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The analyses, opinions and findings of these papers represent the views of the authors, they are not necessarily those of the Banco de Portugal or the Eurosystem

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# Central Bank Interventions, Demand for Collateral, and Sovereign Borrowing Costs

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## **Abstract**

We analyze the effect of unconventional monetary policy, in the form of collateralized lending to banks, on sovereign borrowing costs. Using our unique dataset on monthly security- and bank-level holdings of government bonds, we document that Portuguese banks increased their holdings of domestic public debt during the allotment of the three year Long-Term Refinancing Operations (LTRO) of the European Central Bank. We argue that domestic banks engaged in a “collateral trade”, which involved the purchase of high-yield bonds with short maturities that could be pledged as collateral for low cost and long-term borrowing from the ECB. This significant increase in bond holdings was concentrated in shorter maturities, as these were especially suited to mitigate funding liquidity risk. The resulting steepening of the sovereign yield curve and the timing and characteristics of government bond auctions are consistent with a strategic response by the debt management agency.

JEL: E44, E52, E63, G21

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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.<sup>1</sup> In response, central banks throughout the world engaged in unprecedented interventions to improve banks' financial conditions and help restore business activity and employment in the real economy. Understanding the transmission of central bank policies is therefore key to design effective regulation and lender-of-last-resort (LOLR) interventions.

In this paper, we study the transmission of unconventional monetary policy to sovereign borrowing costs. Our laboratory is Portugal in 2011-2012, during the implementation of the European Central Bank (ECB) 3-year Long Term Refinancing Operation. Portugal is an ideal candidate for our analysis as it has been severely hit by the crisis – 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.<sup>2</sup> 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.<sup>3</sup>

In December 2011, the ECB announced an extraordinary supply of three-year collateralized loans, the 3-Year Long Term Refinancing Operation (vLTRO), consisting of two allotments at that unprecedented maturity. Banks that sought to borrow from vLTRO had to post eligible collateral on pre-determined dates (allotment dates). vLTRO was announced on 8 December 2011 and funds were allotted on 21 December 2011 and 29 February 2012. We find that (i) the first allotment consisted mainly of roll over of previous (shorter-term) ECB borrowing, (ii) holdings of government bonds increased between the two allotments, (iii) these purchases help explain the amount borrowed

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1. See Brunnermeier and Sannikov (2014), He and Krishnamurthy (2013), and Gertler and Kiyotaki (2010) 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 (2014), Popov and van Horen (2013), and Acharya *et al.* (2014a) present evidence on the negative real effects of the European sovereign debt crisis.

2. 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.

3. Non-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 insurance companies, pension funds, brokerages, etc..

from the LOLR at the second allotment, (iv) the vLTRO announcements stimulated demand for short-term government debt by 18 percentage points of amounts issued, and long-term debt by around 2 percentage points. Banks were lacking collateral at the time of vLTRO announcement and were not able to gather sufficient collateral to get *new* borrowing on the first allotment. We show that, between the two allotments, banks scrambled to obtain eligible collateral in the form of government bonds, in order to access the second and last vLTRO allotment. The timing and magnitude of these purchases is strongly suggestive of their value as collateral to tap the lender of last resort facility. This suggests that financial institutions with access to the ECB liquidity facilities took advantage of a profitable “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 LOLR in exchange of a cheap three year loan. With this policy design, the ECB mitigated banks’ funding risk as bonds with maturity less than three years would be converted into cash that could then be used to repay the ECB loan at maturity. On the other hand, bonds with maturity in excess of three years still subjected banks to several types of risks (market and funding liquidity) by the time the loan matured.

The interaction between the different constraints faced by banks and the ECB intervention generated an expansion in demand for government debt, with a preference for shorter-maturity government bonds. We develop a theoretical framework that formalizes this intuition and yields two additional empirical implications, confirmed in the data: (i) following the central bank operation, the sovereign curve steepens, and (ii) the government accordingly adjusts the composition of its bond issuance. We then compare two approaches to unconventional monetary policy: the vLTRO-style, or long-term collateralized lending to financial intermediaries, and the QE-style, long-term purchases of assets in secondary markets. We show that these may have different implications for aggregate variables, such as yield curves and the aggregate maturity gap in the economy.

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 the lender of last resort policies can influence banks government debt portfolio choice and exacerbate the link between sovereigns and domestic financial sectors. Second, in contrast to quantitative easing, we show that vLTRO-like operations might cause a yield curve steepening. Due to the granularity and specificity of our data, we cannot replicate our analysis for other troubled eurozone sovereigns. However, we present some evidence that some other peripheral countries experienced aggregate effects similar to the ones we report for Portugal. Moreover, the importance of vLTRO-like policies is growing also outside the eurozone, for example in countries such as Russia and China. In Russia, the central bank implemented a vLTRO-style policy in July 2013, dubbed “Russia QE” by the government. This policy was implemented through collateralized lending by

the CBR to banks at the unprecedented maturity of 12 months.<sup>4</sup> The implicit objective of this operation was not to stimulate demand for sovereign debt, but rather for corporate debt and reduce demand 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.<sup>5</sup> The policy seems to be primarily aimed at assuaging liquidity problems faced by local banks, as well as to minimize 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 inspired by the recent Euro crisis that analyzes the role of linkages and feedback loops between the sovereign and the financial sector. [Acharya et al. \(2014b\)](#) 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. In the absence of fiscal integration, risky governments issue too much debt as they do not fully internalize the costs of default. [Broner et al. \(2010\)](#) add a meaningful role for secondary markets to an otherwise traditional sovereign default model and show that repatriation is a punishment for increased default probability. 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 funding 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

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4. The 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 \(2013\)](#)

5. While 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 as collateral. Besides, the maturity is unprecedented. See [FT Alphaville \(2015\)](#) for an informal description of this program.



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.<sup>6</sup> 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.\* \(2013\)](#) 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.

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 focus our attention on an unconventional monetary policy measure, where the ECB fulfills its role as a lender of last resort. The transmission of vLTRO to private lending is studied, among others, by [Andrade \*et al.\* \(2014\)](#). 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. [Trebesch 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. Our findings have implications for the link between the management of sovereign debt, and the performance of unconventional monetary policy. [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,

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

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.

Finally, 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 Quantitative Easing 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.\* \(forthcoming\)](#). We contribute to the literature on policy coordination in two ways: first, we show evidence that the Portuguese Treasury also behaved strategically, taking advantage of investor’s preference for short-term debt that arises from liquidity and collateral constraints. Second, we show that programs that involve providing incentives for private investors to acquire government debt can have the opposite effect of programs where assets are directly purchased by 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 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 take advantage of the granularity of the dataset to test the model implications. In [Section 5](#), we compute aggregate effects and discuss the impact of vLTRO on sovereign borrowing costs and government bond issuance. [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 motivating 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 data on mutual funds obtained from the website of the Portuguese Securities Market Commission (CMVM). This is a monthly panel from January 2005 to September 2013, after which it becomes a quarterly panel (available until September 2014).

The first dataset contains monthly information on the composition of the balance sheets of all monetary and financial institutions regulated by BdP. The full sample contains 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.<sup>7</sup> 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 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 institutions such as mutual funds, hedge funds, brokerages, and pension funds (among others). For each institution, we have data on book, face, and market value of all holdings of Portuguese government debt (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.<sup>8</sup>

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7. More specifically, the different dimensions for which data are available are: (i) Asset category: banknotes and coins, loans and equivalent (with repricing date up to 1 year, 1 to 5 years, more 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.

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

The CMVM dataset consists on aggregate information on the balance sheets of Portuguese mutual funds. This information helps us add detail about institutions already present in our securities dataset and add entities who 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, namely banks can borrow from the monetary authority by pledging collateral in exchange for cash loans.<sup>9</sup>

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.<sup>10</sup> 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 policy tool, since banks could simply access and rollover the shorter-term MROs, while hedging the interest rate risk using financial instruments. 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).<sup>11</sup>

*Very Long-Term Refinancing Operations.* On 8 December 2011, as the Eurozone crisis deteriorated even further, the European Central Bank

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9. The 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: [Statute of the ESCB](#). For more details on the architecture of the European monetary policy, see [Mercier and Papadia \(2011\)](#).

10. See [Eisenschmidt et al. \(2009\)](#) for a detailed description.

11. Interestingly, 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.



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).

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”.<sup>12</sup> The two operations were conducted with full allotment, meaning that there was no limit to the loan a bank could get, provided that it posted enough eligible collateral.<sup>13</sup> The interest rate was very low, based on the overnight rate during the loan period, which was around 1% at the time of announcement. Participating banks had to pledge eligible collateral to get funding. The lender of last resort (LQLR) evaluated the collateral using a publicly available schedule. This schedule assigned a haircut, based on ratings, asset class, and residual maturity. For example, a covered bond rated AAA with residual maturity of 8 years had an haircut of 6.5, requiring the bank to pledge 106.5 in collateral to obtain a loan with a face value of 100. 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 with the LOLR. The solid line shows long-term borrowings (with maturity exceeding 2 years), namely vLTRO1 and vLTRO2, accessed in December 2011 and February 2012, respectively. Note

12. Before 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 LTROs 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 Website](#)

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

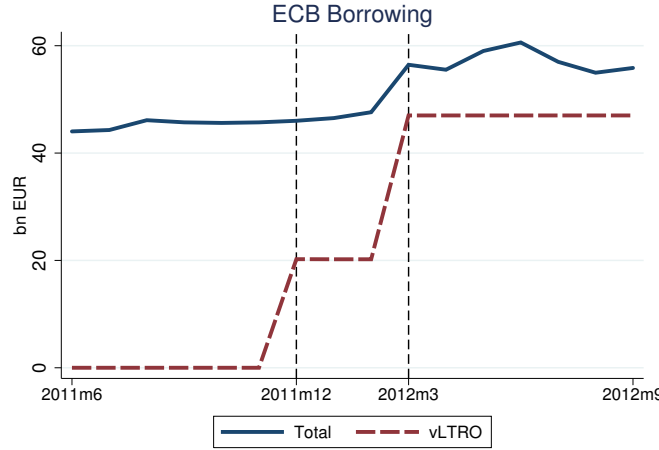


FIGURE 2: **Central Bank Borrowing.** This figure plots the evolution of total ECB borrowing (dashed red line) and long-term ECB borrowing (blue solid line) from January 2011 to December 2012. Borrowing is defined long-term if its maturity exceeds two years. Long-term borrowing from ECB coincides with the vLTROs in this sample period.

the different behavior of banks at the two uptakes: the effective net uptake (“new” borrowing) of 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 corresponds to a significant increase in total borrowing. Table D.1 in Appendix D disentangles short- and long-term borrowing from the ECB and reports the number of banks with positive debt with the LOLR. During the first allotment banks reduced their short-term ECB borrowing by €19.9 bn and 16 banks tapped vLTRO for €20.2 bn. The total ECB borrowing is substantially 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.<sup>14</sup>

#### 2.4. vLTRO and the Demand for Collateral

We now analyze banks’ holdings of government bonds. We take a closer look at the evolution of domestic government bonds held by banks in the period between the two allotments (intra-allotment period). Figure 3 compares banks

14. A 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.

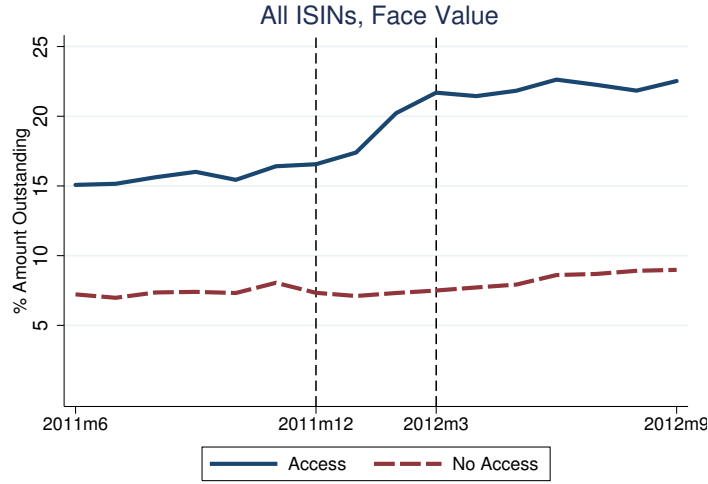


FIGURE 3: **Holdings of Domestic Government Debt, vLTRO period.** This figure plots the evolution of the quantity of domestic government bonds held by banks and non-banks, around the vLTRO period. The quantity is measured as the total face value divided by the total amount outstanding.

(that could tap vLTRO) and non-banks (that were excluded from vLTRO) throughout 2011 and 2012. The vertical lines correspond to each of the two allotments, December 2011 and March 2012.<sup>15</sup> From the figure, it emerges that the behavior of non-banks hardly changed around the vLTRO period while banks increased their holdings significantly *between* the two allotments. This behavior is significantly different from the one that is observed before the first and after the second allotments.

### 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 LOLR 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

15. The allotment took place on the last day of February 2012, but the funds were only effectively made available one day later, thus vLTRO uptakes are only reflected in March 2012.

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-time three-year liquidity facility provided by the LOLR. Not surprisingly, vLTRO2, giving participants more time to gather collateral, saw greater participation.

We first develop a simple model to illustrate the portfolio choice of banks' and its general equilibrium effect. 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. Second, we test our narrative 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. These assets mature 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 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  $\pi_2$  are profits at  $t = 2$  that arise from portfolio choices made at  $t = 1$ . Banks enter this period with available resources  $W_1$  (which can potentially be negative), and can either rebalance their long-term debt portfolio,  $b'_L$ , or store/borrow resources  $d$ . When  $d \geq 0$ , banks are able to 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 then write profits 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  $\text{€}$ . 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.<sup>16</sup> The bank faces a budget constraint, and a collateral constraint for money market borrowing. The budget constraint at  $t = 0$  is

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

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

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

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

$$q_1 \leq a$$

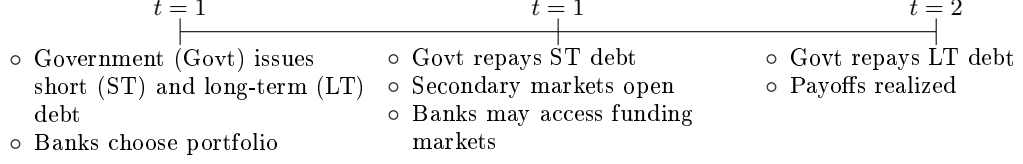
We assume that  $F$ , the distribution for  $a$ , has support  $[\underline{q}, \bar{q}]$ , where  $\bar{q} < 1$  (so that interest rates are always strictly positive).

*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  $\gamma$  of short-term debt, and a fraction  $1 - \gamma$  of long-term debt. These fractions are taken as exogenous, and there is no strategic behavior on the part of the fiscal authority for the moment.

### 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

16. We can think of this wealth as being available funds from short-term investments that have just matured, i.e.  $W_0 = D + E - L$ , where  $D, E, L$  are deposits/debt, equity and loans/non-pledgeable assets, respectively.

FIGURE 4: **Timeline for the Model**

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 B](#). 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 and simplifies considerably the solution to the model.

Letting  $(\lambda, \delta, \eta)$  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

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

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

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

since it yields a certain cash-flow of 1 in the second period, while long-term debt yields a worst-case payoff of  $\underline{q} < 1$ . This preference is scaled by the multiplier on the liquidity constraint,  $\eta$ .

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

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

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

We proceed to characterize the equilibrium in terms of thresholds over the ratio of available resources to the face value of government debt  $\omega \equiv \frac{W_0}{B}$  and the initial cost of borrowing  $R$ . The following proposition illustrates the possible regimes that can arise depending on the model's parameters.

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

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

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

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,  $\epsilon > 0$ , but no constraints are binding,  $\delta = \eta = 0$ , and prices satisfy*

$$\begin{aligned} q_S &= \frac{1}{R} \\ q_L &= \frac{\tilde{q}}{R} \end{aligned}$$

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

$$\begin{aligned}\omega &= h_S q_S \gamma + h_L q_L (1 - \gamma) \\ q_S &= \frac{1}{R + \delta h_S} \\ q_L &= \frac{\tilde{q}}{R + \delta h_L}\end{aligned}$$

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

$$\begin{aligned}q_S &= \frac{1}{R} \\ q_L &= \frac{\tilde{q} + \eta \underline{q}}{R(1 + \eta)}\end{aligned}$$

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,

$$\begin{aligned}q_S &= \frac{1}{R} \frac{h_L(\gamma + \underline{q}(1 - \gamma)) - (1 - h_L)R\omega}{\gamma(h_L - h_S)} \\ q_L &= \frac{1}{R} \frac{(1 - h_S)R\omega - h_S(\gamma + \underline{q}(1 - \gamma))}{(1 - \gamma)(h_L - h_S)}\end{aligned}$$

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

Once either  $R$  or  $\omega$  decrease, banks start borrowing. There is a region when constraints do not bind, and banks simply borrow to purchase short-term and long-term debt at risk-neutral prices: there is complete pass-through of the costs of external financing to government yields. If either  $R$  or  $\omega$  decrease further, one or more constraints start binding. For these regions, since either  $\delta > 0$ , or  $\eta > 0$ , or both, there will be a preference for short-term debt. This means that a transition from one of the previous regions will be associated with a larger increase (or smaller decrease) in the price of short-term debt, relative to long-term debt. That is, with a steepening of the yield curve.

We can use our stylized model to analyze the 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

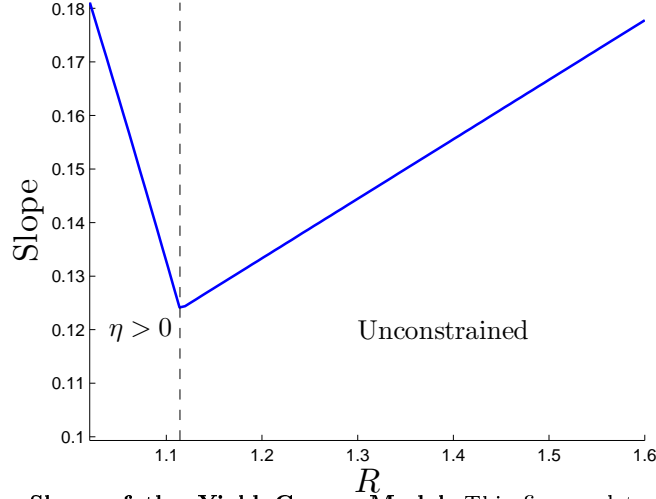


FIGURE 5: **Slope of the Yield Curve, Model.** This figure plots the slope of the Treasury's yield curve as a function of borrowing costs  $R$ . The dashed line indicates the transition from an unconstrained equilibrium to one where the liquidity constraint binds,  $\eta > 0$ .

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 are constant, and the haircut on short-term debt is smaller,  $h_S < h_L$ .<sup>17</sup>

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

Figure 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 costs can actually *increase* the slope of the yield curve. The following sections empirically explore the

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

behavior of private agents in greater detail, as well as evidence of strategic response by the treasury, which we leave unmodelled.

#### 4. Empirical Analysis

In this section, we present empirical evidence to argue that the rapid increase of holdings of government debt between the two allotments was 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 LOLR. 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 a world where there are implicit guarantees by the government and a substantial degree of sovereign-bank linkages, banks and sovereigns 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. This is the logic underlying several theoretical models, such as that of [Gennaioli et al. \(2014b\)](#). 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.<sup>18</sup> 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

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18. Without the option of early repayment - which only occurs after one year - banks are required to either pledge additional collateral or place cash in margin call deposits at the ECB should the collateral drop in value. According to the ECB Risk Control Framework, marketable assets that are used as collateral are marked to market daily.

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.

Second, due to the fact that the described trade involves purchase of an asset that is pledgeable as collateral to raise the 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.<sup>19</sup>

We now proceed as follows: first, we present evidence that suggests that a combination of surprise and collateral constraints meant that the first allotment was mostly rollover of previous short-term debts, consistent with the evidence presented at the end of [Section 2](#). We then formally show that the pattern of purchase of government bonds changed significantly during the intra-allotment period, and that bond purchases explain a significant part of the cross-sectional variation of new borrowing at the second allotment, even after controlling for other forms of collateral, such as foreign sovereign bonds, bank bonds (e.g., covered, uncovered, government guaranteed), other marketable and non-marketable assets. The purchase of new collateral allowed banks to undertake new borrowing and keep their liquidity risk under control, while profiting from the trade. We also present evidence that most of these purchases were concentrated in short-term government bonds.

#### **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, and (ii) banks had little time to prepare themselves for the first allotment. If all assets that were eligible as collateral were already being used to borrow from the LOLR, 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 data suggests. [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

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

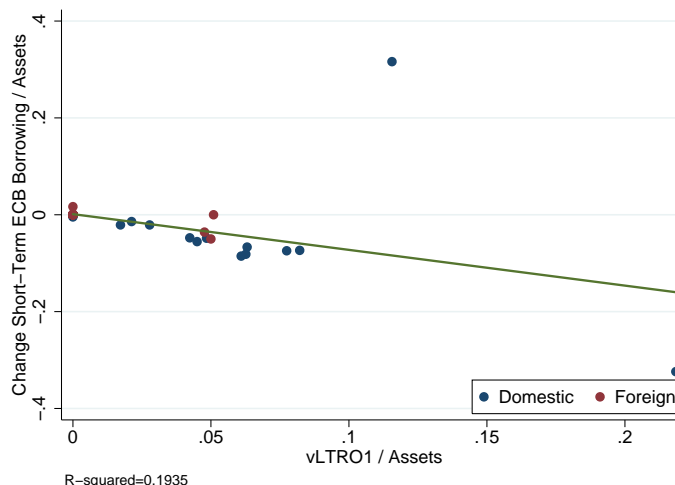


FIGURE 6: **vLTRO1 Changes in Total and Short-term Borrowing from the ECB.** The figure plots total vLTRO1 uptake against the change in short-term ECB borrowing between November 2011 and December 2011, as a percentage of assets in November 2011.

this line. This shows that there was no significant changes in total borrowing as a percentage of assets (except for two domestic outliers), in spite of considerable variation in vLTRO uptakes, and that vLTRO1 was essentially used to replace (rollover) shorter term debt.

*4.1.1. Stigma.* Stigma, and not the collateral demand dynamics that we exploit, 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.<sup>20</sup> The idea is that 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.

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

20. See [Peristiani \(1998\)](#), [Furfine \(2001\)](#), [Furfine \(2003\)](#). For more recent studies, see [Ennis and Weinberg \(2013\)](#) and [Armantier et al. \(2013\)](#).



shorter-term borrowing. Concerns regarding stigma usually belie the LOLR’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.<sup>21</sup>

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

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

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  $\Delta C_i$  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,

$$\text{vLTRO2}_i = \text{vLTRO2}_i^N + \text{vLTRO2}_i^R$$

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

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

that any variations in the pool of eligible collateral  $C_i$  between the vLTRO allotments should be a good predictor of the new borrowings component.

To test this hypothesis, we rely on the following identification 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 LOLR.<sup>22</sup> 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

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

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,

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

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.

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22. Strictly 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.

Eligible collateral at the ECB falls in two broad asset classes: marketable assets and non-marketable assets. The first comprises debt instruments such as unsecured bonds, asset-backed securities and covered bank bonds. The second class includes fixed-term deposits from eligible monetary policy counterparties, credit claims (bank loans), and non-marketable retail mortgage-backed debt instruments.<sup>23</sup> The period of the vLTRO were 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 was borne by the NCB. On February 9, twenty days before the second allotment, BdP detailed the criteria for Portugal regarding these additional credit claims. Portfolios of mortgage-backed loans and other loans to households, as well as of loans to non-financial corporations became increasingly pledgeable as collateral. The expansion of these rules also suggests banks were collateral scarce at the time of the first allotment. Although we do not have asset-level data on the holdings of these classes of assets by banks, we rely on aggregate measures of pledged collateral for each bank. These measures include non-marketable assets whose risk was borne by the Eurosystem, additional credit claims (ACCs), government guaranteed bank bonds (GGBBs) issued from a government fund expanded around the time of the troika intervention in mid-2011, and other marketable assets. These can be interpreted as borrowing constraints, since the amounts account for haircuts. Figure 7 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.

We include these as regressors in addition to changes in Portuguese government bond holdings. We decompose these into price and quantity changes to control for the changes in the prices of holdings, since our argument is based on increases in quantities.<sup>24</sup> Considering the face value of the holdings of a bond  $j$  held by bank  $i$  in period  $t$  that we obtain from the securities dataset as being  $q_{i,j,t}$ . Since we also have information on the market value of these holdings,  $pq_{i,j,t}$ , we can calculate the price as  $p_{i,j,t} = \frac{pq_{i,j,t}}{q_{i,j,t}}$ . We then decompose the total change in the market values of holdings as:

23. See section 6 of ECB (2011) for additional details on the eligibility of assets as collateral in the Eurosystem.

24. For Portuguese government bonds, we are not considering changes in haircuts.

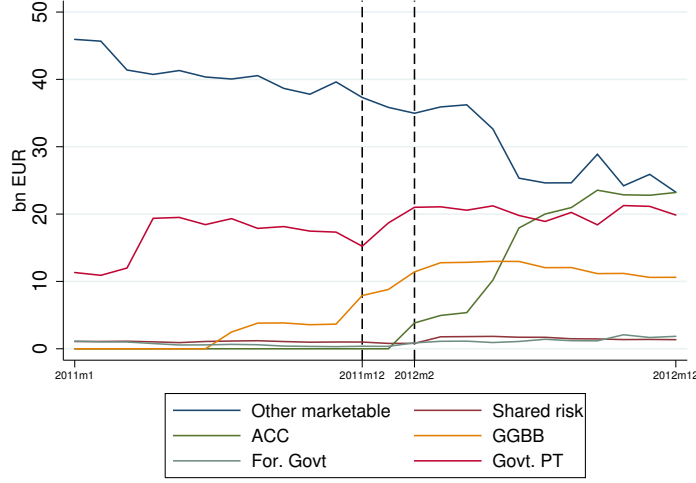


FIGURE 7: **Pledged collateral by type of eligible asset.** The figure plots aggregates amounts of assets pledged as collateral with the Eurosystem, discounted by haircuts. The categories included are exhaustive and include, for marketable assets: Portuguese Government Bonds, Foreign Government Bonds, GGBBs and other marketable assets; for non-marketable assets: ACCs, shared risk framework non-marketable assets.

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

By adding and subtracting  $p_{i,j,t} q_{i,j,t-1}$  and simplifying, we obtain:

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

These changes can be easily aggregated across banks and calculated for different lagged periods. We then estimate the following specification:

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

where  $X_{i,\text{Feb12}-\text{Nov11}}$  represents additional measures of collateral. We divide each of the changes in value by total assets in February 2012, to scale the change by the size of the 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

Dependent variable: $\Delta$ Total ECB Borrowing <sub>Feb12-Mar12</sub>				
	(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. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

and other marketable assets.<sup>25</sup> These results suggest that the banks in our sample relied substantially on the acquisition of domestic government bonds as a means to access new borrowings from the second vLTRO allotment, even after we take into account the collateral eligibility expansion during this period, particularly ACCs, but also the increasing use of GGBBs. They also help explain the study of domestic government bonds, since they are one of the few sources of collateral whose eligibility was not affected by the measures around this period, while still being an essential part of the scramble for collateral.

## 5. Aggregate Impact and General Equilibrium Effect

### 5.1. Quantifying the Impact on Demand

Having established that domestic government debt was an important source of collateral during the intra-allotment, we now show empirically that: (i) the vLTRO announcement led to an increase in demand for government debt; (ii) this increase was concentrated in shorter maturities, as our model predicts; and (iii) we try to quantify the impact of the announcement.

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

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

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,

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

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 treatment dummies are:  $\text{vLTRO}_t$ , equal to 1 on and after December 2011;  $\text{Access}_i$ , equal to 1 if entity  $i$  is a MFI with access to the vLTRO; and  $\text{Short-Term}_j$ , equal to 1 if ISIN  $j$  expires on or before February 2015, 3 years after the second allotment.  $X_{i,j,t}$  includes entity-, ISIN- and time-level controls: it 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.<sup>26</sup> Table 2 shows the results.<sup>27</sup>

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

26. We do not include periods on or beyond June 2012, since this is the month when several large Portuguese banks access the recapitalization fund offered by the government, a potential confounding factor.

27. Table D.2 shows that our results are robust to changing this window to a smaller period around the operations.

	Dependent variable: $\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}}$	
	All Bonds	Issued before Dec2011
Short-Term <sub>j</sub> × Access <sub>i</sub> × vLTRO <sub>t</sub>	0.00220*** (0.0000522)	0.000181** (0.0000649)
Short-Term <sub>j</sub> × vLTRO <sub>t</sub>	-0.0000587 (0.000108)	0.000160 (0.000139)
Short-Term <sub>j</sub> × Access <sub>i</sub>	0.00353*** (0.000390)	0.00353*** (0.000390)
Access <sub>i</sub> × vLTRO <sub>t</sub>	0.000293*** (0.0000583)	0.000293*** (0.0000572)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Jun2011-May2012	Jun2011-May2012
N	259,272	242,589
adj. R <sup>2</sup>	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. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

portfolio rebalancing undertaken through secondary markets. Standard errors are clustered at the investor sectoral level.<sup>28</sup>

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

28. Each 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.

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, for example, equally), 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.

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 the increase in home bias by banks that was generated by the vLTRO: after the announcement, banks with access tended to increase their holdings of government bonds across maturities. The triple interaction shows that the effect was stronger for short than for long.

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 C](#).

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 our sample period). Our results do not change much when we change the sample: 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. 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



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

where  $\text{vLTRO}_i$  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  $\text{Assets}_i$  is the value of assets of entity  $i$  in the same period. This variable simply measures the fraction of assets that are funded by long-term ECB borrowing after the second allotment. We then adapt our baseline specification,

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

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 is an endogenous variable, since increased holdings of government debt after the announcement but before the second allotment affect the pool of collateral owned by the bank and, therefore, how much the bank can borrow. To address this concern, we take advantage of the fact that a large part of vLTRO borrowing was rollover of past ECB borrowing, and instrument vLTRO intensity with total ECB borrowing intensity (ECB borrowing as a percentage of assets) *before* the beginning of the sample. In principle, choosing borrowing intensity before the announcement, say in November 2011, would be enough, but we choose to instrument intensity with a measure that precedes the beginning of the sample to dispel any other endogeneity concerns.

Since our sample starts in June 2011, we choose ECB borrowing as a percentage of assets in May 2011 as an instrument for total vLTRO borrowing. The results are presented in [Table 3](#).<sup>29</sup> 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, is positive and very significant on purchases of short-term bonds after the vLTRO announcement. The third line reveals that vLTRO borrowing led to increased purchases of government bonds overall. A back-of-the-envelope calculation reveals that the aggregate impact of vLTRO borrowing was economically large: for each bank, a 1 p.p. increase of vLTRO borrowing over assets led to an increase in the holdings of short-term bonds of 3 basis points of amount outstanding, and 0.5 basis points for long-term bonds. Computing the aggregate measure of intensity, we find a total impact of 7.6 p.p. of amount outstanding for each short-term ISIN and 1.4 p.p. of amount outstanding for each long-term ISIN. These results are robust to controlling for new issuances, as well as to changing the length of the window around the announcement.

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29. [Table D.3](#) presents the results for the shorter window.

	Dependent variable: $\frac{H_{i,j,t}}{\text{Amount Outstanding}_{j,t}}$	
	All Bonds	Issued before Dec2011
Short-Term <sub>j</sub> × Intensity <sub>i</sub> × vLTRO <sub>t</sub>	0.0261*** (0.00252)	0.0261*** (0.00256)
Short-Term <sub>j</sub> × vLTRO <sub>t</sub>	0.000102** (0.0000403)	0.000101** (0.0000409)
Intensity <sub>i</sub> × vLTRO <sub>t</sub>	0.00597*** (0.00108)	0.00597*** (0.00109)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Jun2011-May2012	Jun2011-May2012
N	259,272	242,589
F-Statistic	98.14	104.97

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 May 2011, before the beginning of the sample. Fixed effects are at the ISIN, entity and month levels. The sample is June 2011 to May 2012. Standard errors in parentheses are robust (sandwich). \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Overall, our results seem to be consistent with the observed behavior of sovereign yields around the allotment period: an increase in demand for short-term debt drives shorter maturity yields down. Furthermore, since the relative preference shifts away from longer-term bonds, towards short-term ones, we observe a slight increase in sovereign borrowing costs at longer maturities.

## 5.2. Public Debt Management

We now turn to analyze 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. We turn to describing the refinancing needs and issuance activity of the Portuguese Treasury during the period of interest.<sup>30</sup>

30. Government 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

*Maturing Debt and Rollover.* Figure 8 shows the rollover activity of the Portuguese government for each semester from January 2010 to December 2013. The lined blue bars indicate the amount of maturing debt and the green solid bars show the total issuance of new debt in every semester. Around the vLTRO announcement (vertical black dashed line, second semester of 2011), the amount of public debt maturing each semester is roughly constant, approximately €20 bn from 2011 to mid-2012. In particular, during the intra-allotment period, there were four short-term zero-coupon bonds maturing for a total of €13.5 bn.<sup>31</sup> This contrasts with the behavior of new issuances, which had been steadily decreasing since late 2010, and reaching a minimum during the second semester of 2011 (when only €3.3 bn of new debt were issued). The solid line is the ratio of maturing to newly issued debt, and reaches a minimum during this time period. Its behavior also shows that in spite of roughly constant levels of maturing debt, issuances restarted after the vLTRO, in the first semester of 2012, reaching 2010 levels.

During the intra-allotment period, the government issued €7.9 bn through 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. Table 4 shows some statistics for these two auctions. The 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.).

*Issuance Characteristics.* The ISIN-level data collected from Bloomberg allows us to analyze in greater detail the characteristics of the bonds issued by the Portuguese government throughout our sample. This relates to a growing body of literature that studies the optimal composition of government debt issuances. Broner *et al.* (2013) show that emerging economies tend to borrow at shorter maturities due to lower costs, 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. Figure E.2 in Appendix E shows the characteristics of Portuguese debt issuances during our sample period. The top panel confirms that the activity, both in terms of number of auctions

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public debt (government debt and debt of some public companies) and is under the supervision of the Ministry of Finance.

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

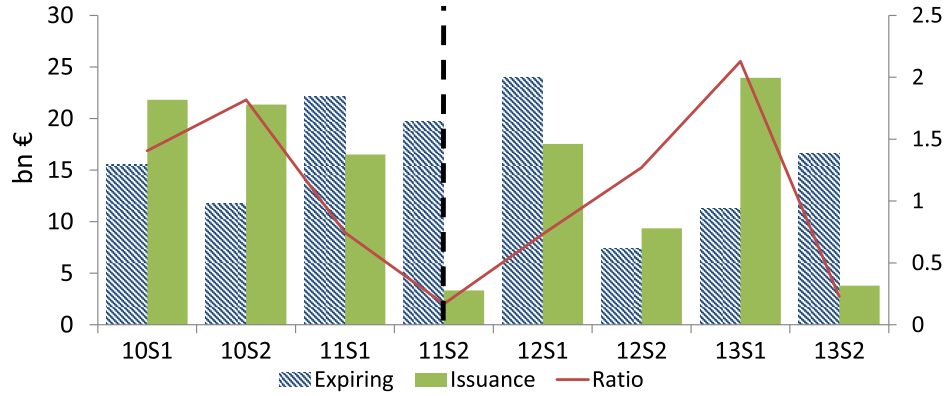


FIGURE 8: **Government Debt Management.** This figure plots the amount of public debt expiring (lined blue columns) and the new public debt issued (solid green columns) from 2010S1 to 2013S2. Both quantities are measured in € bn on the primary axis. The red solid line (secondary axis) is the ratio of amount issued over debt maturing. Source: Bloomberg.

Issuance Date	Maturity	ISIN	Average Yield (%)	Amount Issued (€bn)
20Jan12	1Y	PTPBTIGE0017	4.986	2.13
20Jan12	6mo	PTPBTHGE0018	4.74	2.34
17Feb12	1Y	PTPBTSGE0015	4.943	2.2
17Feb12	6mo	PTPBTRGE0016	4.332	1.2

TABLE 4. **Intra-Allotment Period Government Bond Issuance.** This table shows the characteristics of the securities issued by the government in the intra-allotment period (21Dec11 - 29Feb12). Source: Bloomberg.

(black bar) and amount issued (transparent orange bar), resumed in 2012 after only three auctions in the last three quarters of 2011. The bottom panel illustrates, for the period ranging from January 2011 to May 2013, the maturity and coupon structure of each issuance. Consistent with the findings of the aforementioned works, the government tends to issue short-term bonds with back-loaded payments during the periods of high volatility and level of bond yields. From March 2011 to October 2012, only zero-coupon bonds were issued (the extreme example of payment back-loading) and there were no auctions for bonds with maturity higher than 2 years.

### 5.3. Effect on Government Bond Yields

During the intra-allotment period, the Portuguese sovereign yield curve rotated, and became steeper. This is illustrated in Figure 9, 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 (3 years) decreases, while the yields on the bonds with maturity greater than the vLTRO increased:

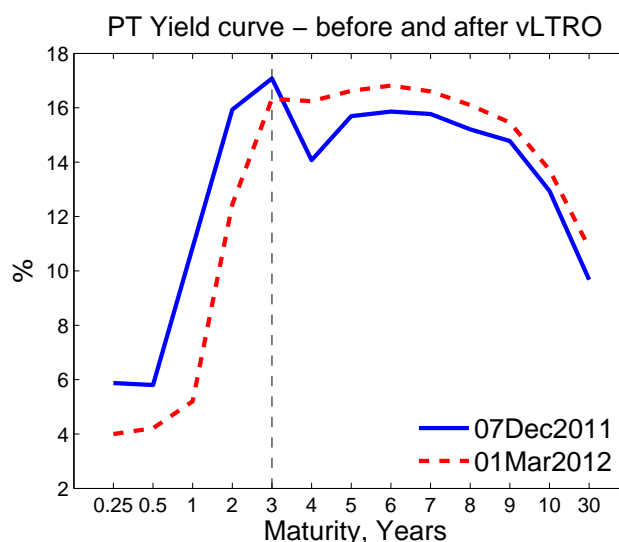


FIGURE 9: **Portugal Yield Curve, pre and post vLTRO.** This figure plots the yield curve (interpolated for missing maturities) on December 8, 2011 and March 3, 2012. December 8 is the date of the announcement of the vLTRO, and February 29 is the date of the second allotment. The horizontal axis of maturities is measured in years.

we did not see a parallel shift of the yield curve, but rather a rotation around the 3 year maturity, that left the yield curve steeper.

The yield curve rotation in this period is also present also in other peripheral countries like Italy and Spain, suggesting that our analysis might be valid in other similar contexts. Figure E.1 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 yield.<sup>32</sup>

A concern is that the changes in the yield curve, and the motive for purchasing bonds, may be unrelated to the vLTRO, but are rather 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

32. These 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.

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 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.

## 6. Conclusion

We ask whether central bank interventions, in the form of supply collateralized loans, affect the borrowing costs of the government. To this end we study the ECB 3Y-LTRO in Portugal and find that banks, during the facility allotment period, increased their purchases of domestic government bonds. Using a portfolio choice model with endogenous government bond supply, we show that banks exploited an attractive collateral trade opportunity buying bonds with maturity equal or less the maturity of the central bank loan, affecting the yield curve slope. Consistent with this finding the Portuguese government was able to borrow at a cheaper short-term rate, following the 3Y-LTRO.

## References

- Acharya, Viral, Tim Eisert, Christian Eufinger, and Christian Hirsch (2014a). “Real Effects of the Sovereign Debt Crisis in Europe: Evidence from Syndicated Loans.” *Working Paper*.
- Acharya, Viral and Sascha Steffen (2015). “The Greatest Carry Trade Ever? Understanding Eurozone Bank Risks.” *Journal of Financial Economics*, 115.
- Acharya, Viral V., Itamar Drechsler, and Philipp Schnabl (2014b). “A Pyrrhic Victory? Bank Bailouts and Sovereign Credit Risk.” *The Journal of Finance*, 69(6), 2689–2739.
- Andrade, Philippe, Christophe Cahn, Henri Fraisse, and Jean-Stephane Mesonnier (2014). “Can the Provision of Long-Term Liquidity Help to Avoid Credit Crunch? Evidence from the Eurosystem’s LTROs.” *Working Paper*.
- Antão, Paula and Diana Bonfim (2008). “Capital Structure decisions in the Portuguese corporate sector.” *Economic Bulletin and Financial Stability Report Articles, Economics and Research Department, Banco de Portugal*.
- Arellano, Cristina and Ananth Ramanarayanan (2012). “Default and the Maturity Structure in Sovereign Bonds.” *Journal of Political Economy*, 120(2), 187–232.
- Armantier, Olivier, Eric Ghysels, Asani Sarkar, and Jeffrey Shrader (2013). “Discount Window Stigma during the 2007-2008 Financial Crisis.” Tech. rep., Federal Reserve Bank of New York.
- Bai, Yan, Seon Tae Kim, and Gabriel P. Mihalache (2015). “The Maturity and Payment Schedule of Sovereign Debt.” (20896).
- Becker, Bo and Victoria Ivashina (2014). “Financial Repression in the European Sovereign Debt Crisis.” *Working Paper*.
- Bocola, Luigi (2014). “The Pass-Through of Sovereign Risk.” 2014 Meeting Papers 1286, Society for Economic Dynamics, URL <http://ideas.repec.org/p/red/sed014/1286.html>.
- Bolton, Patrick and Olivier Jeanne (2011). “Sovereign Default Risk and Bank Fragility in Financially Integrated Economies.” *IMF Economic Review*, 27(3), 162–194.
- Broner, Fernando, , Alberto Martin, and Jaume Ventura (2010). “Sovereign Risk and Secondary Markets.” *American Economic Review*, 100(4), 1523–1555.
- Broner, Fernando, Guido Lorenzoni, and Sergio Schmukler (2013). “Why Do Emerging Economies Borrow Short Term?” *Journal of the European Economic Association*, 11(1), 67–100–142.
- Brunnermeier, Markus K. and Yuliy Sannikov (2014). “A Macroeconomic Model with a Financial Sector.” *American Economic Review*, 104(2), 379–421.
- Buch, Claudia M., Michael Koetter, and Jana Ohls (2013). “Banks and sovereign risk: A granular view.” Discussion Papers 29/2013, Deutsche Bundesbank, Research Centre, URL <http://ideas.repec.org/p/zbw/bubdps/292013.html>.

- Chodorow-Reich, Gabriel (2014a). “Effects of Unconventional Monetary Policy on Financial Institutions.” *Brookings Papers on Economic Activity*, 48(1 (Spring)), 155–227.
- Chodorow-Reich, Gabriel (2014b). “The Employment Effects of Credit Market Disruptions: Firm-level Evidence from the 2008-09 Financial Crisis.” *Quarterly Journal of Economics*, 129(1), 1–59.
- Crosignani, Matteo (2015). “Why Are Banks Not Recapitalized During Crises?” *Working Paper*.
- Crosignani, Matteo, Miguel Faria-e-Castro, and Luís Fonseca (2015). “The Portuguese Banking System during the Sovereign Debt Crisis.” *Banco de Portugal Economic Studies*, 1(2), 43–80.
- Drechsler, Itamar, Thomas Drechsel, David Marques-Ibanez, and Philipp Schnabl (2014). “Who Borrows from the Lender of Last Resort?” *Working Paper*.
- ECB (2002). “Public Consultation: Measures to Improve the Efficiency of the Operational Framework for Monetary Policy.”
- ECB (2011). *The Implementation of Monetary Policy in the Euro Area*. General Documentation on Eurosystem Monetary Policy Instruments and Procedures.
- Eisenschmidt, Jens, Astrid Hirsh, and Tobias Linzert (2009). “Bidding Behaviour in the ECB’s Main Refinancing Operations During The Financial Crisis.” *Working Paper*.
- Ennis, Huberto M. and John A. Weinberg (2013). “Over-the-counter loans, adverse selection, and stigma in the interbank market.” *Review of Economic Dynamics*, 16(4), 601 – 616.
- FT Alphaville (2012). “Deutsche Bank voices stigma concerns about LTRO.” URL <http://ftalphaville.ft.com/2012/02/03/866841/deutsche-bank-concerned-by-offer-of-ecb-loans/>.
- FT Alphaville (2013). “Russia’s LTRO (or LTROski, if you insist).” URL <http://ftalphaville.ft.com/2013/07/30/1585802/russias-ltro-or-ltroski-if-you-insist//>.
- FT Alphaville (2015). “A Chinese LTRO: the trouble with market based financing continues.” URL <http://ftalphaville.ft.com/2015/04/28/2128002/a-chinese-ltro-the-trouble-with-market-based-financing-continues/>.
- Furfine, Craig (2001). “The reluctance to borrow from the Fed.” *Economics Letters*, 72(2), 209 – 213.
- Furfine, Craig (2003). “Standing Facilities and Interbank Borrowing: Evidence from the Federal Reserve’s New Discount Window.” *International Finance*, 6(3), 329–347.
- Gennaioli, Nicola, Alberto Martin, and Stefano Rossi (2014a). “Banks, Government Bonds, and Default: What do the Data Say?” (10044).
- Gennaioli, Nicola, Alberto Martin, and Stefano Rossi (2014b). “Sovereign Default, Domestic Banks, and Financial Institutions.” *The Journal of Finance*, 69(2), 819–866.



- Gertler, Mark and Nobuhiro Kiyotaki (2010). "Financial Intermediation and Credit Policy in Business Cycle Analysis." In *Handbook of Monetary Economics, Handbook of Monetary Economics*, vol. 3, edited by Benjamin M. Friedman and Michael Woodford, chap. 11, pp. 547–599. Elsevier, URL <http://ideas.repec.org/h/eee/monchp/3-11.html>.
- Greenwood, Robin, Samuel G. Hanson, Joshua S. Rudolph, and Lawrence Summers (2014). "Government Debt Management at the Zero Lower Bound." Tech. rep., Hutchins Center Working Paper No. 5.
- Greenwood, Robin, Samuel G. Hanson, and Jeremy C. Stein (forthcoming). "A Comparative-Advantage Approach to Government Debt Maturity." *Journal of Finance*.
- He, Zhiguo and Arvind Krishnamurthy (2013). "Intermediary Asset Pricing." *American Economic Review*, 103(2), 732–70.
- Hildebrand, Thomas, Jorg Rocholl, and Alexander Schulz (2012). "Flight to Where? Evidence from Bank Investments During the Financial Crisis." *Working Paper*.
- Ivashina, Victoria and David Scharfstein (2010). "Loan Syndication and Credit Cycles." *American Economic Review*, 100(2), 57–61.
- Kashyap, Anil K. and Jeremy C. Stein (2000). "What Do a Million Observations on Banks Say about the Transmission of Monetary Policy?" *American Economic Review*, 90(3), 407–428.
- Krishnamurthy, Arvind, Stefan Nagel, and Annette Vissing-Jorgensen (2014). "ECB Policies involving Government Bond Purchases: Impact and Channels." Mimeo.
- Mercier, Paul and Francesco Papadia (2011). "The Concrete Euro. Implementing Monetary Policy in the Euro Area." *Oxford University Press*.
- Peristiani, Stavros (1998). "The Growing Reluctance To Borrow At The Discount Window: An Empirical Investigation." *The Review of Economics and Statistics*, 80(4), 611–620.
- Popov, Alexander and Neeltje van Horen (2013). "The impact of sovereign debt exposure on bank lending: Evidence from the European debt crisis." DNB Working Papers 382, Netherlands Central Bank, Research Department, URL <http://ideas.repec.org/p/dnb/dnbwpp/382.html>.
- Trebesch, Christoph and Jeromin Zettelmeyer (2014). "ECB Interventions in Distressed Sovereign Debt Markets: The Case of Greek Bonds." CESifo Working Paper Series 4731, CESifo Group Munich, URL [http://ideas.repec.org/p/ces/ceswps/\\_4731.html](http://ideas.repec.org/p/ces/ceswps/_4731.html).
- Uhlig, Harald (2013). "Sovereign Default Risk and Banks in a Monetary Union." *German Economic Review*, 15(1), 23–41.

## Appendix A: Dataset Construction

In this section, we provide a more detailed description of the data that we use, and how we transform. As mentioned in the main text, our master dataset results from the merger of three datasets:

1. Monetary and Financial Statistics, a proprietary dataset from the BdP, that includes monthly balance sheet data for all monetary and financial institutions regulated by the BdP. We have data on book values, disaggregated by type of asset/liability, type of counterpart, geographical location of counterpart, and, for some assets and liabilities, maturity.<sup>33</sup> Monetary and financial institutions are divided in three categories: banks, savings institutions, and money market mutual funds. Most of the institutions are banks; savings institutions is an obsolescent category that applies only to agricultural credit cooperatives. MMF's are small given the undeveloped nature of the Portuguese money funds market.
2. *Sistema Integrado de Estatísticas de Títulos* (SIET), another proprietary dataset from the BdP, which contains monthly information on quantity (face value), book value, and market value for all ISINs that refer to debt instruments issued by the Portuguese central government and a few public companies, and that are owned by financial institutions domiciled in Portugal. This dataset corresponds to the universe of financial institutions in Portugal, conditional on them owning any of these securities. It includes several types of institutions, including monetary and financial institutions, mutual funds, hedge funds, pension funds, brokerage companies, etc.
3. CMVM, a public dataset on the portfolio composition of all mutual funds that are allowed to operate in Portugal. This dataset is extracted and compiled from the CMVM website, to which all mutual funds are required, by law, to submit a detailed composition of their portfolio at market values. This dataset is monthly until September 2013, after which it becomes quarterly.

For the MFS dataset, we keep the following information for each bank, in each period: assets, cash and equivalents, lending, lending to households, lending to non-financial firms, holdings of non-equity securities, holdings of government debt, holdings of Portuguese government debt, holdings of GIIPS government debt, holdings of equity securities, other assets. For the other side

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

of the balance sheet: equity and reserves, demand deposits, savings deposits, time deposits, repo, securities, other liabilities, short-term (less than 1 year) borrowing from the central bank, medium-term (1-2 years) borrowing from the central bank, long-term (more than 2 years) borrowing from the central bank.

For the CMVM dataset, we retain the following characteristics: assets, net asset value, equities, non-government bonds, domestic government bonds, foreign government bonds, deposits, shares in other funds.

For each of the MFS and CMVM institutions, we also manually classify them as to whether they are foreign (i.e. wholly-owned subsidiaries of a foreign company), and as to whether they are subsidiaries. This information is obtained by crossing information with other databases (SNL Financial, Bankscope, Bloomberg), as well as checking the institution's websites.

For the SIET dataset, we keep its original structure, a three-dimensional panel  $(j, i, t)$ , where  $j \in J$  is an ISIN, owned by institution  $i \in N$  at time  $t \in T$ . For each observation, the SIET gives us quantity (face value), market value, and book value. The latter is only available for certain institutions, but we only use it for consistency purposes. Note that while the datasets intersect, neither is contained in each other: the MFS includes monetary financial institutions which may not own any Portuguese sovereign debt security and thus are excluded from the SIET dataset, while the SIET dataset includes other types of institutions that are not included in the MFS dataset, such as pension funds, etc. The CMVM dataset includes some money market funds which are both in SIET and MFS, some mutual funds which are in SIET (i.e. those who have domestic government bonds) and others who are not (those who do not have domestic government bonds).

## Appendix B: Theory Appendix

### *B.1. 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,

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

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

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

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,  $R\epsilon$  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

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

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

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

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

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

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

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

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

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

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

Letting  $(\lambda, \delta, \eta)$  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

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

## ***B.2. A Simple Model of Margin Calls and Collateral Trade***

Consider a risk-neutral investor that lives for three periods,  $t = 0, 1, 2$ , and can choose at  $t = 0$  to undertake a leveraged investment on either a short-term bond maturing at  $t = 1$ , a medium-term bond maturing at  $t = 2$ , or a long-term bond that does not mature in the investor's lifetime. The investor can partially finance this investment with a collateralized loan that matures at  $t = 2$ . If the value of the collateral falls (or the collateral matures) before the loan is due, the investor is subject to a margin call and needs to raise sufficient liquidity to compensate the lender for this shortfall. We assume that raising liquidity is costly: each unit of liquidity raised at  $t = 1$  costs  $r$  at  $t = 2$ .

The bonds are priced by deep-pocketed, risk-neutral investors with discount factor  $\eta < 1$ . This means that the price of a bond with maturity  $s$  is  $\eta^s$  at

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

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

Let us analyze separately the payoffs of investing in a short, medium and long-term bond. Let  $h \in (0, 1)$  denote the haircut on collateral, and  $R$  the interest rate on the vLTRO loan. Since we want to focus on the relative preference for different maturities, and not on the desirability of the carry trade *per se*, we assume that  $\eta < 1 + R$ , so that an unconstrained carry trade is always profitable at any maturity. We assume that there is storage with return unity.<sup>34</sup>

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

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

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

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

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

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

---

34. Basically, the investor can save for a net return of zero and borrow for a net cost of  $r$ .

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

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

So that, if the probability of a downwards revaluation (and the magnitude of that revaluation) is high enough, and exceeds the return benefits of investing in a long-term bond, the investor may prefer to invest in a medium-term bond. We can derive similar conditions, under which  $\pi_L \leq \pi_S$ . They are mainly related to liquidity risk: the short-term investment exposes the bank to no type of liquidity risk whatsoever. The medium-term bond exposes the bank to margin call risk, with probability  $\alpha$ . The long-term bond exposes the bank to both margin call *and* funding liquidity risk at the final period, since the bond's payoff (its price on the secondary market) may be uncertain. Since there is no discounting, the unconstrained, risk-neutral investor would simply prefer the bond that offers the ex-ante higher return, which is the long-term bond by assumption. Due to liquidity risk, emanating both from margin calls and uncertain prices at loan maturity, the investor may prefer to invest at the shorter term.<sup>35</sup>

## Appendix C: Estimating the Demand Impact

### C.1. Aggregate 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,

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

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

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

---

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

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

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

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,

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

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

$$\begin{aligned} \hat{\alpha}_{\text{Total}}^{\text{Long-Term}} &= 0.0208 \\ \hat{\alpha}_{\text{Supply}}^{\text{Long-Term}} &= 0.0208 \end{aligned}$$

### ***C.2. Intensive Margin***

When computing the intensive margin impact of vLTRO borrowing, we proceed in a similar way. We obtain the following estimates from specification 10,

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

The total impact is then

$$\hat{\Lambda}_{\text{Intensity}}^{\text{Short-Term}} = \hat{\beta}_1 + \hat{\beta}_2 + \hat{\beta}_3$$

Then, summing across banks and respective intensities, we obtain

$$\begin{aligned} \hat{\alpha}_{\text{Intensity}}^{\text{Short-Term}} &= 0.0762 \\ \hat{\alpha}_{\text{Intensity}}^{\text{Long-Term}} &= 0.0141 \end{aligned}$$



**Appendix D: Additional Tables**

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

TABLE D.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
Short-Term <sub>j</sub> × Access <sub>i</sub> × vLTRO <sub>t</sub>	0.00160*** (0.0000375)	0.000439*** (0.0000450)
Short-Term <sub>j</sub> × vLTRO <sub>t</sub>	-0.00000439 (0.0000481)	0.000122 (0.000104)
Short-Term <sub>j</sub> × Access <sub>i</sub>	0.00378*** (0.000389)	0.00378*** (0.000389)
Access <sub>i</sub> × vLTRO <sub>t</sub>	0.000188*** (0.0000440)	0.000188*** (0.0000436)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Aug2011-Mar2012	Aug2011-Mar2012
N	169,494	162,663
adj. R <sup>2</sup>	0.129	0.129

TABLE D.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
Short-Term <sub>j</sub> × Intensity <sub>i</sub> × vLTRO <sub>t</sub>	0.00981*** (0.00310)	0.00981*** (0.00312)
Short-Term <sub>j</sub> × vLTRO <sub>t</sub>	0.000147*** (0.0000463)	0.000146*** (0.0000466)
Intensity <sub>i</sub> × vLTRO <sub>t</sub>	0.00403*** (0.00126)	0.00403*** (0.00127)
Period FE	✓	✓
ISIN FE	✓	✓
Entity FE	✓	✓
Sample	Aug2011-Mar2012	Aug2011-Mar2012
N	169,494	162,663
F-Statistic	79.24	83.43

TABLE D.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 May 2011, before the beginning of the sample. Fixed effects are at the ISIN, entity and month levels. The sample is August 2011 to March 2012. Standard errors in parentheses are robust (sandwich). \* p<0.10, \*\* p<0.05, \*\*\* p<0.01.

## Appendix E: Additional Plots

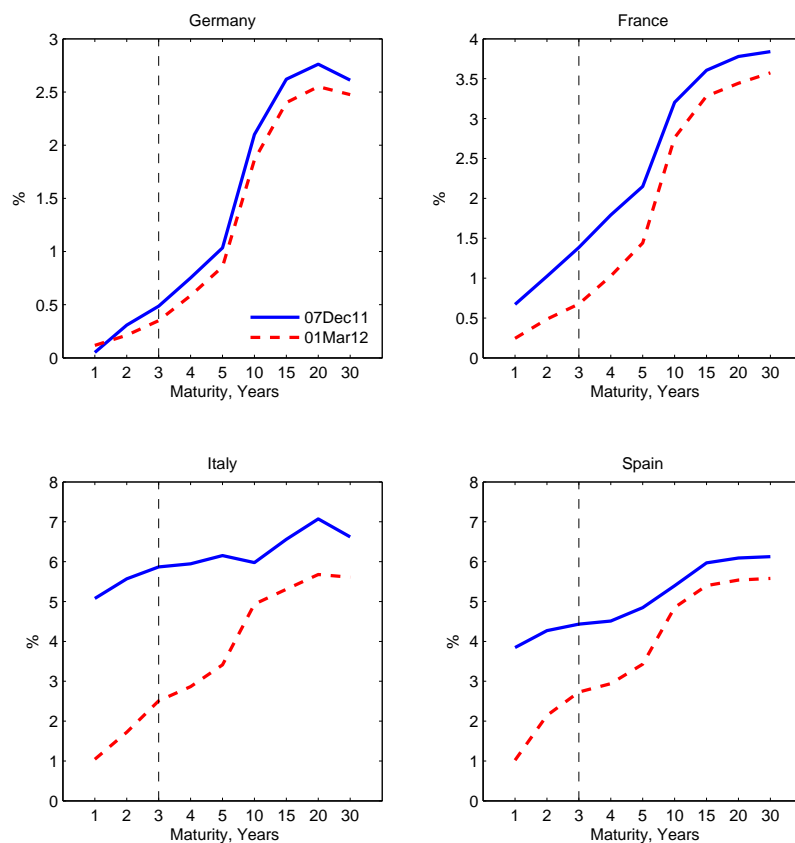


FIGURE E.1: **Yield Curves around the vLTRO.** This figure plots the 1-30 year yield curves for four eurozone countries, on the day before the vLTRO announcement (solid blue), and on the day after the second allotment (dashed red). The two upper plans are core countries, Germany and France. The two lower 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.

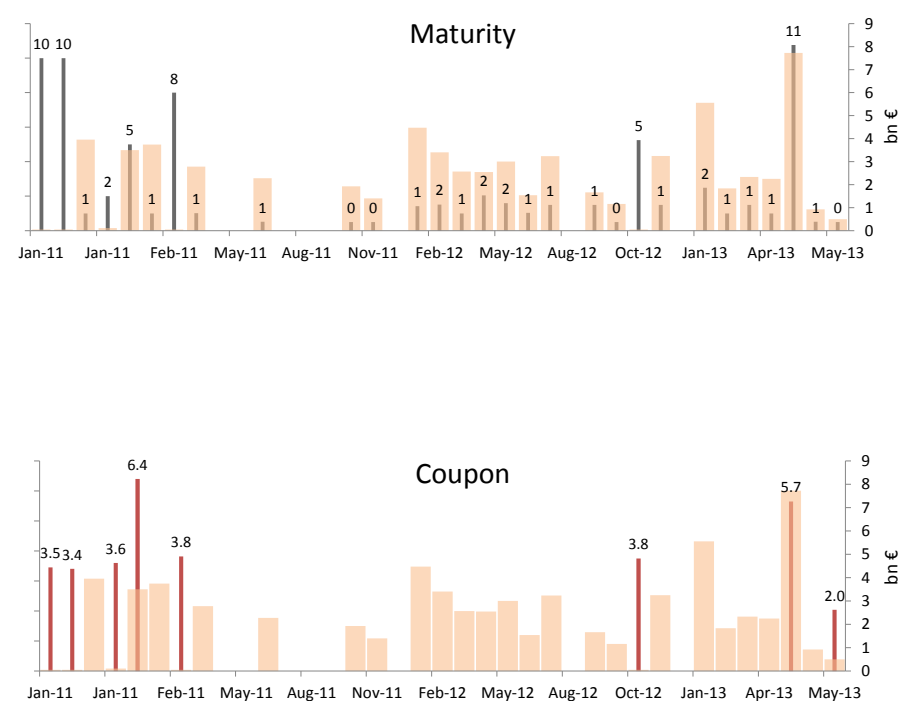


FIGURE E.2: **Issuance Characteristics.** This figure shows the issuance activity and maturity and coupon structure of bonds. The first panel shows the maturity (dark gray bars) of each issuance and the amount issued. The second panel shows the coupon rate (dark red bars) of each issuance and the amount issued. The latter, in both panels, is measured in €bn (y-axis) and illustrated by transparent orange bars.

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