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

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

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1 Abstract

We analyze a large and potentially unintended consequence of the largest liquidity injection ever conducted by a central bank: the European Central Bank’s (ECB) Three-Year Long-Term Refinancing Operations announced in December 2011 at the height of the euro crisis. Using a unique dataset of monthly security- and bank-level holdings of government bonds for Portugal, we find that Portuguese banks engaged in a “collateral trade”, buying high yield domestic government bonds and pledging them to secure ECB funding. Banks purchased mostly short-term bonds so as to match the maturity of central bank loans with the maturity of the securities backing them. The impact of bank collateral trade is economically large as banks purchased short- and long-term government bonds for 8.4% and 3.1% of amount outstanding, respectively. The observed steepening of the sovereign yield curve and pickup in public debt issuance are consistent with an effect on prices and a strategic reaction by the government debt agency. We argue that this phenomenon, together with other unconventional ECB policies, led to a stealth recapitalization of the banking sector of at least 7.2% of book equity.

JEL: E58, G21, G28, H63

Keywords: Lender of Last Resort; Unconventional Monetary Policy; Sovereign Debt; Bank Portfolio Choice

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2 Introduction

The importance of financial intermediaries for the macroeconomy has become evident in the last decade. The collapse of the U.S. subprime mortgage market and the subsequent increase of peripheral European sovereign yields impaired these regions’ financial sectors, which in turn transmitted the shocks to firms and households and contributed to long-lasting recessions.\(^1\) As part of the policy response, central banks throughout the world provided liquidity to the banking sector to counter ongoing credit contractions, effectively acting as lenders of last resort.

In this paper, we document a possibly unintended consequence of the largest liquidity injection ever conducted, the Three-Year Long Term Refinancing Operation (LTRO), adopted by the European Central Bank (ECB) at the height of the eurozone crisis. As in a textbook case of a lender of last resort intervention, the official goal was to “support bank lending and liquidity in the euro area money market”. We show, however, that the LTRO induced banks to buy risky government bonds and pledge them as collateral to the central bank, in what we call a “collateral trade”. Note that we do not analyze the effect of the LTRO on private credit supply nor claim that our results imply that the intervention was unsuccessful. Actually, we show that the “collateral trade”, while exacerbating the vicious sovereign-banking loop, might have helped peripheral countries to refinance their debt, raising the possibility that the effect on government bond holdings was not entirely unintended.\(^2\)

The ECB’s policy design was simple. In December 2011, the ECB announced that eurozone banks could obtain a three-year loan from the central bank on two allotment days (December 21, 2011 and February 29, 2012), provided that they pledged sufficient eligible collateral. The ECB accepted a wide range of securities and set haircuts and interest rates to make the loans more favorable compared to the private market in order to attract banks, especially in the eurozone periphery. We use Portugal, one of the countries most severely hit by the sovereign debt crisis, during 2011 and 2012, as a laboratory to study the LTRO.\(^3\) To unveil the effect of the LTRO on sovereign bond holdings, we take advantage of a novel proprietary dataset from the

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\(^2\)As hinted at by then French President Nicolas Sarkozy, who remarked 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.”

\(^3\)The ten-year Portuguese bond spread reached more than 16% at the peak of the crisis. See Reis (2013) for an account of the years leading up to the crisis.
national central bank (Banco de Portugal, henceforth BdP). We are the first ones, to our knowledge, to analyze security- and bank-level holdings of domestic government bonds in a peripheral country during the crisis.

Motivated by the observed increase in risky government bond holdings during the allotment of the LTRO loans, we build a simple model to formalize the claim that banks engaged in a “collateral trade” that consisted of purchasing high yield domestic government bonds and pledging them at the central bank in exchange for cheap lender of last resort liquidity. The intuition is as follows: in an environment with costly external financing, banks hold liquid reserves as insurance against shocks. If the central bank steps in and provides cheap loans against high yield securities, banks can use their cash reserves to purchase such collateral securities and pledge them to obtain liquidity from the central bank and replenish their original reserves. This strategy allows banks to maintain a cash buffer throughout (as opposed to a traditional carry trade) and make a profit if the asset yields a return that exceeds the cost of the loan.4

Banks can minimize funding liquidity risk by matching the maturity of the bonds purchased with the maturity of central bank loans. In fact, compared to bonds maturing before the central bank loan (“short-term” bonds), bonds maturing after (“long-term” bonds) expose banks to the risk that their prices may be lower by the time the central bank loan matures. As banks demand more short-term public debt, the sovereign yield curve steepens allowing the government debt agency to issue public debt, taking advantage of the lower yields, especially at short maturities.

In our context, domestic government bonds are the perfect security for peripheral banks to use to engage in the “collateral trade”. First, euro denominated government bonds, compared to other asset classes, have a zero capital requirement, making them particularly attractive from a regulatory capital standpoint. Second, in addition to their high yield in this period, domestic government bonds are even more attractive in risky countries as banks can use them to risk-shift, governments might pressure domestic institutions to buy them (moral suasion), and/or banks might voluntarily hold them to increase the chance of being bailed out. The model generates four predictions: (i) banks buy government bonds after the announcement to borrow at the LTRO, (ii) such purchases are caused by the LTRO, (iii) the sovereign yield curve steepens, and (iv) the sovereign debt agency issues more public debt after the announcement. The last two predictions highlight what might have been a not completely unintended consequence of the intervention, as the collateral trade...

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4This intuition is clearly illustrated by the following excerpt from Banco Carregosa’s 2012 Annual report (a medium-sized bank in our sample): “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.”

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price effect might have helped governments refinance their debt at lower yields.

We start our empirical analysis by testing the first and second predictions. First, we show that banks that buy more government bonds between the announcement and the last LTRO allotment borrow more at the central bank facility. In particular, consistent with buy-and-pledge behavior, banks borrow roughly €1 at the LTRO for every €1 of government bonds purchased. Second, we show that the LTRO causes government bond purchases by comparing, in a difference-in-differences setting, holdings of bonds maturing before (“short-term” bonds) and after (“long-term” bonds) the central bank loan. We find that banks buy more short-term relative to long-term government bonds after the LTRO announcement, controlling for time-varying bank characteristics and bank-bond heterogeneity using fixed effects.

Our results are economically significant: we find that the LTRO causes a €4.1 billion increase in demand for short-term bonds, equivalent to 8.4% of the total amount outstanding at the time. Consistent with the preference for short-term securities, the impact on long-term bonds is more limited as the LTRO causes an increase in demand of only €2.8 billion, equivalent to 3.1% of the amount outstanding. We employ three additional tests to confirm our causal claim. First, we show that the effect does not appear in other periods, with the exception of November 2011, where it coincides with another (smaller, but similar) ECB liquidity injection. Second, we take advantage of a public dataset on mutual fund asset holdings and confirm that our results do not extend to these financial intermediaries which have no access to ECB liquidity. Third, we show that our results hold in the intensive margin, namely that the more a bank borrows at the LTRO, the greater its preference for short-term government bonds.

We then provide, in the absence of clean econometric tests, evidence consistent with the third and the fourth predictions. First, we show that the Portuguese sovereign yield curve steepens during the LTRO allotment. In particular, comparing prices before and after the intervention, yields at a maturity of more than three years are basically unchanged, while short-term yields collapse, as yields at a shorter than two-year maturity drop by 500 bps and the three-year yield drops by 250 bps. To link the shift in the yield curve with the collateral trade, we analyze the yield curve in other countries. Consistent with our narrative, we observe a steepening in other peripheral countries like Spain and Italy where risky domestic public debt was likely to have been used for the collateral trade. On the other hand, we do not observe sovereign yield curve steepening in core countries like Germany and France. Second, we test the last prediction and show that the Portuguese sovereign debt agency, which had basically stopped issuing public debt during the six months before the LTRO, resumed public debt issuance right after the operation announcement. As the government rollover need was constant before and after the announcement, and is thus unlikely to explain this abrupt change in issuance behavior, this evidence is consistent with a strategic reaction by the sovereign debt agency to improved market conditions.

Given the post-LTRO drop in yields, the collateral trade effectively constituted a stealth recapitalization of
the financial sector as banks made capital gains on their sovereign bond portfolio. Using our granular data, we are able to show that the ECB measures adopted between December 2011 and July 2012 led to capital gains of about €3.0 billion, equivalent to 7.2% of book equity. The collateral trade alone is responsible for €0.8 billion, equivalent to 1.8% of book equity.

Our contribution is twofold. First, we add to the growing literature on the linkages between sovereign and credit risk. In particular, many papers analyze the increase in bank risky sovereign bond holdings during the eurozone crisis and argue that banks’ portfolio choice is caused by either moral suasion or risk-shifting. In this paper, we characterize a phenomenon that enabled banks to satisfy this preference for domestic government bonds. Our work thus complements these traditional explanations. Second, we contribute to the literature by offering a comparison between quantitative easing (QE)-style and LTRO-style interventions. While our narrative may make it seem like LTRO-style interventions are a type of indirect QE, we show that the LTRO caused a steepleasing of the sovereign yield curve, an effect that is at odds with the curve flattening usually associated with QE or Maturity Extension Programs.

Our results extend outside the eurozone as the importance of LTRO-like policies has expanded around the world, with the implementation of similar policies in countries such as the U.S., the UK, Russia, and China. In the UK, the Bank of England and the Treasury launched the Funding for Lending Scheme in July 2012, offering loans with maturity up to four years “to incentivise banks and building societies to boost their lending to the UK real economy”. In the U.S., the Federal Reserve established the Term Auction Facility in December 2007, auctioning 28-day and 84-day collateralized loans to “address funding pressures”. In Russia, the central bank (CBR) conducted a LTRO-style policy in July 2013, dubbed “Russia QE” by the press. This policy was implemented through collateralized lending by the CBR to banks at an unprecedented maturity of 12 months. The implicit objective of this operation was to stimulate demand not for sovereign debt but rather for corporate debt, as well as to reduce demand pressure for short-term funding. In China, LTRO-style loans have been offered by the People’s Bank of China (PBoC), in exchange for collateral in the form of bonds issued by Chinese local governments. This policy seems to be aimed primarily at assuaging liquidity problems faced by local banks, as well as minimizing the impact of a potential rollover crisis for

5The Duma had previously allowed the central bank to increase maturity at its own discretion. In addition, the collateral base was expanded to encompass securities that were not accepted in private money markets. See FT Alphaville (2013).

6While the financial press has repeatedly referred to this policy as the “Chinese QE”, this characterization is incorrect in light of the distinction we made above. Popular commentators argue that this policy is aimed at stimulating demand for local government debt; while the PBoC has always engaged in collateralized lending to banks as part of its regular conduct of monetary policy, this is the first time that it has accepted this type of debt as collateral. In addition, the maturity is unprecedented. See FT Alphaville (2015) for an informal description of this program.
over-indebted local governments. In this respect, it was adopted in a context that is very similar to the one faced by the ECB in late 2011.

**Related Literature**  Our paper is related to four strands of literature. First, we contribute to the growing body of literature analyzing the role of linkages and feedback loops between the sovereign and the financial sector. Acharya et al. (2014a) model a loop between sovereign and financial sector credit risk and find evidence of two-way feedback from credit default swap (CDS) prices. Bolton and Jeanne (2011) present a model where diversification of banks’ holdings of sovereign bonds leads to contagion and Broner et al. (2010) show that public debt repatriation through secondary markets is a punishment for increased default probability. In the context of the eurozone crisis, the increase in holdings of government bonds by European banks has been documented by Acharya and Steffen (2015), who show that large and undercapitalized banks engaged in a carry trade, purchasing peripheral government bonds while funding their positions in wholesale funding markets. Several authors of recent studies claim that the observed pattern is consistent with moral suasion from governments and/or bank risk-shifting. Our paper is closer to Drechsler et al. (forthcoming), who study the collateral pledged to the ECB in the pre-LTRO period and show that banks’ use of a lender of last resort is associated with risk-shifting behavior.

Compared to previous studies, our comprehensive dataset allows us to analyze *security-level* domestic government bond holdings in the cross-section of the *universe* of Portuguese banks, crucially including the smaller entities that are neither publicly traded nor included in stress tests. Until now the literature employed either: (i) European Banking Authority stress test data where only approximately 60 systemically important banks were included (approximately 20 from the periphery, 4 from Portugal) or (ii) Bankscope data, where the nationality of the bond portfolio is not disclosed. These datasets tend to include only large and publicly listed banks, ignoring privately-owned banks and subsidiaries of foreign banks, which make up a substantial fraction of the banking sector in Portugal. To our knowledge, the only studies that use comparable datasets are Buch et al. (2015) and Hildebrand et al. (2012), both focused on Germany. They find that worse-capitalized banks held more government bonds and shifted investments to securities that are eligible to be posted as collateral at the ECB. Unlike these two papers, we focus on a peripheral country

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7Drechsler et al. (forthcoming), Acharya et al. (2014b) suggest that this behavior is consistent with risk-shifting. Becker and Ivashina (2014), De Marco and Macchiavelli (2016), and Ongena et al. (2016) suggest that this behavior is consistent with moral suasion. Altavilla et al. (2016) show that both behaviors are in place. Crosignani (2015) shows that these two hypotheses are intertwined, as governments have an incentive to keep domestic banks undercapitalized. Uhlig (2013) also shows that regulators might allow banks to hold risky domestic bonds, thus shifting sovereign default losses to the common central bank.

8See Acharya and Steffen (2015) and Gennaioli et al. (2014) for studies that use these two data sources.
whose financial sector was severely hit by the crisis and, therefore, targeted by the lender of last resort intervention.

Second, our findings on the impact of the LTRO on portfolio choice relate to the vast literature on the transmission of monetary policy through the financial sector. In their seminal paper, Kashyap and Stein (2000) focus on the bank lending channel of conventional monetary policy. Like Chodorow-Reich (2014a) on the U.S. case, we focus our attention on a specific measure of unconventional monetary policy, where the ECB fulfills its role as a lender of last resort. A rich body of empirical literature has emerged that focuses on the analysis of the transmission of the LTRO to private lending through the financial sector. This important question is studied, among others, by Andrade et al. (2015) and Carpinelli and Crosignani (2015), who find a positive impact on lending by French and Italian banks, respectively. On a less positive note, van der Kwaak (2015) and Corbisiero (2016) build general equilibrium models to study the impact of the LTRO and find that its cumulative impact on output is essentially zero. Trebesch and Zettelmeyer (2014) study the effect on government bond prices and ECB behavior in mid-2010, when the ECB decided to buy government bonds in the secondary market under the “Securities Market Program”. We focus on a different type of intervention (collateralized borrowing as in LTROs) aimed at relaxing banks’ liquidity constraints. Our data on assets and liabilities is not granular enough to discuss the transmission of the LTRO to private lending.

Third, our analysis of the behavior of domestic banks and the banking sector demand for domestic sovereign debt relates to the equally large literature on sovereign debt management. Bai et al. (2015) show that countries react to crises by issuing debt with shortened maturity and promised payments closer to maturity (payments are more back-loaded). Issuance of shorter maturity government bonds during periods of sovereign distress also has been documented by Broner et al. (2013), who show that, for emerging economies, borrowing short-term is cheaper than borrowing long-term, especially during crises. Arellano and Ramanarayanan (2012) document the same pattern in emerging markets and show that maturity shortens as interest rate spreads of government debt rise. In their model, short-term debt is more effective at providing incentives to repay while long-term debt is a hedge against fluctuations in interest rate spreads. Our paper proposes an alternative explanation for the reliance of sovereigns on short-term public bonds: the debt agency faces high demand for short-term bonds because these are the best suited asset class to pledge to the central bank.

Fourth, our analysis relates to the emerging literature on the interaction and coordination of fiscal and monetary policies during the financial crisis. Greenwood et al. (2014) present evidence that the U.S. Treasury behaved strategically during the Federal Reserve QE program, taking advantage of the reduction in longer-term yields to increase the maturity of its debt. This evidence is consistent with the behavior predicted by the trade-off model of optimal maturity of government debt developed by Greenwood et al. (2015). We contribute to the literature on policy coordination in two ways: first, we show evidence that suggests that
the Portuguese Treasury might also have behaved strategically, taking advantage of investors’ preference for short-term debt that arises from liquidity and collateral constraints. Second, we discuss the fact that programs involving incentives for private investors to acquire government debt can have very different effects than programs where assets are directly purchased by public institutions (such as central banks). In particular, while direct asset acquisition programs such as QE tend to flatten the yield curve, indirect acquisition programs such as the LTRO interact with investors’ constraints to steepen the yield curve. This has consequences for the strategic reaction of the fiscal authority, who chooses to tilt the maturity structure of its issuances towards the longer end in the first case, and towards the shorter end in the second, so as to take advantage of the respective decreases in yields.

The rest of the paper proceeds as follows. In Section 3, we describe the data and provide some institutional background on the conduct of monetary policy in the eurozone. In particular, we describe the LTRO liquidity provision in detail and present the key stylized fact that motivates our analysis. In Section 4, we develop a theoretical framework that tries to rationalize this fact while yielding additional empirical implications. In Section 5, we take advantage of the granularity of our data to test the empirical predictions of our model. In Section 6, we discuss some of the aspects and results of our analysis in greater detail. Section 7 concludes.

### 3 Data and Setting

In this section, we illustrate the institutional background, describe the data, and present the stylized fact that motivates our analysis.

#### 3.1 Institutional Background

During the European sovereign crisis, the ECB provided liquidity to eurozone banks, effectively acting as a lender of last resort. In particular, starting in 2008, banks in peripheral countries (Greece, Italy, Ireland, Portugal, and Spain) became increasingly reliant on central bank liquidity to compensate for the contraction of private sources of funding.\(^9\)

The ECB provides liquidity to the financial sector using collateralized loans. Any bank located in the euro-

\(^9\)The role of ECB as a lender of last resort during the crisis is analyzed by, among others, Acharya et al. (2015), Carpinelli and Crosignani (2015), Drechsler et al. (forthcoming), and Garcia-de-Andoain et al. (forthcoming).
zone can obtain a cash loan from the monetary authority, provided that it pledges sufficient collateral. Over this collateral requirement, there is no limit on the amount of funds that a bank can obtain from the central bank. Eligible collateral includes government bonds, asset-backed securities, covered bonds, and corporate bonds. While 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). For example, a Portuguese bank can pledge a covered bond rated AAA with residual maturity of 8 years and market value of €100. After applying the haircut, 6.5% in this case, the ECB provides a loan of €93.5 to the bank. Note that any bank, be it a safe German bank or a risky Spanish bank, faces the same haircuts and interest rate. The maturity of the loan is typically either one week or three months.

During the second half of 2011, the sovereign crisis worsened considerably with sovereign CDS spreads of large countries such as Italy and Spain reaching record highs in November. On December 8, 2011, the ECB announced the provision of two unprecedented three-year maturity loans, the three-year long term refinancing operation (“the”LTRO hereafter). The stated goal of the policy was to provide long-term funding to banks in order to “support bank lending and money market activity”. Long maturity and below market price for these loans made this liquidity operation very attractive. In particular, 800 eurozone banks tapped the facility, obtaining liquidity of €1 trillion, making this the largest liquidity injection in the history of central banking.

Figure 1 shows the timeline of the operation. The December 8 announcement is closely followed by the allotment of the first loan (LTRO1), on December 21 and, two months later, by the second and last allotment (LTRO2), on February 29. We refer to the period between the announcement and LTRO2 as the “allotment

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10 The absence of a limit on the amount of funds that banks can borrow from the ECB was introduced in October 2008 (“full allotment” policy). We describe the ECB collateral framework in greater detail in the Online Appendix.

11 The ECB normally offers two types of loans, varying by maturity: (i) MRO loans with a maturity of one week and (ii) LTRO loans with a maturity of three months. During the crisis, in 2010 and 2011, 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 and one 12-month maturity LTRO was allotted in October 2011.

12 The ECB adopted other non-standard monetary policy operations: (i) U.S. dollar liquidity-providing operations, (ii) three covered bond purchase programs, (iii) purchases of government bonds in the secondary market under the Securities Market Programme, (iv) a series of targeted longer-term refinancing operations (TLTROs), (v) the ABS purchase program, and (vi) the “Expanded Asset Purchase Programme”. These measures are not the focus of this paper. The announcement of the three-year LTRO can be found at ECB (2011).

13 The terms of the ECB loans, namely the haircut and the interest rate, were more attractive compared to the private market, especially for banks located in peripheral countries. This implicit subsidy is discussed in Drechsler et al. (forthcoming). Perhaps not surprisingly, more than two thirds of the total Three-Year LTRO loans was allotted to banks in peripheral countries, where such subsidy was particularly large.
Figure 1: LTRO Timeline. This figure illustrates the timeline of the LTRO intervention. The announcement (December 8, 2011) is followed by the two allotments (December 21, 2011 and February 29, 2012).

3.2 Data

Our main dataset is the merger of two proprietary datasets from the Portuguese central bank (Banco de Portugal, or BdP). These datasets are monthly panels from January 2005 to May 2014.

The first dataset contains monthly information on the composition of the balance sheets of all monetary and financial institutions regulated by BdP. This unbalanced panel contains information on 81 banks, 10 savings institutions, and 13 money market funds. An observation consists of the value held in a given month, by a given institution, of an asset in a specific category vis-à-vis all counterparties in a given institutional sector and geographical area. This dataset allows us to determine, for example, the value of all non-equity securities whose issuer is the German central government, that were held by bank \( i \) in January 2006. Along with bank-level security holdings, we observe standard balance sheet characteristics. Observations are measured in book value. As a complement, we obtain information on the collateral pool of Portuguese banks at the ECB by instrument: government debt, marketable assets, additional credit claims, and government guaranteed bank bonds.

The second dataset contains monthly security-level data of all holdings of Portuguese government debt by domestically regulated institutions. The universe of entities of this second dataset is larger than that of the first, as it includes all non-monetary financial 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 of all holdings of Portuguese government debt at the security (ISIN) level. We cross with bond-level information such as yield, residual maturity, and amount issued, obtained from Bloomberg. Note that we do not have

\[14\] In the Online Appendix, we provide a more detailed description of the dataset.

\[15\] We are able to match more than 98\% of the value of holdings in the dataset with Bloomberg.
standard balance sheet characteristics (e.g., total assets) for the institutions appearing only in the second dataset.

To address this gap, we obtained publicly available data on mutual fund portfolio composition from the website of the Portuguese Securities Market Commission (CMVM). This allows us to gather data on the total assets of mutual funds holding domestic government bonds included in the security-level dataset and other mutual funds. The security level dataset has 709 entities. Of these, 52 are banks or money market funds included in the first dataset. Some other 286 are matched with the CMVM dataset. The remaining 371 are unmatched, so we do not have balance sheet information for them. \[16\]

![Figure 2: Holdings of Domestic Government Debt.](image)

This figure plots the evolution of the quantity 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 total face value in billion euro. The two vertical dashed lines delimit the allotment period.

### 3.3 Aggregate Bank Behavior and the LTRO

As we have described the institutional setting and data, we now present the stylized fact that motivates our analysis: banks buy government bonds in the allotment period.

\[16\] The CMVM dataset has 479 entities. Of these, 12 are money market funds in the first dataset; 286 are in the second dataset and 181 are unmatched, i.e., are mutual funds which did not hold domestic government bonds in the period of our sample. In practice, since we require balance sheet size information for most of our empirical tests, we will mainly use the information on banks and mutual funds.
Figure 2 compares aggregate government bond holdings of banks (which could access the LTRO) and non-banks (which were excluded from the LTRO) from June 2011 to June 2012. The vertical lines correspond to the announcement and the second (and last) allotment. We plot the total face value of holdings by each category. Note that since we are using face values as opposed to market values, the figure does not reflect changes in prices that took place during this period. The behavior of non-banks (dashed line) hardly changed during the LTRO period while banks (solid line) increased their holdings significantly after the announcement and before the second and last allotment (LTRO2). This behavior is also markedly different from that observed before the announcement and after the second allotment, when holdings seemed to be growing at a much smaller rate. Bond issuance cannot explain this fact. As a % of amount outstanding, banks increased their holdings of government bonds from 17.7% in November 2011 to 21.3% in February 2012, while non-banks slightly decreased theirs from 7.7% to 7.0%.17

4 Theoretical Background

Having shown that institutions with access to the ECB liquidity increased their government bond holdings after the announcement and before the last LTRO allotment, we now provide a narrative to justify this fact theoretically and link it with the maturity choice of the portfolio of public debt. Our model also provides additional empirical implications that we can confront with the data.

Our hypothesis is that banks used this unprecedented liquidity provision to fund a “collateral trade”: they purchased high yield eligible collateral, mainly in the form of government bonds, to pledge it to the three-year liquidity facility provided by the central bank. In this section, we will develop this argument rigorously.

In particular, we develop a simple model to illustrate the reaction of banks' portfolio choice to the availability of the new funding opportunity and its equilibrium effects. We show (i) how a decrease in borrowing costs can have an asymmetric impact on bond yields at different maturities due to liquidity and collateral constraints and (ii) how a decrease in borrowing costs for investors can lead to a steepening of the yield curve. In the following sections, we test the validity of our narrative by taking advantage of the granularity of our dataset.

17 We cannot normalize quantities in Figure 2 by total assets as we do not observe assets of non-banks.
4.1 Setup

The economy lasts for three periods, \( t = 0, 1, 2 \). It is populated by a continuum of domestic banks, international investors and the government. At the beginning of \( t = 0 \), the government issues short and long-term debt. This consists of zero-coupon bonds maturing at \( t = 1 \) and \( t = 2 \), respectively. This debt is initially purchased by domestic banks. Banks care only about their payoffs 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 and the sequence of events is depicted in Figure 3.

**Banks**  Banks are risk-neutral and care only about their profits at the end of \( t = 2 \)

\[
U = E_0[\pi_2] \tag{1}
\]

where \( \pi_2 \) are profits at \( t = 2 \) that arise from portfolio choices made at \( t = 1 \). Banks enter this period with available resources \( W_1 \) (which can potentially be negative), and can either rebalance their long-term debt portfolio, \( b'_L \), or store/borrow resources \( d \). When \( d \geq 0 \), banks store resources at a unit return between \( t = 1 \) and \( t = 2 \). When \( d < 0 \), banks borrow from external funding markets at a unit cost \( \kappa > 1 \). We can write profits at \( t = 2 \) 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 \( W_1 \) come from choices made at \( t = 0 \).

In the initial period, banks solve a more sophisticated portfolio allocation problem: they can purchase short-term bonds \( b_S \), long-term bonds \( b_L \), store cash \( c \), or borrow from money markets/lender of last resort \( \mathcal{E} \).

Both short-term bonds and cash yield a unit return, while money market borrowing has a unit cost of \( R \). This means that available resources at \( t = 1 \) can be written as

\[
W_1 = b_S + q_1 b_L + c - R \mathcal{E}
\]
At $t = 0$, the bank has some level of initial resources $W_0 > 0$ available.\footnote{We can think of this wealth as being available funds from short-term investments that have just matured, i.e. $W_0 = D + E - L$, where $D, E, L$ are deposits/debt, equity and loans/non-pledgeable assets, respectively.} The bank faces a budget constraint, and a collateral constraint for money market borrowing. The budget constraint at $t = 0$ is

$$W_0 + \mathcal{E} = q_S b_S + q_L b_L + c$$

(2)

And the collateral constraint on external borrowing states that total borrowing $\mathcal{E}$ cannot exceed a weighted average of the value of pledgeable assets,

$$\mathcal{E} \leq (1 - h_L) q_L b_L + (1 - h_S) q_S b_S$$

(3)

where the only pledgeable assets are government debt, of any maturity, and $h_L, h_S$ are the haircuts on long and short-term debt, respectively. This collateral constraint is a modeling device to account for 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.

**International Investors** International investors are risk-neutral, deep-pocketed traders who operate in secondary markets for long-term debt at $t = 1$. They are willing to purchase any amount of debt, generating a perfectly elastic demand curve. There is, however, uncertainty regarding their outside option or valuation, $a \sim F$. At $t = 1$, they are willing to purchase long-term debt if and only if they break even, thus pinning down the price. They purchase debt if and only if

$$q_1 \leq a$$

We assume that $F$, the distribution for $a$, has support $[\underline{q}, \bar{q}]$, where $\bar{q} < 1$ (so that interest rates are always strictly positive).

**Government/Treasury** The treasury manages public debt issuances for the government. We assume that the government seeks to issue a face value of $B$ at $t = 0$, and the Treasury issues a fraction $\gamma$ of short-term debt and a fraction $1 - \gamma$ of long-term debt. These fractions are taken as exogenous and there is no strategic behavior on the part of the fiscal authority for the moment.
Government (Govt) issues short (ST) and long-term (LT) debt
Banks choose portfolio

Govt repays ST debt
Secondary markets open
Banks may access funding markets

Govt repays LT debt
Payoffs realized

Figure 3: Timeline for the Model

4.2 Characterizing the Equilibrium

There are three markets: long-term debt at $t = 1$ and $t = 0$ and short-term debt at $t = 0$. At $t = 1$, the market for long-term debt features international investors on the buy side and domestic banks on the sell side. In equilibrium, the price must equal the inverse return on international investors’ outside option,

$$q_1 = a$$

We describe the detailed solution to the banks’ problem in periods $t = 1$ and $t = 0$ in Appendix A. We let $\kappa \to \infty$, the costs of accessing funding markets at $t = 1$ become prohibitive. While stark, this assumption captures a motive to hold liquid reserves at any point in time (due to regulatory constraints, for example) and simplifies considerably the solution to the model. This effectively makes the bank risk-averse in the second period, equivalent to imposing a liquidity constraint that states that the bank must hold non-negative balances at $t = 1$.

Letting $(\lambda, \delta, \eta)$ denote the Lagrange multipliers on the budget, collateral and liquidity constraints, respectively, and defining

$$\tilde{q} \equiv E_0 \left[ \frac{1}{q_1} \right]^{-1}$$

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

$$\tilde{q} - q_L[\lambda - \delta(1 - h_L)] + q\eta \leq 0 \perp b_L \geq 0$$
$$1 - q_S[\lambda - \delta(1 - h_S)] + \eta \leq 0 \perp b_S \geq 0$$
$$1 - \lambda + \eta \leq 0 \perp c \geq 0$$
$$-R + \lambda - \delta - \eta R \leq 0 \perp \mathcal{E} \geq 0$$

An equilibrium in this model is a pair of prices $(q_S, q_L)$, $t = 0$ bank policies $(b_L, b_S, c, \mathcal{E})$, and $t = 1$ bank policies $(b'_L(q_1), d(q_1))$, such that policies solve the optimization problems for banks at the respective periods.
and all markets clear: the secondary market for long-term debt at \( t = 1 \) and the primary markets for short and long-term debt at \( t = 0 \).

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, \( \delta \). 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, \( \eta \).

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

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

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 \( \lambda \) 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 proceed to characterize the equilibrium in terms of thresholds over the ratio of available resources to the face value of government debt \( \omega \equiv \frac{W_0}{B} \) and the initial cost of borrowing \( R \). The following proposition illustrates the possible 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, \( \epsilon = \delta = \eta = 0 \), and prices satisfy

\[
q_S = \frac{\omega}{\gamma + \tilde{q}(1 - \gamma)} \\
q_L = \frac{\tilde{q} \omega}{\gamma + \tilde{q}(1 - \gamma)}
\]

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

\[
q_S = \frac{1}{R}, \\
q_L = \frac{\hat{q}}{R}
\]

3. For $R\omega \in [h_S\gamma + h_L\hat{q}(1 - \gamma), (\hat{q} - q)(1 - \gamma)]$, the collateral constraint binds, $\delta > 0$, but the liquidity constraint does not, $\eta = 0$. Prices solve the following system

\[
\omega = h_S q_S \gamma + h_L q_L (1 - \gamma) \\
q_S = \frac{1}{R + \delta h_S} \\
q_L = \frac{\hat{q}}{R + \delta h_L}
\]

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

\[
q_S = \frac{1}{R} \\
q_L = \frac{\hat{q} + \eta q}{R(1 + \eta)}
\]

where

\[
\eta = \frac{(\hat{q} - q)(1 - \gamma)}{R\omega} - 1
\]

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

\[
q_S = \frac{1}{R} \left( h_L \frac{(\gamma - q)(1 - \gamma)) - (1 - h_L) R\omega}{\gamma(h_L - h_S)} \right) \\
q_L = \frac{1}{R} \left( (1 - h_S) R\omega - h_S (\gamma + q(1 - \gamma)) \right) \frac{1}{(1 - \gamma)(h_L - h_S)}
\]

The above proposition defines regions for the equilibrium depending on the value of $R\omega$. If the value of this term is very high, banks do not borrow and simply price government debt out of their initially available resources. This can be the case when resources are ample ($\omega$ is high), or when borrowing costs are prohibitive ($R$ is high).

Once either $R$ or $\omega$ decrease, banks start borrowing. There is a region when constraints do not bind, and banks simply 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 $\omega$ decrease further, one or more constraints start binding. For these regions, since either $\delta > 0$, or $\eta > 0$, or both, there will
be a preference for short-term debt. This 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.

We can use our stylized model to analyze the equilibrium effects of banks’ portfolio choice on prices. We do this by letting the pre-allotment period correspond to a situation with dire wholesale funding conditions, high interest rate $R_0$, while the allotment period corresponds to an improvement of these conditions, $R_1 < R_0$, a lower interest rate on wholesale funding. 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). We maintain throughout that haircuts are constant, and the haircut on short-term debt is smaller, $h_S < h_L$.\(^{19}\)

In our model, for the same $\omega$, if the decrease in $R$ is large enough, the economy can experience a change in regime: in particular, the economy can switch from an unconstrained equilibrium to one where banks are constrained, and thus have a preference for short-term debt.

Figure 4 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 (yields become more compressed). However, if the decrease in $R$ is large enough so as 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 induced by the constraint, a decrease in borrowing costs can actually increase the slope of the yield curve.

### 4.3 Treasury Response and Equilibrium Effects

Our model can be extended to account for the response of the treasury (the debt management agency) and the total price effects given that response. In the spirit of Greenwood et al. (2015), we extend the model to endogenize the choice of $\gamma$, the maturity structure chosen by the treasury. Assume, as before, that the treasury needs to finance a total face value of $B$, but can now choose the maturity structure of sovereign debt. In particular, $\gamma$ is now taken to be a control. We assume that the treasury’s objective is to maximize

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\(^{19}\)During the intra-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.
Figure 4: Slope of the Yield Curve, Model. 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 revenue that is raised from the issuance, $q_S \gamma B + q_L (1 - \gamma) B$. Additionally, we also assume that the treasury has a preference for maturity diversification: in a frictionless world, it would issue a fraction $\bar{\gamma}$ of short-term debt, and a fraction $1 - \bar{\gamma}$ of long-term debt, for reasons that we leave unmodelled.\(^{20}\) We write the treasury’s problem as

$$\max_{\gamma \in [0,1]} q_S \gamma B + q_L \gamma B - \frac{1}{2} B \phi (\gamma - \bar{\gamma})^2$$

where the last term captures the losses from deviating from the optimal exogenous maturity structure and $\phi$ captures the relative costs of deviating from this maturity structure. The solution to this problem is given by

$$\gamma = \bar{\gamma} + \frac{q_S - q_L}{\phi}$$

with $\gamma \in [0, 1]$ at all times. The government sets the fraction of short-term debt equal to its unconstrained optimum plus an adjustment term that favors the cheaper maturity, divided by the cost of deviating from the optimal maturity structure.

The following result characterizes the full equilibrium of the model, allowing for government reaction, in a

\(^{20}\) The focus on total revenues as an objective can be motivated by the problem of a government that faces an exogenous stream of expenditures that need to be financed with distortionary taxes.
certain region of the equilibrium space.

**Proposition 2.** Assume that $\phi$ is large enough and that banks are liquidity-constrained, $\eta > 0$. Then, a decrease in $R$ has the following effects:

1. $q_S / q_L \uparrow$, *the slope of the yield curve increases*

2. $\gamma \uparrow$, *the government issues more short-term debt and banks purchase more short-term debt.*

The proposition establishes that in what we will consider to be the empirically relevant region of the equilibrium space, an improvement in borrowing conditions for banks (our way of modeling the LTRO) can lead to a steepening of the yield curve that is accompanied by a strategic reaction of the Treasury, increasing the supply of shorter term debt.

## 5 Empirical Analysis

The model just presented provides a narrative linking the LTRO with the increased bank government bond holdings illustrated in Section 3. We claim that banks’ borrowing behavior at the LTRO and purchases of government bonds after the intervention announcement are driven by a “collateral trade” motive that induced a higher demand for collateral during the December 2011-February 2012 allotment period. More specifically, we argue that the ECB intervention provided banks with an attractive opportunity that consisted of investing in high yield collateral securities, in the form of domestic sovereign bonds, that were then pledgeable to the central bank.

Government bonds, particularly domestic ones, are the best type of high yield security to engage in this trade for several reasons. First, any euro-denominated government bond has a zero risk weight in determining bank capital requirements. Purchasing a bond issued by a eurozone country is therefore a very cheap way, from a regulatory standpoint, to gain access to ECB liquidity. Second, in addition to this preferential treatment, *domestic* government bonds are even more attractive in risky countries during the crisis. In a setting characterized by extensive implicit and explicit government guarantees over the banking system and a substantial degree of sovereign-bank linkages, banks and sovereigns tend to default in the same set of states of the world. Due to risk-shifting, government debt thus offers a better return to domestic banks than to foreign ones, and public debt tends to be repatriated.\(^{21}\) The only states of the world that

---

\(^{21}\)When sovereigns and banks default in the same states of the world, banks do not internalize any losses when choosing their portfolios. If there are other agents in the market who price this risk, government debt will thus appear to be underpriced from the bank’s perspective (see Crosignani (2015)).
may lead banks not to deem domestic sovereign debt safe investments are those in which the price of the purchased bonds may change (in the absence of both sovereign and bank default), thereby affecting the bank’s capacity to repay the ECB loan, or resulting in the ECB issuing a margin call to the bank.\footnote{Without the option of early repayment - which only occurs after one year - banks are required to either pledge additional collateral or place cash in margin call deposits at the ECB should the collateral drop in value.}

Having motivated our focus on domestic government bonds, we now summarize the four key predictions of our model. We will test them in the next four subsections.

**Prediction 1: Banks buy collateral to borrow at the LTRO.** Banks engaging in the collateral trade need to buy eligible collateral securities and pledge them at the LTRO. Therefore, we should observe that purchases of collateral during the allotment period correlate with bank LTRO borrowing.

**Prediction 2: LTRO causes government bond purchases.** The LTRO induces banks to engage in a “collateral trade”, buying high yield government bonds. More specifically, according to our model, banks buy short-term bonds in order to match the maturity of central bank 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 ECB liquidity causes a steepening of the sovereign yield curve.

**Prediction 4: The sovereign debt agency issues more (short-term) debt.** As short-term sovereign yields collapse, the sovereign debt agency reacts by increasing public debt issuance using short-term bonds.

### 5.1 Banks’ Buy-and-Borrow Behavior

In this section, we test whether collateral securities purchased in the allotment period are then pledged to the ECB to obtain LTRO funds, as predicted by our model (Prediction 1). Again, we focus on domestic government bonds and check whether banks that purchased more domestic public debt obtain more LTRO funds.\footnote{We cannot distinguish pledged and unpledged securities in our dataset.} Driven by the observation that government bond holdings increase between December 2011 and February 2012, we focus on the second allotment (LTRO2).\footnote{There are several reasons that might inhibit banks from using LTRO1 and not LTRO2 for their collateral trade: (i) uncertainty (resolved before LTRO2 as suggested by Andrade et al. (2015)) that tapping LTRO might send a bad signal to the market, (ii) little time (two weeks compared to three months for LTRO2) to buy government bonds in the secondary market, and (iii) window-dressing so as not to show increased}
We classify ECB-eligible assets in five categories: domestic government bonds, other marketable assets (e.g. foreign government bonds, ABSs, covered bonds), government guaranteed bank bonds, additional credit claims, and specific non-marketable assets (shared risk). In Figure 5, we show the time-series evolution of aggregate collateral pledged by Portuguese banks to the Eurosystem. Banks have replaced other marketable assets with domestic government bonds in their collateral pools, while additional ECB and government measures helped further increase the list of eligible assets through the use of additional credit claims, i.e. private sector loans, and of government guaranteed bank bonds, which, despite their large value, were used by a very small number of banks.

Figure 5: Pledged Collateral by Type of Eligible Asset. This figure plots aggregates amounts of assets pledged as collateral with the Eurosystem, discounted by haircuts. The categories included are exhaustive and for marketable assets include: domestic government bonds, government guaranteed bank bonds (GGBB) and other marketable assets; for non-marketable assets: additional credit claims (ACC), shared risk framework non-marketable assets.

To show the link between LTRO borrowing and domestic government bonds purchases more formally, we run the following simple cross-sectional regression in the subsample of financial institutions (banks and savings institutions) that have access to ECB liquidity:

\[
LTRO2_i = \alpha + \beta \Delta \text{Govt}_i, \text{Feb12-Nov11} + \gamma \Delta \text{Other Collateral}_i, \text{Feb12-Nov11} + \epsilon_i
\]  

(4)

government bond holdings on the 2011 annual report (based on bank balance sheet as of December 31). In Section 6.4, we analyze bank behavior at LTRO1 and further motivate our focus on LTRO2. We provide additional details regarding ECB collateral framework in the Online Appendix.
| LTRO2 Uptake |  
|-------------|---
| $\Delta$Govt (Face Value) | 1.089***  
| (0.010)       |  
| $\Delta$Govt (Market Value) | 1.207***  
| (0.009)       |  
| $\Delta$ACC  | 0.800***  
| (0.038)       |  
| $\Delta$GGBB | 2.012***  
| (0.260)       |  
| $\Delta$Other Marketable | 0.793***  
| (0.047)       |  
| Observations | 68  
| R-squared    | 0.941 |

Table 1: Banks' Buy-and-Borrow Behavior. This table presents the estimation results for specification (4). 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. Eligible collateral includes domestic government bonds, additional credit claims (ACC), government guaranteed bank bonds (GGBB), and other marketable securities. All independent variables are normalized by bank assets in November 2011. In the first (second) column, we measure changes in government bond holdings using face (market) values. In the Online Appendix, we provide a detailed description of the ECB collateral framework. Robust standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

where the dependent variable is the total uptake at LTRO2, $\Delta$Govt$_{i, \text{Feb12-Nov11}}$ measures changes in holdings of domestic government bonds, and $\Delta$Other Collateral$_{i, \text{Feb12-Nov11}}$ is a vector of changes in holdings of other types of collateral. All changes are measured between November 2011 (the last observation before the announcement) and February 2012 (LTRO2 date). LTRO2 was allotted on the last day of February but settled on March 1; hence our February observations are the last snapshot before the LTRO2 borrowing that is seen only in March data. All variables are normalized by bank assets in November 2011 as large banks are more likely to buy more securities and borrow more at the central bank in absolute amounts.

If banks are buying government bonds and using them to borrow at LTRO2, the $\beta$ coefficient should be close to 1. We show the estimation results in Table 1, where we measure changes in government bond holdings using face values (column (1)) and market values (column (2)). We include both measures since bank borrowing capacity at the ECB depends on the market value of collateral assets, but changes measured in market value might simply reflect price movements, not changes in actual bank holdings of a security. Consistent with a buy-and-pledge behavior, the coefficient of interest is close to 1, suggesting that banks did borrow approximately €1 for each euro of increased government bond holdings during the allotment period. The regression also includes, as controls, changes in the other three collateral categories used.
in this period by Portuguese banks to obtain central bank liquidity: additional credit claims, government
guaranteed bank bonds, and other marketable assets.

## 5.2 LTRO Causes Purchases of Domestic Government Bonds

We now test whether the LTRO caused an increase in government bond holdings (Prediction 2). Our model
suggests that institutions with access to this liquidity facility have an incentive to rebalance their government
bond portfolio towards securities maturing before the second LTRO loan (February 2015). Hereafter, we
refer to these securities as “short-term” bonds.

The intuition is as follows: if a bank engages in the collateral trade using government bonds with maturity
exceeding that of the ECB loan, it will be highly exposed to funding liquidity risk. If those bonds drop in price
during the term of the ECB 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. Either of these situations force the bank to
raise additional funds to either meet the margin call or repay the loan, which might be very costly in a crisis
setting and increase uncertainty regarding liquidity management. If bonds have a term that is shorter than
the loan, however, the risk associated with the margin call is lower, and the bond matures - becomes cash
- before the loan is due. This still results in a margin call, which the bank can cover with the newly available
funds, and so entails much less risk. In addition, the bank obtains an additional profit since the bond yield
exceeds the borrowing cost in the first place.\footnote{To formalize this reasoning, we present in the Online Appendix a very simple model of liquidity risk that illustrates the main trade-offs inherent to bond maturity. The model presents conditions under which a portfolio manager prefers to invest in shorter-term bonds even in the absence of any time discounting. The reason is that in an environment where raising liquidity is costly, the risk of margin calls dominates the benefit from investing in an asset with a higher expected return.}

The first step in our empirical test is to properly measure bank-level changes in government bond holdings
of different maturities. Such a variable requires particular care as one needs to simultaneously take into
account that large banks will likely buy more bonds (i.e. normalize by bank size) and that the amounts
of short- and long-term bonds outstanding might be different and change over time (i.e. normalize by
amounts outstanding). The second normalization is particularly important in our context as (i) new bonds
might be issued and existing bonds mature each month and (ii) the distribution of maturities of Portuguese
government bonds is skewed with more long-term than short-term government bonds outstanding.\footnote{In February 2012, short-term government bonds were 35% of the total amount outstanding.}

Consider the following example. Bank A and Bank B both buy €50 in short-term government bonds and

\begin{align*}
\text{Bank A} & \quad \text{Bank B} \\
\text{€50 in short-term bonds} & \quad \text{€50 in short-term bonds} \\
\text{(i.e. normalize by bank size)} & \quad \text{(i.e. normalize by bank size)} \\
\end{align*}
€50 in long-term government bonds. If Bank A is larger than Bank B, and we are interested in analyzing the relative preference for government bonds, we should divide bank holdings by bank total 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 after normalizing 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 compared to the long-term outstanding.

We tackle these two concerns by defining the following variable

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

This variable measures the share of public debt outstanding of maturity $m$ (“short” or “long”) held by institution $i$ in month $t$, divided by the size of institution $i$ relative to the size of the financial sector in month $t$. The numerator captures the share of short- or long-term government bonds outstanding held by one institution. The denominator scales the numerator so that holdings of large institutions do not have a disproportionate impact on the coefficients. While this measure makes it less obvious how to interpret directly the regression coefficients, we use the results to provide estimates of the aggregate impact of the effects.

To test Prediction 2, we first run the following two specifications on the subsample of institutions that have access to ECB liquidity (i.e. banks and savings institutions) in the period running from June 2011 to June 2012:

$$\text{Holdings}_{i,\text{Short},t} = \alpha + \beta \text{Post}_t + \eta_i + \epsilon_{i,t} \quad (5a)$$
$$\text{Holdings}_{i,\text{Long},t} = \alpha + \beta \text{Post}_t + \eta_i + \epsilon_{i,t} \quad (5b)$$

where the dependent variable is the share of short-term (long-term) public debt outstanding held by bank $i$ in month $t$ divided by the size of bank $i$ relative to the size of financial sector in month $t$, Post$_t$ is a time dummy equal to 1 after, and including, December 2011, and $\eta_i$ is an institution fixed effect. We classify a

---

28 We decided to end our sample period in June 2012 in order not to overlap with Draghi’s July 26, 2012 OMT announcement, also known as “whatever it takes” speech.
As having short maturity if it matures before or on February 2015, the LTRO maturity. With these two simple regressions, we ask whether banks purchased more short-term (long-term) government bonds after the LTRO announcement relative to the pre-announcement period.

We then run the following standard difference-in-differences specification for the same sample period and banks:

\[
\text{Holdings}_{i,m,t} = \alpha + \beta \text{Post}_t \times \text{Short}_m + \eta_{i,t} + \xi_{i,m} + \epsilon_{i,m,t}
\]

where \(\text{Short}_m\) is a dummy variable equal to 1 for the portion of the sovereign bond portfolio maturing on or before February 2015, \(\eta_{i,t}\) are institution-time fixed effects, and \(\xi_{i,m}\) are institution-maturity fixed effects. The goal is to test whether banks bought more short-term government bonds relative to long-term government bonds after the announcement of LTRO relative to the pre-announcement period.

Table 2 shows the estimation results for specifications (5a), (5b), and (6). The first two columns show that banks increase their holdings of both short- and long-term government bonds after the LTRO announcement. Consistent with our model, the effect is more pronounced for bonds with shorter maturities. This finding is confirmed by the difference-in-differences estimation result in the third column. The coefficient of the interaction term is positive and significant, showing that banks bought more short-term relative to long-term government bonds after the LTRO announcement, after controlling for institution-bond maturity and institution-time varying heterogeneity using fixed effects.

**Aggregate Impact** To get a sense of the quantitative importance of our results, we calculate the aggregate impact of the LTRO announcement on the demand for government bonds. We use the results in the first two columns of Table 2. For each bank-maturity observation in February 2012, we perform the following calculation:

\[
\text{Demand Boost}_{i,m} = \beta_m \frac{\text{Assets}_{i,\text{Feb12}}}{\text{Total Assets}_{\text{Feb12}}} \frac{\text{Amount Outstanding}_{m,\text{Feb12}}}{\text{Amount Outstanding}_{m,\text{Feb12}}}
\]

where \(\beta_{\text{short}}\) and \(\beta_{\text{long}}\) are the coefficients in specifications (5a) and (5b). The result is the impact, measured in euros, on the demand for a given maturity of a given bank during the post-LTRO period. We then aggregate these amounts across the banking sector. We find that the LTRO announcement boosted demand for short-term bonds by €4.1 billion, around 8.4% of the amount outstanding. Regarding long-term
Table 2: LTRO and Government Bond Purchases. This table presents the results of specifications (5a), (5b) and (6). The dependent variable in column (1) (column (2)) is the share of total short (long) term public debt outstanding held by financial entity \( i \) divided by the size of entity \( i \) relative to total asset of the financial sector. The dependent variable in column (3) is the share of public debt of maturity \( m \) outstanding held by entity \( i \) divided by the size of entity \( i \) relative to total asset of the financial sector. This regression includes only institutions with access to the LTRO, i.e. banks and savings institutions. Independent variables include a Post\(_t\) dummy equal to one on and after December 2011 and a Short\(_m\) dummy equal to one if the government bond portfolio matures on or before February 2015 (LTRO maturity). The sample is monthly from June 2011 to June 2012. Robust standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

<table>
<thead>
<tr>
<th></th>
<th>Holdings(_{i,Short,t})</th>
<th>Holdings(_{i,Long,t})</th>
<th>Holdings(_{i,m,t})</th>
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</thead>
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<td>Post</td>
<td>0.086***</td>
<td>0.031***</td>
<td>0.054***</td>
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<td></td>
<td>(0.023)</td>
<td>(0.006)</td>
<td>(0.021)</td>
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<td>Post × Short</td>
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<td></td>
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</tr>
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<td>✓</td>
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<td></td>
<td></td>
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<tr>
<td>Institution-Time FE</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>Specification</td>
<td>(5a)</td>
<td>(5b)</td>
<td>(6)</td>
</tr>
<tr>
<td>Observations</td>
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<td>893</td>
<td>1,786</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.762</td>
<td>0.847</td>
<td>0.908</td>
</tr>
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</table>

bonds, demand was boosted by €2.8 billion, around 3.1% of the amount outstanding, leading to a total boost of 5.0% across maturities. Relative to the size of the banking sector, these were increases of 0.7% and 0.5% in terms of the total assets of the banking sector, respectively. This suggests that the LTRO had an economically significant impact on the demand for government debt, especially at short maturities.

**Placebo**  A potential concern in our difference-in-differences setting is that the described effect might also be present in periods other than the treatment period. Such case would hinder our causal claim suggesting that our specifications might suffer from an omitted variables bias, as holdings of short-term government bonds might be driven by unobservables.

To this end, we run placebo regressions, simulating the application of the treatment in every month in the sample. Interestingly, on four dates a weaker treatment is actually in place as the ECB adopted other longer-than-usual liquidity provisions: three 6-month LTROs were allotted in April 2010, May 2010, and August 2011 and one 12-month LTRO was allotted in October 2011. The one in October is particularly relevant, since its maturity is already long enough to allow banks to match the maturity buying government
Figure 6: **Placebo Test.** This figure plots interaction coefficients from specification (7). The solid black lines plot coefficients and the dashed blue lines delimit the 90% confidence interval. The vertical dashed line indicates the LTRO announcement date (December 2011).

We run the following specification for every month between June 2010 and May 2013:

\[
\text{Holdings}_{i,m,t} = \alpha + \beta I_t \times \text{Short}_m + \eta_{i,t} + \xi_{i,m} + \epsilon_{i,m,t} 
\]  

(7)

where \(I_t\) is an indicator variable equal to 1 in period \(t\) and 0 otherwise, \(\eta_{i,t}\) are institution-time fixed effects, and \(\xi_{i,m}\) are institution-maturity fixed effects. For the purpose of these placebo regressions, and due to the larger sample period, we now classify as *Short* all bonds expiring within 36 months of the treatment date. This means that this new definition coincides exactly with our previous definition for February 2012. Our variable of interest is the coefficient \(\beta\) of the indicator variable at different points in our sample.

In Figure 6, we plot the coefficients on the interaction term for each separate regression. The solid black

---

\(^{29}\)Banks were allowed to rollover the October one-year allotment into LTRO1. See [www.ecb.europa.eu/press/pr/date/2011/html/pr111208_1.en.html](http://www.ecb.europa.eu/press/pr/date/2011/html/pr111208_1.en.html). In Section 6.5, we discuss what is different about these longer-term LTROs with one- and three-year maturities relative to the standard three-month LTROs.
line plots the coefficient of interest on the indicator variable in a given period and the dashed blue lines delimit the 90% confidence interval. Outside of the period of the LTROs, the coefficient is close to 0 or even negative. In the three-year window we are studying, the coefficient only becomes positive and significant around the LTRO period. The coefficient is close to 0 until October 2011, but in November 2011 it spikes upward, one week before the LTRO announcement, likely capturing the effects of the one-year LTRO settled at the end of October that was eventually replaced by the three-year LTRO.

**Mutual Funds as a Control Group** Our identification strategy relies on the assumption that in absence of the LTRO, banks would not buy more (short-term) government bonds after the announcement compared to the pre-announcement period. If such identification assumption is not satisfied, our results might suffer from an omitted variable bias. So far, our analysis has used the subsample of financial institutions that have access to ECB liquidity, namely banks and savings institutions. We now check the plausibility of the identification assumption by analyzing the behavior of mutual funds, the only type of institution that we observe in our data and that has no access to ECB liquidity.\(^{30}\) We conduct two tests. First, we re-run the regressions in Table 2 for the subsample of mutual funds. Second, we run the following triple-difference specification:

\[
\text{Holdings}_{i,m,t} = \alpha + \beta \text{Post}_t \times \text{Short}_m \times \text{Bank}_i + \eta_{i,t} + \xi_{i,m} + \mu_{m,t} + \epsilon_{i,m,t}
\]  

(8)

where the only new variable is Bank, a dummy equal to 1 if the financial institution has access to the LTRO.

We run specification (8) in the full sample of banks, saving institutions, and mutual funds and estimate the coefficient of the triple interaction saturating the regression with institution-time, institution-maturity, and time-maturity fixed effects.

We show the estimation results in Table 3. In the first three columns, we illustrate the results of the specifications in Table 2 for the sub-sample of mutual funds. The fourth column shows the results of the triple difference specifications in equation (8). The first three columns show that mutual funds are not more likely

\(^{30}\) Following the description in Section 3.2, we use mutual funds as a control group; in particular, mutual funds which held domestic government bonds at any point in our larger sample between 2005 and 2014. Table C.1 in the Appendix presents results using a broader sample that includes the universe of mutual funds as a control group. This includes mutual funds that never hold domestic government bonds at any point in our sample period. Our results are robust to this alternative sample selection. We did not adopt this larger sample as our preferred specification because of to the high degree of portfolio specialization of these institutions, especially when compared to banks.
Table 3: Access to ECB Liquidity and Government Bond Purchases. Columns (1)-(3) of this table replicates the estimation reported in Table 2 for the subsample of mutual funds that hold domestic government bonds at any point during our sample period. Column (4) presents the results of specification (8). The dependent variable in column (1) (column (2)) is the share of total short (long) term public debt outstanding held by financial entity $i$ divided by the size of entity $i$ relative to total asset of the financial sector. The dependent variable in columns (3) and (4) is the share of public debt of maturity $m$ outstanding held by entity $i$ divided by the size of entity $i$ relative to total asset of the financial sector. Independent variables include a Post$_t$ dummy equal to one after, and including, December 2011, a Short$_m$ dummy equal to one if the government bond portfolio matures on or before February 2015 (LTRO maturity), and a Access$_i$ dummy equal to one for institutions that have access to ECB liquidity. The sample is monthly from June 2011 to June 2012. Robust standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

<table>
<thead>
<tr>
<th></th>
<th>$Holdings_{i,Short,t}$</th>
<th>$Holdings_{i,Long,t}$</th>
<th>$Holdings_{i,m,t}$</th>
<th>$Holdings_{i,m,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post $\times$ Short</td>
<td>-0.014 (0.018)</td>
<td>0.034*** (0.004)</td>
<td>-0.048** (0.019)</td>
<td>0.102*** (0.028)</td>
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<tr>
<td>Post $\times$ Short $\times$ Access</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
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<td>✓ ✓</td>
<td>✓ ✓</td>
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<tr>
<td>Institution-Time FE</td>
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<td>✓ ✓</td>
<td>✓ ✓</td>
<td>✓ ✓</td>
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<tr>
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<td>Mutual Funds</td>
<td>Mutual Funds</td>
<td>Full</td>
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<tr>
<td>Specification</td>
<td>(5a)</td>
<td>(5b)</td>
<td>(6)</td>
<td>(8)</td>
</tr>
<tr>
<td>Observations</td>
<td>3,233</td>
<td>3,233</td>
<td>6,466</td>
<td>8,252</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.868</td>
<td>0.954</td>
<td>0.939</td>
<td>0.938</td>
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</tbody>
</table>

Table C.2 in the Appendix replicates the results of Table 2 and Table 3 using a different definition of short maturity. In that table, we redefine a bond as “Short” if it is at most three years away from maturing. Our results are robust to this alternative maturity definition.

**Intensive Margin** Our theoretical framework suggests also that the larger the LTRO borrowing, the stronger the demand for shorter-term collateral. A natural way to test this hypothesis is to extend our...
baseline specification to include an interaction term with a continuous variable that reflects the intensity of LTRO borrowing. We define intensity for bank \(i\) as follows:

\[
\text{Intensity}_i = \frac{\text{LTRO}_i}{\text{Assets}_i}
\]

where \(\text{LTRO}_i\) is total long-term borrowing from the ECB at the end of March 2012 by entity \(i\) (the first observation that includes the second allotment), and \(\text{Assets}_i\) is the value of assets of entity \(i\) in the same period. This variable simply measures the fraction of assets that are funded by long-term ECB borrowing after the second allotment. We then adapt our specifications (5a), (5b), and (6) to:

\[
\begin{align*}
\hat{\text{Holdings}}_{i,\text{Short},t} &= \alpha + \beta \text{Post}_t \times \text{Intensity}_i + \eta_i + \xi_t + \epsilon_{i,t} \\
\hat{\text{Holdings}}_{i,\text{Long},t} &= \alpha + \beta \text{Post}_t \times \text{Intensity}_i + \eta_i + \xi_t + \epsilon_{i,t} \\
\hat{\text{Holdings}}_{i,m,t} &= \alpha + \beta \text{Post}_t \times \text{Short}_m \times \text{Intensity}_i + \eta_{i,t} + \xi_{i,m} + \nu_{t,m} + \epsilon_{i,m,t}
\end{align*}
\]

Notice that the inclusion of the intensity variable allows us to introduce more restrictive fixed effects for time in (9a) and (9b), and for the interaction between time and maturity in (9c). A problem with these adapted specifications is that we measure intensity as total ECB borrowing by the end of the second allotment, three months after the policy has been announced. Naturally, this poses a significant endogeneity problem, since increased holdings of government debt affect the pool of collateral owned by the bank and, therefore, how much the bank is able to borrow. To address this issue, we take advantage of the fact that a considerable part of LTRO borrowing was rollover of past ECB borrowing. For this reason, we instrument \(\text{Intensity}_i\) with total ECB borrowing as a percentage of assets in September 2011. Exogeneity of the instrument arises from our timing identification assumption: that the LTRO was an unexpected policy and, hence, any ECB borrowing in late September 2011, a week before the announcement of a 1-year LTRO and two months before the announcement of the 3-year LTRO, is independent from any change in the behavior of government bond purchases occurring after the announcement. The results are presented in Table 4: again, we find a positive impact on both short and long-term bond purchases, with a stronger effect on the former. This difference is also statistically significant, as confirmed by the difference-in-differences specification in column (6). These confirm the existence of our finding on the intensive margin.
### Table 4: LTRO and Government Bond Purchases: Intensive Margin

This table presents the results of specifications (9a), (9b) and (9c). The dependent variable in columns (1) and (4) (columns (2) and (5)) is the share of total short (long) term public debt outstanding held by financial entity $i$ divided by the size of entity $i$ relative to total asset of the financial sector. The dependent variable in columns (3) and (6) is the share of public debt of maturity $m$ outstanding held by entity $i$ divided by the size of entity $i$ relative to total asset of the financial sector. This regression includes only entities with access to LTRO, i.e. banks and savings institutions. Independent variables include a Post, 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, continuous variable equal to LTRO borrowing divided by assets in March 2012. In columns (4)-(6), total borrowing from the ECB in September 2011 is used as an instrument for Intensity. The sample is monthly from June 2011 to June 2012. Robust standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

<table>
<thead>
<tr>
<th></th>
<th>Holdings$_{i,Short,t}$</th>
<th>Holdings$_{i,Long,t}$</th>
<th>Holdings$_{i,m,t}$</th>
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<td>Post $\times$ Intensity</td>
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<td>0.009***</td>
<td>0.022***</td>
<td>0.008***</td>
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<tr>
<td></td>
<td>(0.011)</td>
<td>(0.002)</td>
<td>(0.007)</td>
<td>(0.002)</td>
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</tr>
<tr>
<td>Post $\times$ Short $\times$ Intensity</td>
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<td>0.029***</td>
<td></td>
<td>0.014**</td>
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<td></td>
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<td>(0.006)</td>
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</tr>
<tr>
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<td>(9b)</td>
<td>(9c)</td>
<td>(9a)</td>
<td>(9b)</td>
<td>(9c)</td>
</tr>
<tr>
<td>Observations</td>
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<td>1,786</td>
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<tr>
<td>R-squared</td>
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<td>0.805</td>
<td>0.876</td>
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<td>First Stage F-stat</td>
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<td>490.4</td>
<td>489.8</td>
<td>490.4</td>
<td>490.4</td>
<td>489.8</td>
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</table>
5.3 Effect on Government Bond Yields

We now ask whether the increased demand for short-term government bonds results in a steepening of the yield curve, as predicted by our model (Prediction 3). In the absence of a clear and clean setting that allows us to formally test this equilibrium outcome, we simply provide evidence consistent with the prediction and discuss potential alternative explanations.

The top left panel of Figure 7 plots the Portuguese sovereign yield curve at three points in time: November 2011, February 2012, and May 2012. In the allotment period, between November and February, we observe that short-term yields fall, driving the steepening of the yield curve that carries on to May 2012. The top right panel plots the time series of the slope for the yield curve, defined as the ten-year minus the one-year yield, from 2009 to 2013. Both figures are consistent with the LTRO inducing higher demand for short-term bonds and affecting prices accordingly.

To investigate the link between the LTRO and the steepening of the sovereign yield curve, we analyze sovereign yield curves in other eurozone countries. According to our model, the collateral trade is more profitable if banks buy high yield sovereign bonds. Hence, we should observe a steepening of the yield curve in risky peripheral countries and not in safe core countries. In the remaining panels of Figure 7, we analyze four large eurozone countries, two peripheral (Italy and Spain) and two core (Germany and France). Consistent with our narrative, we observe sovereign yield curve steepening only in the two risky peripheral countries. 31

One concern is that the changes in the yield curve may be unrelated to the LTRO and instead connected with the ECB Securities Markets Programme (SMP) launched in May 2010. As the SMP consisted of purchases of sovereign bonds in the secondary market (a textbook QE operation), observed changes in prices might be caused by purchases of short-term securities by the central bank. However, Krishnamurthy et al. (2014) 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. If anything, the contemporaneous SMP effect would work against our results, since purchases of bonds at longer maturities should flatten, not steepen, the yield curve. 32

31 We choose larger countries precisely because their respective bond markets are larger and more liquid. This should alleviate concerns that this type of movements in the yield curve may be related to the illiquidity of the Portuguese sovereign bond market during this time.

32 It is also unlikely that the SMP program influenced agents’ behavior during the allotment period, given the shroud of secrecy around the details of the central bank purchases. We do not find it plausible that expectations regarding the program substantially affected the behavior of market participants, who were unaware of the type and quantity of securities that the ECB was purchasing. In fact, the details of the SMP,
such as amounts traded and securities purchased, were never disclosed: the only way through which the total volume of operations was known was through auxiliary open market operations that aimed at sterilizing the impact of the bond purchases.
Figure 7: Evolution of the Sovereign Yield Curve. This figure shows the time series evolution of sovereign yields in Portugal, Italy, Spain, France, and Germany. The left column plots snapshots for these countries’ yield curves at three different points in time (end of the month dates): November 2011, February 2012, and May 2012. The horizontal axis measures maturity in years and the vertical axis measures the percentage yield to maturity. The right column plots the time series (daily frequency) of the slope for the yield curve, measured as the ten-year yield minus the one-year yield, from 2009 to 2013. Portuguese spreads are obtained using the 6-month yield as one-year yields are not available on Bloomberg during parts of the sample. The vertical dashed line corresponds to the LTRO announcement on December 8, 2011.
5.4 Public Debt Management

We now ask whether the increased demand for short-term government bonds and the equilibrium effects on the sovereign yield curve may lead to increased public debt issuance, as the sovereign debt management agency takes advantage of lower yields to auction new bonds (Prediction 4). As in the previous subsection, in the absence of a clean empirical setting, we provide evidence consistent with this last model prediction.

In Figure 8, we plot monthly issuance volumes of public debt from June 2010 to April 2013. The dashed vertical line corresponds to the LTRO announcement in December 2011. The figure documents that the debt agency increases debt issuance after the LTRO announcement, an observation that cannot be explained by rollover needs as, before and after the LTRO, the amount of public debt maturing each semester is roughly constant, approximately €20 billion from 2011 to mid-2012.

Interestingly, during the allotment period, there are four short-term zero-coupon bonds maturing for a total of €13.5 billion and the government issues €7.9 billion using four zero-coupon bonds with maturities of one year (two bonds) and six-months (two bonds). This behavior is consistent with the prediction of the model, which states that the debt management agency has an incentive to tilt its issuances towards the short-end of the curve in response to market prices.

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33 Government debt is managed by the Agência de Gestão da Tesouraria e da Dívida Pública - IGCP, an autonomous public agency in charge of managing consolidated public debt (government debt and the debt of some public companies).

34 This exercise relates to a growing body of literature that studies the optimal composition of government debt issuances. Broner et al. (2013) show that emerging economies tend to borrow at shorter maturities due to lower costs. Arellano and Ramanarayanan (2012) motivate the same finding by observing that the incentives to repay, which are particularly important during downturns, are more effectively given by short-term debt. In a recent contribution, Bai et al. (2015) show that, during crises, governments issue shorter-maturity bonds with back-loaded payments. This latter feature allows the government to smooth consumption by aligning payments with future output.

35 In Figure B.1 in the Appendix, we show public debt monthly maturing volumes.

36 Three have a one year maturity and one has a six-month maturity. The amount of one-year debt issued was similar across auctions, but the government issued twice as much six-month debt during the first auction. Both one-year securities had a very similar price across auctions, while the six-month securities had different yields: the February issue was much cheaper for the government (4.33% compared to 4.74% in January.).
6 Discussion

Having presented evidence for the collateral trade mechanism, we now proceed to discuss five additional aspects that arise naturally from our analysis. First, which banks engaged in the collateral trade the most? Second, how did banks fund the collateral trade in the first place? Third, how much did they profit from it? Fourth, why did banks rely mostly on the second LTRO allotment for the collateral trade? And, finally, what is the role of the long LTRO maturity in attracting banks to borrow at the central bank?

6.1 Bank Heterogeneity

So far, according to our narrative, there is no reason why a bank should not engage in this collateral trade. In fact, the LTRO gives every bank the opportunity to invest in high-yield government bonds that can be then pledged as collateral to the central bank, regardless of its balance sheet characteristics. It is nevertheless important to understand which banks engage in this behavior the most in order to inform policy about the transmission of this (possibly) unintended consequence and shed light on what drives bank portfolio choice during large-scale liquidity provisions.

In the third and fourth columns of Table 5, we divide banks in two subsamples: banks that engaged and banks that did not engage in the collateral trade activity. We find that only 15 banks took advantage of the ECB liquidity provision to buy government bonds. These are large and highly levered institutions, responsible for 83% of total LTRO borrowing. In the last column, for those 15 institutions, we compute...
Table 5: Bank Characteristics and Government Bond Purchases. This table shows which banks engaged the most in the collateral trade. The third (fourth) column shows summary statistics in November 2011 (cross-sectional mean) for the group of banks with zero (strictly positive) collateral trade activity. The fifth column shows correlation between each balance sheet variables and the collateral trade activity in the subsample of institutions that have a 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. IIGS government bonds are government bonds issued by Italy, Ireland, Greece, and Spain. Securities liabilities are securities issued for funding purposes (e.g., bonds, commercial paper). Short-term funding are securities issued with a maturity less than one year, short-term deposits, and repurchase agreements. For the purpose of the last column, total assets is the natural logarithm of total assets.

| Variable (BS)       | Unit     | No Trade | Trade > 0 | \( \rho((BS, Trade) | Trade > 0) \) |
|---------------------|----------|----------|-----------|-----------------|
| Number of Banks     |          | 54       | 15        |                 |
| Total Assets        | bn euro  | 2.4      | 29.4      | -53.2%          |
| Leverage            | A/E      | 6.0      | 11.0      | -25.2%          |
| Cash Reserves       | % Assets | 0.1      | 0.3       | -22.0%          |
| Securities          | % Assets | 10.6     | 25.4      | 41.8%           |
| Total Govt. Bonds   | % Assets | 2.3      | 6.3       | 51.6%           |
| Domestic Govt. Bonds| % Assets | 1.9      | 5.7       | 57.3%           |
| IIGS Govt. Bonds    | % Assets | 0.3      | 0.5       | -3.4%           |
| Equities            | % Assets | 1.8      | 3.2       | -7.8%           |
| 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%           |
| Net Borr. from Banks| % Assets | 18.0     | -1.9      | -14.6%          |
| Deposits            | % Assets | 29.8     | 30.7      | -14.3%          |
| Short-term Funding  | % Assets | 57.7     | 59.8      | 26.4%           |

Correlations between each balance sheet variable measured in November 2011 and bank-level collateral trade activity. Within the group of institutions that engage in the trade, banks that buy more government bonds tend to be smaller, have lower leverage, and hold relatively larger government bond portfolios. How do we rationalize these findings? Banks with high leverage and heavily reliant on short-term funding are hit the most during the sovereign crisis. Hence, our evidence suggests that relatively healthier banks engage in the collateral trade the most. As we discuss in the next subsection, banks need to purchase government bonds in the intra-allotment period before obtaining new liquidity from the central bank at LTRO2 and therefore need some initial balance sheet capacity to purchase new government bonds. It is likely that relatively more solid institutions have easier access to funding compared to more fragile institutions. These findings are consistent with Carpinelli and Crosignani (2015), who find that Italian banks with less runnable liabilities bought more government bonds in this period and with Abbassi et al. (forthcoming), who find that better-capitalized German banks increase their investments in securities, especially in those that had a
larger price drop, compared to worse-capitalized banks during the crisis.\textsuperscript{37}

\section*{6.2 Funding the Collateral Trade}

Banks that want to engage in the collateral trade need to buy the securities \textit{before} pledging them at the central bank. The timing of this strategy is the key difference with respect to a standard carry trade where banks buy high-yield securities \textit{after} obtaining (cheaper) funding. How then did Portuguese banks finance the collateral trade?

To answer this question, Table 6 aggregates the balance sheet of our sample banks before and at the time of the second LTRO allotment (November 2011 and February 2012, respectively) and presents levels and changes for several balance sheet items. We observe that new borrowing from the central bank amounted to €1.9 billion in the first allotment and the period up to the second allotment, so that a significant part of the total LTRO1 €20.2 billion uptake was used to rollover existing short- and medium-term ECB borrowing. Balance sheets increase from €571.2 billion to €582.7 billion, while equity is mostly stable, leading to a small increase in leverage. There is a marginal decrease in cash reserves and the bulk of the adjustment on the assets side seems to come from private credit, which falls by around €4 billion euros during this period. The fall in credit is particularly pronounced for non-financial firms. The fact that private credit is falling during this period as balance sheets expand suggests that the collateral trade might have a crowding out effect.

\section*{6.3 LTRO as a Stealth Recapitalization}

We now focus on the implications of the LTRO for financial stability. On the one hand, increased holdings of domestic government bonds exacerbated the vicious link between sovereign and banks. On the other hand, rising government bond prices effectively constituted a “stealth-recapitalization” of the banking sector as government bond securities held by banks increased in value, another possibly intended consequence, allowing banks to realize capital gains.\textsuperscript{38}

Thanks to the richness of our data, we can compute bank-level capital gains caused by the LTRO and thus

\textsuperscript{37}Our story is therefore consistent with classical models of arbitrage whereby less specialized or traditional investors enter a particular market if returns are sufficiently high.

\textsuperscript{38}We employ this term in the same sense as Brunnermeier and Sannikov (2013), who present a model where the central bank can recapitalize banks through open market operations and capital gains.
<table>
<thead>
<tr>
<th></th>
<th>Nov11</th>
<th>Feb12</th>
<th>Change</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL ASSETS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>1 603</td>
<td>1 477</td>
<td>-126</td>
<td>0.0</td>
</tr>
<tr>
<td>Securities</td>
<td>139 879</td>
<td>151 540</td>
<td>11 661</td>
<td>2.0</td>
</tr>
<tr>
<td>Equities</td>
<td>24 930</td>
<td>26 864</td>
<td>1 935</td>
<td>0.3</td>
</tr>
<tr>
<td>Total Private Credit</td>
<td>292 830</td>
<td>288 814</td>
<td>-4 016</td>
<td>-0.7</td>
</tr>
<tr>
<td>Lending to Firms</td>
<td>121 363</td>
<td>117 561</td>
<td>-3 802</td>
<td>-0.7</td>
</tr>
<tr>
<td>Lending to Households</td>
<td>143 149</td>
<td>142 422</td>
<td>-728</td>
<td>-0.1</td>
</tr>
<tr>
<td>Lending to Banks</td>
<td>69 778</td>
<td>72 227</td>
<td>2 449</td>
<td>0.4</td>
</tr>
<tr>
<td>Other Assets</td>
<td>42 216</td>
<td>41 734</td>
<td>-482</td>
<td>-0.1</td>
</tr>
<tr>
<td><strong>TOTAL LIABILITIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equity</td>
<td>42 045</td>
<td>42 587</td>
<td>542</td>
<td>0.1</td>
</tr>
<tr>
<td>Securities Issued</td>
<td>90 809</td>
<td>98 103</td>
<td>7 294</td>
<td>1.3</td>
</tr>
<tr>
<td>ECB Total</td>
<td>45 724</td>
<td>47 611</td>
<td>1 888</td>
<td>0.3</td>
</tr>
<tr>
<td>Up to 1 year</td>
<td>38 274</td>
<td>26 298</td>
<td>-11 976</td>
<td>-2.1</td>
</tr>
<tr>
<td>1 to 2 years</td>
<td>7 450</td>
<td>1 100</td>
<td>-6 350</td>
<td>-1.1</td>
</tr>
<tr>
<td>More than 2 years</td>
<td>0</td>
<td>20 213</td>
<td>20 213</td>
<td>3.5</td>
</tr>
<tr>
<td>Borrowing from Banks</td>
<td>164 448</td>
<td>165 349</td>
<td>902</td>
<td>0.2</td>
</tr>
<tr>
<td>Deposits</td>
<td>195 481</td>
<td>197 223</td>
<td>1 742</td>
<td>0.3</td>
</tr>
<tr>
<td>Repo</td>
<td>7 760</td>
<td>6 403</td>
<td>-1 357</td>
<td>-0.2</td>
</tr>
<tr>
<td>Other Liabilities</td>
<td>24 968</td>
<td>25 379</td>
<td>411</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table 6: Banking Sector Aggregate Balance Sheet Nov11-Feb12. This table shows the aggregate banking sector balance sheet at November 2011 and February 2012. Categories are measured in million euros. The last column displays the change as a % of assets in November 2011. The additional levels of disaggregation of balance sheet categories (indented) are not exhaustive. February 2012 does not include the second LTRO allotment, which was settled only in March.

measure the extent of this stealth recapitalization scheme. Our strategy is straightforward: for each bank, we compute the increase in value of the November 2011 government bond portfolio between November 2011 and February 2012. More formally, we define bank i LTRO stealth recapitalization $SR_i$(LTRO) as:

$$SR_i(LTRO) = \sum_{j \in J} \Delta p_{j, Nov11-Feb12} \times Q_{i,j, Nov11}$$  \hspace{1cm} (10)

where $j$ is a security, $J$ 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 held of security $j$ by bank $i$ at time $t$ measured in nominal value.

---

39Banks hold government bonds in their banking book and in their trading book. While only the latter is marked to market, we decide to use market values for all government bonds held so as to better capture their true value should the bank decide to sell them in the secondary market or pledge them in repo operations.
Table 7: Stealth Recapitalization, Summary Statistics. This table shows summary statistics for stealth recapitalizations measures defined in (10), (11a), and (11b), aggregated across the entire banking system $\sum_{i \in N} SR_i$. The first column shows the total value in million euros. The second column shows the total value divided by total assets, and the third column shows the total value divided by total book equity.

<table>
<thead>
<tr>
<th>Stealth Recapitalization</th>
<th>Total</th>
<th>% Assets</th>
<th>% Equity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTRO</td>
<td>583.6</td>
<td>0.10%</td>
<td>1.39%</td>
</tr>
<tr>
<td>LTRO + OMT</td>
<td>3023.3</td>
<td>0.53%</td>
<td>7.19%</td>
</tr>
<tr>
<td>Collateral Trade + OMT</td>
<td>775.1</td>
<td>0.14%</td>
<td>1.84%</td>
</tr>
</tbody>
</table>

We present the results of this computation on the first line of Table 7. The total Portuguese banking sector LTRO stealth recapitalization is €583.6 million, equivalent to 1.4% of total book equity (0.1% of total assets). Note that our calculations are likely to be a lower bound on the recapitalization gains for two reasons. First, they ignore bonds maturing between these months, as these stop being held and priced. In addition, other asset prices are also affected through equilibrium/portfolio rebalancing effects.\(^{40}\) Admittedly, from a theoretical point of view, the effect on prices should be entirely visible on the announcement day. However, as sovereign bond markets were very illiquid during this time period and the only active participants were the banks we are studying, which were likely to be constrained, we should instead expect prices to reflect binding constraints, liquidity premia and many other factors other than the pure expected present discounted values of these securities’ cash flows.

While the LTRO managed to halt the collapse of government bond prices, yields started trending back towards their pre-crisis levels only in the summer of 2012.\(^{41}\) A key moment during the crisis was Mario Draghi’s July OMT announcement, also known as the “whatever it takes” speech, when the ECB signalled that it was ready to undertake unprecedented measures to sustain sovereign bond prices.\(^{42}\) Hence, compared to the LTRO in isolation, the *combination* of the LTRO and the OMT constituted a more sizable stealth recapitalization of peripheral banking sectors in the first half of 2012. To include the OMT in the

\(^{40}\)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. See Tobin (1958) and Gertler and Karadi (2011).

\(^{41}\)In Figure B.2 in the Appendix, we show Portuguese sovereign yields during our sample period.

\(^{42}\)For an analysis of the effect of the OMT announcement on bank balance sheets, see Acharya et al. (2016).
quantification of the stealth recapitalization, we define the following two alternative measures:

\[
SR_i(\text{LTRO + OMT}) = \sum_{j \in J} \Delta p_{j,\text{Nov11-Aug12}} \times Q_{i,j,\text{Nov11}}
\]

\[
SR_i(\text{Collateral Trade + OMT}) = \sum_{j \in J} \Delta p_{j,\text{Feb12-Aug12}} \times \Delta Q_{i,j,\text{Nov11-Feb12}}
\]

where the first measure simply computes bank government bond portfolio gains using the price increase between November 2011 and August 2012 and the second computes bank gains from the collateral trade following the OMT effect.

The last two lines of Table 7 show the results. The price effect of the LTRO and OMT combined on November 2011 banks’ government bond portfolios combined caused €3.0 billion total gains for banks, equivalent to 7.2% of total book equity (0.5% of total assets). The gains that banks obtained from their collateral trade due to the price increase between February 2012 and August 2012 amounts to €775 million, equivalent to 1.8% of total book equity (0.14% of total assets). These are economically large numbers, 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).  

6.4 Bank Behavior at LTRO1

In the empirical analysis, we mainly focus on the LTRO uptake at the second and last allotment on February 29, 2012. For example, in Section 5.1, we show that banks bought government bonds between the announcement and LTRO2 and pledged them at LTRO2. Our choice of focusing on this second date is entirely driven by the observation that the increase in government bond holdings on bank balance sheet happens almost entirely in the first two months of 2012, as documented in Figure 2.

It is important to note that banks could have used both allotments to engage in the collateral trade. They could have bought eligible collateral in the ten days after the announcement and pledged it at the first

\[^{43}\text{The CPP was the direct equity purchase program of the Troubled Asset Relief Program (TARP). This figure corresponds to the October-December 2008 period, when the bulk of the funds were disbursed. Book equity and total assets are measured at the end of September 2008, the last week before the program announcement.}\]
allotment. We now focus on how banks actually behaved at the first allotment. Figure 9 plots LTRO1 uptake against changes in short-term ECB borrowing, and illustrates that there is a negative relationship between the two. The slope of the fitted regression line is very close to $-1$ and most institutions are very close to this line. This shows that there were no significant changes in total borrowing as a percentage of assets, in spite of considerable variation in LTRO uptakes, and that LTRO1 was essentially used to replace (rollover) shorter-term debt. The first allotment was almost entirely used to rollover outstanding short-term debt at longer maturities.

Why did banks use almost exclusively LTRO2 for the collateral trade? There are three possible explanations. First, there might have been stigma associated with borrowing at LTRO1. If banks initially perceived borrowing from the LTRO as a bad signal during the first allotment, but such fears were dispelled by wide participation, this could potentially explain why they avoided borrowing in the first allotment, but undertook positive net borrowing during the second allotment.\(^44\) Second, banks might have had not enough time,
between the December 8 announcement and the December 21 allotment, to buy eligible collateral in the secondary market. Third, banks might have decided to delay purchases of risky collateral to the new calendar year, in order not to show their increased holdings of risky securities on the Annual Report as of December 31.

### 6.5 The Role of Central Bank Loan Maturity

Prior to the December 2011 LTRO announcement, the ECB was providing liquidity to banks, against the same types of collateral, but at a much shorter maturity, typically two-week or three-month. In other words, the only difference between the LTRO and pre-existing facilities was the long maturity.

In a frictionless world, loan maturity should not matter. The three-year LTRO would be a redundant policy tool as banks would be indifferent between rolling over short-term central bank loans and obtaining a long-term loan, as long as there were no substantial differences in loan rates. On the other hand, in a world with uncertainty regarding the future role of the central bank as a liquidity provider, long maturity loans offer banks an insurance against possible future changes in the central bank’s stance. This was likely the case for the three-year LTRO which was widely tapped, as €1 trillion was allotted to approximately 800 eurozone banks.

Additionally, Portuguese banks were essentially excluded from wholesale funding markets at the time of the LTRO announcement. This meant that their main source of non-deposit liquidity was the ECB, which was only providing liquidity at short maturities. The LTRO thus offered an opportunity for banks to diversify the maturity structure of their liabilities.

### 7 Conclusion

We analyze the impact of the largest liquidity injection operation in the history of central banking on the portfolio choice of Portuguese banks. While the stated objective of this policy was to stimulate economic activity by supporting the financial sector, we show that it expanded the demand for collateral, in the form as the discount window operated by the Federal Reserve in the U.S., may be seen as signalling funding and liquidity problems and may raise concerns regarding the health of the institution. Indeed, stigma was a major concern for policymakers during the design of other policy interventions, such as the TARP. See Bernanke (2015) for an insider account.
of domestic government debt, and this effect was more salient at shorter maturities. We argue that the transmission mechanism was based on what we call a “collateral trade channel”, through which banks exploited an attractive trade involving the purchase of collateral assets with maturity shorter than the long-term central bank loan. This allowed banks to earn a positive return while mitigating funding liquidity risks. We rationalize this intuition using a simple theoretical framework, which yields two additional equilibrium predictions that are consistent with the data: the yield curve steepens and the government reacts by reducing the maturity of its debt issuances.

Our analysis is purely positive and we make no normative judgements on these indirect consequences. On the one hand, our findings are consistent with a stabilizing impact, based on the fact that the reduction in yields of assets to which banks were already substantially exposed led to an implicit recapitalization that could have helped stabilize the domestic financial system. Additionally, the expansion in the demand for domestic government debt contributed to stabilizing sovereign funding markets during a time of great distress. On the other hand, not only did this phenomenon intensify the bank-sovereign “doom loop”, but also this policy effectively consisted of the indirect financing of government debt by the ECB, which may be at odds with the monetary authority mandate and raise a plethora of other questions.

We believe that our analysis uncovers previously unstudied effects of what we call LTRO-style policies, long-term collateralized lending to the financial system by the monetary authority. These effects are especially interesting when compared to QE-style policies. In the former, through the channels that we uncovered, the monetary authority engages in indirect purchases of shorter-term assets. This leads to a steepening of the yield curve and to a reduction of the aggregate maturity gap, as banks increase the maturity of their liabilities. If these assets are public debt, the government will have an incentive to react to market conditions by issuing more short-term debt. In contrast, large-scale asset purchase programs such as the ones conducted by the Federal Reserve (QE, MEP) consisted of direct purchases of longer-term assets. This leads to a flattening of the yield curve, and also leads to a reduction of the aggregate maturity gap of the private sector, but through a different channel: while the LTRO reduces the maturity gap by raising the maturity of liabilities, QE instead reduces the average maturity of assets outstanding. For the treasury, the incentives are the opposite, as it becomes more attractive to issue debt at longer maturities.

We believe that our findings contribute to the comparative analysis of unconventional monetary policy operations, by identifying previously unexplored effects that may be of great interest to policymakers. The effects on the aggregate maturity gap of the private sector, yield curve, and government strategy may be important for the design of policies aimed at macroeconomic stabilization and promotion of financial stability. We think that these are very interesting avenues for future research.
References


FT ALPHAVILLE (2013): “Russia’s LTRO (or LTROski, if you insist),” .


A Theory Appendix

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,

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

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 $\kappa > 1$, 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

$$b_S + q_1 b_L + c - R\mathbb{E} < 0$$

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, $R\mathbb{E}$ 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

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

$$d = \begin{cases} 
  0 & \text{if } q_1 \geq \frac{R\mathbb{E} - c - b_S}{b_L} \\
  b_S + q_1 b_L + c - R\mathbb{E} & \text{otherwise}
\end{cases}$$
Note then that the expected value of $t = 2$ profits at $t = 0$ can be written as

$$E_0[\pi_2] = \int_q^{\bar{q}} E_{bL, bS, c, AC} \left[ b_L + \frac{bS + c - R\mathcal{E}}{q_1} \right] dF(q_1) + \int_{\bar{q}}^{\bar{q}} \left[ b_L + \frac{bS + c - R\mathcal{E}}{q_1} \right] dF(q_1)$$

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

$$\max_{bL, bS, c, AC} E_0[\pi_2] \quad \text{s.t.}$$

$$W_0 + \mathcal{E} = qSbS + qLbL + c$$

$$\mathcal{E} \leq (1 - hL)qLbL + (1 - hS)qSbS$$

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

$$E_0[\pi_2] = \int_q^{\bar{q}} \left[ b_L + \frac{bS + c - R\mathcal{E}}{q_1} \right] dF(q_1) = b_L + (bS + c - R\mathcal{E})E_0 \left[ \frac{1}{q_1} \right]$$

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

$$bS + c + qbL - R\mathcal{E} \geq 0$$

Letting $(\lambda, \delta, \eta)$ denote the Lagrange multipliers on the budget, collateral and liquidity constraints, respectively, and defining

$$\tilde{q} \equiv E_0 \left[ \frac{1}{q_1} \right]^{-1}$$

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

$$\tilde{q} - qL[\lambda - \delta(1 - hL)] + q\eta \leq 0 \quad bL \geq 0$$

$$1 - qS[\lambda - \delta(1 - hS)] + \eta \leq 0 \quad bS \geq 0$$

$$1 - \lambda + \eta \leq 0 \quad c \geq 0$$

$$-R + \lambda - \delta - q\etaR \leq 0 \quad \mathcal{E} \geq 0$$
**Proof of Proposition 2**  We assume that we are in Region 4 of Proposition 1 throughout. For this, we assume that $\phi$ is large enough such that the change in $R$ has a small enough impact on $\gamma$ so as not to leave this region. We assume that $\bar{\gamma} \in (0, 1)$, and that $\phi$ is large enough such that $\gamma \in (0, 1)$, and both maturities will be issued in equilibrium, since this is the empirically relevant case. With our extension, the equilibrium of the model is now described by the following system

\[
\begin{align*}
q_S &= \frac{1}{R} \\
n_L &= \frac{q}{R} + \frac{\omega}{1 - \gamma} \\
\gamma &= \bar{\gamma} + \phi^{-1}(q_S - q_L)
\end{align*}
\]

We can solve for $\gamma$, yielding

\[
\gamma = \left[\frac{1 + \bar{\gamma}}{2} + \frac{1 - q}{2\phi R}\right] \pm \sqrt{\left[\frac{1 + \bar{\gamma}}{2} + \frac{1 - q}{2\phi R}\right]^2 - \left[-\frac{\omega}{\phi} + \bar{\gamma} + \frac{1 - q}{\phi R}\right]}
\]

We select the minus root, since it is one that produces a solution that is economically meaningful and satisfies $\lim_{\phi \to \infty} \gamma = \bar{\gamma}$. The derivative of $\gamma$ with respect to $R$ is

\[
\frac{d\gamma}{dR} = -\frac{1 - q}{2\phi R^2} \left[1 + \frac{1}{2} \sqrt{1 + \frac{1 - q}{2\phi R^2} - \left[-\frac{\omega}{\phi} + \bar{\gamma} + \frac{1 - q}{\phi R}\right]}\right]
\]

and it is negative for large enough $\phi$, thus establishing the second result. To establish the first, let $\Omega$ denote the slope of the yield curve,

\[
\Omega \equiv \frac{q_S}{q_L} = \frac{1 - \gamma}{\omega R + (1 - \gamma)q}
\]

So that

\[
\frac{d\Omega}{dR} = -\frac{\omega}{(\omega R + (1 - \gamma)q)^2} \left[1 - \gamma + R \frac{d\gamma}{dR}\right]
\]

For $\phi$ large enough, $\frac{d\gamma}{dR} \to 0$, and so the above term is strictly negative, establishing our claim. □
Figure B.1: Public Debt Maturing Volume. This figure shows monthly maturing volumes of Portuguese public debt (billion euros) from June 2010 to April 2013. Maturities and volumes are taken from Bloomberg.

Figure B.2: Portuguese Sovereign Yields. These figures show the time series of Portuguese 5Y, 10Y, 30Y Sovereign Yields from November 2009 to January 2013. The dashed vertical lines correspond to (i) the LTRO announcement (December 8, 2011), (ii) the second LTRO allotment (February 29, 2012), and (iii) the OMT announcement (July 26, 2012).
### Additional Tables

<table>
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<th>$\text{Holdings}_{i,\text{Long},t}$</th>
<th>$\text{Holdings}_{i,m,t}$</th>
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<td><strong>Post</strong></td>
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<td>(0.003)</td>
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<tr>
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<tr>
<td><strong>Post \times Short \times Access</strong></td>
<td></td>
<td></td>
<td>0.094***</td>
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<td>(0.026)</td>
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<td>0.954</td>
<td>0.940</td>
<td>0.938</td>
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</table>

**Table C.1: Access to ECB Liquidity and Government Bond Purchases, Robustness.** This table replicates the results in Table 3 when we include all the institutions for which we have balance sheet information: the universe of banks and mutual funds in Portugal. In practice, this means that mutual funds which never hold domestic government bonds at any point in our samples are also included. Robust standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$. 
Table C.2: Access to ECB Liquidity and Government Bond Purchases, Robustness. This table presents the results of specification (5a) in columns (1) and (4), specification (5b) in columns (2) and (5), and specification (6) in columns (3) and (6). Column (7) shows the results for specification (8). The sample in columns (1)-(3) includes only institutions with access to ECB liquidity. The sample in columns (4)-(6) includes only institutions with no access to ECB liquidity. Column (7) shows an estimation on the full sample. The dependent variable in column (1) and (4) (column (2) and (5)) is the share of total short (long) term public debt outstanding held by financial entity $i$ divided by the size of entity $i$ relative to total asset of the financial sector. The dependent variable in column (3) and (6)-(7) is the share of public debt of maturity $m$ outstanding held by entity $i$ divided by the size of entity $i$ relative to total asset of the financial sector. The key difference relative to the main text is that now $Short$ is a dummy equal to one at time $t$ if the bond matures at $t + 3$ years or before. All other variables are defined as in Table 2 and Table 3. The sample period runs monthly from June 2011 to June 2012. Robust standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.