

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

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Abstract

We analyze some of the potentially unintended consequences of the largest liquidity injection ever conducted by a central bank: the European Central Bank's three-year Long-Term Refinancing Operations conducted in December 2011 and February 2012. Using an unique dataset on monthly security- and bank-level holdings of government bonds for Portugal, we analyze the impact of this unconventional monetary policy operation on the demand for government debt. We find that: (i) Portuguese banks significantly increased their holdings of domestic government bonds after the announcement of this policy; (ii) This increase in holdings was tilted towards shorter maturities, with banks rebalancing their sovereign debt portfolios towards shorter term bonds. We employ a theoretical framework to argue that domestic banks engaged in a “collateral trade”, which involved the purchase of high yield bonds with maturities shorter than the central bank borrowing in order to mitigate funding liquidity risk. Our model delivers general equilibrium implications that are consistent with the data: the yield curve for the Portuguese sovereign steepens after the announcement, and the timing and characteristics of government bond auctions are consistent with a strategic response by the debt management agency.

JEL: G21, G28, H63, E58

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1 Introduction

The importance of financial intermediaries for the macroeconomy has become evident in the last decade. The collapse of the US subprime mortgage market and the subsequent increase of peripheral European government yields impaired the respective financial sectors, which in turn transmitted the shock to the real sector and contributed to long-lasting recessions.¹ As part of the policy response to the largest financial crisis since the Great Depression, central banks throughout the world engaged in unprecedented interventions to improve conditions in the financial sector in order to help restore business activity and employment in the real economy. Understanding the transmission channels of central bank policies is therefore essential to design effective *ex-ante* regulation as well as *ex-post* lender-of-last-resort (LOLR) interventions.

In this paper, we study the transmission of unconventional monetary policy to sovereign borrowing costs through the banking sector. Our laboratory is Portugal in 2011-2012, during the implementation of the European Central Bank's (ECB) 3-year Long Term Refinancing Operation. Portugal is an excellent candidate for our analysis as it has been severely hit by the sovereign debt crisis² – the 10-year Portuguese bond spread reached more than 16% at the peak of the crisis – and its economy is heavily dependent on bank lending.³ Our novel dataset combines a wealth of disaggregated information at the monthly frequency, and results from the combination of two datasets: (i) detailed balance sheet composition of all monetary and financial institutions regulated as such by the Portuguese central bank (Banco de Portugal, henceforth BdP); (ii) security-level data on the holdings of Portuguese sovereign debt by all financial institutions in the country, including non-monetary institutions.⁴

¹See [Gertler and Kiyotaki \(2010\)](#), [He and Krishnamurthy \(2013\)](#), and [Brunnermeier and San-nikov \(2014\)](#) for macroeconomic models with a financial sector. [Ivashina and Scharfstein \(2010\)](#) and [Chodorow-Reich \(2014b\)](#) present evidence on the negative real effects of the 2008 financial crisis. [Bocola \(2015\)](#), [Popov and van Horen \(2013\)](#), and [Acharya et al. \(2014b\)](#) present evidence on the negative real effects of the European sovereign debt crisis.

²See [Reis \(2013\)](#) for an account.

³[Antão and Bonfim \(2008\)](#) look at the corporate debt structure of Portuguese firms and find that bank lending accounted for 64% of total corporate credit in 2007.

⁴Non-Monetary Financial Institutions is the designation used by the ECB to broadly denote all financial companies that do not accept deposits from the public. These include, for example, insurance companies, pension funds, and brokerages.

We focus our analysis on a particular episode. In December 2011, the ECB announced an extraordinary measure that consisted of collateralized lending to banks at the unprecedented maturity of three years, the 3-Year Long Term Refinancing Operation (vLTRO).⁵ This intervention ultimately provided eurozone banks with more than 1 trillion euros: to our knowledge, this was the largest liquidity operation ever conducted by a central bank. These funds were distributed in two allotments. Banks that sought to borrow from the vLTRO had to post eligible collateral on pre-determined dates (the allotment dates). The vLTRO was announced on 8 December 2011, and the allotment dates were 21 December 2011 and 29 February 2012. We find that, for Portuguese banks, (i) the first allotment consisted mainly of roll over of previous (shorter-term) ECB borrowing, (ii) holdings of domestic government bonds significantly increased between the two allotments, (iii) these intra-allotment purchases explain a significant part of the cross-sectional variation in the amounts borrowed at the second allotment, even when controlling for the accumulation of other types of collateral. In short, we show that the vLTRO announcement triggered a scramble for collateral with emphasis placed on domestic government bonds.

The timing and magnitude of the intra-allotment government bond purchases is strongly suggestive of their value as collateral to access the liquidity facilities of the ECB. We further argue that banks engaged in a “collateral trade” that consisted of purchasing government bonds with maturity less or equal than three years (the maturity of the vLTRO) and pledging them at the ECB in exchange for a cheaper three year loan. Using a theoretical framework, we show that this behavior is optimal in terms of mitigating funding liquidity risk for the bank: if there is enough uncertainty about the path of future prices for sovereign bonds, a bank can minimize funding risks by investing in assets with a maturity that is shorter than their liabilities. This allows the bank to: (i) conserve a cash buffer throughout (as opposed to what happen in a traditional carry trade), (ii) make a profit if the asset yields a return that exceeds the cost of the loan. By investing on bonds with a maturity shorter than three years, those assets mature before the ECB loan is due. On the other hand, longer term bonds expose the bank to the risk that their prices may be lower by the time the loan matures.

⁵From *very* long-term refinancing operation. As we explain in the following sections, the ECB conducts LTRO’s at shorter maturities, hence we adopt a different terminology to distinguish this particular, one of a kind intervention.

Using a triple-difference specification, we show that this preference for short-term bonds is borne by the data: we compare institutions with access to the ECB’s liquidity facilities to those that do not have access, in terms of their purchases of government bonds with maturities shorter and longer than three years, before and after the vLTRO announcement. We find that the vLTRO announcement had a very positive and significant impact on purchases of shorter term bonds by institutions with access to the vLTRO. This impact is also economically large: we find an aggregate demand impact of 12 to 17 percentage points of total amounts issued for bonds with maturity less than 3 years. The vLTRO increased demand for government debt across all maturities, but the impact on longer maturities was more muted, where we find an aggregate impact of 1.3 to 2.1 percentage points of total amounts issued.

We then combine the triple-difference specification with an instrumental variables approach and find that the portfolio substitution between long and shorter term bonds is also observed at the intensive margin, as our model predicts: banks that borrowed more at the vLTRO tended to substitute more towards shorter and away from longer term bonds. Our model yields additional predictions that are consistent with the empirical evidence: (i) following the central bank operation, the sovereign curve steepens, and (ii) the government adjusts the composition of its bond issuance accordingly.

Our contribution is twofold. First, to our knowledge, this is the first attempt to evaluate the impact of unconventional monetary policy on sovereign borrowing costs. Our results suggest that lender-of-last-resort policies can influence the government debt portfolio composition of financial intermediaries and therefore exacerbate the link between the sovereign and domestic financial sectors. We show that this particular intervention had economically significant consequences that were possibly unintended by the ECB. We abstract from normative issues related to optimal policy design: our analysis is purely positive, and take no stance on whether these consequences are desirable or not.

Second, we contribute to the comparative analysis of large scale unconventional monetary policies across the globe by highlighting some key differences between vLTRO-style and QE-style policies through some of the channels that we identify in this paper. vLTRO-style policies may contribute to a steepening of the term structure of interest rates, an effect that is at odds with the impact of QE-style policies and may have important implications for financial stability and the aggregate maturity gap. Due to the granularity and specificity of our data, we cannot replicate our analysis for other troubled eurozone sovereigns. However, we do present some evidence that other peripheral

countries experienced aggregate effects that are similar to the ones we report for Portugal. Moreover, the importance of vLTRO-like policies has grown beyond the eurozone, with similar policies being implemented in countries such as Russia and China. In Russia, the central bank (CBR) conducted a vLTRO-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.⁶ The implicit objective of this operation was not to stimulate demand for sovereign debt but rather for corporate debt, as well as to reduce demand pressures for short-term funding. In China, vLTRO-style loans have been offered by the People’s Bank of China (PBoC), in exchange of collateral in the form of bonds issued by Chinese local governments as collateral.⁷ The policy seems to be primarily aimed at assuaging liquidity problems faced by local banks, as well as to minimizing the impact of a potential rollover crisis by over-indebted local governments. In this respect, it is 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 the sovereign and the financial sector credit risk and find evidence of the two-way feedback from 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 context of the eurozone crisis, the increasing holdings of government bonds by European banks have been documented by [Acharya and Steffen \(2015\)](#), who show that large and undercapitalized banks engaged in a carry trade going long peripheral government bonds while fund-

⁶The 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 \(2013\)](#).

⁷While the financial press has repeatedly referred to this policy as the “Chinese QE”, this characterization is incorrect in light of the distinctions 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, it is the first time that it accepts this type of debt is collateral. Besides, the maturity is unprecedented. See [FT Alphaville \(2015\)](#) for an informal description of this program.

ing their positions in wholesale funding markets. [Drechsler et al. \(2014\)](#) and [Becker and Ivashina \(2014\)](#) suggest that this behavior is consistent with risk-shifting and moral suasion, respectively. [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. Compared to previous studies, our comprehensive dataset allows us to describe 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.⁸ 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 used comparable datasets are [Buch et al. \(2015\)](#) and [Hildebrand et al. \(2012\)](#), both focused on Germany. They find that worse-capitalized banks hold more government bonds and that banks shifted investments to securities that are eligible to be posted as collateral at the ECB. Compared to these two papers, we focus on a peripheral country whose financial sector was severely hit by the crisis and, therefore, targeted by the lender-of-last-resort intervention.⁹

Second, our findings on the impact of vLTRO 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 \(2014a\)](#) for the case of the US, we

⁸See [Acharya and Steffen \(2015\)](#) and [Gennaioli et al. \(2014\)](#) for studies that use this data.

⁹Even though we focus on the portfolio of sovereign debt, our stylized facts on lending to the private sector in the pre-vLTRO period are also related to the literature on the transmission of sovereign debt shocks to the real sector, through the contraction of credit supply. [Krishnamurthy et al. \(2014\)](#) study the impact on sovereign yields of several ECB programs that involved either the direct or the indirect purchase of sovereign bonds. Both [Ivashina and Scharfstein \(2010\)](#) for the case of Lehman Brothers, as well as [Acharya et al. \(2014b\)](#), [Bofondi et al. \(2013\)](#), [Bottero et al. \(2015\)](#), and [Popov and van Horen \(2013\)](#) for the case of the European sovereign crisis document negative real effects of banks' exposure to risky government bonds, namely through reduced lending to non-financial institutions. [Almeida et al. \(2015\)](#) also show the aforementioned negative effect through credit rating downgrades.

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 vLTRO to private lending through the financial sector. This important question is studied, among others, by [Andrade et al. \(2014\)](#), who find a positive impact on lending by French banks. Our data on assets and liabilities is not granular enough to discuss the transmission of vLTRO to private lending. Our paper is closer to [Drechsler et al. \(2014\)](#), who study the collateral pledged at the ECB in the pre-vLTRO period and show that banks' usage of the lender of last resort is associated with risk-shifting behavior. In a less positive note, [van der Kwaak \(2015\)](#) studies the impact of LTROs through the lens of a rich DSGE model and finds that their cumulative impact on output is zero. [Trebesh and Zettelmeyer \(2014\)](#) study the effect on government bond prices and ECB behavior in mid-2010, when the European Central bank decided to buy government bonds in the secondary market under the "Securities Market Program". Compared to this contribution, we focus on a different type of intervention (collateralized borrowing as in vLTROs), aimed at relaxing banks' liquidity constraints.

Third, our analysis of the behavior of domestic banks, and the banking sector's demand for domestic sovereign debt also 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 has been also 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 an hedge against fluctuations in interest rate spreads. Our paper proposes an alternative explanation for the reliance of sovereigns on short-term public bonds as the debt agency faces high demand for short term bonds as these are the best suited asset class to pledge at 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 US Treasury behaved strategically during the Federal Reserve's QE programme, 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 discuss evidence that suggests that the Portuguese Treasury might also have behaved strategically, taking advantage of investor’s 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 vLTRO 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 2](#), we illustrate the data and provide some institutional background on the conduct of monetary policy in the eurozone. In particular, we describe the vLTRO in detail and present two related stylized facts. In [Section 3](#), we develop a theoretical framework that provides a narrative linking the two facts while yielding additional empirical implications. In [Section 4](#), we use the granularity of our data to establish a direct link between the announcement of the vLTRO and government bond purchases in the period between the two allotments. In [Section 5](#), we compute aggregate effects and discuss the impact of vLTRO on sovereign borrowing costs and the government’s bond issuance strategy. [Section 6](#) concludes.

2 Data and Institutional Setting

In this section, we first describe the dataset and the institutional setting and then present two stylized facts that motivate our analysis.

2.1 Dataset Description

We use two proprietary datasets from *Banco de Portugal* (BdP), the Portuguese central bank. These datasets are monthly panels from January 2005 to May 2014. We complement these with mutual fund portfolio data that is obtained from the website of the Portuguese Securities Market Commission (CMVM). This is a monthly panel ranging from January 2005 to September 2013, after which it becomes a quarterly panel (available until September 2014).

The first dataset from BdP 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 82 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.¹⁰ This dataset allows us to determine, for example, the value of all non-equity securities whose issuer was the German central government, that were held by bank i in January 2006. Observations are measured in book value. [Crosignani et al. \(2015\)](#) describes this dataset in more detail and analyzes the evolution of the balance sheets for the Portuguese monetary financial sector during the full sample period.

The second dataset contains monthly security-level data of all holdings of 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 in-

¹⁰More specifically, the different dimensions for which data are available are: (i) Asset category: banknotes and coins, loans and equivalent (with repricing date up to 1 year, 1 to 5 years, more than 5 years), securities except equity holdings (up to 1 year, 1 to 2 years, more than 2 years), equity holdings, physical assets, and other assets (of which derivatives); (ii) Counterparty's geographical area: Portugal, Germany, Austria, Belgium, Cyprus, Slovenia, Spain, Estonia, Finland, France, Greece, Netherlands, Ireland, Italy, Latvia, Luxembourg, Malta, Slovakia, European Monetary Union excluding Portugal, Non-EMU Countries, European Central Bank; (iii) Counterparty's institutional sector: monetary and financial institutions, social security administration, local government, regional government, insurance and pension funds, private individuals, central government, other financial intermediaries, non-financial firms, other sectors. For the other side of the balance sheet, the counterparty classification is the same, and the liability categories are: demand deposits, deposits redeemable at notice (less than 90 days, more than 90 days), other deposit equivalents (less than 1 year, 1 to 5 years, more than 5 years), repurchase agreements, securities (up to 1 year, more than 1 year), other liabilities, capital and reserves.

stitutions 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 (as well as debt of major public companies) at the security (ISIN) level. We cross this dataset with bond-level information such as yield, residual maturity, and amount issued, obtained from Bloomberg.¹¹

The CMVM dataset contains information on the portfolio holdings of all Portuguese mutual funds. This information helps us add detail about institutions already present in our securities dataset, and add entities that did not have Portuguese government debt throughout this period.

2.2 Borrowing from the ECB

The Eurosystem’s open market operations are conducted through collateralized loans: banks can borrow from the monetary authority by pledging collateral in exchange for cash loans.¹²

Regular open market operations consist of one-week and three-month liquidity providing facilities, called main refinancing operations (MROs) and longer-term refinancing operations (LTROs), respectively. MROs are the main policy tool, accounting for approximately 75% of the overall liquidity provided by the monetary authority in normal times.¹³ MROs are designed to support the maturity and liquidity transformation roles of banks and to signal the central bank’s monetary policy stance. On the other hand, the three month LTROs are designed to provide “a good opportunity for smaller counterparties, which have limited or no access to the interbank market, to receive liquidity for a longer period”. In a world with frictionless markets, LTROs are a redundant

¹¹We are able to match more than 98% of the value of the dataset with Bloomberg.

¹²The difference with respect to U.S.-style open market operations (liquidity supplied through purchases of Treasury bonds) goes back to the Statute of the European System of Central Banks (ESCB), which states, in Article 18 , that “the ECB and the national central banks may (i) operate in the financial markets by buying and selling outright (spot and forward) or under repurchase agreement and by lending or borrowing claims and marketable instruments, whether in euro or other currencies, as well as precious metals; (ii) conduct credit operations with credit institutions and other market participants, with lending being based on adequate collateral.” Source: [ESCB \(2012\)](#). For more details on the architecture of European monetary policy, see [Mercier and Papadia \(2011\)](#).

¹³That is, pre-2008. See [Eisenschmidt et al. \(2009\)](#) for a detailed description.



Figure 1: Timeline of the vLTRO. This figure illustrates the timeline of the vLTRO facility. The announcement (8 December 2011) is followed by two allotment dates (21 December 2011 and 29 February 2012).

policy tool, since banks could simply access and rollover the shorter-term MROs, while hedging the interest rate risk using financial instruments such as swaps. If hedging is costly, however, LTROs become an attractive option for banks that want to increase and diversify the maturity of their funding while ensuring themselves against interest rate and liquidity risk (namely the risk of losing access to shorter-term lending).¹⁴

Very Long-Term Refinancing Operations On 8 December 2011, as the eurozone experienced dire macroeconomic conditions, the European Central Bank announced two unprecedented “very” long-term LTROs (vLTROs), which provided three-year funding to participating banks (with the option of early repayment after one year) to “support bank lending and money market activity”.¹⁵ The two operations were

¹⁴Interestingly, in October 2002, banks were consulted by the ECB on whether to eliminate LTRO. Banks almost unanimously rejected the proposal in January 2003, arguing that LTRO played an important role in their liquidity management, allowing them to diversify the maturity of liabilities (see [ECB \(2002\)](#) and [ECB \(2002\)](#) for details on the consultation and its rejection by participating banks). Banks also argued that “LTRO plays an important role in credit institutions’ liquidity contingency plans”, i.e. their plans for obtaining liquidity during times of general market tension or when faced with individual liquidity problems.

¹⁵Before vLTRO, the ECB strengthened the 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. The ECB adopted other non-standard monetary policy operations: (i) US 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 vLTRO can be found at [ECB \(2011b\)](#).

conducted with full allotment, meaning that there was no limit to the loan a bank could get, provided that it posted enough eligible collateral.¹⁶ As a result of these two allotments, the ECB injected more than 1 trillion euros in liquidity in the eurozone banking system. To our knowledge, this was the largest single liquidity injection in the history of central banking. The interest rate was very low, based on the overnight rate during the loan period, which was around 1% at the time of announcement and expected to remain low. Participating banks had to pledge eligible collateral to get funding. The lender of last resort evaluated the collateral using a publicly available schedule. This schedule assigned a haircut based on rating, asset class, and residual maturity. For example, a covered bond rated AAA with residual maturity of 8 years faced a haircut of 6.5%, requiring the bank to pledge 106.5 euros in collateral to obtain a loan with a face value of 100 euros. [Figure 1](#) shows the timeline of the two vLTROs. The first operation (vLTRO1) was allotted on 21 December 2011 and the second operation (vLTRO2) on 29 February 2012.

2.3 vLTRO and new ECB borrowing

[Figure 2](#) plots the evolution of all liabilities whose counterparty is the ECB for Portuguese banks between June 2011 and September 2012. The solid line plots total borrowing from the ECB, while the dashed line corresponds to long-term borrowings, with maturity exceeding 2 years. During this time period, the two vLTRO allotments were the only instances where financial institutions could contract central bank liabilities at this maturity. The vertical lines correspond to the allotment months: December 2011 and March 2012.¹⁷ Note the different behavior of banks at the two allotments: the effective net uptake (“new” borrowing, net of existing borrowings) at vLTRO1 is almost non-existent, with long-term borrowing increasing substantially, but total borrowing remaining essentially unchanged. The same is not true for the vLTRO2, which

¹⁶Compared to previous operations, the two vLTROs also relaxed the collateral eligibility requirements.

¹⁷The second allotment was conducted on the last day of February, but the funds were only effectively made available one day late, thus vLTRO borrowings at the second allotment are only reflected in March 2012.

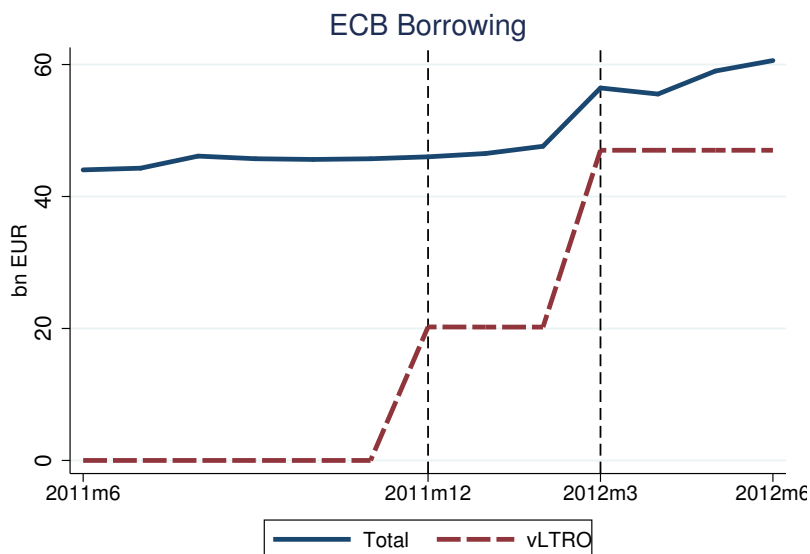


Figure 2: Central Bank Borrowing. This figure plots the evolution of total ECB borrowing (blue solid line) and long-term ECB borrowing (red dashed line) from June 2011 to September 2012 by Portuguese banks. Borrowing is defined long-term if its maturity exceeds two years. Long-term borrowing from the ECB coincides with the vLTROs for this sample period.

corresponds to a significant increase in total borrowing. [Table B.1](#) in [Appendix B](#) disentangles short- and long-term borrowing from the ECB and provides more detail on existing debt and net uptakes. During the first allotment, banks reduced their short-term ECB borrowing by €19.9 bn and 16 banks tapped vLTRO for €20.2 bn. Total ECB borrowing is essentially unchanged between November 2011 and December 2011 confirming that the aggregate *net* uptake of the first allotment was basically zero. In contrast, total ECB borrowing jumps from €47.6 bn to €56.4 bn around the second allotment with banks obtaining €26.8 bn funding from vLTRO2.¹⁸

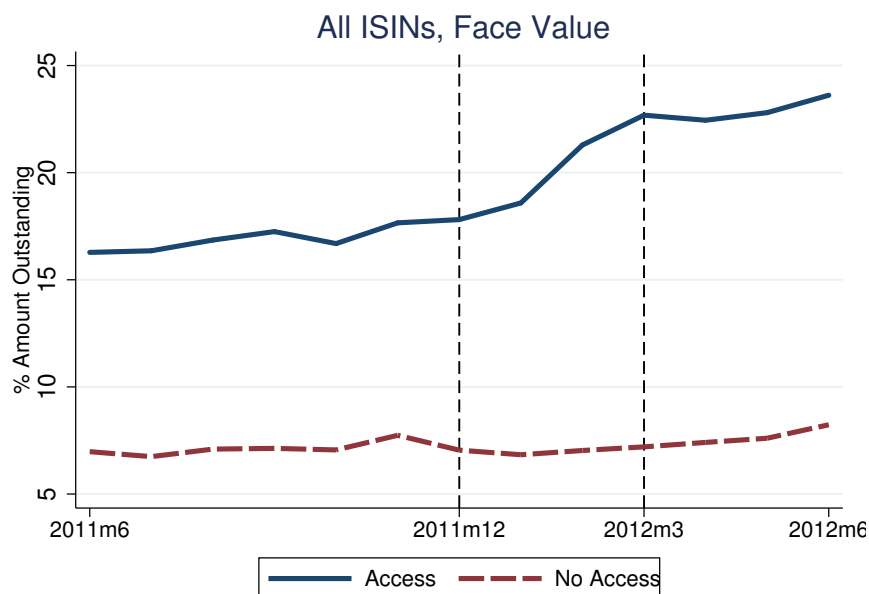


Figure 3: Holdings of Domestic Government Debt, vLTRO period. This figure plots the evolution of the quantity of domestic government bonds held by banks (solid blue line) and non-banks (dashed red line), around the vLTRO period. Quantity is measured as the total face value divided by the total amount outstanding.

2.4 vLTRO and government debt holdings

We now turn to the evolution of domestic government bonds held by banks in the period between the two allotments (what we call the intra-allotment period). [Figure 3](#) compares banks (that could access vLTRO) and non-banks (that were excluded from vLTRO) from June 2011 to September 2012. The vertical lines correspond to each of the two allotments, December 2011 and March 2012. We plot the total face value of holdings by each category, as a percentage of the total face value outstanding in that month. We want to emphasize that this figure presents face values as opposed to market values. This allows us to ignore the effects of changes in prices and focus on quantities and total exposures. From the figure, it emerges that the behavior of non-

¹⁸A total of 18 banks were borrowing from the ECB in November 2011. All of them access at least one the vLTROs (15 of them tap vLTRO1 and all of them tap vLTRO2). In total, 16 tap vLTRO1 and 23 tap vLTRO2. The remaining banks are institutions that accessed the vLTRO but were not borrowing from the ECB before.

banks hardly changed around the vLTRO period while banks increased their holdings significantly *between* the two allotments. This behavior is also markedly different from the one that is observed before the first and after the second allotments, where holdings seem to be growing at a much smaller and constant rate.

3 Theoretical Background

Having shown that (i) vLTRO2 accounted for the entire new vLTRO borrowing in the operation and (ii) institutions with access to the ECB's liquidity facilities increased their government bond holdings in the intra-allotment period, we now provide a narrative linking these two facts while yielding additional empirical implications. Our hypothesis is that banks, having a substantial share of their eligible assets already pledged at the LOLR in November 2011, did not have available collateral to tap vLTRO1. They instead used this facility to rollover previous ECB borrowing at the better terms of the vLTRO. Crucially, banks had only two weeks to prepare for vLTRO1 and almost three months for vLTRO2. Hence, in the intra-allotment period they gathered eligible collateral to take advantage of the one-shot three-year liquidity facility provided by the LOLR. Not surprisingly, vLTRO2, giving participants more time to gather collateral, saw greater participation (both at the intensive and extensive margins).

In this section, we develop a simple model to illustrate the reaction of banks' portfolio choice to the availability of such funding opportunity, and its general equilibrium effects. In particular, 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.

3.1 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. This will be the only source of uncertainty in the model, making the price of long-term debt at $t = 1$ uncertain. The timeline of the model and the sequence of events is depicted in [Figure 4](#).

Banks Banks are risk-neutral, and care only about their profits at the end of $t = 2$

$$\mathcal{U} = \mathbb{E}_0[\pi_2] \tag{1}$$

where π_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

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

and the resource 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 $t = 0$. At 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 € . Both short-term bonds and cash yield a unit return, while money market borrowing has a unit cost of R . This means that

$$W_1 = b_S + q_1 b_L + c - R\text{€}$$

At $t = 0$, the bank has some level of resources $W_0 > 0$ available.¹⁹ The bank faces

¹⁹We 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.

a budget constraint, and a collateral constraint for money market borrowing. The budget constraint at $t = 0$ is

$$W_0 + \mathbb{E} = q_S b_S + q_L b_L + c \quad (2)$$

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

$$\mathbb{E} \leq (1 - h_L) q_L b_L + (1 - h_S) q_S b_S \quad (3)$$

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 γ 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.

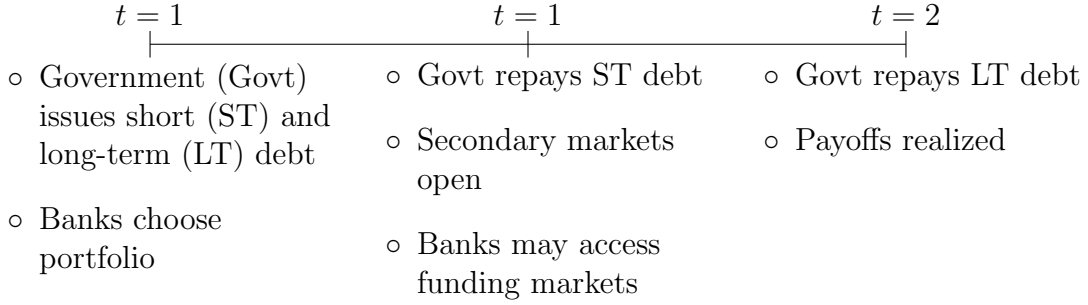


Figure 4: Timeline for the Model

3.2 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 $\kappa \rightarrow \infty$, the costs of accessing funding markets at $t = 1$ to 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.

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

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

as the expected value of the price of the long-term bond at $t = 1$ adjusted by a Jensen

term, we can write the first-order conditions for the bank's problem as

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

An equilibrium in this model is a pair of prices (q_S, q_L) , $t = 0$ bank policies $(b_L, b_S, c, \mathbb{E})$, 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, δ . The second is that short-term debt allows for better liquidity management, since it yields a certain cash-flow of 1 in the second period, while long-term debt yields a worst-case payoff of $\underline{q} < 1$. This preference is scaled by the multiplier on the liquidity constraint, η .

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

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

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

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

where λ measures the marginal cost of funds for the bank. If any of the constraints is active, however, the bank's preference is tilted towards short-term debt. This means

that, for the same quantities of outstanding debt, the price of short-term debt increases relative to the price of long-term debt. Thus the yield curve becomes steeper.

We 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, $\mathcal{E} = \delta = \eta = 0$, 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 $R\omega \in [\min\{(\tilde{q} - \underline{q})(1 - \gamma), h_S\gamma + h_L\tilde{q}(1 - \gamma)\}, \gamma + \tilde{q}(1 - \gamma)]$, banks borrow, $\mathcal{E} > 0$, but no constraints are binding, $\delta = \eta = 0$, and prices satisfy

$$q_S = \frac{1}{R}$$

$$q_L = \frac{\tilde{q}}{R}$$

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

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

$$q_S = \frac{1}{R + \delta h_S}$$

$$q_L = \frac{\tilde{q}}{R + \delta h_L}$$

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

$$q_S = \frac{1}{R}$$

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

where

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

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

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

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

The 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 (ω is high), or when borrowing costs are prohibitive (R is high).

Once either R or ω 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 ω 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 general 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 potentially borrow in wholesale markets at longer maturities, the interest rate was prohibitive. We thus model the vLTRO 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

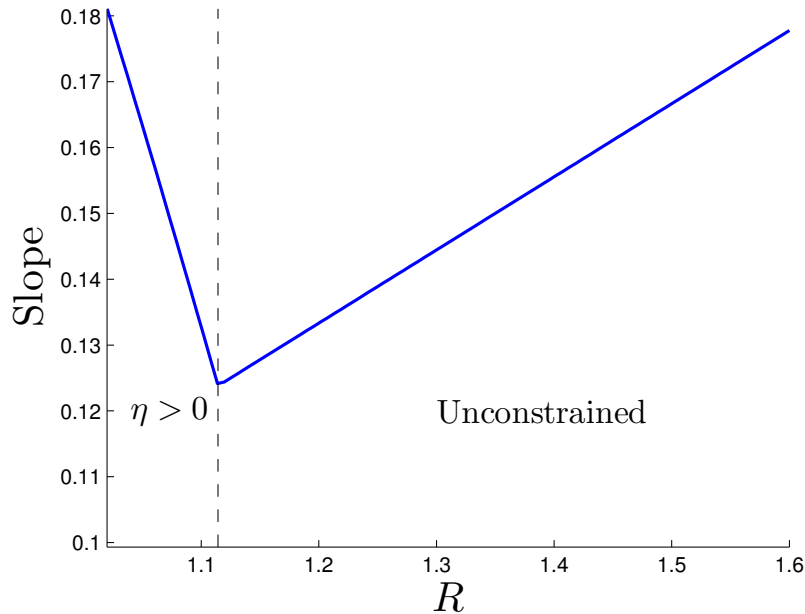


Figure 5: Slope of the Yield Curve, Model. This figure plots the slope of the Treasury’s yield curve as a function of borrowing costs R . The dashed line indicates the transition from an unconstrained equilibrium to one where the liquidity constraint binds, $\eta > 0$.

are constant, and the haircut on short-term debt is smaller, $h_S < h_L$.²⁰

In our model, for the same ω , 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 5 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

²⁰During 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.

costs can actually *increase* the slope of the yield curve.

3.3 Treasury Response and General 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 γ , 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, γ is now taken to be a control. We assume that the treasury's objective is to maximize 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.²¹ We write the treasury's problem as

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

where the last term captures the losses from deviating from the optimal exogenous maturity structure, and ϕ 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 certain region of the equilibrium space.

Proposition 2. *Assume that ϕ is large enough, and that banks are liquidity-constrained,*

²¹The 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.

$\eta > 0$. 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 vLTRO) 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.

4 Empirical Analysis

In this section, we present empirical evidence to argue that the two stylized facts that we presented in Section 2 – the borrowing behavior at each of the two vLTRO allotments, and the rapid increase in holdings of government debt between the two allotments – are tightly connected. Ultimately, we are interested in showing that these two facts were mostly driven by a “collateral trade” motive that induced a higher demand for collateral in the form of domestic government debt. We argue that the vLTRO provided banks, particularly domestic ones, with an attractive opportunity that consisted of investment in high-yield short-maturity domestic sovereign bonds that were then pledgeable at the ECB.

Two features, in particular, made this trade extremely attractive. First, from the perspective of a domestic bank, this was a particularly safe trade when used to invest in short-term debt. By short-term, we mean bonds with a maturity that is inferior to the maturity of the ECB loan. In an environment characterized by extensive implicit and explicit government guarantees over the banking system and a substantial degree of sovereign-bank linkages, banks and sovereigns will tend to default at the same time. 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. The only states of the world that may lead banks not to deem domestic sovereign debt as a safe asset are those in which the price of the purchased bonds may change, thereby affecting the

bank's capacity to repay the ECB loan or resulting in the ECB issuing a margin call to the bank.²² Thus, while the bank disregards the (direct) credit risk of the sovereign, the bond still exposes the buyer to funding liquidity risk. If the bank engages in this trade using long-term bonds, with maturity exceeding that of the ECB loan, it will be highly exposed to funding liquidity and margin risk: if those bonds drop in price during the term of the ECB loan, not only the bank may receive a margin call, but the bond itself may be worth less at 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 costly and increases 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. Besides, it results in an additional profit for the bank since the bond yield was greater than the borrowing cost in the first place.²³

Second, due to the fact that the described trade consists of purchasing an asset that is pledgeable as collateral to raise funds, banks were able to take leveraged positions: the purchase of the asset relaxes the borrowing constraint, up to the haircut. This is consistent with the increase in new, net borrowing from the vLTRO that is observed at the second allotment, after banks have gathered new collateral.²⁴

We now proceed in three steps. First, we present evidence suggesting that a combination of surprise and collateral constraints meant that the first allotment was mostly rollover of previous short-term debts, consistent with the aggregate statistics illustrated in [Section 2](#). Second, we show that the pattern of purchase of government

²²Without 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. According to the ECB Risk Control Framework, marketable assets that are used as collateral are marked to market daily.

²³Compared to other asset classes (e.g., covered and uncovered bank bonds, asset backed securities, etc.), euro denominated government bonds have also a preferential treatment as they carry a zero risk weight.

²⁴To formalize this reasoning, we present a very simple model of liquidity risk that illustrates the main trade-offs inherent to bond maturity in the Online Appendix. 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.

bonds changed significantly during the intra-allotment period, and that these bond purchases explain a significant part of the cross-sectional variation of new borrowing at the second allotment. Third, we discuss potential alternative explanations. In the next section, we take advantage of this empirical analysis to formally test the model's predictions and establish a causal impact emanating from the vLTRO's announcement.

4.1 vLTRO1 and Rollover

The first allotment was mostly used to rollover outstanding short term debt at longer maturities. This, along with the fact that there were only two weeks between the announcement of the vLTRO program on the 8 December, and the first allotment on the 21 December, suggests that (i) the announcement was a surprise, with banks not having sufficient time to react to the announcement, or (ii) banks had little available collateral to access the first allotment, or a combination of the two. If all assets that were eligible as collateral were already being used to borrow from the ECB, the lack of time to accumulate more eligible collateral should manifest itself by low levels of new net borrowing, and high levels of rollover of short-term debt.

Indeed, this is what the cross-sectional evidence of vLTRO uptakes seems to suggest. [Figure 6](#) plots vLTRO1 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 (except for two outliers) are very close to this line. This shows that there was no significant changes in total borrowing as a percentage of assets, in spite of considerable variation in vLTRO uptakes, and that vLTRO1 was essentially used to replace (rollover) shorter term debt.

4.2 vLTRO2 and the Demand for Collateral

While vLTRO1 could be considered a surprise, the same is not true of the second allotment: having been announced on the 8 December, banks had almost three months, until 29 February to prepare themselves. This allowed them to gather the necessary collateral during this period, and consequently increase their net borrowings during the second allotment. We claim that this increased demand for collateral manifested itself through increased holdings of domestic government debt, driven by the carry

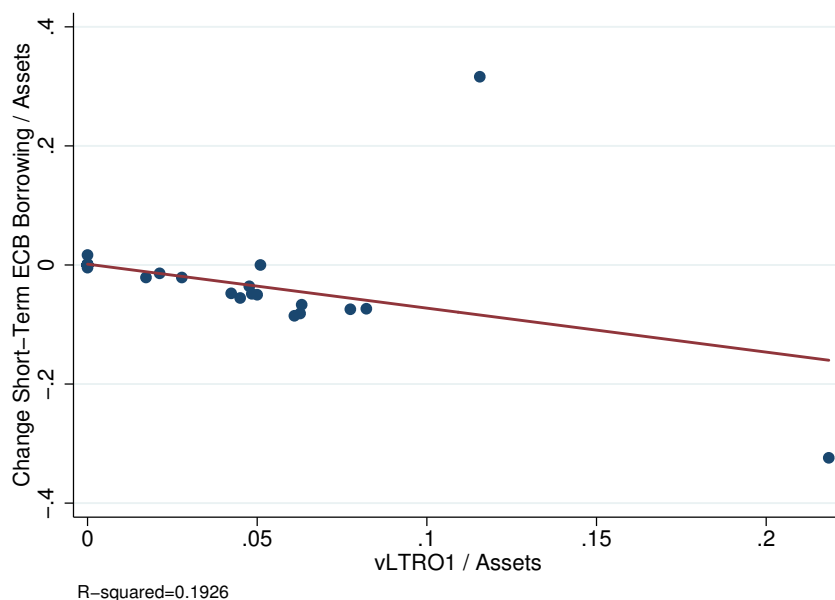


Figure 6: vLTRO1 Changes in Total and Short-term Borrowing from the ECB. The figure plots total vLTRO1 uptake against the change in short-term ECB borrowing between November 2011 and December 2011, as a percentage of assets in November 2011.

trade motive described above. The channel that we propose can then be summarized as follows,

$$\text{vLTRO Announcement} \Rightarrow \text{Demand for Collateral} \uparrow \Rightarrow \text{Demand for Govt}^{\text{PT}} \uparrow$$

Why focus on government bonds? At this stage, it is important to explain why do we focus on domestic government debt over other types of collateral. In principle, the channel that we describe above is valid for any type of collateral that is pledgeable at the ECB. We focus on Portuguese government debt for three main reasons: first, it is a publicly traded asset with observable and measurable market prices. This allows us to isolate changes in prices and focus on changes in quantities. Second, and as we will show in this section, domestic government debt was a very important source of collateral for the second allotment of the vLTRO. Finally, and as we explain later, other types of collateral were subject to the relaxation of collateral eligibility requirements during the intra-allotment period, while eligibility requirements for Portuguese government debt remained constant throughout. This eliminates potentially confounding factors that would be present if we analyzed the evolution of holdings of other types of collateral during the same period.

Measuring new net borrowing from the ECB Our hypothesis is testable to the extent that increased holdings of eligible collateral should generate an increase in net borrowing at the time of the vLTRO2 allotment. To help us formalize our argument, let C_i be a measure of eligible collateral held by bank i , and ΔC_i be the change in the amount of collateral held by bank i between the vLTRO announcement and the vLTRO2 allotment. vLTRO uptake for a particular bank i can be decomposed in two components: a “rollover” component that corresponds to the part of the total uptake that is used to transform already-existing ECB borrowings in longer-term debt, and a “new borrowing” component that corresponds to new borrowings that are unrelated to rollover,

$$\text{vLTRO2}_i = \underbrace{\text{vLTRO2}_i^N}_{\text{New “net” borrowing}} + \underbrace{\text{vLTRO2}_i^R}_{\text{Rollover}}$$

As described in previous sections, the vLTRO and the shorter-term ECB open market operations, the MRO and the LTRO, had essentially the same collateral requirements. Banks could rollover all their short-term borrowings with no visible variation in the pool of eligible collateral, $\Delta C_i = 0$. This suggests that any variations in the pool of eligible collateral C_i between the vLTRO allotments should be able to explain a substantial part of the variability in the new net borrowing component.

To test this hypothesis, we rely on the following assumption: the rollover component of the vLTRO is equal to any change in short-term borrowings from the ECB that is observed around the time of the allotment (between February 2012 and March 2012).

$$\text{vLTRO2}_i^R = -\Delta \text{Short-Term ECB Borrowing}_{i,\text{Feb12-Mar12}} \quad (4)$$

The main requirement of this assumption is that there are no changes in short-term ECB borrowing at the time of the allotment that are completely unrelated to rollover. That is, we are excluding the possibility that banks could have reduced (or increased) their shorter-term borrowings from the ECB for reasons that are completely unrelated to the vLTRO at the time of the allotment. We believe this to be a relatively mild assumption, since vLTRO should (weakly) dominate any other sources of central bank

funding.²⁵ This assumption allows us to identify the new borrowings component of the vLTRO. To see this, note that we can decompose the change in total ECB borrowings between February and March 2012 as

$$\Delta\text{Total ECB Borrowing}_i = \text{vLTRO2}_i + \Delta\text{Short-Term ECB Borrowing}_{i,\text{Feb12-Mar12}}$$

Imposing our assumption, (4), we obtain

$$\Delta\text{Total ECB Borrowing}_{i,\text{Feb12-Mar12}} = \text{vLTRO2}_i^N$$

Impact of collateral purchases on new borrowing Since all changes in short-term borrowing around the allotment are assumed to correspond to the rollover component, we can measure the net uptake component of the vLTRO by looking directly at changes in total ECB borrowing around this period. With this fact in mind, we test our hypothesis by regressing the new borrowings component of vLTRO on the change in eligible collateral. We consider the following specification,

$$\text{vLTRO2}_i^N = \alpha + \beta\Delta C_{i,\text{Nov11-Feb12}} + \epsilon_i \quad (5)$$

where the left-hand side is the new borrowings component of vLTRO2, as measured by the change in total ECB borrowing between February and March 2012, scaled by total assets in February 2012. The right-hand side includes a measure of the change in total eligible collateral between December 2011 and February 2012.

Eligible collateral at the ECB falls in two broad asset classes: marketable assets and non-marketable assets. The first comprises debt instruments such as unsecured bonds, asset-backed securities, and covered bank bonds. The second class includes fixed-term

²⁵Strictly speaking, we are also implicitly assuming that the entire stock of vLTRO1 borrowing is also being rolled over in this operation, since we identify vLTRO2 borrowing as the change in long-term borrowing from the ECB between February and March 2012.

deposits from eligible monetary policy counterparties, credit claims (bank loans), and non-marketable retail mortgage-backed debt instruments.²⁶ The vLTRO period was characterized by an expansion of the eligible collateral. On the day of the announcement of the operations, the ECB also announced collateral availability by allowing riskier asset-backed securities and allowing national central banks (NCBs) to temporarily allow additional credit claims that satisfy their specific criteria, as long as the risks of this acceptance were assumed by the NCB.²⁷

We include these as regressors in addition to changes in Portuguese government bond holdings. Since the ECB marks to market the value of collateral on a daily basis, an institutions' borrowing capacity depends on the market value of its assets. This poses a problem to our analysis, since it creates the possibility that banks that did not change their holdings of government bonds borrowed more simply because the market value of their portfolios increased during the intra-allotment period. This is an important factor, since our argument is based on changes in quantities. In order to account for this possibility, we take advantage of the granularity of our dataset and decompose changes in the market value of banks' holdings of government bonds into price and quantity components.

Let the face value of the holdings of a bond j held by bank i in period t that we obtain from the securities dataset be denoted by $q_{i,j,t}$. Since we also have information on the market value of these holdings, $pq_{i,j,t}$, we can compute the average recorded price as

²⁶See section 6 of [ECB \(2011a\)](#) for additional details on the eligibility of assets as collateral in the Eurosystem.

²⁷On February 9, twenty days before the second allotment, BdP detailed the criteria for Portugal regarding these additional credit claims. Portfolios of mortgage-backed loans and other loans to households, as well as of loans to non-financial corporations became increasingly pledgeable as collateral. The expansion of these rules also suggests banks were collateral scarce at the time of the first allotment. Although we do not have asset-level data on the holdings of these classes of assets by banks, we rely on aggregate measures of pledged collateral for each bank. These measures include non-marketable assets whose risk was borne by the Eurosystem, additional credit claims (ACCs), government guaranteed bank bonds (GGBBs) issued from a government fund expanded around the time of the troika intervention in mid-2011, and other marketable assets. These can be interpreted as borrowing constraints, since the amounts account for haircuts. [Figure C.1](#) in the Appendix plots the aggregate amounts for the Portuguese monetary financial system. Between the end of December and the end of February, when the second allotment took place, the pledged amounts of Portuguese government bonds, as well as GGBB increased significantly. It is also visible that banks started using ACCs as soon as they were allowed, in February, but only after the vLTROs were they used as significant sources of collateral.

$p_{i,j,t} = \frac{pq_{i,j,t}}{q_{i,j,t}}$. We then decompose the total change in the market values of holdings as:

$$\Delta pq_{i,j,t} = p_{i,j,t}q_{i,j,t} - p_{i,j,t-1}q_{i,j,t-1} \quad (6)$$

By adding and subtracting $p_{i,j,t}q_{i,j,t-1}$, and simplifying, we can obtain the following decomposition

$$\Delta pq_{i,j,t} = \underbrace{p_{i,j,t}\Delta q_{i,j,t}}_{\text{Qty change}} + \underbrace{\Delta p_{i,j,t}q_{i,j,t-1}}_{\text{Price change}} \quad (7)$$

We can compute explicitly each of the terms, and include them separately in the regression. This allows us to isolate, for each bond and for each institution, the change in portfolio value that arose from an actual increase in holdings or from valuation gains. These terms are measured in euros, and are therefore easily aggregated across bonds for each institution. Letting $P_{i,t} = \sum_{j \in J} p_{i,j,t}$ and $Q_{i,t} = \sum_{j \in J} q_{i,j,t}$, we estimate equation 5 as follows

$$\begin{aligned} \Delta \text{Total ECB Borrowing}_{i,\text{Mar12}-\text{Feb12}} &= \alpha + \beta_1 P_{i,\text{Feb12}} \Delta Q_{i,\text{Feb12}-\text{Nov11}} + \\ &+ \beta_2 \Delta P_{i,\text{Feb12}-\text{Nov11}} Q_{i,\text{Feb12}} + \\ &+ \beta_3 X_{i,\text{Feb12}-\text{Nov11}} + \epsilon_i \end{aligned} \quad (8)$$

where $X_{i,\text{Feb12}-\text{Nov11}}$ represents additional measures of collateral. We scale each of the regressors by total assets in February 2012, so as to control for the size of each institution. Table 1 presents the results.

Columns (1) and (3) present the result for the whole sample, while columns (2) and (4) include only domestic institutions. The first two columns include only changes in quantities and prices for Portuguese bonds between November 2011 and February 2012, while the last two columns include additional collateral measures, such as additional credit claims, government guaranteed bank bonds and other marketable assets.²⁸ We like to interpret these results as a partial correlation: they suggest that, even when

²⁸Non-marketable assets in the shared-risk framework were not a significant source of collateral during this period.

Dependent variable: $\Delta\text{Total ECB Borrowing}_{\text{Feb12-Mar12}}$				
	(1)	(2)	(3)	(4)
GovtPT Qty change	0.146 (0.212)	0.184** (0.0681)	0.369*** (0.0637)	0.241*** (0.0670)
GovtPT Price change	✓	✓	✓	✓
Other collateral			✓	✓
Sample	Full	Domestic	Full	Domestic
N	71	36	71	36
adj. R^2	0.034	0.653	0.915	0.699

Table 1: Demand for Collateral. This table presents the results of specification (8). The dependent variable is the change in total ECB borrowing between February 2012 and March 2012, scaled by total assets in February 2012. The regressors show changes in quantities and prices of holdings of Portuguese government bonds, and changes in other sources of collateral such as additional credit claims, government guaranteed bank bonds and other marketable assets between December 2011 and February 2012, divided by assets in February 2012. Even-numbered columns include only domestic institutions. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

controlling for any other types of collateral that banks could have raised to access the ECB’s liquidity facilities, domestic government bonds still played a very important role. In particular, this takes into account types of collateral whose eligibility requirements were relaxed during this period (while eligibility requirements for domestic government bonds did not change). Thus, even when the institutional setting was changing to induce preference for *other* types of collateral, banks still relied on domestic government bonds to access the ECB’s liquidity facilities.

4.3 Stigma as an Alternative Explanation

Stigma, and not the collateral demand dynamics that we focus on, is a potential explanation for the borrowing behavior that we observe between the first and second allotments. There is an old and vast literature on stigma associated with borrowing from the lender of last resort that is too large to be reviewed here.²⁹ The idea is that

²⁹See Peristiani (1998), Furfine (2001), Furfine (2003). For more recent studies, see Ennis and Weinberg (2013) and Armantier et al. (2013).

borrowing from standing facilities, such as the discount window that is 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 by policymakers during the design of other policy interventions, such as the Troubled Asset Relief Program.³⁰

If banks initially perceived borrowing from the vLTRO 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.

We first note that while net uptakes were very small in the first allotment, gross uptakes were substantial. As we documented, banks engaged in substantial gross uptakes during the first allotment in order to roll over previous shorter-term borrowing. Concerns regarding stigma usually belie the lender of last resorts's concern for protecting the privacy of participants in standing facilities: indeed the ECB never published the identities of the banks that participated in the vLTRO. We note, however, using anecdotal evidence from press articles around the allotment dates that there was substantial self-reporting by participating banks.

At the time of the allotment, most large banks issued public statements explicitly stating the quantities that were borrowed from the vLTRO. Most statements described access to a new funding source as a significant positive shock. This suggests that stigma was not an issue for this unconventional liquidity provision operation.³¹

5 Aggregate Impact and General Equilibrium Effects

Having established that domestic government debt was an important source of collateral during the intra-allotment, we now show empirically that: (i) the vLTRO *an-*

³⁰See [Bernanke \(2015\)](#) for an insider account.

³¹Our analysis applies to Portuguese banks only; some core country banks such as Deutsche Bank explicitly voiced stigma concerns regarding vLTRO participation, see [FT Alphaville \(2012\)](#).

nouncement led to a causal expansion in the demand for government debt; (ii) this increase was concentrated in shorter maturities, as our model predicts; and (iii) this increase is economically significant. We also show that other predictions of the model are borne by the data: the portfolio substitution between long and short-term bonds operated at the intensive margin, being stronger for banks that borrowed more from the ECB. Finally, we show that the model’s predictions regarding the behavior of the yield curve and the government’s debt management strategy are consistent with the data.

5.1 Quantifying the Impact on Demand

Our model suggests that banks with access to the ECB’s liquidity facilities had an incentive to rebalance their collateral portfolios towards the shorter end of the yield curve. We therefore analyze the impact of the vLTRO announcement on the demand for public debt, distinguishing bonds with a residual maturity shorter than the maturity of the vLTRO’s second allotment (expiration date on or before February 2015), which we call “short-term” bonds, and longer.

To test whether the vLTRO announcement had a differential impact on the demand for bonds with different remaining maturities, and across different types of institutions, we take advantage of the richness of our dataset and adopt a triple-difference approach. We focus on heterogeneity across three dimensions: for securities, we distinguish between short and long-term, where short refers to whether the bond expires before or after the vLTRO borrowing matures; for entities, we distinguish between the MFI’s that can legally access the ECB’s open market operations and financial institutions that cannot, such as money market funds and non-MFI financial institutions (e.g. mutual and pension funds, etc.); for time, we distinguish between the pre-vLTRO period, the months before December 2011, and the post-vLTRO period, after the announcement.

We base our analysis in the following triple-difference specification,

$$\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}} = \beta \times \text{vLTRO}_t \times \text{Access}_i \times \text{Short-Term}_j + \gamma' X_{i,j,t} + \epsilon_{i,j,t} \quad (9)$$

where $H_{i,j,t}$ are holdings (measured in face value) of ISIN j by entity i in month t and $\text{Amount Outstanding}_{j,t}$ is the total face value outstanding of ISIN j at month t . The

	Dependent variable: $\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}}$	
	All Bonds	Issued before Dec2011
Short-Term _{<i>j</i>} × Access _{<i>i</i>} × vLTRO _{<i>t</i>}	0.00220*** (0.0000522)	0.000181** (0.0000649)
Short-Term _{<i>j</i>} × vLTRO _{<i>t</i>}	-0.0000587 (0.000108)	0.000160 (0.000139)
Short-Term _{<i>j</i>} × Access _{<i>i</i>}	0.00353*** (0.000390)	0.00353*** (0.000390)
Access _{<i>i</i>} × vLTRO _{<i>t</i>}	0.000293*** (0.0000583)	0.000293*** (0.0000572)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Jun2011-May2012	Jun2011-May2012
<i>N</i>	259,272	242,589
adj. <i>R</i> ²	0.126	0.127

Table 2: Estimating demand impact. This table presents the results of specification (9). The dependent variable are the holdings of ISIN *j* by entity *i* in month *t* (measured in face value), divided by the total amount outstanding of ISIN *j* at month *t* (also in face value). The regressors are a dummy equal to 1 if the period is after the vLTRO announcement, December 2011, a dummy equal to 1 if the entity is a MFI with access to the ECB open market operations (MFI's excluding money market funds), and a dummy equal to 1 if the bond is short-term (expires before the vLTRO loan matures, in February 2015). Fixed effects are at the ISIN, entity and month levels. The sample is June 2011 to May 2012. Standard errors in parentheses are clustered at the entity's institutional type level. * p<0.10, ** p<0.05, *** p<0.01.

treatment dummies are: vLTRO_{*t*}, equal to 1 on and after December 2011; Access_{*i*}, equal to 1 if entity *i* is a MFI with access to the vLTRO; and Short-Term_{*j*}, equal to 1 if ISIN *j* expires on or before February 2015, 3 years after the second allotment. $X_{i,j,t}$ is a vector of controls that includes all double interactions between the treatment dummies, as well as entity-, ISIN- and time-level fixed effects.

We run our baseline specification on a six-month window around the vLTRO announcement in December 2011: from June 2011 to May 2012. We choose to terminate the window on May 2012 for two reasons: first, several large Portuguese banks accessed a government-financed recapitalization fund in June 2012. Second, the ECB launched the Outright Monetary Transactions programme in August 2012. These two policy

interventions are potential confounding factors that we wish to avoid.³²

Table 2 shows the results for the 6-month window. The first column includes all bonds outstanding during the period, while the second column excludes all bonds issued on and after December 2011. By excluding these bonds, we are controlling for potential concerns regarding any strategic response by the debt management agency, and focus only on portfolio rebalancing undertaken through secondary markets. Standard errors are clustered at the investor sector level.³³

The first line of the table presents our main result: the triple interaction between the vLTRO, Access and Short-Term dummies is always statistically significant. This establishes that MFI's with access to the ECB's liquidity facilities increased their holdings of ISIN's with maturity shorter than the vLTRO after the announcement of the policy (as a percentage of the total amount outstanding). The magnitude of the coefficient is smaller when bonds issued after the announcement are excluded, suggesting that issuances undertaken after the policy was announced played an important role during this period.

While the second column controls for net supply effects, one could think that there is something particular to short-term bonds that led to their repatriation to the Portuguese financial system after the policy was announced, and that is unrelated to whether an institution can access the ECB's operations or not. Assuming that this repatriation would take place uniformly across different types of financial institutions (i.e. it would affect banks and mutual funds equally, for example), this possibility is excluded by the fact that, in the second line, the interaction between Short-Term and the vLTRO dummies is not statistically significant. This reveals that non-MFI institutions did not increase their holdings of short-term bonds in a statistically significant manner after the announcement, and that access to the ECB played an important role in establishing this preference.

³²Table B.2 shows that our results are robust to changing the size of this window.

³³Each entity in our sample is classified according to a functional criterion, in one of the following investor sectors: monetary and financial institutions (including money market mutual funds), mutual investment funds and companies (excluding money market mutual funds), venture capital companies, financial brokerage companies, holding companies, other financial intermediaries, mutual guarantee companies, non-depository credit institutions, financial auxiliaries, insurance companies, and pension fund companies.

The third line interacts Short-Term with Access and reveals that banks tend to hold government bond portfolios with shorter maturities than other financial institutions. This is expectable due to the long investment horizons of some of these financial institutions, such as pension funds.

Finally, the fourth line reveals a result that is interesting by itself and the subject of a large literature: the vLTRO announcement caused an increase in the home bias by institutions that had access to the liquidity facilities. Banks increased their holdings of government bonds across maturities. The triple interaction term presents a more novel result, stating that this effect was stronger for short than for long maturities.

To get a sense of the quantitative importance of these results, we calculate the aggregate impact of the vLTRO announcement on the demand for government bonds. These calculations are described in [Appendix D](#). We find that, on average over short-term ISIN's, the vLTRO announcement boosted demand by 17.7 percentage points of the amount issued. When bonds issued after December 2011 are excluded, the impact is equal to 3.4 percentage points. For long-term bonds, the impact is smaller but still positive: 2.1 percentage points, regardless of whether bonds issued after December 2011 are excluded or not (no long-term bonds were issued after the announcement in the sample period we consider for the regressions).³⁴ This suggests that the vLTRO had an economically significant impact on the demand for government debt, especially at short maturities.

Intensive Margin Our theoretical framework suggests that the larger the share of vLTRO borrowing, the stronger should be the demand for shorter-term collateral. A natural way to test this hypothesis is to replace the Access dummy for a continuous variable that reflects the intensity of vLTRO borrowing. We define intensity simply as

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

³⁴Our results do not change much when we change this sample period: if we consider the 4 months around the announcement (August 2011 to March 2012), we observe an increase of 12.5 p.p. for short-term bonds, 4.5 p.p. when new issuances are excluded, and 1.3 p.p. for long-term bonds.

where $vLTRO_i$ 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 $Assets_i$ 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 baseline specification,

$$\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}} = \beta \times vLTRO_t \times \text{Intensity}_i \times \text{Short-Term}_j + \gamma' X_{i,j,t} + \epsilon_{i,j,t} \quad (10)$$

A problem with this adapted specification 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.

Taking advantage of the fact that a considerable part of vLTRO borrowing was rollover from past ECB borrowing, we choose total ECB borrowing as a percentage of assets in November 2011 as an instrument for the intensity of vLTRO borrowing. Exogeneity of the instrument arises from our timing identification assumption: that the vLTRO was an unexpected policy and, hence, any ECB borrowing in late November 2011, one week before the announcement, is independent from any change in the behavior of government bond purchases occurring after the announcement has taken place.

The results are presented in [Table 3](#).³⁵ The first column includes all bonds outstanding and issued during the period, while the second column excludes new issuances, after December 2011.

The impact of vLTRO borrowing intensity, as a fraction of assets, on purchases of short-term bonds after the vLTRO announcement is positive and very significant. This confirms the model's predictions regarding the intensity margin: the more long-term borrowing a bank took from the ECB, the more short-term debt it purchased (over long-term debt). The second line confirms our previous point that the vLTRO announcement did not cause a generalized increase in the demand of short-term debt by

³⁵[Table B.3](#) presents the results for the shorter 4-month window.

	Dependent variable: $\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}}$	
	All Bonds	Issued before Dec2011
$vLTRO_t \times \text{Short}_j \times \text{Intensity}_i$	0.0370*** (0.00122)	0.0140*** (0.000969)
$vLTRO_t \times \text{Short}_j$	0.0000295 (0.0000446)	0.000120 (0.0000982)
$vLTRO_t \times \text{Intensity}_i$	-0.0240*** (0.000436)	-0.00797*** (0.000110)
$\text{Short}_j \times \text{Intensity}_i$	0.0252*** (0.00288)	0.0511*** (0.0000982)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Jun2011-May2012	Jun2011-May2012
N	259,272	242,589
adj. R^2	0.124	0.125

Table 3: Estimating demand impact, intensive margin. This table presents the results of specification (10). The dependent variable are the holdings of ISIN j by entity i in month t (measured in face value), divided by the total amount outstanding of ISIN j at month t (also in face value). The regressors are a dummy equal to 1 if the period is after the vLTRO announcement, December 2011, a dummy equal to 1 if the bond is short-term (expires before the vLTRO loan matures, in February 2015), and an intensity measure that is equal to long-term ECB borrowing divided by total assets in March 2012. This variable is instrumented using total ECB borrowing as a percentage of assets in November 2011, before the vLTRO announcement. Fixed effects are at the ISIN, entity and month levels. The sample is June 2011 to May 2012. Standard errors in parentheses are clustered at the investor sector level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

all financial institutions - this increase was restricted to banks that had access to the ECB's liquidity facilities. The third line, the interaction between the vLTRO dummy and the intensity variable, is negative and significant. This is evidence that banks that borrowed more from the vLTRO not only purchased more short-term in absolute terms, but also substituted more from long-term to short-term. When interpreting these results in light of the previous ones, we conclude that while the vLTRO announcement caused an increase in the demand for public debt across maturities, banks that borrowed more tilted their preference more for short-term debt than banks that borrowed less.

5.2 Effect on Government Bond Yields

Consistent with the “collateral trade” channel, the Portuguese sovereign yield curve rotated, and became steeper during the intra-allotment period. This is illustrated in [Figure 7](#), which plots the yield curve for different maturities (in years) on the date of the announcement of the vLTRO, and some days after the second allotment. A striking fact is that the yields of all bonds with maturity smaller than the vLTRO (three years) decreases, while the yields on the bonds with maturity greater than the vLTRO increased: we did not see a parallel shift of the yield curve, but rather a rotation around the three year maturity that left the yield curve steeper.

The yield curve rotation in this period is also present in other peripheral countries like Italy and Spain, suggesting that our analysis might be valid in other similar contexts. [Figure C.2](#) plots yield curves for four eurozone countries, on the date before the vLTRO announcement (December 7, 2011) and the day after the second allotment (March 1, 2012). The upper panels correspond to two core countries, Germany and France, while the lower two panels represent two members of the GIIPS, Italy and Spain. Plots for core countries do not show the yield curve steepening, consistent with the fact that the collateral trade motive is present only if domestic government bonds offer a high enough yield.³⁶

A concern may be that the changes in the yield curve, and the motive for purchasing bonds, may be unrelated to the vLTRO, and instead connected with other unconventional ECB interventions that were active at the time. A prime suspect is the Securities Markets Programme (SMP) launched by the ECB in May 2010; this initiative purchased sovereign bonds in secondary markets. 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.

In the first round of the program, that took place until August 2011, the targeted

³⁶These data are taken from Bloomberg, who aggregates secondary market prices using survey data from broker-dealers. Bloomberg does not report any data if a security is not liquid enough on a given day, in which situation prices would be relatively meaningless. Due to the lack of data, we do not present plots for the remaining two GIIPS, Ireland and Greece.

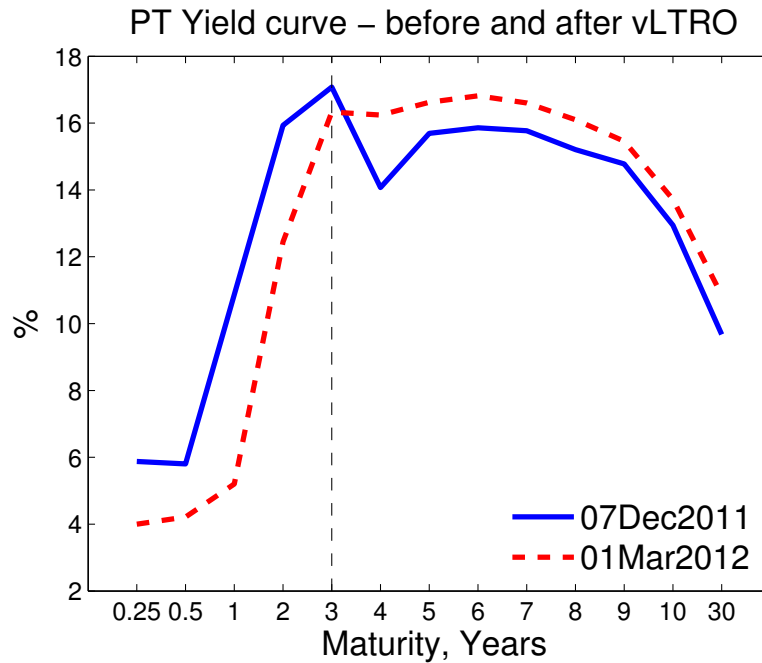


Figure 7: Portugal Yield Curve, pre and post vLTRO. This figure plots the yield curve (interpolated for missing maturities) on December 8, 2011 and March 3, 2012. December 8 is the date of the announcement of the vLTRO, and February 29 is the date of the second allotment. The horizontal axis of maturities is measured in years.

countries were Greece, Ireland, and Portugal. In the second round, starting in the summer of 2011, the program focused on the purchase of Italian and Spanish bonds. Thus the focus was not in purchases of Portuguese bonds in the immediate pre- and the intra-allotment periods. Still, the ECB could have caused the observed impact on yield curves if it was purchasing bonds at the short-end of the term structure. [Krishnamurthy et al. \(2014\)](#), in their analysis of ECB bond-purchase programs, show that the average remaining maturity of Portuguese bonds in the SMP portfolio was of about 5 years during 2011, suggesting that most purchases were made at longer maturities. If anything, this effect would work against our results, since the purchase of bonds at longer maturities should flatten, not steepen, the yield curve.

It is also unlikely that this programme influenced agents' behavior during the intra-allotment period, given the shroud of secrecy in which the details of the purchases were involved. Unaware of the type of and quantity of securities that the ECB was purchasing, we do not find it plausible that expectations regarding the program affected substantially the behavior of market participants such as Portuguese banks.

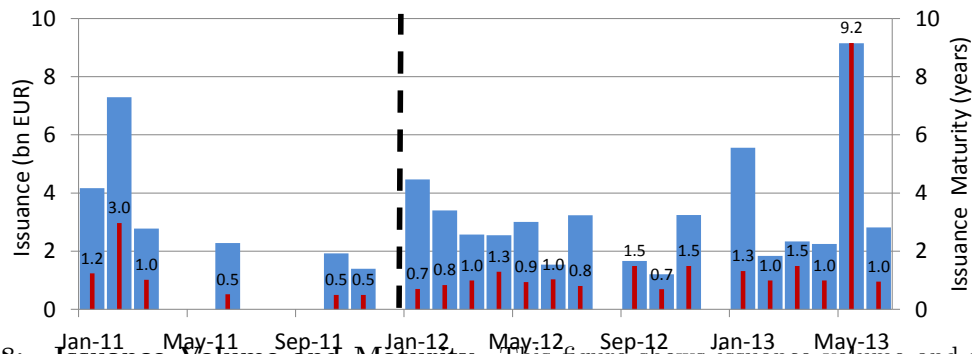


Figure 8: Issuance Volume and Maturity. This figure shows issuance volume and maturity during the period January 2011 - June 2013. Thick bars illustrate monthly issuance volume (bn €, primary axis). Thin bars illustrate volume average maturity of new public debt issuance (years, secondary axis). Maturity and volumes are taken from Bloomberg.

5.3 Public Debt Management

We now look at the behavior of the government debt agency during the intra-allotment period. In particular, we show that the available evidence is consistent with the Portuguese Treasury acting strategically by issuing securities whose demand was boosted by vLTRO.³⁷

The security-level dataset collected from Bloomberg allows us to analyze in greater detail the characteristics of the bonds issued by the Portuguese government throughout our sample. This exercise relates to a growing body of literature that studies the optimal composition of government debt issuances.³⁸ Figure 8 illustrates, for the period ranging from January 2011 to May 2013, the maturity and volume of monthly public debt issuance. The thick bars show, in billion euros, the amount issued and the thin bars show, in years, the average maturity of monthly issuance.

The figure also documents that the debt agency ramped up debt issuance after the vLTRO announcement. This observation cannot be explained by rollover needs as,

³⁷Government debt is managed by the *Agência de Gestão da Tesouraria e da Dívida Pública - IGCP*, an autonomous public agency that is in charge of managing consolidated public debt (government debt and debt of some public companies) and is under the supervision of the Ministry of Finance.

³⁸Broner et al. (2013) show that emerging economics tend to borrow at shorter maturities due to lower costs, and 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.

before and after the vLTRO, the amount of public debt maturing each semester was roughly constant, approximately €20 bn from 2011 to mid-2012. Interestingly, during the intra-allotment period, there were four short-term zero-coupon bonds maturing for a total of €13.5 bn.³⁹ During the intra-allotment period, the government issued €7.9 bn using four zero-coupon bonds with maturities of one year (two bonds) and six-months (two bonds). These issuances took place in two days (20 January 2012 and 17 February 2012), and in each of these days, a one-year and a six-month bond were issued.⁴⁰ This behavior is consistent with the prediction of the model, that argues that the debt management agency will have incentives to tilt its issuances towards the short-end of the curve in response to the market incentives generated by the introduction of the vLTRO.

6 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 had two possibly unintended consequences: it expanded the demand for collateral, in the form 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 lower than the long-term central bank loan. This allowed them to earn a positive return while mitigating funding liquidity risks. We rationalize this intuition using a simple theoretical framework, that yields two additional predictions that are consistent with the data: the yield curve steepens, and the government reacts by reducing the maturity of its debt issuances.

³⁹Three of them had a one year maturity and one of them had six-month maturity. The latter had a €2.3 bn face value.

⁴⁰The amount issued of one-year debt was similar across auctions, but for six-month debt, the government issued twice as much six-month debt during the first auction. Both 1-year securities had a very similar price across auctions, while the 6-month securities had different yields: the February issue was much cheaper for the government (4.332% compared to 4.74% in January.).

Our analysis is purely positive, and we make no normative judgements on these indirect consequences. On one hand, we could argue for a stabilizing impact, based on the fact that to the extent that this policy led to a reduction in yields of assets to which banks were already substantially exposed, it involved an implicit recapitalization that could have helped stabilize the domestic financial system. Additionally, the expansion in the demand for domestic government debt could have helped stabilize sovereign funding markets at a time of great distress. On the other hand, one could argue that these effects meant that this policy effectively consisted of indirect financing of government debt by the ECB, which may be at odds with the monetary authority's mandate and raise a plethora of other questions.

We believe that our analysis uncovers previously unstudied effects of what we call vLTRO-style policies, long-term collateralized lending to the financial system by the monetary authority. These effects are especially interesting when compared to those of QE-style policies. In the former, through the channels that we uncovered, the monetary authority engages in indirect purchases of short-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 government debt, the government will have an incentive to react to market conditions by issuing more short-term debt.

In contrast, through large-scale asset purchase programs as the ones conducted by the Federal Reserve (QE) consist on the direct purchases of long-term assets. This leads to a flattening of the yield curve, and it also leads to a reduction of the aggregate maturity gap of the private sector, but by a different channel: while vLTRO 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.

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A Theory Appendix

Bank portfolio choice In this appendix, we describe the solution to the bank's problem in the model in [Section 3](#).

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,

$$\begin{aligned} \max_{b'_L, d} & [b'_L + d \{\mathbf{1}[d \geq 0] + \kappa \mathbf{1}[d < 0]\}] \\ \text{s.t.} & \\ & W_1 = q_1 b'_L + d \end{aligned}$$

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 $\kappa q_1 > 1$, 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

$$b_S + q_1 b_L + c - R\epsilon < 0$$

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

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

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

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

In order to illustrate the forces at play, we now assume that $\kappa \rightarrow \infty$: 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 $\kappa \rightarrow \infty$, we can restate the bank's problem as follows: the objective function now

becomes

$$\mathbb{E}_0[\pi_2] = \int_{\underline{q}}^{\tilde{q}} \left[b_L + \frac{b_S + c - R\mathfrak{E}}{q_1} \right] dF(q_1) = b_L + (b_S + c - R\mathfrak{E})\mathbb{E}_0 \left[\frac{1}{q_1} \right]$$

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

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

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

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

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

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

Proof of Proposition 2 We assume that we are in Region 4 of Proposition 1 throughout. For this, we assume that ϕ is large enough such that the change in R has a small enough impact on γ so as not to leave this region. We assume that $\bar{\gamma} \in (0, 1)$, and that ϕ 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

$$\begin{aligned} q_S &= \frac{1}{R} \\ q_L &= \frac{q}{R} + \frac{\omega}{1 - \gamma} \\ \gamma &= \bar{\gamma} + \phi^{-1}(q_S - q_L) \end{aligned}$$

We can solve for γ , yielding

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

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

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

and it is negative for large enough ϕ , thus establishing the second result. To establish the first, let Ω denote the slope of the yield curve,

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

So that

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

For ϕ large enough, $\frac{d\gamma}{dR} \rightarrow 0$, and so the above term is strictly negative, establishing our claim. \square

B Additional Tables

	Tot tapped (bn €)			No. banks			Total Assets
	Short	vLTRO	ECB Total	Short	vLTRO	ECB Total	
Nov-11	45.7	--	45.7	18	--	18	552.1
Dec-11	25.8	20.2	46.0	19	16	21	551.9
Feb-12	27.4	20.2	47.6	18	15	20	559.9
Mar-12	9.4	47.0	56.4	16	23	23	557.2

Table B.1: Borrowing from the lender of last resort. This table shows the amount borrowed and the number of borrowing banks for the different types of ECB open market operations during the allotment periods. The first three columns show the amount borrowed from: shorter term operations (MRO's and LTRO's), vLTRO, and total ECB borrowing around the months of the first and second vLTRO allotment. The following three columns show the number of banks participating in each type of operation. The final column is the value of total assets in bn €.

	Dependent variable: $\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}}$	
	All Bonds	Issued before Dec2011
$vLTRO_t \times \text{Short}_j \times \text{Access}_i$	0.00160*** (0.0000375)	0.000439*** (0.0000450)
$vLTRO_t \times \text{Access}_i$	0.000188*** (0.0000440)	0.000188*** (0.0000436)
$\text{Short}_j \times \text{Access}_i$	0.00378*** (0.000389)	0.00378*** (0.000389)
$vLTRO_t \times \text{Short}_j$	-0.00000439 (0.0000481)	0.000122 (0.000104)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Aug2011-Mar2012	Aug2011-Mar2012
N	169,494	162,663
adj. R^2	0.129	0.129

Table B.2: Estimating demand impact, 4-month window. This table presents the results of specification (9). The dependent variable are the holdings of ISIN j by entity i in month t (measured in face value), divided by the total amount outstanding of ISIN j at month t (also in face value). The regressors are a dummy equal to 1 if the period is after the vLTRO announcement, December 2011, a dummy equal to 1 if the entity is a MFI with access to the ECB open market operations (MFI's excluding money market funds), and a dummy equal to 1 if the bond is short-term (expires before the vLTRO loan matures, in February 2015). Fixed effects are at the ISIN, entity and month levels. The sample is August 2011 to March 2012. Standard errors in parentheses are clustered at the entity's institutional type level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Dependent variable: $\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}}$	
	All Bonds	Issued before Dec2011
$vLTRO_t \times \text{Short}_j \times \text{Intensity}_i$	0.0211*** (0.00102)	0.0120*** (0.000823)
$vLTRO_t \times \text{Short}_j$	0.0000848 (0.0000687)	0.000120 (0.000101)
$vLTRO_t \times \text{Intensity}_i$	-0.0128*** (0.000300)	-0.00605*** (0.000112)
$\text{Short}_j \times \text{Intensity}_i$	0.0568*** (0.00319)	0.0676*** (0.00318)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Aug2011-Mar2012	Aug2011-Mar2012
N	169,494	162,663
adj. R^2	0.126	0.126

Table B.3: Estimating demand impact, intensive margin. This table presents the results of specification (10). The dependent variable are the holdings of ISIN j by entity i in month t (measured in face value), divided by the total amount outstanding of ISIN j at month t (also in face value). The regressors are a dummy equal to 1 if the period is after the vLTRO announcement, December 2011, a dummy equal to 1 if the bond is short-term (expires before the vLTRO loan matures, in February 2015), and an intensity measure that is equal to long-term ECB borrowing divided by total assets in March 2012. This variable is instrumented using total ECB borrowing as a percentage of assets in November 2011, before the vLTRO announcement. Fixed effects are at the ISIN, entity and month levels. The sample is August 2011 to March 2012. Standard errors in parentheses are clustered at the investor sector level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C Additional Plots

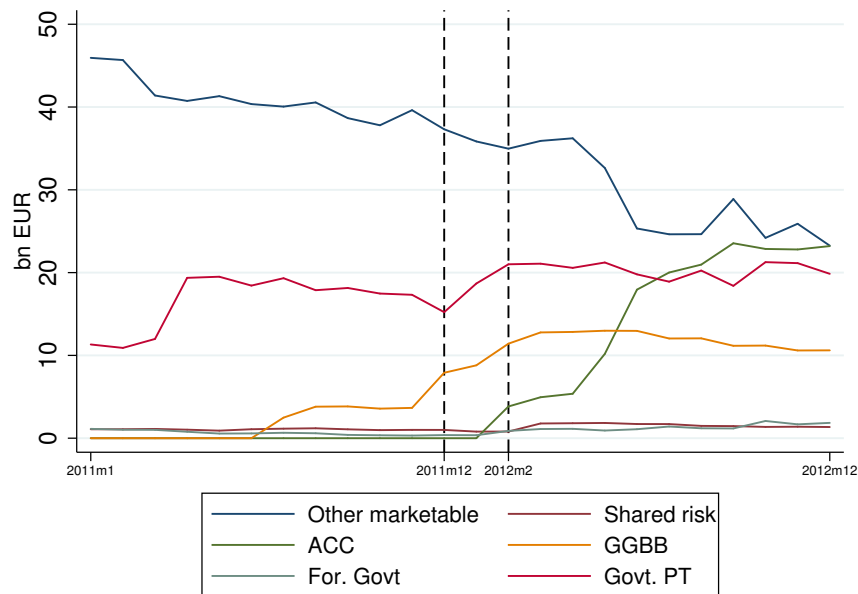


Figure C.1: Pledged collateral by type of eligible asset. The figure plots aggregates amounts of assets pledged as collateral with the Eurosystem, discounted by haircuts. The categories included are exhaustive and include, for marketable assets: Portuguese Government Bonds, Foreign Government Bonds, GGBBs and other marketable assets; for non-marketable assets: ACCs, shared risk framework non-marketable assets.

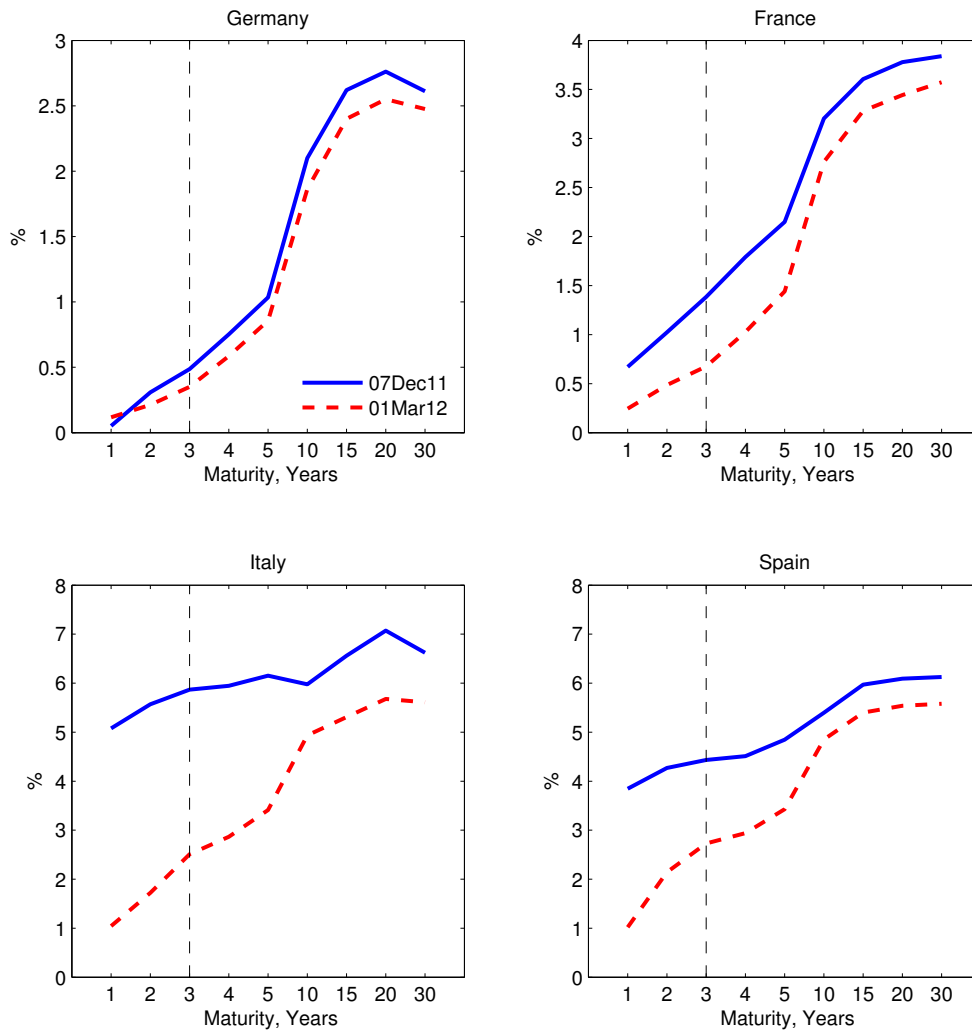


Figure C.2: Yield Curves around the vLTRO. This figure plots the 1-30 year yield curves for four eurozone countries, on the day before the vLTRO announcement (solid blue), and on the day after the second allotment (dashed red). The two upper panels are core countries, Germany and France. The two lower panels are periphery countries, Italy and Spain. Data taken from Bloomberg, based on a daily survey of broker-dealers on secondary debt markets. The dashed vertical line corresponds to 3 year maturity - the same maturity as the vLTRO loan.

D Estimating the Demand Impact

First, we estimate the demand impact on short-term bonds. Consider an expanded version of specification 9, where we include the statistically significant coefficients,

$$\left(\frac{\hat{H}_{i,j,t}}{\text{Amount Outstanding}_{j,t}} \right) = \hat{\beta}_1 \times \text{vLTRO}_t \times \text{Access}_i \times \text{Short-Term}_j \\ + \hat{\beta}_2 \text{vLTRO}_t \times \text{Access}_i + \hat{\beta}_3 \text{Access}_i \times \text{Short-Term}_j$$

We want to compare the demand by MFI's of Short-Term bonds after the vLTRO, to the demand before the vLTRO. The total impact can be computed as

$$\hat{\Lambda}^{\text{Short-Term}} = \hat{\beta}_1 + \hat{\beta}_2$$

We now want to compute the magnitude of the impact as a percentage of total amount outstanding. To achieve this, we write

$$\hat{H}_{i,j,t} = \hat{\Lambda}^{\text{Short-Term}} \times \text{Amount Outstanding}_{j,t}$$

We sum over i to obtain the estimate of the demand impact,

$$\hat{\alpha}_t^{\text{Short-Term}} = \frac{\sum_{i:\text{Access}_i=1} \hat{H}_{i,j,t}}{\text{Amount Outstanding}_{j,t}} = \hat{\Lambda}^{\text{Short-Term}} \times \left(\sum_{i \in I} \text{Access}_i \right)$$

We compute the average impact over the period by taking time averages of all variables. The number of MFI's with Access in our sample (in the 12-month window) is 71. This implies the following estimates,

$$\hat{\alpha}_{\text{Total}}^{\text{Short-Term}} = 0.1770 \\ \hat{\alpha}_{\text{Supply}}^{\text{Short-Term}} = 0.0337$$

We can repeat the exercise for long-term bonds. The total impact is now simply equal to

$$\hat{\Lambda}^{\text{Long-Term}} = \hat{\beta}_2$$

Repeating the computations, we obtain $\hat{\alpha}_{\text{Total}}^{\text{Long-Term}} = 0.0208$ and $\hat{\alpha}_{\text{Supply}}^{\text{Long-Term}} = 0.0208$