
Repo	7,760	6,403	-1,357	-0.2

Table 5: Banking Sector Aggregate Balance Sheet. This table shows the aggregate banking sector balance sheet in November 2011 and February 2012. Quantities are in millions of euros. The last column displays the change as a % of assets in November 2011.

in the collateral trade and banks that did not engage in the collateral trade and analyze their balance sheet characteristics. The 15 banks that engaged in the collateral trade are the largest banks, responsible for 83% of total LTRO borrowing in Portugal.[49] In the last column, we compute correlations between balance sheet variables measured in November 2011 and bank-level purchases of government bonds for these 15 banks. We find that banks that purchased more government bonds tend to be smaller, have lower leverage, and hold relatively larger portfolios of securities.

Our evidence suggests that large banks, usually counterparties of ECB open market operations, engaged in the collateral trade. Within this group, healthier banks with likely easier access to funding engaged in the collateral trade the most, consistent with the need to buy government bonds

[49] The small number of banks that engage in the collateral trade limits the extent to which we can further exploit across-bank heterogeneity.

Variable (BS)	Unit	Sample: No Trade Nov11 Mean	Sample: Trade> 0 Nov11 Mean	Sample: Trade> 0 $corr(BS, Trade)$
Number of Banks		54.0	15.0	
Total Assets	bn euro	2.4	29.4	−53.2 %
Leverage	A/E	6.0	11.0	−25.2 %
Securities	% Assets	10.6	25.4	41.8 %
Govt. Bonds	% Assets	2.3	6.3	51.6 %
Lending to Firms	% Assets	27.7	17.2	−35.1 %
Lending to Households	% Assets	21.9	15.5	−19.9 %
Securities Issued	% Assets	1.7	9.8	−27.7 %
ECB Borrowing	% Assets	1.7	9.4	30.8 %
Deposits	% Assets	29.8	30.7	−14.3 %
Short-term Funding	% Assets	57.7	59.8	26.4 %

Table 6: Bank Characteristics and Government Bond Purchases. This table shows bank characteristics and collateral trade activity. The third (fourth) column shows cross-sectional means in November 2011 for the group of banks with zero (strictly positive) collateral trade activity. The fifth column shows the correlation between each balance sheet variable and the collateral trade activity in the subsample of institutions that have strictly positive collateral trade activity. Collateral trade activity is defined as government bond purchases between November 2011 and February 2012, divided by assets in November 2011. Securities are holding of securities, except equities. Short-term funding refers to securities issued with a maturity of less than one year, short-term deposits, and repurchase agreements. In the last column, total assets is the natural logarithm of total assets.

before obtaining LTRO liquidity. These findings are also consistent with Carpinelli and Crosignani (2018), who find that Italian banks with less runnable liabilities purchased more government bonds in this period, and with Abbassi et al. (2016), who find that better capitalized banks increased their investments in securities during the crisis.

5.3 Collateral Trade Profits

As bond prices changed after the LTRO, the collateral trade generated ex-post profits.[50] We compute three profit measures for each bank. The first is a narrow measure of "LTRO profits," equal to the change in value between November 2011 and February 2012 of the November 2011 government bond portfolio. The second measure extends the time horizon to August 2012, therefore including the drop in yields that followed the Outright Monetary Transactions (OMT) program

[50] These profits effectively constituted a "stealth recapitalization" in the sense of Brunnermeier and Sannikov (2013). Note that these profits are not necessarily caused by the LTRO, as prices are also likely affected by other factors.

announcement. The third measure computes gains on government bonds purchased during the allotment period following the OMT announcement. More formally, we define these measures as

$$\Pi_i(\text{LTRO}) = \sum_{j \in \mathcal{J}} \Delta p_{j,\text{Nov11-Feb12}} \times Q_{i,j,\text{Nov11}} \tag{8a}$$

$$\Pi_i(\text{LTRO + OMT}) = \sum_{j \in \mathcal{J}} \Delta p_{j,\text{Nov11-Aug12}} \times Q_{i,j,\text{Nov11}} \tag{8b}$$

$$\Pi_i(\text{Collateral Trade + OMT}) = \sum_{j \in \mathcal{J}} \Delta p_{j,\text{Feb12-Aug12}} \times \Delta Q_{i,j,\text{Nov11-Feb12}} \tag{8c}$$

where j is a security, $\mathcal{J}$ is the set of government bonds outstanding in our sample period, i is a bank, $\Delta p_{j,t-T}$ is the change in market price of security j between t and T, and $Q_{i,j,t}$ is the amount of security j held by bank i at time t measured at face value.[51]

We present the results of this computation in Table 7. The combined price movements during the LTRO and the OMT constituted a sizable stealth recapitalization of Portuguese banks of about 7.2% of book equity in the first half of 2012.[52] The collateral trade purchases exposed banks further to the coming price increases, constituting an additional 1.8% of equity in profits. Our calculations likely represent a lower bound, as (i) we ignore bonds maturing between these months and (ii) other asset prices are also affected through equilibrium and portfolio rebalancing effects.[53] These numbers are economically large, even when compared with *direct* recapitalizations. For example, the U.S. Capital Purchase Program consisted of a $197.5 billion injection, equivalent to 16.5% of book equity (1.7% of total assets).[54]

[51] We compute mark-to-market profits on the entire government bond portfolio, regardless of bonds being in the banking or trading book. Our choice better captures the true portfolio value should the bank decide to sell these bonds in the secondary market or pledge them in repo operations.

[52] Acharya et al. (2017) find that the OMT announcement caused gains of 8% of equity for banks.

[53] As the value of government bonds increases and constraints are relaxed, financial intermediaries also become less likely to fire sell other assets, which in turn raises their prices. We do not quantify this portfolio balance channel.

[54] The Capital Purchase Program was the direct equity purchase program of the Troubled Asset Relief Program

Profits Π_i	Total	% Assets	% Equity
LTRO	€584 M	0.10%	1.39%
LTRO + OMT	€3,023 M	0.53%	7.19%
Collateral Trade + OMT	€775 M	0.14%	1.84%

Table 7: Collateral Trade Profits. This table shows the profit measures defined in (8a)-(8c) aggregated across the entire banking system $\sum_{i \in N} \Pi_i$. The first column shows the total value in millions of euros. The second (third) column shows the total value divided by total assets (total book equity).

6 Conclusion

We analyze the design of lender-of-last-resort interventions in the context of the largest liquidity injection in the history of central banking: the three-year LTRO announced by the ECB in December 2011. We show that the provision of long-term liquidity induced banks to engage in a collateral trade by purchasing high-yield eligible collateral securities with maturity equal to or shorter than the central bank loan in order to mitigate the risk associated with this trade.

While our analysis is purely positive, we believe that it sheds light on the trade-offs that should be considered when analyzing the desirability of this type of interventions. On the one hand, our findings are consistent with stabilizing effects on the banking sector (ex-post profits led to an implicit recapitalization) and the sovereign (lower yields due to higher demand for bonds) during a time of great distress. On the other hand, as banks almost exclusively used domestic government bonds, not only did this policy intensify the bank-sovereign "doom loop," but also effectively consisted of indirect financing of government debt by the ECB, which may be at odds with the monetary authority's mandate and raise a plethora of other questions.

Our findings contribute to the comparative analysis of unconventional monetary policies, such as large-scale asset purchases (LSAP). In our setting, the central bank engages in *indirect* purchases of short-term assets. Increased demand leads to a steepening of the yield curve and to a reduction

(TARP). This number corresponds to the October-December 2008 period, when the bulk of the funds was disbursed.

of the aggregate maturity mismatch, as banks increase the maturity of their liabilities. In contrast, LSAP programs such as the ones conducted by the Federal Reserve (QE, MEP) consist of *direct* purchases of longer-term assets, leading to a flattening of the yield curve and to a reduction of the aggregate maturity mismatch of the private sector, by reducing the average maturity of assets outstanding.

Our analysis uncovers previously unexplored effects of the design of central bank liquidity provision during crises. The effects on the aggregate maturity mismatch of the private sector and sovereign yield curve inform policies aimed at restoring financial stability and promoting macroeconomic stabilization. These are very interesting avenues for future research.

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A Model of the Collateral Trade

In this section, we develop a model of the collateral trade. In the Online Appendix, we include additional derivations and present a simple model that explicitly takes into account margin calls.

A.1 Setup

The economy lasts for three periods, $t = 0, 1, 2$, and is populated by a continuum of domestic banks and international investors. At the beginning of $t = 0$, banks can invest in short- and long-term bonds, maturing at $t = 1$ and $t = 2$, respectively. Banks care only about their profits at the end of $t = 2$, when all assets have matured. At $t = 1$, short-term debt matures and banks can rebalance their long-term debt portfolios. International investors may purchase this long-term debt, but their valuation of the asset is uncertain. Thus, the only source of uncertainty in the model is the price of long-term debt at $t = 1$. The timeline of the model is shown in Figure A.1.

Banks Banks are risk-neutral and care only about their profits at the end of the final period, $\mathcal{U} = \mathbb{E}_0[\pi_2]$. Banks can rebalance their portfolios at $t = 1$: They enter this period with available resources $W_1 \in \mathbb{R}$ and can rebalance their long-term debt portfolio b'_L or save/borrow resources d. When $d \geq 0$, banks save resources at a unit return between $t = 1$ and $t = 2$. When $d < 0$, banks borrow from external funding markets at a linear cost $\kappa > 1$. Profits at $t = 2$ can be written as

$$\pi_2 = b'_L + d\left\{\mathbb{1}[d \geq 0] + \kappa \mathbb{1}[d < 0]\right\}$$

and the flow of funds constraint for banks at $t = 1$ is

$$q_1 b'_L + d = W_1$$

where q_1 is the price of long-term debt at $t = 1$. Available resources W_1 result from choices made at $t = 0$: In this initial period, banks can purchase short-term bonds b_S or long-term bonds b_L, accumulate cash c, or borrow from money markets/lenders of last resort €. Both short-term bonds and cash yield a unit return, while money market borrowing has a linear cost of R. Available resources can then be written as

$$W_1 = b_S + q_1 b_L + c - R€$$

At $t = 0$, the bank has access to initial resources $W_0 > 0$. It faces a budget constraint given by

$$W_0 + € = q_S b_S + q_L b_L + c \tag{A.1}$$

as well as a collateral constraint on external borrowing, stating that € cannot exceed a weighted average of the value of pledgeable assets

$$€ \leq (1 - h_L) q_L b_L + (1 - h_S) q_S b_S \tag{A.2}$$

where h_L, h_S are the haircuts on long- and short-term debt, respectively.[55]

International Investors International investors are risk-neutral, deep-pocketed traders who operate in secondary markets for long-term debt at $t = 1$. Their demand for debt is perfectly elastic, but their valuation/outside option is uncertain, $a \sim F^a \subseteq [\underline{q}, \bar{q}]$, with $\bar{q} < 1$. For this reason, they determine the price of long-term debt at $t = 1$, purchasing if and only if $q_1 \leq a$.

[55] This modeling device reflects the fact that most wholesale and central bank borrowing is undertaken through repurchase agreements, and public debt is a prime source of collateral for these contracts.

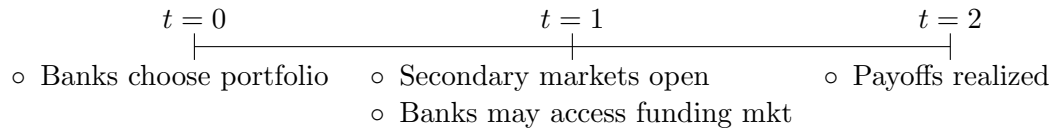

Figure A.1: Timeline for the Model.

A.2 Equilibrium

There are three markets: long-term debt at $t = 1$ and $t = 0$ and short-term debt at $t = 0$. At $t = 1$, international investors determine the bond price as $q_1 = a$. A detailed solution to the banks' problem is described in the Online Appendix. We let $\kappa \to \infty$ to reflect prohibitive costs of accessing funding markets at $t = 1$; this assumption captures a motive to hold liquid reserves and reflects difficulties in accessing private funding markets. It effectively makes the bank risk-averse and is equivalent to imposing a liquidity constraint on the banks' balances at $t = 1$, $W_1 \geq 0$. An equilibrium is a pair of prices (q_S, q_L) and bank policies at $t = 0$ and $t = 1$ such that banks optimize and all markets clear. We characterize the equilibrium in terms of thresholds over $\omega \equiv \frac{W_0}{B}$ (the ratio of initial bank resources to the stock of government debt) and initial borrowing cost R. The following proposition illustrates the regimes that can arise depending on the model's parameters.

Proposition 1. *The equilibrium is characterized as follows:*

1. *For $R\omega \geq \gamma + \tilde{q}(1-\gamma)$, banks do not borrow, €$= \delta = \eta = 0$, and prices satisfy*

$$q_S = \frac{\omega}{\gamma + \tilde{q}(1-\gamma)} \quad ; \quad q_L = \frac{\tilde{q}\omega}{\gamma + \tilde{q}(1-\gamma)}$$

2. *For $R\omega \in \left[\min\{(\tilde{q} - \underline{q})(1-\gamma), h_S\gamma + h_L\tilde{q}(1-\gamma)\}, \gamma + \tilde{q}(1-\gamma)\right]$, banks borrow, €$> 0$, but no constraints are binding, $\delta = \eta = 0$, and prices satisfy*

$$q_S = \frac{1}{R} \quad ; \quad q_L = \frac{\tilde{q}}{R}$$

3. *For $R\omega \in \left[(\tilde{q} - \underline{q})(1-\gamma), h_S\gamma + h_L\tilde{q}(1-\gamma)\right]$, the collateral constraint binds, $\delta > 0$, but the*

liquidity constraint does not, $\eta = 0$. Prices solve the following system

$$\omega = h_S q_S \gamma + h_L q_L (1-\gamma)$$

$$q_S = \frac{1}{R + \delta h_S} \quad ; \quad q_L = \frac{\tilde{q}}{R + \delta h_L}$$

4. *For $R\omega \in \left[h_S\gamma + h_L\tilde{q}(1-\gamma), (\tilde{q} - \underline{q})(1-\gamma)\right]$, the liquidity constraint binds, but the collateral constraint does not. Prices satisfy*

$$q_S = \frac{1}{R} \quad ; \quad q_L = \frac{\tilde{q} + \eta \underline{q}}{R(1+\eta)}$$

$$\textit{where} \qquad \eta = \frac{(\tilde{q} - \underline{q})(1-\gamma)}{R\omega} - 1$$

5. *For $R\omega < \min\{(\tilde{q} - \underline{q})(1-\gamma), h_S\gamma + h_L\tilde{q}(1-\gamma)\}$, both the liquidity and the collateral constraints bind. Prices satisfy*

$$q_S = \frac{1}{R}\frac{h_L(\gamma + \underline{q}(1-\gamma)) - (1-h_L)R\omega}{\gamma(h_L - h_S)} \quad ; \quad q_L = \frac{1}{R}\frac{(1-h_S)R\omega - h_S(\gamma + \underline{q}(1-\gamma))}{(1-\gamma)(h_L - h_S)}$$

The model equilibrium depends on the value of $R\omega$. When $R\omega$ is very high, either borrowing costs are prohibitive or banks have ample resources. In either case, banks do not borrow. Once either R or ω fall, banks start borrowing. There is a region where constraints do not bind and banks borrow to purchase short-term and long-term debt at risk-neutral prices: There is complete pass-through of the costs of external financing to government yields. If either R or ω decrease further, one or more constraints start binding. For these regions, as either $\delta > 0$, or $\eta > 0$, or both, there will be a preference for short-term debt. This preference means that a transition from one of the previous regions will be associated with a larger increase (or smaller decrease) in the price of short-term debt relative to long-term debt – that is, with a steepening of the yield curve.

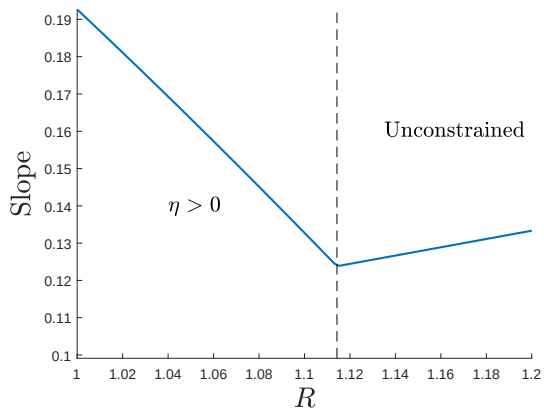

Figure A.2: Model Effects of the LTRO. This figure plots the slope of the sovereign yield curve as a function of borrowing costs R. The dashed line indicates the transition from an unconstrained equilibrium to one where the liquidity constraint binds, $\eta > 0$.

The LTRO The LTRO is modeled as a comparative static on R: we assume that external borrowing costs R_0 are initially prohibitive and the allotment period corresponds to an improvement of these conditions, $R_1 < R_0$.[56] We maintain throughout that haircuts are constant and the haircut on short-term debt is smaller, $h_S < h_L$.[57] Keeping ω constant, a large enough decrease in R can cause the equilibrium regime to change: The economy can switch from an unconstrained equilibrium to one where banks are constrained and thus have a preference for short-term debt.

Figure A.2 plots the slope of the yield curve as a function of R. For high levels of R, the bank is unconstrained and the slope of the yield curve behaves in the usual manner: if borrowing costs decrease, the slope decreases. However, if the decrease in R is large enough to bring the economy to an equilibrium where liquidity (or collateral) constraints bind, the sign of the relationship inverts: Due to the preference for short-term debt, a decrease in borrowing costs can *increase* the slope of the yield curve. We argue that this is the empirically relevant region.

[56] While Portuguese banks could have potentially borrowed in wholesale markets at longer maturities, the interest rate was prohibitive. We thus model the LTRO as a decrease on the interest rate for wholesale funding at a maturity that is large enough such that it matches (or exceeds) the maturity of some of the assets that can be pledged as collateral (short-term bonds, which we interpret as bonds with maturity shorter than three years).

[57] During the allotment period, the haircuts applied by the Eurosystem to Portuguese bonds ranged from 5.5% for bonds with maturity less than one year to 10.5% for bonds with maturity greater than ten years.

B Additional Plots

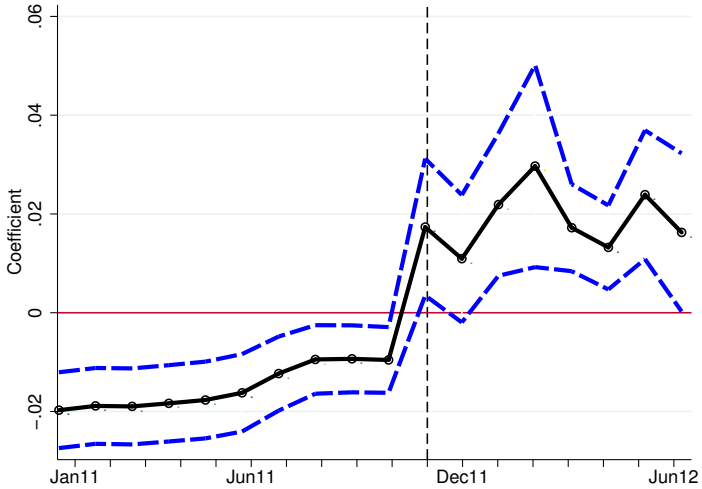

Figure B.1: Placebo Test, Intensive Margin. This figure plots interaction coefficients from a modified version of specification (4), where the interaction term is further multiplied by *Intensity*. The sample period is from January 2011 to June 2012. The dashed lines delimit the 95% confidence interval. Standard errors are double clustered at the bank-maturity and period level. The dashed vertical line indicates the last date before the LTRO announcement.

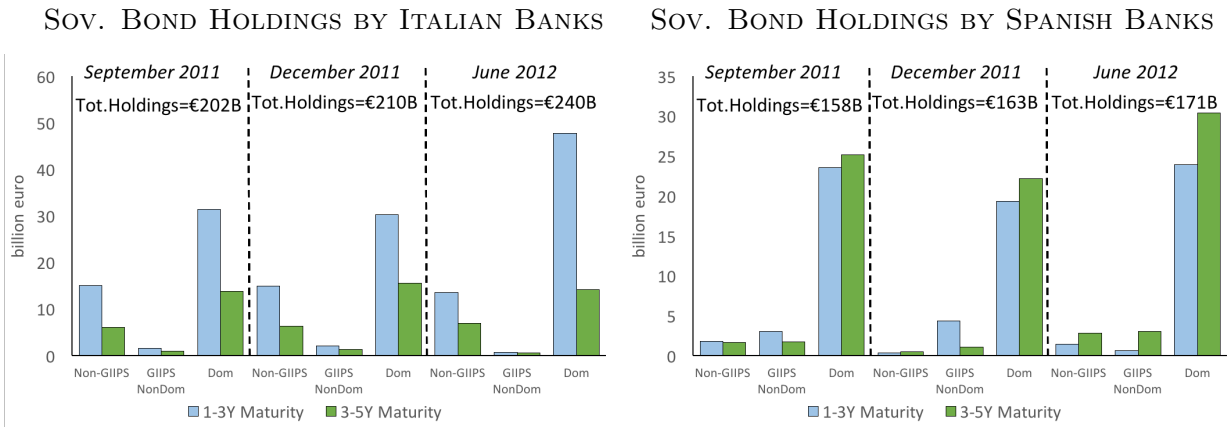

Figure B.2: The Collateral Trade in Italy and Spain: Non-GIIPS, GIIPS Non-Domestic, and Domestic Holdings. This figure shows holdings of sovereign bonds of 1-3Y maturity (light blue bars) and 3-5Y maturity (dark green bars) by Italian banks (left panel) and Spanish banks (right panel) at the time of the three stress tests of September 2011, December 2011, and June 2012. Holdings are in billions of euro and disaggregated in holdings of non-GIIPS, GIIPS non-domestic, and domestic sovereign bonds.

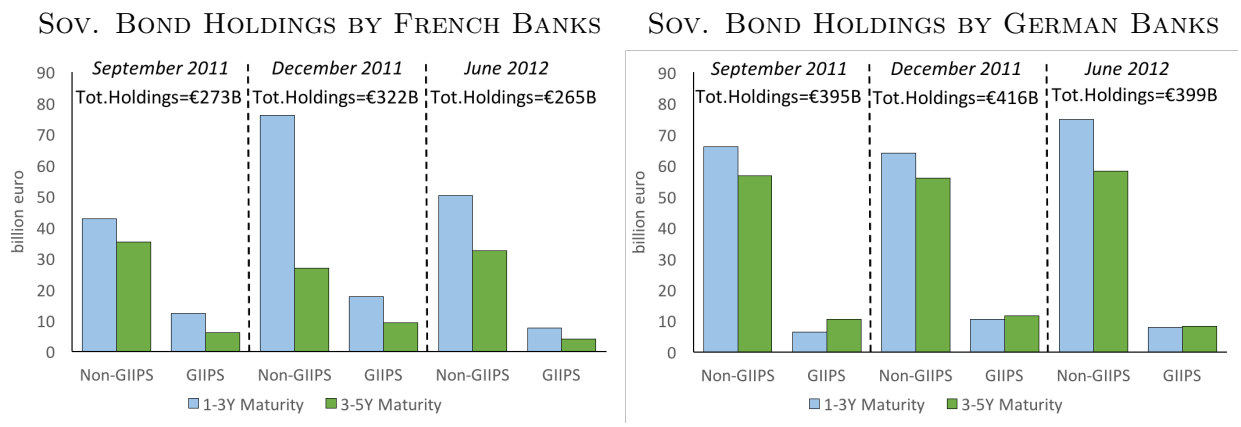

Figure B.3: The Collateral Trade in France and Germany. This figure shows holdings of sovereign bonds of 1-3Y maturity (light blue bars) and 3-5Y maturity (dark green bars) by French banks (left panel) and German banks (right panel) at the time of the three stress tests of September 2011, December 2011, and June 2012. Holdings are measured in billions of euro and disaggregated in holdings of GIIPS and non-GIIPS sovereign bonds.

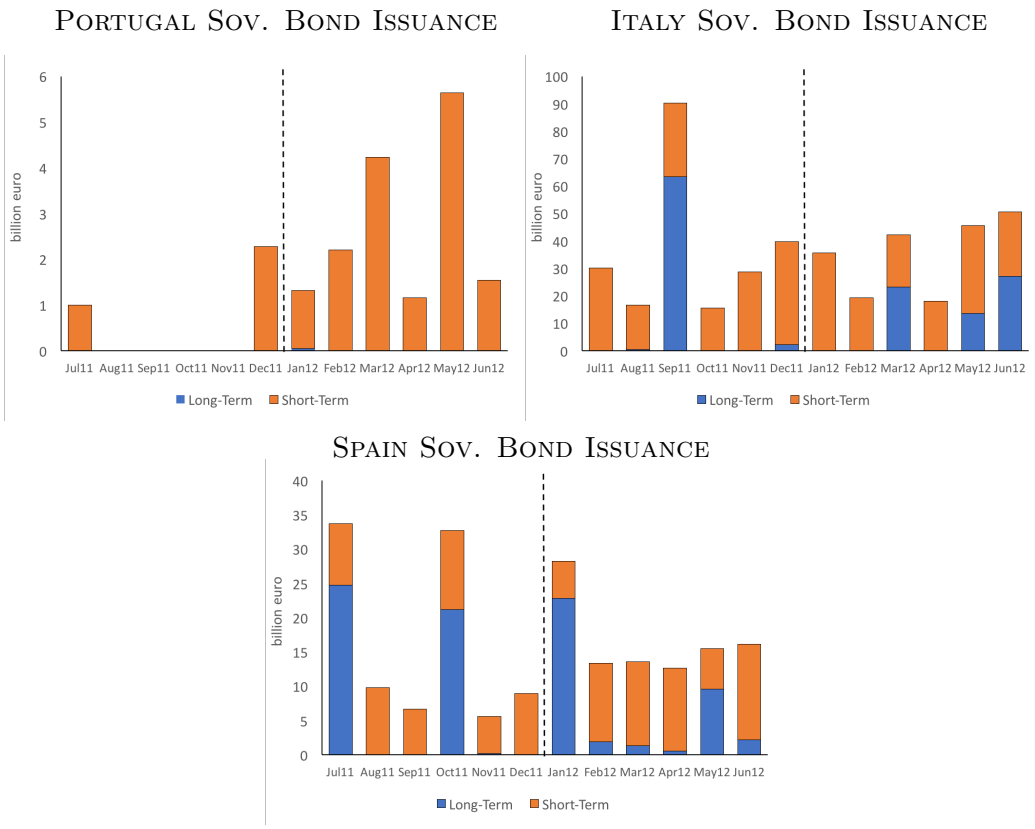

Figure B.4: Public Debt Issuance. This figure shows monthly public debt issuance (billions of euro) in Portugal, Italy, and Spain. The blue (orange) bars correspond to issuance maturing after (before) the LTRO. Source: Bloomberg.

C Additional Tables

LHS Var.: $\widetilde{\text{Holdings}}_{i,m,t}$	(1)	(2)	(3)	(4)	(5)
Post	0.323*	0.081*			
	(0.154)	(0.044)			
Post × Short			0.245**	0.245**	0.242*
			(0.104)	(0.104)	(0.128)
Bank FE	✓	✓	✓		
Maturity FE	✓	✓	✓	✓	
Time FE			✓		
Bank-Time FE				✓	✓
Bank-Maturity FE					✓
Specification	(2a)	(2a)	(3)	(3)	(3)
Sample Bonds	Short-Term	Long-Term	Full Sample	Full Sample	Full Sample
Observations	2,478	2,478	4,956	4,956	4,950
R-squared	0.346	0.524	0.258	0.337	0.686

Table C.1: LTRO and Government Bond Purchases, Alternative Clustering. This table presents the results of specifications (2a) in column (1), (2b) in column (2), and (3) in columns (3)-(5). The dependent variable is the share of total public debt outstanding of maturity m held by bank i divided by the assets of bank i relative to the assets of the financial sector. Independent variables include a Post dummy equal to one on and after December 2011 and a Short dummy equal to one if the government bond portfolio matures on or before February 2015. Column (1) and column (2) only include bonds maturing on or before and after February 2015, respectively. The sample period includes 12 months and runs at a monthly frequency from June 2011 to May 2012. The sample includes only banks. Standard errors double clustered at the bank and month levels are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

LHS Var.: $\widetilde{\text{Holdings}}_{i,m,t}$	(1)	(2)	(3)	(4)	(5)	(6)
Post × Intensity	0.086***	0.019*				
	(0.028)	(0.009)				
Post × Short × Intensity			0.067**	0.067**	0.067*	0.065*
			(0.028)	(0.027)	(0.034)	(0.031)
Entity FE	✓	✓	✓			
Time FE	✓	✓	✓			
Maturity FE	✓	✓	✓	✓		
Entity-Time FE				✓	✓	✓
Entity-Maturity FE					✓	✓
Time-Maturity FE						✓
Specification	(6a)	(6b)	(6c)	(6c)	(6c)	(6c)
Sample Bonds	Short-Term	Long-Term	Full	Full	Full	Full
Observations	2,478	2,478	4,956	4,956	4,950	4,950
R-squared	0.409	0.548	0.361	0.401	0.702	0.702

Table C.2: LTRO and Government Bond Purchases: Intensive Margin, Alternative Clustering. This table presents the results of specifications (6a), (6b), and (6c). The dependent variable is the share of total public debt outstanding of maturity m held by bank i 2adivided by the assets of bank i relative to the assets of the financial sector. Columns (1) and (2) only include bonds maturing on or before February 2015 and after February 2015, respectively. Columns (3)-(6) include all bonds. Independent variables include a Post_t dummy equal to one on and after December 2011, a Short_m dummy equal to one if the government bond portfolio matures on or before February 2015, and an Intensity_i variable equal to LTRO borrowing divided by assets in November 2011. The sample period includes 12 months and runs at a monthly frequency from June 2011 to May 2012. The sample includes only banks. Standard errors double clustered at the bank-bucket and period levels are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Online Appendix to "The (Unintended?) Consequences of the Largest Liquidity Injection Ever"*

Matteo Crosignani
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Miguel Faria-e-Castro
FRB St. Louis

Luís Fonseca
London Business School

In this Online Appendix, we illustrate the dataset construction (section OA.1), present additional derivations of the model developed in the paper appendix (section OA.2), develop a simple model of the collateral trade taking into account that the central bank may trigger margin calls (section OA.3), illustrate the ECB collateral framework (section OA.4), present additional figures (section OA.5), and present additional tables (section OA.6).

OA.1 Dataset Construction

Our final dataset is the merger of two proprietary datasets.

1. Monetary and Financial Statistics (MFS), a proprietary dataset from the BdP, that includes monthly balance sheet data for all monetary and financial institutions regulated by the BdP. We have data on book values, disaggregated by type of asset/liability, type of counterpart, geographical location of counterpart, and, for some assets and liabilities, maturity.[1] Monetary and financial institutions are divided in three categories: banks, savings institutions, and money market mutual funds. Most of the institutions are banks; savings institutions is an obsolescent category that applies only to agricultural credit cooperatives. Money market funds are small given the undeveloped nature of the Portuguese money funds market. More specifically, the different dimensions for which data are available are: (i) Asset category: banknotes and coins, loans and equivalent (with repricing date up to 1 year, 1 to 5 years, more

*Date: May 2018. Not for publication. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System, the European Central Bank, Banco de Portugal, or anyone associated with these institutions.

[1] Maturity, as classified by the MFS, refers to next residual repricing maturity, or time left until the next repricing date. Lending, for example, is disaggregated as lending with maturity less than 1 year, between 1 and 5 years, and more than 5 years. This measure of maturity does not coincide with contractual residual maturity if the contract is repriced at a frequency lower than its contractual maturity. Due to the institutional characteristics of the Portuguese financial markets, most long-term loans such as mortgages are floating rate loans, indexed to some reference rate such as the Euribor. This means that they are classified as short-term loans in our dataset.

than 5 years), securities except equity holdings (up to 1 year, 1 to 2 years, more than 2 years), equity holdings, physical assets, and other assets (of which derivatives); (ii) Counterparty's geographical area: Portugal, Germany, Austria, Belgium, Cyprus, Slovenia, Spain, Estonia, Finland, France, Greece, Netherlands, Ireland, Italy, Latvia, Luxembourg, Malta, Slovakia, European Monetary Union excluding Portugal, Non-EMU Countries, European Central Bank; (iii) Counterparty's institutional sector: monetary and financial institutions, social security administration, local government, regional government, insurance and pension funds, private individuals, central government, other financial intermediaries, non-financial firms, other sectors. For the other side of the balance sheet, the counterparty classification is the same, and the liability categories are: demand deposits, deposits redeemable at notice (less than 90 days, more than 90 days), other deposit equivalents (less than 1 year, 1 to 5 years, more than 5 years), repurchase agreements, securities (up to 1 year, more than 1 year), other liabilities, capital and reserves. Crosignani et al. (2015) describes this dataset in more detail and analyzes the evolution of the balance sheets for the Portuguese monetary financial sector during the full sample period.

2. *Sistema Integrado de Estatísticas de Títulos* (SIET), another proprietary dataset from the BdP, which contains monthly information on quantity (face value), book value, and market value for all ISINs that refer to debt instruments issued by the Portuguese central government and a few public companies, and that are owned by financial institutions domiciled in Portugal. This dataset corresponds to the universe of financial institutions in Portugal, conditional on them owning any of these securities. It includes several types of institutions, including monetary and financial institutions, mutual funds, hedge funds, pension funds, brokerage companies, etc.

For the MFS dataset, we keep the following information for each bank, in each period: assets, cash and equivalents, lending, lending to households, lending to non-financial firms, holdings of non-equity securities, holdings of government debt, holdings of Portuguese government debt, holdings of GIIPS government debt, holdings of equity securities, and other assets. For the other side of the balance sheet: equity and reserves, demand deposits, savings deposits, time deposits, repo, securities, other liabilities, short-term (less than 1 year) borrowing from the central bank, medium-term (1-2 years) borrowing from the central bank, and long-term (more than 2 years) borrowing from the central bank.

For the SIET dataset, we keep its original structure, a three-dimensional panel (j, i, t), where j is an ISIN, owned by institution i at time t. For each observation, the SIET gives us quantity (face value), market value, and book value. The latter is only available for certain institutions, but we only use it for consistency purposes. Note that while the datasets intersect, neither is contained in each other: the MFS includes monetary financial institutions which may not own any Portuguese sovereign debt security and thus are excluded from the SIET dataset, while the

SIET dataset includes other types of institutions that are not included in the MFS dataset, such as pension funds, etc.

OA.2 Model Derivations

Bank Portfolio Choice, Equilibrium Conditions, and Proposition 1 We solve the banks' problem backwards, starting at $t = 1$. At this period, the bank chooses how to rebalance its long-term debt portfolio and whether to store/borrow from funding markets,

$$\max_{b'_L, d} \left[b'_L + d \left\{ \mathbf{1}[d \geq 0] + \kappa \mathbf{1}[d < 0] \right\} \right]$$

$$\text{s.t.}$$

$$W_1 = q_1 b'_L + d$$

Using the budget constraint, note that setting $d \geq 0$ is equivalent to setting

$$b'_L \leq \frac{W_1}{q_1}$$

In this case, the bank's payoff at $t = 2$ is equal to

$$\pi_2|_{d \geq 0} = b'_L + W_1 - q_1 b'_L$$

Since $q_1 < 1$, the bank seeks to set b'_L as high as possible. Will it ever set b'_L such that $d < 0$? In this case, the payoff is

$$\pi_2|_{d<0} = b'_L + \kappa W_1 - \kappa q_1 b'_L$$

We will assume that funding costs are high enough that $\kappa \underline{q} > 1$, in which case the optimal policy is to set $b'_L = 0$, and so $d < 0$ is inconsistent with optimality. The bank still runs the risk of borrowing: assuming it cannot short-sell long-term bonds, $b'_L \geq 0$, the bank needs to borrow whenever $W_1 < 0$. This occurs when

$$b_S + q_1 b_L + c - R€ < 0$$

Note that it occurs whenever the value of the portfolio is low enough due to a low realization of q_1, or whenever the bank has borrowed enough at $t = 0$, that is, $R€$ is high. In such case, the value of the payoff is

$$\pi_2|_{d<0, b'_L = 0} = \kappa W_1 < 0$$

We can then characterize the bank's strategies at $t = 1$, given q_1, as

$$b'_L = \begin{cases} b_L + \frac{b_S + c - R€}{q_1} & \text{if } q_1 \geq \frac{R€ - c - b_S}{b_L} \\ 0 & \text{otherwise} \end{cases}$$

$$d = \begin{cases} 0 & \text{if } q_1 \geq \frac{R€ - c - b_S}{b_L} \\ b_S + q_1 b_L + c - R€ & \text{otherwise} \end{cases}$$

Note then that the expected value of $t = 2$ profits at $t = 0$ can be written as

$$\mathbb{E}_0[\pi_2] = \int_{\underline{q}}^{\frac{R€ - c - b_S}{b_L}} \kappa \left[b_S + q_1 b_L + c - R€ \right] \mathrm{d}F(q_1) + \int_{\frac{R€ - c - b_S}{b_L}}^{\bar{q}} \left[b_L + \frac{b_S + c - R€}{q_1} \right] \mathrm{d}F(q_1)$$

The bank's problem at $t = 0$ is then,

$$\begin{aligned} &\max_{b_L, b_S, c, €} \mathbb{E}_0[\pi_2] \\ &\quad \text{s.t.} \\ &\quad W_0 + € = q_S b_S + q_L b_L + c \\ &\quad € \leq (1 - h_L) q_L b_L + (1 - h_S) q_S b_S \end{aligned}$$

In order to illustrate the forces at play, we now assume that $\kappa \to \infty$: the costs of financing in the intermediate period are prohibitive. The bank is infinitely averse to seeking out funding in the intermediate period and will therefore adjust its $t = 0$ decisions to avoid any shortfall. We believe that, while stark, this assumption captures the motive for holding liquid asset reserves at any point in time. Additionally, it simplifies considerably the solution and characterization of the model.

For $\kappa \to \infty$, we can restate the bank's problem as follows: the objective function now becomes

$$\mathbb{E}_0[\pi_2] = \int_{\underline{q}}^{\bar{q}} \left[b_L + \frac{b_S + c - R€}{q_1} \right] \mathrm{d}F(q_1) = b_L + (b_S + c - R€) \mathbb{E}_0 \left[\frac{1}{q_1} \right]$$

and the bank faces an additional (liquidity) constraint, imposing a zero shortfall in the second period even for the worst realization of q_1

$$b_S + c + \underline{q} b_L - R€ \geq 0$$

Letting (λ, δ, η) denote the Lagrange multipliers on the budget, collateral and liquidity constraints, respectively, and defining

$$\tilde{q} \equiv \mathbb{E}_0 \left[\frac{1}{q_1} \right]^{-1}$$

as the expected value of the price of the long-term bond at $t = 1$ adjusted by a Jensen term, we can write the first-order conditions for the bank's problem as

$$\begin{aligned}
\tilde{q} - q_L[\lambda - \delta(1 - h_L)] + \underline{q}\eta \leq 0 \perp b_L \geq 0 \\
1 - q_S[\lambda - \delta(1 - h_S)] + \eta \leq 0 \perp b_S \geq 0 \\
1 - \lambda + \eta \leq 0 \perp c \geq 0 \\
-R + \lambda - \delta - \eta R \leq 0 \perp \text{€} \geq 0
\end{aligned}$$

Assuming that $b_S, b_L > 0$, and so that both first-order conditions bind, we can write the slope of the yield curve as

$$\frac{1}{q_L} - \frac{1}{q_S} = (\lambda - \delta)\left[\frac{1}{\tilde{q} + \underline{q}\eta} - \frac{1}{1 + \eta}\right] + \delta\left[\frac{h_L}{\tilde{q} + \underline{q}\eta} - \frac{h_S}{1 + \eta}\right]$$

Notice first that if none of these constraints bind, $\delta = \eta = 0$, the bank prices debt at each maturity using a traditional unconstrained arbitrage condition that equates inter-period returns,

$$\frac{1}{q_S} = \frac{\tilde{q}}{q_L} = \lambda$$

where λ measures the marginal cost of funds for the bank. If any of the constraints is active, however, the bank's preference is tilted towards short-term debt. This means that, for the same quantities of outstanding debt, the price of short-term debt increases relative to the price of long-term debt. Thus the yield curve becomes steeper.

We focus on equilibria with strictly positive yields, $q_S, q_L < 1$. From bank optimality, this means that cash is always a strictly dominated asset, $c = 0$. From the bank's optimality conditions, notice that there are two factors that may motivate a preference for short- over long-term debt from the bank's perspective: the first is if short-term debt commands a more favorable haircut, $h_S < h_L$. This preference is scaled by the multiplier on the collateral constraint, δ. The second is that short-term debt allows for better liquidity management, since it yields a certain cash-flow of 1 in the second period, while long-term debt yields a worst-case payoff of $\underline{q} < 1$. This preference is scaled by the multiplier on the liquidity constraint, η.

OA.3 Model of Margin Calls and the Collateral Trade

Consider a risk-neutral investor that lives for three periods, $t = 0, 1, 2$ and can choose at $t = 0$ to undertake a leveraged investment on either a short-term bond maturing at $t = 1$, a medium-term bond maturing at $t = 2$, or a long-term bond that does not mature in the investor's lifetime. The investor can partially finance this investment with a collateralized loan that matures at $t = 2$. If

the value of the collateral falls (or the collateral matures) before the loan is due, the investor is subject to a margin call and needs to raise sufficient liquidity to compensate the lender for this shortfall. We assume that raising liquidity is costly: each unit of liquidity raised at $t = 1$ costs r at $t = 2$.

The bonds are priced by deep-pocketed, risk-neutral investors with discount factor $\eta < 1$. This means that the price of a bond with maturity s is η^s at $t = 0$. At each subsequent period $t = 1, 2$, with probability α, these investors may receive a preference shock that lowers their discount factor permanently by a factor of $\rho^- < \eta$, or raises their discount factor permanently by a factor of $\rho^+ > \eta$. Thus the price of a bond with maturity s at $t = 1$ becomes $(\rho^x \eta)^s$ after shock $x \in \{-, +\}$. This revaluation may trigger a margin call for longer maturity bonds. We assume that $\alpha\rho^- + (1-\alpha)\rho^+ < 1$, so that the yield curve is always upward sloping (longer-term bonds are cheaper). This means that the frictionless yields for each of the bonds are

$$
\begin{aligned}
y_S &= \frac{1}{\eta} \\
y_M &= \frac{1}{\eta^2} \\
y_L &= \frac{\alpha\rho^- + (1-\alpha)\rho^+}{\eta^2}
\end{aligned}
$$

Let us analyze separately the payoffs of investing in a short-, medium- and long-term bond. Let $h \in (0, 1)$ denote the haircut on collateral, and R the interest rate on the LTRO loan. Since we want to focus on the relative preference for different maturities, and not on the desirability of the carry trade *per se*, we assume that $\eta < 1 + R$, so that an unconstrained carry trade is always profitable at any maturity. We assume that there is storage with return unity.[2]

A short-term bond costs η at $t = 0$ and is completely riskless, yielding 1 at $t = 1$. The bank invests by borrowing $h\eta$. Since the collateral matures before the loan, the bank is requested to deposit $h\eta$ at $t = 1$. Since $1 > h\eta$, this margin call is inconsequential and the bank does not need to raise any external liquidity. It receives the margin call deposit at $t = 2$, and repays the loan plus interest. The total profit from this trade is

$$\pi_S = -\eta + h\eta + (1 - h\eta) + [h\eta - (1 + R)h\eta] = 1 - \eta - Rh\eta$$

Given the bank's initial capital, $k < \eta^3$, it can purchase a quantity equal to $\frac{k}{(1-h)\eta}$, and so the

[2]Basically, the investor can save for a net return of zero and borrow for a net cost of r.

profit of this trade is equal to

$$\pi_S = \frac{k}{1-h}\left[\frac{1}{\eta} - 1 - Rh\right]$$

Similarly, we can show that the profits for investing in medium and long-term bonds are given by

$$\pi_M = \frac{k}{1-h}\left[\frac{1+\alpha rh\rho^-\eta}{\eta^2} - 1 - Rh - \alpha rh\right]$$
$$\pi_L = \frac{k}{1-h}\left[\frac{\alpha\rho^-\eta + (1-\alpha)\rho^+\eta + \alpha rh(\rho^-)^2\eta^2}{\eta^3} - 1 - Rh - \alpha rh\right]$$

We can show that $\pi_L \leq \pi_M$ if

$$\alpha rh\rho^-\eta(1-\rho^-\eta) \geq \alpha\rho^- + (1-\alpha)\rho^+ - 1$$

So that, if the probability of a downwards revaluation (and the magnitude of that revaluation) is high enough, and exceeds the return benefits of investing in a long-term bond, the investor may prefer to invest in a medium-term bond. We can derive similar conditions, under which $\pi_L \leq \pi_S$. They are mainly related to liquidity risk: the short-term investment exposes the bank to no type of liquidity risk whatsoever. The medium-term bond exposes the bank to margin call risk, with probability α. The long-term bond exposes the bank to both margin call *and* funding liquidity risk at the final period, since the bond's payoff (its price on the secondary market) may be uncertain. Since there is no discounting, the unconstrained, risk-neutral investor would simply prefer the bond that offers the ex-ante higher return, which is the long-term bond by assumption. Due to liquidity risk, emanating both from margin calls and uncertain prices at loan maturity, the investor may prefer to invest at the shorter term.[3]

OA.4 ECB Collateral Framework and the LTRO

Eligible collateral at the ECB falls in two broad asset classes: marketable assets and non-marketable assets. The first comprises debt instruments such as unsecured bonds, asset-backed securities, and covered bank bonds. The second class includes fixed-term deposits from eligible monetary policy counterparties, credit claims (bank loans), and non-marketable retail mortgage-backed debt instruments.[4] The LTRO period was characterized by an expansion of the eligible collateral. On

[3]Our analysis is robust to adding an additional period, so that the investor would obtain a certain payoff from the long-term bond. This would, however, still entail funding risk at loan maturity, since the investor would need to either sell the bond (as in our set-up) or raise costly external funds to repay the loan.

[4]See Section 6 of ECB (2011) for additional details on the eligibility of assets as collateral in the Eurosystem.

the day of the announcement of the operations, the ECB also announced collateral availability by allowing riskier asset-backed securities and allowing national central banks (NCBs) to temporarily allow additional credit claims that satisfy their specific criteria, as long as the risks of this acceptance were assumed by the NCB.

On February 9, twenty days before the second allotment, BdP detailed the criteria for Portugal regarding these additional credit claims. Portfolios of mortgage-backed loans and other loans to households, as well as of loans to non-financial corporations became increasingly pledgeable as collateral. The expansion of these rules also suggests banks were collateral scarce at the time of the first allotment. Although we do not have asset-level data on the holdings of these classes of assets by banks, we rely on aggregate measures of pledged collateral for each bank. These measures include non-marketable assets whose risk was borne by the Eurosystem, additional credit claims (ACCs), government guaranteed bank bonds (GGBBs) issued from a government fund expanded around the time of the troika intervention in mid-2011, and other marketable assets.

References

Crosignani, M., M. Faria-e-Castro, and L. Fonseca (2015): "The Portuguese Banking System during the Sovereign Debt Crisis," *Banco de Portugal Economic Studies*, 1, 43–80.

ECB (2011): *The Implementation of Monetary Policy in the Euro Area*, general Documentation on Eurosystem Monetary Policy Instruments and Procedures.

OA.5 Additional Figures

Figure OA.1: Holdings of Domestic Government Debt, Normalized by Assets. This figure plots the evolution of domestic government bonds held by banks, divided by total assets, from June 2011 to June 2012. The two vertical dashed lines delimit the LTRO allotment period.

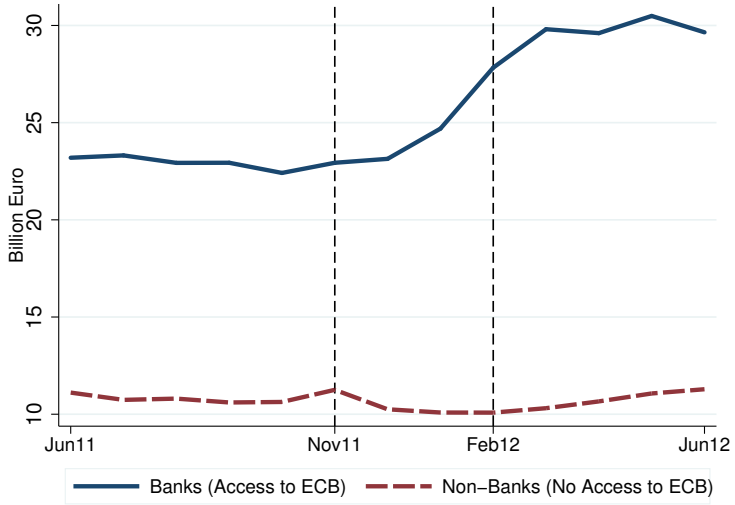

Figure OA.2: Holdings of Domestic Government Debt. This figure plots the evolution of domestic government bonds held by banks (solid line) and non-banks (dashed line) from June 2011 to June 2012. Quantity is measured as the face value in billions of euro. We cannot normalize quantities in the figure by total assets, as we do not observe assets of non-banks. The two vertical dashed lines delimit the allotment period.

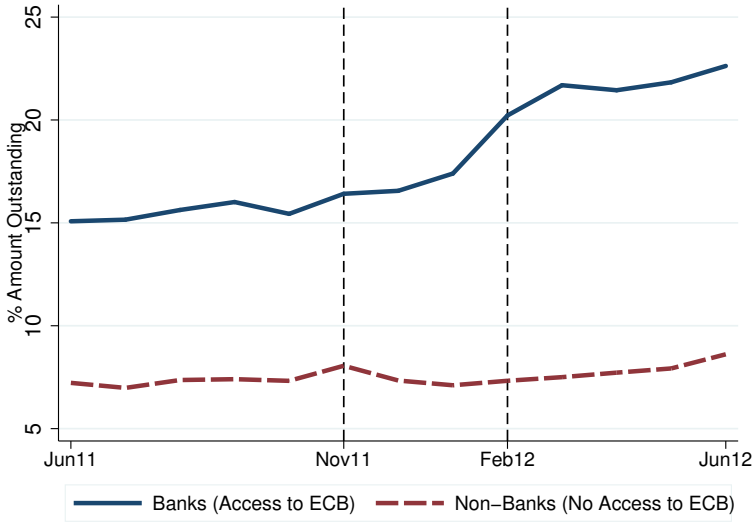

Figure OA.3: Holdings of Domestic Government Debt, Normalized by Amount Outstanding. This figure plots the evolution of domestic government bonds held by banks (solid line) and non-banks (dashed line) from June 2011 to June 2012, normalized by the stock of public debt outstanding. The two vertical dashed lines delimit the LTRO allotment period.

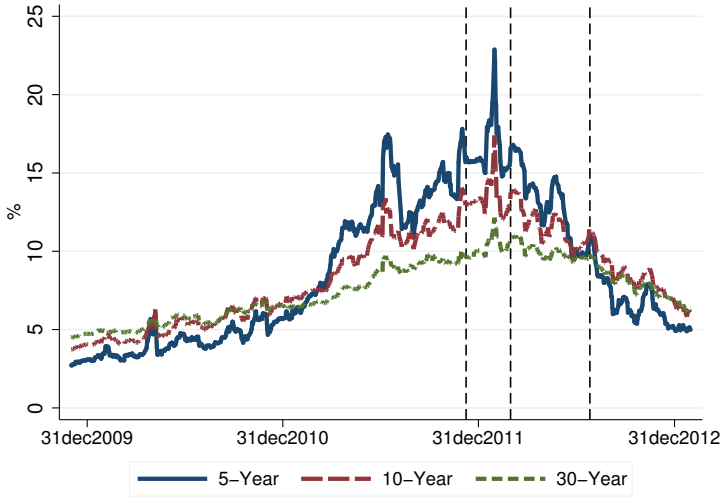

Figure OA.4: Portuguese Sovereign Yields. This figure shows the time series of Portuguese 5Y, 10Y, 30Y sovereign yields from November 2009 to January 2013. The dashed vertical lines correspond to the LTRO announcement (December 8, 2011), the second LTRO allotment (February 29, 2012), and the OMT announcement (July 26, 2012).

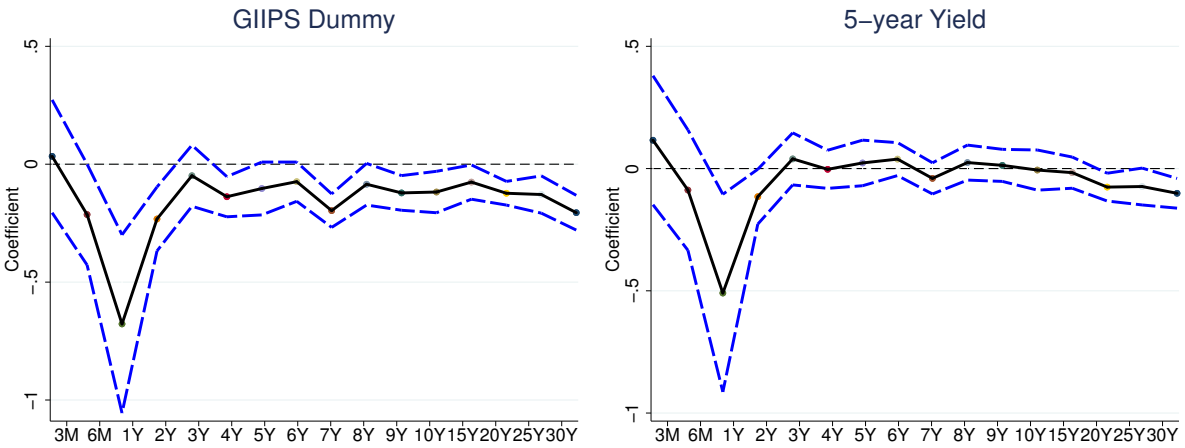

Figure OA.5: Yield Curve Steepening, October 2011 1-Year LTRO. This figure plots the $\beta_{(m)}$ estimates of specification (7) as a function of maturity (m). Regressions are estimated separately for each maturity; the sample period is daily from September 27 to October 17 (the announcement date is October 6); and sample countries are the Netherlands, Portugal, Spain, France, Ireland, Belgium, Germany, Italy, Austria, Finland, Cyprus, Slovakia, and Slovenia. In the left panel, Risk is a dummy equal to 1 for Ireland, Italy, Spain, and Portugal. In the right panel, Risk is the log of the 5-year yield on September 26, 2011. Dashed lines delimit the 99% confidence interval. Standard errors are robust. Source: Bloomberg.

OA.6 Additional Tables

LHS Var.: LTRO2	(1)	(2)	(3)	(4)	(5)
ΔGovt (Face Value)		1.089***		0.933***	
		(0.010)		(0.091)	
ΔGovt (Market Value)			1.207***		1.034***
			(0.009)		(0.098)
ΔGGBB	1.575***	2.012***	2.060***	1.196**	1.229**
	(0.300)	(0.260)	(0.200)	(0.583)	(0.553)
ΔACC	0.935***	0.800***	0.800***	0.837***	0.838***
	(0.320)	(0.038)	(0.037)	(0.031)	(0.030)
ΔOtherMarketable	1.062**	0.793***	0.792***	0.802***	0.801***
	(0.441)	(0.047)	(0.046)	(0.036)	(0.035)
Total $\text{Collateral}_{\text{Nov11}}$				0.218*	0.221*
				(0.131)	(0.125)
Balance Sheet Controls	✓	✓	✓	✓	
Observations	68	68	68	68	68
R-squared	0.187	0.941	0.943	0.960	0.962

Table OA.1: Banks' Buy-and-Borrow Behavior, Robustness. This table presents the estimation results for specification (1), without bank-level controls X_i. The dependent variable is total uptake at LTRO2 normalized by total assets in November 2011. Independent variables include changes in holdings of central bank eligible collateral between November 2011 and February 2012, and the stock of eligible collateral in November 2011. Eligible collateral includes domestic government bonds, additional credit claims (ACC), government guaranteed bank bonds (GGBBs), and other marketable securities. All variables are normalized by bank assets in November 2011. All independent variable are haircut-adjusted. In the first (second) column, we measure changes in government bond holdings using face (market) values. In this Online Appendix, we provide a detailed description of the ECB collateral framework. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

LHS Var.: LTRO2	(1)	(2)	(3)	(4)	(5)
Δ Govt (Face Value)		0.822***		0.738***	
		(0.174)		(0.219)	
Δ Govt (Market Value)			1.013***		0.948***
			(0.207)		(0.184)
Δ GGBB	2.662**	2.698**	2.763**	1.715**	1.762**
	(1.126)	(1.157)	(1.139)	(0.694)	(0.666)
Δ ACC	0.859***	0.820***	0.815***	0.864***	0.859***
	(0.049)	(0.051)	(0.051)	(0.049)	(0.049)
Δ Other Marketable	0.793***	0.790***	0.790***	0.813***	0.813***
	(0.048)	(0.052)	(0.052)	(0.049)	(0.050)
Total $\text{Collateral}_{\text{Nov11}}$				0.250*	0.254*
				(0.139)	(0.133)
Δ Cash	-0.625	0.522	0.405	2.485	2.451
	(5.441)	(2.910)	(2.943)	(2.845)	(2.747)
Δ Non-Govt Bonds	-0.931***	-0.234*	-0.155	-0.135	-0.031
	(0.053)	(0.135)	(0.140)	(0.200)	(0.142)
Δ Equity Holdings	0.006	-0.129	-0.143	-0.336*	-0.357**
	(0.140)	(0.123)	(0.121)	(0.170)	(0.155)
Δ Non-PT Govt Bonds	-0.750***	-0.062	0.022	-0.288	-0.185
	(0.258)	(0.300)	(0.307)	(0.309)	(0.292)
Δ Lending	-0.884***	-0.222*	-0.146	-0.124	-0.025
	(0.041)	(0.124)	(0.130)	(0.193)	(0.137)
Δ Book Equity	0.791***	0.131	0.054	0.148	0.050
	(0.152)	(0.206)	(0.214)	(0.213)	(0.170)
Δ Securities Issued	0.051	-0.445	-0.514	-0.470	-0.555
	(1.046)	(1.012)	(1.014)	(0.622)	(0.620)
Δ Demand Deposits	0.772***	0.196*	0.124	0.131	0.040
	(0.086)	(0.115)	(0.120)	(0.176)	(0.129)
Δ Saving Deposits	1.721**	0.631	0.362	0.387	0.088
	(0.683)	(0.742)	(0.737)	(0.531)	(0.501)
Δ Time Deposits	0.935***	0.234*	0.154	0.137	0.033
	(0.040)	(0.133)	(0.138)	(0.206)	(0.145)
Δ Repo Borrowing	0.398*	0.071	0.032	-0.011	-0.062
	(0.216)	(0.320)	(0.346)	(0.227)	(0.257)
Balance Sheet Controls	✓	✓	✓	✓	✓
Observations	68	68	68	68	68
R-squared	0.935	0.947	0.948	0.968	0.970

Table OA.2: Banks' Buy-and-Borrow Behavior, Robustness. This table presents the estimation results for specification (1). Columns (4) and (5) corresponds to Columns (1) and (2) of Table 1 in the main text. The dependent variable is total uptake at LTRO2 normalized by total assets in November 2011. Independent variables include changes in holdings of central bank eligible collateral between November 2011 and February 2012, the stock of eligible collateral in November 2011, and changes in balance sheet components (assets and liabilities). Eligible collateral includes domestic government bonds, additional credit claims (ACC), government guaranteed bank bonds (GGBBs), and other marketable securities. Assets include: cash, non-sovereign bond holdings, non-domestic sovereign bond holdings, equity holdings, and loans. Liabilities include: book equity, securities issued, demand deposits, saving deposits, time deposits, and repo. All variables are normalized by bank assets in November 2011. All independent variable are haircut-adjusted. In the first (second) column, we measure changes in government bond holdings using face (market) values. In this Online Appendix, we provide a detailed description of the ECB collateral framework. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

LHS: $\text{Holdings}_{i,m,t}/\text{AmtOutstanding}_{m,t}$	(1)	(2)	(3)	(4)	(5)
Post	0.371**	0.047*			
	(0.157)	(0.024)			
Post × Short			0.329**	0.329**	0.324**
			(0.149)	(0.129)	(0.140)
Bank FE	✓	✓	✓		
Maturity FE	✓	✓	✓	✓	
Time FE			✓		
Bank-Time FE				✓	✓
Bank-Maturity FE					✓
Specification	(2a)	(2a)	(3)	(3)	(3)
Sample Bonds	Short-Term	Long-Term	Full Sample	Full Sample	Full Sample
Observations	2,478	2,478	4,956	4,956	4,950
R-squared	0.402	0.507	0.285	0.375	0.679

Table OA.3: LTRO and Government Bond Purchases, Alternative Dependent Variable. This table presents the results of specifications (2a) in column (1), (2b) in column (2), and (3) in columns (3)-(5). The dependent variable is the share of total public debt outstanding of maturity m held by bank i. Independent variables include a Post dummy equal to one on and after December 2011 and a Short dummy equal to one if the government bond portfolio matures on or before February 2015. Column (1) and column (2) only include bonds maturing on or before and after February 2015, respectively. The sample period includes 12 months and runs at a monthly frequency from June 2011 to May 2012. The sample includes only banks. Standard errors double clustered at the bank-maturity and month levels are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.