The Effect of Central Bank Liquidity Injections on Bank Credit Supply *

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Abstract

We study the effectiveness of central bank liquidity injections in restoring bank credit supply following a wholesale funding run. We combine the Italian credit registry with bank-security level holdings and analyze the transmission of the European Central Bank (ECB) 3-year Long Term Refinancing Operation. Exploiting a regulatory change that expands the pool of eligible collateral, we show that banks more affected by the run use ECB liquidity to restore credit supply, while less affected banks to increase their holdings of high-yield government bonds. Our findings show that the ECB intervention had a 2% positive effect on bank credit supply.

JEL: E50, E58, G21, H63

Keywords: Central bank liquidity, lender of last resort, bank credit supply, wholesale funding market

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1 Introduction

Since the 2008 financial crisis, many central banks have adopted unprecedented measures to restore and mantain the regular functioning of financial markets. The designs of these so-called "unconventional" monetary policies vary and include new communication strategies, large scale asset purchases, and capital and liquidity injections.[1] While a large body of research analyzes the negative effect of asset market disruptions on bank credit supply, little work has been done on how central banks can sustain lending in bad times.[2] Our goal is to narrow this gap and contribute to policy making by evaluating the effectiveness of unconventional monetary policy and documenting the channels through which it operates.

In this paper, we ask whether central banks can increase bank credit supply by lending to banks. The theory behind the transmission of extraordinary liquidity provisions is based on the observation that banks hold less liquid assets than liquid liabilities and are therefore vulnerable to sudden funding contractions, or runs.[3] Following a run, intermediaries might be unable, especially during bad times, to promptly replace their funding sources and therefore might be forced to engage in costly fire sales, reducing credit supply. Central banks can counter this negative effect by providing liquidity, at more attractive terms compared to the private market, to avoid an inefficient credit contraction ("credit crunch").

[1] In the U.S., the Term Asset-Backed Securities Loan Facility (TALF) and the Term Auction Facility (TAF) helped banks refinance their short-term debt and the Capital Purchase Program (CPP) and Capital Assistance Program (CAP) increased the availability of capital. Outside the U.S., the Bank of England "Funding for Lending Scheme" and the European Central Bank 3-year Long Term Refinancing Operation and Targeted Long Term Refinancing Operation provided long-term funding to banks. Several central banks (e.g., Fed, ECB, BoJ) also used large scale asset purchases.

[2] The effect of bank funding shocks on credit supply is studied by Khwaja and Mian (2008), Schnabl (2012), and Paravisini (2008). In recent work, Agarwal et al. (2015) and Di Maggio et al. (2015) analyze the pass-through of expansionary monetary policy to households.

[3] The fragility induced by banks' reliance on short-term funding is analyzed in Diamond and Dybvig (1983). The role of central banks as the lender of last resort goes back to Bagehot (1873).

In our empirical setting, we examine the effect of the largest liquidity injection ever conducted, the December 2011 European Central Bank (ECB) long-term liquidity provision, on Italian bank credit supply. The intervention, called the 3-year Long Term Refinancing Operation (LTRO), consisted of the unlimited offering of three-year maturity collateralized cash loans. On two "allotment" dates, December 21, 2011 and February 29, 2012, Eurozone banks could obtain a three-year loan provided that they pledged sufficient collateral. Unprecedented in scale, the ECB liquidity facility provided $1.37 trillion to 800 Eurozone banks with the official goal of "supporting bank lending."[4]

We study the transmission to the Italian bank credit supply for three reasons. First, Italian banks are hit by sudden withdrawals in their foreign wholesale funding sources in the second half of 2011 allowing us to study a textbook case of how a negative shock (run) and a positive shock (central bank liquidity provision) affect credit supply.[5] Second, as Italian and Spanish banks are the largest users of funds, our results shed light on the effectiveness of this unprecedented operation.[6] Third, we take advantage of a unique dataset obtained by matching the Italian credit registry with detailed information on bank characteristics obtained from supervisory and statistical reports submitted to the Bank of Italy. In particular, we observe all outstanding loans to firms with a balance above $32,000 (€30,000).

The analysis of this intervention poses two empirical challenges. First, as borrowers are not randomly assigned to banks, we need to control for borrower observable and unobservable heterogeneity. In other words, if we observe an increase in credit granted by bank j to

[4]The official LTRO goal was to provide "credit support measures to support bank lending and liquidity in the euro area money market." Source: ECB website [link]. Banks used approximately half of the liquidity injection to rollover previous exposure to the central bank.

[5]In the six months preceding the LTRO, there is a significant contraction of foreign deposits (mainly certificates of deposit and commercial paper held in the U.S.) and Eurozone centrally cleared repurchase agreements (see Bank of Italy (2011a) and Bank of Italy (2011b)).

[6]Italian banks obtain $290 billion (€225 billion) in the two allotments, approximately 26% of total LTRO loans.

borrower i following the intervention, it might be that the borrower is *demanding* more credit rather than the bank supplying more. To address this problem, we take advantage of the richness of our dataset by selecting firms that borrow from two or more banks and plugging firm fixed effects into our regressions (Khwaja and Mian (2008)). Second, banks can *choose* how much to borrow from the central bank. Hence, using the liquidity uptakes as a source of variation, we would probably capture other bank characteristics and our results would suffer from an omitted variable bias. To this end, we use bank reliance on the foreign wholesale market in June 2011, prior to the run, as a measure of differential bank exposure to the funding shock and, consequently, to the central bank intervention. The intuition is straightforward. Banks with larger foreign wholesale market exposure are more affected by the run and are therefore more likely to benefit from the central bank intervention.

The following example illustrates our empirical strategy. We consider firm F1 that borrows from bank B1 and bank B2. The two banks have a high and low exposure to the foreign wholesale market in June 2011, respectively. We compare the stock of credit granted by bank B1 to firm F1 and the stock of credit granted by bank B2 to firm F1 during (i) the *normal* period (June 2010 - May 2011) when funding markets are well functioning, (ii) the *run* period (June 2011 - December 2011) when we observe sizable withdrawals in the foreign wholesale market, and the (iii) *intervention* period (January 2012 - June 2012) after the central bank steps in providing liquidity to the banking sector.

Our analysis yields several findings. First, we show that banks with a large exposure to the foreign wholesale market reduce their credit supply during the run and expand it during the intervention period, compared to banks with a smaller exposure. Of course, bank funding structure is not randomly assigned: for example, in our sample, exposed intermediaries have a smaller household deposit base and are larger and more levered. We control for these observable differences and show that our results are robust to the inclusion of several balance sheet controls.

Second, we find that, banks do not reduce their credit supply during the run period

to some firms more than others. However, following the liquidity provision, banks increase their credit supply to low leverage firms and, holding bank foreign wholesale market exposure constant, small and low leverage banks drive the increase in credit supply. Taken together, these findings are consistent with a positive transmission of central bank liquidity.

Third, we confirm that some firms are hit during the run period and benefit from the intervention. Note that, in isolation, our findings so far do not imply that firms are hit by the credit contraction nor take advantage of the credit expansion. In fact, in a frictionless world, firms are able to switch lenders during bad times so to effectively "undo" the credit crunch. In such a world, central bank interventions do not affect credit volumes as firms are not constrained as a result of the credit contraction. Collapsing our dataset at the firm level, we find that borrowers (i) are unable to completely substitute the reduced credit from exposed banks with new credit from non-exposed banks and (ii) increase total credit used after the intervention.

Having documented the evolution of credit supply for exposed and non-exposed banks, we also examine the actual uptakes of the liquidity facility. We face another empirical challenge. The central bank provides three-year collateralized liquidity by applying a haircut lower than the private market one. This haircut subsidy, together with the long loan maturity, successfully attracts all banks to tap the facility, *regardless* of their exposure to the foreign wholesale run. In other words, it is not the case that banks that suffer the run choose to tap the central bank liquidity more. Hence, we need to disentangle the liquidity uptakes driven by the run from those uptakes driven by other motives.

To this end, we exploit a regulatory intervention by the Italian government. The day after the first LTRO allotment, the government approved a Decree Law allowing banks to obtain, for a fee, a government guarantee on part of their balance sheet. As government guaranteed assets are eligible collateral at the ECB, the scheme effectively gives banks a technology to manufacture collateral. The scheme is very popular as banks created and pledged 88$ billion (€69 billion) worth of new collateral at the second allotment, corresponding to a third of

total uptakes.

We find that the uptakes backed by the government regulatory intervention are caused by the run in the foreign wholesale market. More specifically, banks hit by the funding shock erode their available collateral to find alternative sources of funding and therefore have scarce central bank eligible collateral at the time of the LTRO allotment. These intermediaries then take advantage of the government scheme to manufacture collateral to access ECB liquidity. The intuition is straighforward and similar, in spirit, to Rothschild and Stiglitz (1976). The scheme creates a separating equilibrium where banks that highly value liquidity self-select into the costly government guarantee program. We find that the uptakes backed by this program are *entirely* responsible for the transmission of LTRO to the credit supply.

Finally, we examine how the relatively less exposed banks use the central bank liquidity. We show that these intermediaries buy liquid assets, in the form of government bonds. Their behavior is consistent with (i) a precautionary motive (as they effectively replenish their pool of liquid assets while lengthening the maturity of funding) and (ii) a carry trade motive as domestic government bonds have a high yield.[7]

Our findings stress the importance of central bank collateral eligibility for the transmission of liquidity injections. We show that banks more affected by the foreign wholesale market run have scarce collateral at the time of the LTRO announcement and therefore have mechanically less access to central bank funds. The temporary eligibility of illiquid assets gives exposed institutions access to central bank liquidity.

Related Literature This paper relates to two strands of literature. First, we constribute to the literature on the effect of negative funding shocks on bank credit supply. Early the-

[7] Crosignani et al. (2015) analyze government bond holdings by Portuguese banks and find that LTRO causes an increased demand for domestic public debt as banks buy government bonds between the two allotments to pledge them at the second allotment.

oretical work (Bernanke and Blinder (1988), Bernanke and Gertler (1989), Holmstrom and Tirole (1997), and Stein (1998)) stresses the importance of credit market frictions for a funding shock to cause a credit supply reduction. While the first contributions to the empirical literature have focused on time series (Bernanke and Blinder (1992), Bernanke (1983)) and cross-sectional analysis (Gertler and Gilchrist (1994), Kashyap et al. (1994), Kashyap and Stein (2000), and Ashcraft (2006)), in more recent work, researchers use within borrower estimation, sometimes together with quasi-exogenous liquidity shocks, to disentangle the credit supply effect from credit demand (Khwaja and Mian (2008), Paravisini (2008), Chernenko and Sunderam (2014), and Schnabl (2012)). In line with the most recent strand of the literature many of our specifications include firm fixed effects to control for borrower observed and unobserved heterogeneity. In our empirical setting, the shock is a run in the foreign wholesale market. As in Iyer and Peydro (2011) and Iyer et al. (2014), we find a reduction in credit supply by banks (ex ante) more exposed to the run.

Following the recent U.S. financial and the Eurozone sovereign debt crisis, many researchers have analyzed the impact of these asset market disruptions on credit supply. In the U.S. context, the effect of the crisis on credit supply and real outcomes is analyzed by, among others, Chodorow-Reich (2014b), Ivashina and Scharfstein (2010), and Puri et al. (2011). In the Eurozone context, in their theoretical work, Bocola (forthcoming) and Perez (2015) analyze, using general equilibrium models, the pass-through of sovereign credit risk on intermediated credit. The related empirical literature (Popov and Van Horen (forthcoming), De Marco (2015), Cingano et al. (2013), Bofondi et al. (2013), Acharya et al. (2015a), Bottero et al. (2015), Del Giovane et al. (2013)) almost unanimously confirms the negative spillover.

Second, we inform the literature on the transmission of monetary policy to credit supply (see Jimenez et al. (2012), Jimenez et al. (2014) for credit to firms and Agarwal et al. (2015) for consumer credit). In particular, we analyze unconventional monetary policy (Chodorow-Reich (2014a), Di Maggio et al. (2015)) in the form of central bank liquidity injections. This

type of intervention relates to the seminal lender of last resort literature (Bagehot (1873), Thornton (1802)) as it is based on the idea that central banks can prevent a credit contraction by supplying liquidity to banks.[8]

In the Eurozone, the effect of ECB interventions during the recent sovereign debt crisis is analyzed in Casiraghi et al. (2013), van der Kwaak (2015), Vissing-Jorgensen et al. (2014), Crosignani et al. (2015), Daetz et al. (2016), Andrade et al. (2015), and Garcia-Posada and Marchetti (2015). The last three papers also study the effect of the 3-year LTRO on credit (in France and Spain, respectively). Compared to these contributions, we innovate in two ways. First, we identify the banks' marginal propensity to borrow (MPB) at the central bank by (i) analyzing the differential impact of the run on banks' funding and (ii) validating our MPB measure using the expansion of the Italian banks' eligible collateral in December 2011. Second, by analyzing the pre-LTRO period, we relate the ECB liquidity injection to the pre-LTRO stress in the foreign wholesale market.

The remainder of the paper is structured as follows. In Section 2, we describe the empirical setting, the dataset, and provide summary statistics. We analyze the effect of the ECB liquidity injections on bank credit supply in Section 3. In Section 4, we discuss the transmission channel exploiting a regulatory intervention by the Italian government in December 2011. In Section 5 we analyze which firms benefit the most from the intervention and report the aggregate effects. In Section **??** we discuss the effect of the liquidity injections on the holdings of liquid assets. Concluding remarks are given in Section 6.

[8]While we observe a run before the ECB, we do not take a stance on whether this is a fundamental or panic-based run, a la Diamond and Dybvig (1983). The existence of non-fundamental runs has been disputed, by pointing out that a solvent bank cannot be illiquid (see Gorton (1985), Jacklin and Bhattacharya (1998), Gorton (1988), Allen and Gale (1998), and Chari and Jagannathan (1988)). Rochet and Vives (2004) bridge a gap between the two views by introducing both liquidity and solvency into an incomplete information model. Drechsler et al. (forthcoming) show that there are also ex post risk-taking incentives. They document that weakly capitalized banks tapped the ECB more by pledging riskier collateral. We contribute to the literature by showing that the central bank can increase bank lending supply by supporting illiquid banks.

2 Setting and Data

Our laboratory is Italy from December 2010 to June 2012. There are three reasons why we choose Italy during this period to study the effect of central bank liquidity injections on bank credit supply. First, we observe a run in the (foreign) wholesale market in the six months before the LTRO, making the analysis of this intervention a textbook case of central bank liquidity provision following a negative shock.[9] Second, as Italian and Spanish banks are the largest LTRO users, our results shed light on the effectiveness of this unprecedented intervention.[10] Third, the supply of bank credit is particularly important in Italy as firms, heavily dependent on intermediated credit, are less likely to issue debt securities in response to a contraction to bank loan supply compared to, for example, U.S. firms (see Langfield and Pagano (2015)).

2.1 Macroeconomic Picture

Up until the end of 2008, the credit risk of core eurozone countries was basically identical to the credit risk of "peripheral". In the next three years, rising concerns about public debt sustainability caused a divergence in the credit risk of core countries with respect to Greece, Italy, Ireland, Portugal, and Spain.[11]

The crisis in Italy can be divided in two periods. During the first period, from 2009 to

[9]The Italian economy and banking sector have been severely hit by the European sovereign debt crisis, with sovereign and financial credit risk reaching record highs in November 2011. The Italian 5-year sovereign (USD denominated) CDS spread and 10-year sovereign bond yields reach record highs on November 15, 2011 and November 25, 2011, respectively. See Figure B.1 in the Appendix.

[10]LTRO loans extended to Italian banks constitute 26% of total LTRO loans, just below Spanish banks. In the Online Appendix, we show LTRO uptakes by country. To get a sense of the magnitude, consider that the Italian share of capital at the ECB was 12.3% as of 1 January 2013. Other big contributions come from Deutsche Bundesbank (18%), Banque de France (14.2%), and Banco de Espana (8.8%).

[11]The top panel of Figure B.1 in the Appendix shows that both the Italian sovereign cost of borrowing and sovereign CDS spread increase from 2009 to the end of 2011.

mid-2011, the Italian government bond prices fell by about 25% while sovereign CDS spreads doubled to reach approximately 200 bps as investors became progressively concerned that the crisis affecting Greece and Portugal was going to spread to Italy. Political uncertainty, large government debt, and the long-standing slack in GDP growth made, and still make, Italy very vulnerable to shocks. Investors' concerns materialized in June 2011 when Standard & Poors downgraded Greek debt to CCC and announcements of an involvement of the private sector in Greek debt restructuring led to contagion to Italy.

During the second period, from mid-2011 to December 2011, investors suddenly started demanding very large risk premia and sovereign CDS spreads and bond yields started increasing very sharply to reach a record high in November 2011.[12] Perhaps not surprisingly, concerns about solvency of the sovereign and its financial sector triggered a run, especially by foreign investors, on bank wholesale funding (Chernenko and Sunderam (2014)).

2.2 Bank Funding During the Crisis

The structure of the funding of the Italian banks has changed significantly since 2008. As overall funding shrank, the composition underwent large variation. From 2008 to mid 2011, the fraction of retail funding slightly increased, whereas wholesale funding - bonds except those held by households, deposits from non-residents, and liabilities towards central counterparties - dropped by 3 percentage points to 33%. Central bank refinancing partially substituted for this drop, reaching 2% of total funding.

[12] Greece was downgraded five times by the three main credit rating agencies in June and July of 2011, as the newly appointed government headed by Prime Minister Evangelos Venizelos implemented, amid protests, the fourth austerity package. As documented in Bofondi et al. (2013), sovereign yields then abruptly rose in Italy too, as investors feared that Italy might also not be able to repay its public debt. With sovereign yields rising, the support for the Italian government fell (the lower chamber rejected the Budget Law in October) forcing Prime Minister Silvio Berlusconi to resign in favor of the technocratic government led by Mario Monti.

From June to December 2011, wholesale funding declined 5 percentage points, to 28% of total funding. This drain in funds was offset by central bank refinancing which, at the end of 2011, represented 9% of total funds. The drastic decline in wholesale funds was driven by a sharp reduction in foreign funding, mainly caused by sudden drops in certificate of deposits and commercial paper held by US money market funds and eurozone centrally cleared repurchase agreements.[13]

In October 2008, the ECB switched to a fixed-rate full-allotment mode for its refinancing operations. This means that eurozone banks can obtain unlimited short-term liquidity from the central bank at a fixed rate, provided that they pledge sufficient eligible collateral. For example, Bank A can pledge government bonds worth €100 and get a two-week cash loan worth €96. The ECB applies a haircut, 4% in this example, that depends on the asset class, residual maturity, rating, and coupon structure of the security. There is no limit on how much a bank can obtain from ECB on a specific loan, provided that it pledges sufficient collateral.[14]

On December 8, 2011, the ECB increased its support to the eurozone banking sector even further, announcing the provision of 3-year maturity loans, allotted on December 21, 2011 (LTRO1) and February 29, 2012 (LTRO2), with the stated goal "to support bank lending and liquidity in the euro area". The fundamental difference between the LTRO and the pre-existing ECB refinancing operations lies basically in the long maturity.[15] The 3-year

[13] In Figure B.2 in the Appendix, we illustrate the time series evolution of various sources of bank funding during our sample period. Giannone et al. (2012), Chernenko and Sunderam (2014), and Bank of Italy (2011a) describe the sudden wholesale market funding contraction.

[14] Eligible collateral includes government and regional bonds, covered bonds, corporate bonds, ABSs, and other uncovered credit debt instruments. The haircut schedule is publicly available on the ECB website. In the Online Appendix, we discuss the ECB collateral framework in greater detail.

[15] In particular, the additional credit claim (ACC) scheme has not yet been introduced, and no major changes have been made on the haircuts of the securities typically used as collateral by Italian banks, including governement bonds. The interest rate on the two long-term loans is an average of the interest

maturity of the LTRO loans allows the ECB to dispel any concern that it might revert to some less expansionary features in its window, such as variable rate and/or fixed allotment. This long-term horizon allows banks to relax their maturity mismatch between assets and liabilities and to undertake a more long-sighted liquidity management. Banks use the LTRO loans to both rollover, at a longer maturity, previous central bank borrowing and to get new borrowing.

2.3 Data

In this section, we describe the dataset construction and empirical work. For greater detail, the reader is referred to the Online Appendix. The unit of observation is at the (i, j, s, t) level, where $i \in \mathcal{I}$ is a firm, $j \in \mathcal{J}$ is a bank, $s \in \mathcal{S}$ is a security, and $t \in \mathcal{T}$ is a date. Data on banks refer to the banking group level, consolidated at the national level.

We combine data from various sources. First, at the (i, j, t) firm-bank-period level, we obtain data on all outstanding loans with amount outstanding above €30,000 from the Italian Credit Registry. We have information on term loans, revolving credit lines, and loans backed by account receivables. For each firm-bank pair, we observe the type of credit, as well as the amounts granted and drawn. The quality of this dataset is extremely high as banks are

rate on the Marginal Refinancing Operation (MRO) rate, to be neutral compared to shorter term loans. As a considerable portion of banks' collateral was already pledged at the ECB at the time of the first LTRO allotment, the ECB relaxes the collateral requirements in two ways at the time of the allotments. First, it reduced the rating threshold for certain asset-backed securities (ABS). At LTRO1 and LTRO2, the ECB starts accepting ABS having a second best rating of at least "single A" in the Eurosystem's harmonized credit scale at issuance and underlying assets comprising residential mortgages and loans to small and medium enterprises. In addition, underlying assets backing the ABS must all belong to the same asset class and cannot include non-performing, structured, syndicated, or leveraged loans. Second, it allowed national central banks to temporary accept additional bank loans (additional credit claims, or ACCs) in addition to those eligible before the intervention. Banks had the option to repay earlier, after one year. The interest rate, paid at maturity, was very low (approximately 1%) and equal to the average rate of MROs over the life of the operation.

Bank-Level		**Jun10**	**Dec10**	**Jun11**	**Dec11**	**Jun12**	**Dec12**
Size	€bn	36.8	36.2	36.1	35.9	37.0	37.2
Leverage	Units	11.8	12.2	12.1	12.5	13.9	14.3
Tier 1 Ratio	Units	19.2	15.4	14.4	13.9	13.7	13.4
RWA	%Assets	69.0%	68.8%	68.1%	67.2%	61.5%	59.9%
Credit to Households	%Assets	18.1%	18.8%	18.7%	18.5%	17.3%	16.7%
Credit to Firms	%Assets	41.7%	42.5%	43.0%	42.8%	39.9%	39.1%
Securities	%Assets	17.4%	16.9%	16.3%	17.3%	24.5%	24.1%
Government Bonds	%Assets	9.0%	9.1%	9.0%	10.6%	17.4%	18.2%
Cash Reserves	%Assets	0.4%	0.5%	0.5%	0.5%	0.4%	0.5%
ROA	Profits/Assets	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%
Central Bank Borr	%Assets	0.8%	2.0%	2.3%	5.7%	11.2%	11.0%
Household Dep	%Assets	29.5%	29.6%	29.4%	30.0%	32.5%	35.9%
Interbank Borr	%Assets	4.0%	4.0%	4.2%	5.2%	4.4%	3.9%

Bank-Firm Level	**Loan Type**	**Sep10-Jun11**	**Jun11-Mar12**	**Mar12-Dec12**
Δln(Total Credit Drawn)	All Types	0.6%	-6.8%	-4.6%
Δln(Total Credit Granted)	All Types	-3.6%	-7.8%	-8.0%
Δln(Total Credit Drawn)	Revolving Credit Lines Only	2.4%	5.6%	4.6%
Δln(Total Credit Granted)	Revolving Credit Lines Only	-1.5%	-0.4%	-2.1%

Table 1: Summary Statistics, Bank Characteristics, and Credit Growth. This table shows summary statistics. The top panel shows cross-sectional means of selected balance sheet characteristics during the sample period. The bottom panel shows credit growth during the (i) September 2010 - June 2011 period, (ii) June 2011 - March 2012 period, and (iii) the March 2012 - December 2012 period. The table shows changes in (i) total credit on term loans and drawn from revolving credit lines and loans backed by account receivables, (ii) total credit granted (committed) on term loans, revolving credit lines, and loans backed by account receivables, (iii) total credit drawn from revolving credit lines, and (iv) total credit granted (committed) on revolving credit lines. Sample firms have multiple relationships. In the Online Appendix, we provide additional summary statistics.

required by law to disclose this information to the Bank of Italy.

Second, at the (j,t) bank-period level, we observe standard balance sheet characteristics and LTRO uptakes from the Supervisory and Statistical Reports submitted by intermediaries to the Bank of Italy. A large fraction of balance sheet characteristics is only available biannualy from consolidated reports. Crucially, we also have monthly information on total borrowing, with different maturities, at ECB, so we are able to isolate banks' LTRO uptakes at both LTRO allotments.

Third, at the (s,j,t) security-bank-period level, we observe, from the Supervisory and

Statistical Reports, holdings of each marketable security held by Italian banks. A typical observation is "holdings by bank j of security s in month t." For each security, we also know whether the security is pledged (at ECB or in the private market) or if it is available. We merge each security with Datastream and Bloomberg to obtain additional time-invariant information (e.g., coupon structure, maturity, issuer, and issue date). Finally, we also match each security to a list of eligible securities and their haircuts at LTRO1 and LTRO2 from the ECB.

Fourth, at the (i, t) firm-period level, we also have information on firms' characteristics from end-of-year balance-sheet data and profitability ratios from the proprietary Cebi-Cerved database. We lose approximately 45% of observations by merging firm-level characteristics with our bank-firm observations.

Our final dataset is obtained by merging all our data sources. We exclude some specific banks from the sample. First, we do not consider foreign banks (branches and subsidiaries) operating in Italy, as we only observe the liquidity injections that they obtain from Bank of Italy and not their overall group exposure to the Eurosystem, which is in fact likely to be much larger. Second, we exclude banks involved in extraordinary administration procedures around the time of the introduction of the LTRO, as their management decisions and credit policies are likely to have very little discretion margins. Third, our final sample does not include cooperative or mutual banks nor their central institutes, as in most cases the former tapped ECB liquidity and then redistributed funds among the latter, but we do not observe the allocation of liquidity among affiliated banks. Finally we exclude banks that specialize in specific activities, such as wealth or non-performing loans management. We then restrict our analysis to banks that were counterparties of Bank of Italy in at least one of the two LTRO allotments. Thus, our final sample consists of 72 banks.

In Table 1, we show, in the top panel, bank-level summary statistics. We observe (i) an increase in size and leverage after December 2011, (ii) a contraction in credit to households and firms after December 2010, (iii) increased holdings of securities and government bonds

between December 2011 and February 2012, and (iv) two jumps in central bank borrowing in correspondence with the two LTRO allotments (December 2011 and February 2012). The bottom panel shows changes in credit during three intervals. Total credit drawn is defined as the sum of term loans, credit drawn from revolving credit lines, and loans backed by account receivables. Granted credit granted is defined as the sum of term loans and credit committed from revolving credit lines and loans backed by account receivables. Changes in both credit granted and drawn are negative and large after June 2011, when Italian banks are hit by the foreign wholesale market run. Interestingly, drawn credit from credit lines increases in bad times as firms likely try to smooth the credit contraction (Ippolito et al. (forthcoming)).

3 Effect on Bank Credit Supply

Our strategy to estimate the causal effect of the central bank liquidity injection on bank credit supply follows two steps. First, in this section, we show that banks more exposed to the foreign wholesale market run reduce credit supply during the run and increase credit supply after the central bank steps in providing liquidity to banks. Second, in Section 4, we take advantage of a regulatory change to the definition of ECB eligible collateral to draw a causal link between the actual bank-level uptakes of central bank liquidity and their credit supply after the intervention.

3.1 Identification Strategy

Before discussing the identification strategy, we illustrate the experiment that we would ideally design to answer our research question. In this setting, we would make the firm-bank match random and also randomly assign central bank liquidity to banks. Using the heterogeneity of ECB liquidity injections as a source of variation, we would be able to estimate the *causal* impact of the central bank liquidity provision on bank credit supply

by simply. The effect on bank credit would be fully attributable to a change in *supply* as borrowers' characteristics would be uncorrelated with liquidity injections. In other words, it would not be the case that borrowers matched with banks that receive large liquidity injections *demand* more/less credit compared to borrowers matched with banks that receive smaller liquidity injections. Moreover, as the liquidity injection is randomly assigned to banks, it would not be the case that some types of banks (e.g., larger or more levered) systematically obtain more central bank funding. Unfortunately, as these two conditions are not satisfied in our setting, we face two empirical challenges.

First, the stock of credit that firm i obtains from bank j at time t is an equilibrium quantity, resulting from both bank supply and firm demand for credit. Hence, we need to isolate the change in bank credit originating from a change in bank credit *supply*. To this end, we restrict our sample to the large number of firms that are borrowing, in any given period, from two or more banks and compare changes in borrowing from different banks *within* firms (Khwaja and Mian (2008)).[16] Using this sample, we can fully control for firm observed and unobserved characteristics using firm fixed effects. In other words, we can compare how the same firm's loan growth from one affected bank changes relative to the loan growth from another less affected bank.

Second, the uptakes of the ECB liquidity are not randomly assigned to banks. Banks can *choose* the amount of cash loans they want to obtain from the central bank. Hence, using the heterogeneity of uptakes as a source of variation, we would probably capture other bank

[16] Our sample includes approximately 1.4 million observations at any given date. In most of our analysis we focus on firms with multiple relationships. Such subsample includes approximately 0.7 million observations (approximately 275,000 unique firms) at any given point in time. Approximately 170,000 firms have two relationships at any given date. More than two relationships are also relatively common. Approximately, at any given date, of the 275,000 unique firms, 60,000 have three relationships, 24,000 have four relationships, and 21,000 have five or more relationships.

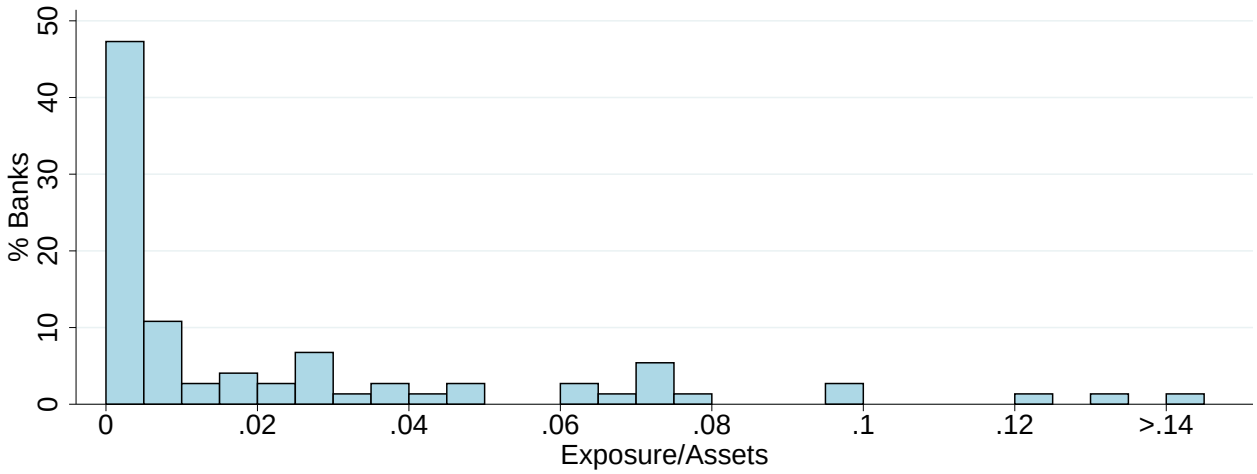

Figure 1: June 2011 Foreign Wholesale Market Exposure. This histogram shows bank-level exposure to the foreign wholesale market run in June 2011. The y-axis is the share of sample banks in percentages. The exposure is defined as the sum of bank exposures to foreign deposits (e.g., commercial paper and certificates of deposit held by U.S. money market funds) and centrally (Eurozone) cleared repurchase agreements, divided by total assets in June 2011.

characteristics and our results would suffer from an omitted variable bias.[17] We use banks pre-run exposure to the foreign wholesale funding in June 2011 as a measure of differential bank exposure to (i) the June 2011 run and, consequently, (ii) the central bank intervention. The intuition is straightforward. Banks with larger exposure to foreign wholesale funding are more affected by the run and are therefore more likely to benefit from the ECB intervention.[18] In Section 4, we link the actual bank-level liquidity uptakes to the wholesale market run.

We define the pre-run (June 2011) exposure as the foreign wholesale funding normalized total assets. Foreign wholesale funding consists of foreign deposits (e.g., commercial paper

[17]Several papers use banks' LTRO uptakes as a source of variation (Andrade et al. (2015), Daetz et al. (2016), Garcia-Posada and Marchetti (2015)). Our two steps identification strategy allows us to better identify the causal effect of central bank liquidity on credit and dissect the transmission channels.

[18]Iyer et al. (2014) use the ex ante exposure to the interbank market to study the effect of the unexpected freeze of the European interbank market on Portuguese bank credit supply in 2008. We use the same source of variation to explain *both* the credit contraction and the credit expansion following the ECB liquidity injection. In Table 6, we show that banks more exposed to the foreign wholesale market funding suffer more from the foreign wholesale market funding contraction.

		Exposed Banks	Non-exposed Banks	Normalized Difference
Size	€bn	70.51	1.82	2.28
Leverage	Units	13.32	11.07	2.22
Tier 1 Ratio	Units	10.86	17.89	-1.80
RWA	%Assets	67.3%	69.2%	-0.54
Credit to Households	%Assets	17.2%	20.4%	-1.36
Credit to Firms	%Assets	41.7%	44.9%	-0.78
Securities	%Assets	16.6%	16.0%	0.23
Govt Bonds	%Assets	8.0%	10.1%	-1.02
Cash Reserves	%Assets	0.4%	0.6%	-2.17
ROA	Profits/Assets	0.26%	0.02%	3.12
Central Bank Borr	%Assets	3.16%	1.38%	2.27
Household Dep	% Assets	24.7%	37.0%	-4.00
Interbank Borr	% Assets	5.5%	2.7%	1.87

Table 2: Exposed and non-Exposed Banks: Summary Statistics. This table shows June 2011 bank summary statistics for the subsamples of exposed and non-exposed banks. Exposed (non-exposed) banks have exposure to the foreign wholesale market above (below) median in June 2011. The table shows balance sheet characteristics (subsample means). The last column shows Imbens and Wooldridge (2009) normalized difference (defined as the average treatment status, scaled by the square root of the sum of the variances). In the Online Appendix, we replicate this table with subsamples based on quartiles.

and certificates of deposit held by U.S. money market funds) and eurozone centrally cleared repurchase agreements. In Figure 1, we show the distribution of banks' pre-run exposure to the foreign wholesale market in June 2011. Approximately 58% of the banks in our sample have a very small exposure, below 1%. However, banks with exposure above 5% are quantitatively important as they hold 75% of total loan to firms in our sample.[19]

Of course, banks' funding mix in June 2011 is correlated with other banks' observable and unobservable characteristics. In Table 2, we show bank summary statistics for the two subsamples of "exposed" and "non-exposed" banks, according to their exposure to the foreign wholesale market in June 2011. Exposed banks (above median exposure) tend to be larger,

[19]In Figure B.3 in the Appendix, we show the correlation between bank exposure to the foreign wholesale market run in June 2011 and bank total credit to firms. The 10th, 30th, 50th, 70th, 90th percentiles of the distribution of the exposure variable across banks are 0.00%, 0.11%, 0.75%, 2.74%, and 7.57%, respectively.

more levered, and more reliant on wholesale funding, compared to non-exposed banks (below median exposure). The difference in observables is intuitive. Large banks obtain a sizable amount of funding through interbank and repo markets. They also have a non-negligible share of total funding coming from foreigners. On the other hand, small banks are usually present in local markets where they have a large household deposit base.[20]

In our empirical analysis, we compare three periods: (i) the *normal* period from December 2010 to June 2011 when funding markets are well functioning; (ii) the *run* period from June 2011 to December 2011 when we observe a run in the foreign wholesale market; and (iii) the *intervention* period from December 2011 to June 2012.[21] In the next subsection, we illustrate the three-period difference-in-difference specification we adopt to compare the stock of credit granted by firm i to bank j in each of these three periods.

3.2 Intensive Margin

We first examine the effect (i) of the *run* and (ii) of the *intervention* on bank credit supply to existing customers (intensive margin). In our baseline specification, we estimate the following model:

$$\begin{aligned}\Delta Log(Credit_{ijt}) = \alpha + \beta_1 Exposure_j \times \mathbb{I}_{Run} + \beta_2 Exposure_j \times \mathbb{I}_{Interv} \\ + \mu_{it} + \gamma_{ij} + \phi' X_{ijt} + \epsilon_{ijt} \end{aligned} \quad (1)$$

[20] In Table C.1 in the Appendix, we show the time series evolution of balance sheet summary statistics for exposed and non-exposed banks.

[21] We decide to end the sample in June 2012 in order to not overlap with the July 2012 Draghi OMT announcement, also known as "whatever it takes" speech, that caused large market-to-market gains on bank holdings of government bonds and other risky securities (see Acharya et al. (2015b)).

where $\mathbb{I}_{Run}$ is a dummy equal to one during the *run* and the *intervention* periods and $\mathbb{I}_{Interv}$ is a dummy equal to one in the *intervention* period. Observations are at the (i, j, t) borrower-bank-period level. We use the four dates that delimit the *normal*, the *run*, and the *intervention* periods, namely December 2010, June 2011, December 2011, and June 2012. The dependent variable is the change in log (stock of) credit granted by bank j to borrower i at time t.[22] $Exposure_j$ is bank j exposure to the foreign wholesale market in June 2011. We add bank-firm fixed effects to absorb any bank-firm time-invariant characteristics, including any time-invariant bank characteristic. We also plug firm-time fixed effects to control for both observable and unobservable firm heterogeneity, crucially capturing firm demand for credit at time t.

Finally, we add time-varying borrower-bank relationship (time-varying) variables, in the vector X_{ijt}, to control for the fact that the same borrower might have a different relationship through time with exposed banks compared to non-exposed banks. These variables are (i) the share of total firm i credit obtained from bank j (measuring the strength of the relationship), (ii) the ratio of drawn credit over committed credit (measuring how close is firm i from exhausting its borrowing capacity from bank j), and (iii) the share of overdraft credit by borrower i with respect to bank j (measuring the extent of an eventual over-borrowing).

Intuitively, as in a standard difference-in-difference setting, the coefficient β_1 captures the difference in credit growth for more exposed banks during the *run* relative to less exposed banks during the *normal* period. Similarly, the coefficient β_2 captures the difference in credit growth for more exposed banks during the *intervention* relative to less exposed banks during the *run* period.[23] We rely on two identification assumptions: (i) exposed banks would

[22] Credit granted and total credit are not necessarily equivalent for revolving credit lines as the former is the total amount *committed* on the credit line. As the amount drawn from a credit line is likely driven by firm demand, we choose to use credit granted as our dependent variable.

[23] In Appendix A, we prove this claim analytically.

have behaved like non-exposed banks during the *run* period in the absence of the run and (ii) exposed banks would have behaved like non-exposed banks in the absence of the ECB intervention during the *intervention* period. Since bank exposure is not randomly assigned across banks, we ensure that our results are robust to the inclusion of many balance sheet characteristics *interacted* with the two time dummies. These characteristics are leverage, tier 1 ratio, non-performing loans, and a *Large* dummy equal to one if a bank belongs to banking group that has assets above €500 billion.

In Table 3, we show estimation results, progressively saturating our specification with fixed effects and controls. In columns (1) and (2), we just include time and bank fixed effects, but no firm-time fixed effects, hence not controlling for credit demand. The sample is the only difference between the two specifications as column (1) covers the full sample and column (2) only includes firms that have multiple relationships. In column (3), we substitute time fixed effects with firm-time fixed effects in order to control for firm credit demand. These preliminary estimation results show a negative (positive) significant effect of the run (intervention) on bank credit supply. Note that results are basically unchanged when we include firm-time fixed effects, suggesting that firm borrowing from more exposed banks are not demanding less credit in the run period and more credit during the intervention period. In other words, firm demand and the endogenous bank-firm matching do not seem to be major identification concerns in this setting.

	$\Delta CREDIT$ (Granted)					
	(1)	(2)	(3)	(4)	(5)	(6)
$Exposure_{Jun11} \times \mathbb{I}_{Run}$	-0.092**	-0.127***	-0.129***	-0.128***	-0.132***	-0.114***
	(0.041)	(0.045)	(0.037)	(0.037)	(0.040)	(0.031)
$Exposure_{Jun11} \times \mathbb{I}_{Interv}$	0.212***	0.247***	0.251***	0.245***	0.172***	0.115**
	(0.054)	(0.061)	(0.044)	(0.043)	(0.043)	(0.053)
$Share$				-0.002***	-0.026***	-0.026***
				(0.000)	(0.001)	(0.001)
$Overdraft$				0.068***	0.251***	0.249***
				(0.003)	(0.027)	(0.026)
$Drawn/Granted$				0.052	0.252	0.250
				(0.032)	(0.223)	(0.220)
$LEV_{Jun11} \times \mathbb{I}_{Run}$						0.141
						(0.207)
$LEV_{Jun11} \times \mathbb{I}_{Interv}$						0.244
						(0.158)
$ROA_{Jun11} \times \mathbb{I}_{Run}$						-0.038*
						(0.020)
$ROA_{Jun11} \times \mathbb{I}_{Interv}$						0.027
						(0.044)
$T1R_{Jun11} \times \mathbb{I}_{Run}$						0.396**
						(0.155)
$T1R_{Jun11} \times \mathbb{I}_{Interv}$						0.362***
						(0.127)
$NPL_{Jun11} \times \mathbb{I}_{Run}$						-0.321*
						(0.185)
$NPL_{Jun11} \times \mathbb{I}_{Interv}$						0.222**
						(0.101)
$Large \times \mathbb{I}_{Run}$						-0.647
						(0.943)
$Large \times \mathbb{I}_{Interv}$						0.615
						(1.518)
Time FE	✓	✓				
Bank FE	✓	✓	✓	✓		
Firm-Time FE			✓	✓	✓	✓
Bank-Firm FE					✓	✓
Sample	Full	Multiple Lenders	Multiple Lenders	Multiple Lenders	Multiple Lenders	Multiple Lenders
Observations	4,434,431	2,322,142	2,322,142	2,322,142	2,171,749	2,171,749
R-squared	0.004	0.005	0.380	0.394	0.700	0.701

Table 3: Liquidity Injections and Credit Supply, Intensive Margin. This table presents the results from specification (1). The dependent variable is the difference in log (stock of) credit granted. $Exposure_{Jun11}$ is the exposure to the foreign wholesale market, divided by assets, in June 2011. $\mathbb{I}_{Run}$ is a dummy equal to one in the *run* and *intervention* periods. $\mathbb{I}_{Interv}$ is a dummy equal to one in the *intervention* period. The *normal* period runs from December 2010 to June 2011. The *run* period runs from June 2011 to December 2011. The *intervention* period runs from December 2011 to June 2012. *Share* is the share of total firm i credit obtained from bank j, *Drawn/Granted* is the ratio of drawn credit over committed credit between bank j and firm i, $Overdraft$ is the share of overdraft credit between borrower i and bank j, LEV is leverage, ROA is return on assets, $T1R$ is the Tier 1 Ratio, NPL is non-performing loans divided by total asset, and *Large* is a dummy equal to one if the bank has assets above €500 billion. The firms in the sample have at least two bank relationships. Standard errors double clustered at the bank and firm level are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

In column (4), we augment the specification with the three relationship control variables to account for any time-varying bank-firm characteristics. The two coefficients of interest are stable and the coefficients on the relationship controls show that banks in this period tend to reduce credit supply to the clients they are most exposed to. In column (5) we substitute bank fixed effects with the more stringent bank-firm fixed effects so to exploit the variation within the same firm-bank pair over time, thereby controlling for any time invariant relationship characteristics. Affected banks' credit supply contraction during the run relative to unaffected banks is then offset by an approximately equivalent increase during the intervention period.[24]

In column (6), we saturate the specification with bank-balance sheet characteristics *interacted* with the two time dummies.[25] We find that during the run credit granted by banks with high exposure at the top decile of the exposure distribution grew by about one percentage point less than credit granted by banks at the bottom decile of the exposure distribution. On the other hand, during the intervention period, credit granted by banks at the top decile of the exposure distribution grew by about one percentage point more than credit granted by banks at the bottom decile of exposure distribution. We find that, during the run, banks with low regulatory capital and high non performing loans reduce credit supply compared to other banks. During the intervention, banks with high non performing loans on balance sheet increase their credit supply compared to banks with less non-performing loans, suggesting that the intervention might have helped also banks with solvency, and not purely liquidity,

[24]When bank-firm fixed effects are included, the number of observations shrinks from 2.32 million to 2.17 million, approximately. With bank fixed effects, the sample includes firms that have multiple credit relationship at each date t. With bank-firm fixed effects, the sample includes only observations about the same bank-firm relationship through time.

[25]Balance sheet variables are measured before time t. In particular, since we have balance sheet characteristics at a biannual frequency, we use characteristics in June 2010, June 2011, and December 2011 when the dependent variable is the change in the log stock of credit in June 2011-December 2010, December 2011-June 2011, and June 2012-December 2011, respectively.

issues.

3.3 Credit Supply Across Firms

We now examine to which firms bank reduce credit during the *run* period and expand credit during the *intervention* period the most. To this end, we use exploit firm-level information on profitability (EBITDA), size, leverage, and credit risk (Z-score). We re-run our most conservative baseline specification (column (6) in Table 3), interacting our main independent variables with firm characteristics, measured in December 2010.[26]

We show the estimation results in Table 4. We report our most conservative baseline specification in column (1), as a reference. In columns (2)-(5), we include triple interaction terms. For example, in column (2) we show how the effect of the run and the intervention on credit supply changes depending on firm size, where the variable $FirmSize$ is the log of firm total assets in December 2010. Similarly, the last three columns include triple interactions with firm profitability, firm leverage, and firm risk. Note that the firm-bank and the time-firm double interactions are absorbed by the fixed effects.

We find that the effect of the run is stable across different firm characteristics, with the exception of risky clients, to which affected banks reduce more credit supply. However, in the *intervention* period, banks with high exposure increase their credit supply, compared to banks with low exposure, especially to large, low profitability, and risky firms. The evidence is consistent with affected banks reducing credit supply to all their existing customers, especially risky ones, and restoring credit supply, reaching for yield.

[26] We lose 45% of observations by merging the firm-level dataset with our bank-firm observations. However, we can still rely on more than a million observations at the four dates of December 2010, June 2011, December 2011, and June 2012. As firm-level characteristics are available at annual frequency, we choose December 2010 as this is the last observation before the run. In Table C.2 in the Appendix, we show firm summary statistics.

	$\Delta CREDIT$ (Granted)				
	(1)	(2)	(3)	(4)	(5)
$Exposure_{Jun11} \times \mathbb{I}_{Run}$	-0.114***	-0.117	-0.122***	-0.117***	-0.082*
	(0.031)	(0.268)	(0.041)	(0.038)	(0.045)
$Exposure_{Jun11} \times \mathbb{I}_{Interv}$	0.115**	-0.424***	0.144**	0.121**	0.075
	(0.053)	(0.148)	(0.059)	(0.056)	(0.048)
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times FirmSize_{2010}$		-0.000			
		(0.019)			
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times FirmSize_{2010}$		0.036***			
		(0.011)			
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times FirmProfitability_{2010}$			0.058		
			(0.202)		
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times FirmProfitability_{2010}$			-0.339***		
			(0.112)		
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times FirmLeverage_{2010}$				-0.018	
				(0.024)	
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times FirmLeverage_{2010}$				0.012	
				(0.036)	
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times FirmRisky_{2010}$					-0.055**
					(0.027)
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times FirmRisky_{2010}$					0.072***
					(0.026)
Firm-Time FE	✓	✓	✓	✓	✓
Bank-Firm FE	✓	✓	✓	✓	✓
Bank Controls (interacted with dummies)	✓	✓	✓	✓	✓
Relantionship Controls	✓	✓	✓	✓	✓
Observations	2,171,749	1,389,799	1,414,211	1,414,211	1,386,784
R-squared	0.701	0.686	0.688	0.688	0.686

Table 4: Liquidity Injections and Credit Supply, Intensive Margin, Heterogeneity Across Firms. This table presents results from specification (1) augmented to include triple interactions with firm balance sheet characteristics. The dependent variable is the difference in log (stock of) credit granted. $Exposure_{Jun11}$ is the exposure to the foreign wholesale market, divided by assets, in June 2011. $\mathbb{I}_{Run}$ is a dummy equal to one in the *run* and *intervention* periods. $\mathbb{I}_{Interv}$ is a dummy equal to one in the *intervention* period. The *normal* period runs from December 2010 to June 2011. The *run* period runs from June 2011 to December 2011. The *intervention* period runs from December 2011 to June 2012. The regression includes time-varying relationship controls (the share of total firm i credit coming from bank j, the ratio of drawn credit over committed credit, and the share of overdraft credit by borrower i with respect to bank j), bank characteristics in June 2011 (leverage, return on assets, tier 1 ratio, non-performing loans divided by total asset, and a dummy equal to one if the bank has assets above €500 billion), interacted with the two time dummies. Firm characteristics are measured in December 2010 and defined as follows: $FirmSize$ is log of total assets; $FirmProfitability$ is EBITDA; $FirmLeverage$ is firm leverage; $FirmRisky$ is a dummy equal to one if the firm is considered risky based on the Z-score greater or equal than 5 (range 1-9). Standard errors double clustered at the bank and firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

3.4 Credit Supply Across Banks

We next examine whether the effect of the exposure to the foreign wholesale market on credit supply varies by bank fundamentals. As anticipated, the foreign wholesale market run and the central bank liquidity provision are unlikely to have hit all banks equally. We should therefore expect the effect on credit supply to vary across banks.

To answer this question, we interact our two main dependent variables with bank balance sheet characteristics, measured in June 2011. For example, we interact the two difference-in-difference regressors with leverage to check whether high levered banks reduced (increased) credit supply to their client more compared to low leverage banks (holding their exposure to the foreign wholesale market funding constant) during the run and intervention periods.

We show results in in Table 5. In column (1), we report once again our most conservative baseline specification that we then augment with triple interactions in columns (2)-(6). During the run, less profitable banks and banks with larger non-performing loan portfolio on balance sheet reduced credit supply more compared to relatively healthier banks. During the intervention period, high leverage banks increased credit supply more compared to low leverage banks.

4 Transmission Channel

In the previous section, we document that banks more exposed to the foreign wholesale market run reduce credit supply during the run and restore credit supply after the central bank intervention, compared to less exposed banks. In this section, we link the actual bank-level liquidity injections to credit supply increase after the central bank intervention and discuss the transmission channel.

	$\Delta CREDIT$ (Granted)					
	(1)	(2)	(3)	(4)	(5)	(6)
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times LEV_{Jun11}$		0.039				
		(0.042)				
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times LEV_{Jun11}$		0.088***				
		(0.027)				
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times ROA_{Jun11}$			2.853***			
			(1.073)			
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times ROA_{Jun11}$			-2.056			
			(1.626)			
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times T1R_{Jun11}$				-0.014		
				(0.046)		
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times T1R_{Jun11}$				0.030		
				(0.064)		
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times NPL_{Jun11}$					-0.078***	
					(0.027)	
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times NPL_{Jun11}$					0.038	
					(0.040)	
$Exposure_{Jun11} \times \mathbb{I}_{Run} \times Large$						-0.523
						(0.323)
$Exposure_{Jun11} \times \mathbb{I}_{Interv} \times Large$						0.799
						(0.745)
$Exposure_{Jun11} \times \mathbb{I}_{Run}$	-0.114***	-0.741	-0.099***	-0.475***	0.019	0.846**
	(0.031)	(0.667)	(0.035)	(0.135)	(0.437)	(0.335)
$Exposure_{Jun11} \times \mathbb{I}_{Interv}$	0.115**	-1.306***	0.090	0.374**	-0.163	-0.358
	(0.053)	(0.444)	(0.065)	(0.186)	(0.608)	(0.513)
$\mathbb{I}_{Run} \times LEV_{Jun11}$	0.141	-0.064	0.096	0.177	0.134	0.330
	(0.207)	(0.160)	(0.196)	(0.210)	(0.217)	(0.244)
$\mathbb{I}_{Interv} \times LEV_{Jun11}$	0.244	-0.294	0.317*	0.229	0.259	0.161
	(0.158)	(0.188)	(0.186)	(0.146)	(0.164)	(0.152)
$\mathbb{I}_{Run} \times ROA_{Jun11}$	-0.038*	-0.056**	-0.058**	-0.106***	-0.041*	-0.011
	(0.020)	(0.028)	(0.023)	(0.029)	(0.022)	(0.023)
$\mathbb{I}_{Interv} \times ROA_{Jun11}$	0.027	-0.015	0.057	0.075	0.034	0.014
	(0.044)	(0.050)	(0.057)	(0.049)	(0.051)	(0.051)
$\mathbb{I}_{Run} \times T1R_{Jun11}$	0.396**	0.295**	0.397**	0.458**	0.408***	0.509***
	(0.155)	(0.125)	(0.158)	(0.174)	(0.135)	(0.179)
$\mathbb{I}_{Interv} \times T1R_{Jun11}$	0.362***	0.141	0.367***	0.339***	0.339***	0.315**
	(0.127)	(0.118)	(0.120)	(0.110)	(0.116)	(0.125)
$\mathbb{I}_{Run} \times NPL_{Jun11}$	-0.321*	-0.434	-0.396*	-0.305*	-0.340*	0.046
	(0.185)	(0.269)	(0.213)	(0.175)	(0.186)	(0.157)
$\mathbb{I}_{Interv} \times NPL_{Jun11}$	0.222**	0.045	0.336*	0.208**	0.261	0.035
	(0.101)	(0.109)	(0.178)	(0.096)	(0.158)	(0.190)
$\mathbb{I}_{Run} \times Large$	-0.647	1.003	4.261	-5.238***	-0.282	-1.659*
	(0.943)	(2.432)	(3.578)	(1.673)	(1.262)	(0.892)
$\mathbb{I}_{Interv} \times Large$	0.615	3.840*	-6.880	3.941	-0.145	1.149
	(1.518)	(2.104)	(7.345)	(3.495)	(2.444)	(1.800)
Relationship Controls	✓	✓	✓	✓	✓	✓
Firm-Time FE	✓	✓	✓	✓	✓	✓
Bank-Firm FE	✓	✓	✓	✓	✓	✓
Observations	2,171,749	2,171,749	2,171,749	2,171,749	2,171,749	2,171,749
Adj. R-squared	0.701	0.701	0.701	0.701	0.701	0.701

Table 5: Liquidity Injections and Credit Supply, Intensive Margin, Effect by Bank Characteristics. This table presents results from specification (1) augmented to include triple interactions with June 2011 bank characteristics. The dependent variable is the difference in log (stock of) credit granted. $Exposure_{Jun11}$ is the exposure to the foreign wholesale market, divided by assets, in June 2011. $\mathbb{I}_{Run}$ is a dummy equal to one in the *run* and *intervention* periods. $\mathbb{I}_{Interv}$ is a dummy equal to one in the *intervention* period. The *normal* period runs from December 2010 to June 2011. The *run* period runs from June 2011 to December 2011. The *intervention* period runs from December 2011 to June 2012. Relationship controls include (i) the share of total firm i credit coming from bank j, (ii) the ratio of drawn credit over committed credit, and (iii) the share of overdraft credit by borrower i with respect to bank j, LEV is leverage, ROA is return on assets, $T1R$ is the tier 1 ratio, NPL is non-performing loans divided by total asset, and $Large$ is a dummy equal to one if the bank has assets above €500 billion. Standard errors double clustered at the bank and firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

4.1 Central Bank Liquidity Uptakes

The LTRO intervention successfully attracted many banks. In our sample, 72 banks tap this facility obtaining €170.1 billion, consisting of a €88.4 billion uptake at LTRO1 and a €117.4 billion uptake at LTRO2. It is an economically large quantity as the median uptake is 9.9% of total assets.[27] Banks' large uptakes are perhaps not surprising. LTRO was an opportunity not to miss for banks, as ECB provided long-term liquidity at more favorable terms compared to the private market.

The distinctive feature of the LTRO, compared to pre-existing liquidity facilities, is the long 3-year maturity. Interest rate and haircut did not change compared to previous standing operations. So why did banks borrow at LTRO? In a world with no uncertainty, LTRO is a redundant tool and should not attract banks as they would be indifferent between borrowing at the central bank at a three-year horizon and borrowing, say, at a two-week maturity and then rolling over bi-weekly for three years. However, the two strategies are not equivalent if there is uncertainty about the ECB's role as a liquidity provider in the next three years. This is definitely the case at the end of 2011 as there was uncertainty about the future of the eurozone and the unlimited feature of ECB liquidity provision.[28]

[27] The average is 10.9% of total assets. Banks' enthusiasm in tapping LTRO funds is also confirmed by the observation that 48 out of the 49 sample banks that are usually counterparty of the ECB open market operations, tap LTRO. We provide additional summary statistics of bank borrowing at LTRO in Table C.3 in the Appendix.

[28] Right after the collapse of Lehman, the ECB started to adopt the so-called "full allotment" procedure in its liquidity provision operations. Under this process, eurozone banks can obtain potentially unlimited liquidity, provided that they pledge sufficient eligible collateral. This procedure was still in place at the time of the two LTRO allotments. However, there was uncertainty on whether this feature would have been in place during the three years of the LTRO. Uncertainty about collateral eligibility and haircuts was not eliminated by taking advantage of the LTRO. In fact, if the value of collateral dropped (or the haircuts increased) during the LTRO period, banks were required to either pledge additional collateral or place cash in margin call deposits at the ECB. According to the ECB Risk Control Framework, marketable assets used as collateral are marked to market daily.

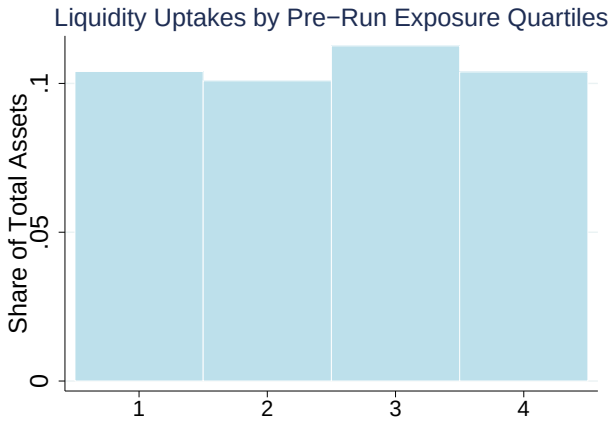

Figure 2: LTRO Uptakes and Bank Exposure to the Foreign Wholesale Market. This histogram shows LTRO uptakes, normalized by assets in December 2011. Banks are divided in four quartiles according to their exposure to the foreign wholesale market in June 2011.

Interestingly, there is little heterogeneity in banks' uptakes of ECB liquidity: banks tap approximately liquidity for 10% of total assets, *regardless* of their exposure to the run. In other words, it is not the case that banks that reduce credit during the run period are also those tapping the liquidity the most. In Figure 2, we divide banks, on the x-axis, in quartiles according to their exposure to the foreign wholesale market in June 2011. Each bar shows, for each quartile, total LTRO uptakes normalized by total assets, showing that their exposure to the run and their uptakes are uncorrelated.

This finding poses an identification challenge as it is not possible to use the pre-run exposure to the foreign wholesale market as an instrument for the LTRO uptakes. Moreover, this finding raises the possibility that the effect on bank credit supply is unrelated to the central bank liquidity provision.

4.2 Identification Strategy

We now exploit a regulatory change introduced by the Italian government that allowed banks to create ECB eligible collateral paying a fee. We claim that LTRO uptakes backed by collateral created using the government program are driven by the run and uptakes backed by regular collateral are driven by other, discretionary, motives. In the remainder of this

section, we describe the government intervention and provide evidence backing our claim.

The government intervention design is simple. It was announced on December 22, 2011, the day after the first LTRO allotment, and immediately effective. From this day onwards, banks could obtain a state guarantee on zero coupon, senior, unsecured, euro-denominated bonds.[29] In the period between the two LTRO allotments, banks took advantage of this law by issuing *and retaining* unsecured bank bonds. A retained issuance is effectively a self-issuance as banks do not place the bonds to market or investors, but keep them on the asset side of the balance sheet. Paying a 1% fee to the Treasury, banks then obtained a government guarantee on these newly created bonds (called Government Guaranteed Bank Bonds, or GGBB) so that they become eligible to be pledged at LTRO2. The popularity of this scheme is shown in the left panel of Figure 3, which shows the total GGBB (self-)issuance reached €79 billion in the two months between the LTRO allotments. The timing of the issuance and the maturity of the bonds coinciding with LTRO maturity strongly suggest that the government scheme is issued to create collateral for the second LTRO allotment. Even if banks could issue GGBBs after the second allotment, they chose not to do so, suggesting that the goal of this collateral creation was to access the second LTRO allotment.[30]

The intuition of our empirical strategy is simple. During the run, between June 2011 and December 2011, banks more affected by the funding contraction eroded their available collateral, by either pledging it in the private market or at the central bank to obtain short-term funding. In December 2011, as the LTRO is announced, these banks had scarce collateral on balance sheet to access central bank LTRO loans. The Italian government intervened by

[29] In the Appendix, we provide a detailed description of the government scheme, as well as anecdotal evidence on its rationale and usage by banks.

[30] Moreover, banks chose to issue GGBBs with maturity matching the maturity of the LTRO loans maturity to minimize their rollover risk at the time of reimbursement. We confirm from our dataset that these securities are pledged at the ECB at the end of February.

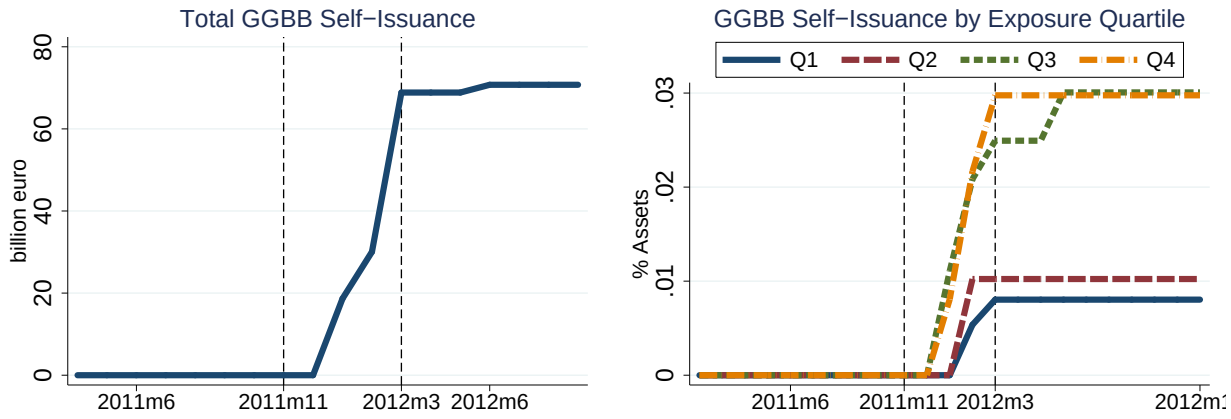

Figure 3: Government Scheme Usage. This figure shows the bank usage of the government law by banks. The left panel illustrates banks' total collateral creation, in billion €. The right panel shows banks collateral creation, normalized by assets in December 2011, for four subsamples of banks according to their exposure to the foreign wholesale market in June 2011. Q1 (Q4) banks are the less (most) exposed to the foreign wholesale market in June 2011.

offering a guarantee on otherwise ineligible assets. On the one hand, banks hit by the run, that eroded their available collateral before the central bank intervention, were willing to pay the government guarantee fee to access LTRO funds. On the other hand, banks relatively unaffected by the run could access LTRO using their own collateral, avoiding the payment of the fee.

Note that, absent the fee, all banks would have chosen to secure additional collateral using the government scheme. However, once a fee was collected, only banks that had scarce collateral were willing to pay to access ECB liquidity. This setting is similar in spirit to Rothschild and Stiglitz (1976) as banks that *self-select* in the costly collateral option had little collateral because of the run. In other words, the usage of the scheme created a separating equilibrium (see also Hertzberg et al. (2015)). In the right panel of Figure 3, we show the time series of the GGBB holdings. Banks are divided into quartiles, according to their exposure to the foreign wholesale funding in June 2011. The higher the exposure, the more the banks took advantage of the new government law, consistent with our narrative.

	$LTRO\ Uptake$		$LTRO\ Uptake^{GGBB}$	
$Exposure_{Jun11}$	0.115	0.137	0.153*	0.180**
	(0.200)	(0.198)	(0.086)	(0.088)
LEV_{Jun11}		0.432**		0.182**
		(0.186)		(0.083)
ROA_{Jun11}		0.028		-0.018
		(0.027)		(0.012)
$T1R_{Jun11}$		0.198***		-0.021
		(0.058)		(0.026)
NPL_{Jun11}		-0.025		0.059
		(0.127)		(0.057)
$Large_{Jun11}$		-6.239		-0.811
		(4.540)		(2.028)
Observations	73	73	73	73
R-squared	0.005	0.213	0.043	0.188

Table 6: Exposure, Collateral, and LTRO Uptakes. This table presents the results from specification (2). The dependent variable in columns (1)-(2) is total LTRO uptake. The dependent variable in columns (3)-(4) is the LTRO uptake backed by government guaranteed bank bonds (GGBB). Independent variables are exposure to the foreign wholesale market, leverage, return on assets, tier 1 ratio, non-performing loans, and a dummy equal to one if a bank belongs to a banking group with assets greater than €500. All variables are normalized by assets in June 2011. *** p<0.01, ** p<0.05, * p<0.1.

We test our claims by running the following simple cross-sectional regression:

$$\Delta y_{jt} = \alpha + \beta Exposure_{j,Jun11} + \mu X_{j,Jun11} + \epsilon_{jt} \tag{2}$$

where we regress LTRO uptakes on bank balance sheet characteristics in June 2011, including the exposure to the run. We show estimation results in Table 6. In columns (1)-(2), the dependent variable is total borrowing at LTRO. Consistent with the non-parametric results shown in Figure 2, we confirm that bank exposure to the run is uncorrelated with the uptake of ECB liquidity, even after controlling for bank balance sheet characteristics. In columns (3)-(4), the dependent variable is LTRO uptake backed by the government scheme, which amounts to roughly one third of total central bank borrowing at LTRO. The estimation results shows that, banks with high exposure to the run took advantage of the government guarantee program to access the central bank liquidity.

4.3 Transmission of Central Bank Liquidity

Having confirmed that LTRO uptakes backed by the government scheme capture the share of total LTRO uptakes driven by the run, we next estimate a standard difference-in-difference specification where we compare the *run* and the *intervention* periods:

$$\Delta Log(Credit_{ijt}) = \alpha + \beta_1 Uptake_j \times \mathbb{I}_{Interv} + \mu_{it} + \gamma_j + \phi' X_{ijt} + \epsilon_{ijt} \tag{3}$$

where the dependent variable is the change in the stock of credit granted by bank j to borrower i at time t. Our dependent variable of interest is $Uptake$, defined as the LTRO uptake divided by assets. In Table 7, we show the estimation results. In column (1), $Uptake$ is defined as the total LTRO uptake and the dependent variable is credit granted. We find that the coefficient is not significant. Of course, this result should be interpreted as a simple correlation as the uptake is endogenous. In columns (2) and (3), we repeat the same exercise splitting the uptake backed by the government guarantee ($GovtScheme$) and the uptake backed by standard liquid collateral ($LiquidCollateral$). Consistent with our analysis of the government regulation, we instrument the former with the June 2011 exposure to the foreign wholesale market. The idea is straightforward. As the government scheme is costly, only banks that have a high marginal propensity to borrow from the central bank will use it. The results confirm that uptakes backed by the government scheme explain the entire transmission.

4.4 Government Bond Holdings

Our examination of the LTRO liquidity injection leaves one open question. While all banks take advantage of the ECB extraordinary liquidity facility, the transmission to credit supply occurs mainly through banks exposed to the foreign wholesale market in June 2011. Therefore, how do unexposed banks use ECB liquidity?

	$\Delta CREDIT$ (Granted)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TotalUptake × *Intervention*	0.104			0.042				
	(0.188)			(0.175)				
GovtScheme × *Intervention*		0.632**	0.614**		0.364**	0.349*	1.417***	1.620**
		(0.257)	(0.254)		(0.180)	(0.190)	(0.304)	(0.756)
LiquidCollateral × *Intervention*			-0.145			-0.156		-0.175
			(0.182)			(0.198)		(0.277)
Bank FE	✓	✓	✓					
Bank-Firm (i, j, t) Controls	✓	✓	✓	✓	✓	✓	✓	✓
Firm-Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Bank-Firm FE				✓	✓	✓		✓
Bal. Sheeet (j, t) Controls (incl. interaction terms)				✓	✓	✓		✓
Model	OLS	OLS	OLS	OLS	OLS	OLS	IV	IV
Observation	1,415,856	1,415,856	1,415,856	1,243,174	1,243,174	1,243,174	1,243,174	1,243,174
Within R-squared	0.3677	0.3676	0.3676	0.3731	0.3732	0.3732	0.4712	0.4701

Table 7: Central Bank Facility Uptakes and Credit Supply. This table presents the results from specification (3). The dependent variable is the difference in log (stock of) credit granted. *TotalUptake* is the total LTRO uptake (sum of the two allotments) divided by assets in December 2011. *LiquidCollateral* is the portion of total uptake backed by liquid collateral, divided by assets in December 2011. *GovtScheme* is the portion of total uptake backed by the government scheme, divided by assets in December 2011. Columns (1)-(3) show the results from a simple OLS regression. Column (4) shows the results of an instrumental variable regression where *GovtScheme* × *Intervention* is instrumented by *Exposure* × *Intervention*. *Intervention* is a dummy equal to one in the *intervention* period and zero in the *run* period. The sample period runs from June 2011 to December 2012. The sample includes only firms with multiple relationships at any time t. Standard errors double clustered at the bank and firm level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

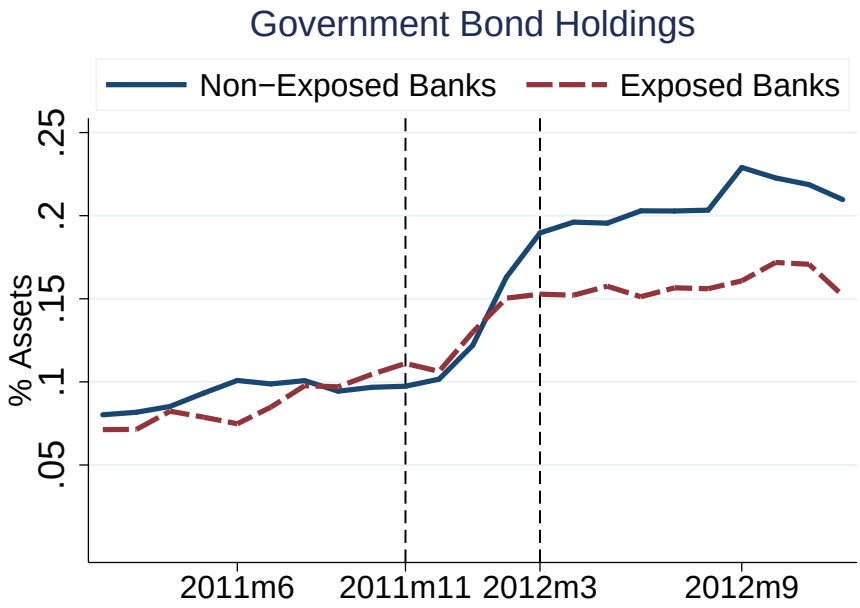

Figure 4: Liquid Asset Holdings. This figure shows government bond holdings, normalized by total assets in December 2011, by banks in our sample. Non-exposed banks are defined as banks in the bottom quartile of exposure to the foreign wholesale market in June 2011. Exposed banks are defined as banks in the top quartile of exposure to the foreign wholesale market in June 2011.

Having analyzed the effect on main illiquid asset class (loans to firms), we now examine how banks manage their liquid asset portfolio. In particular, we study government bonds, the largest and most liquid asset class.[31] Figure 4 shows the evolution of government bond holdings for the two subsamples of exposed (top exposure quartile) and non-exposed (bottom exposure quartile) banks. We observe a rapid increase of holdings between the two LTRO allotment dates. The pattern is more pronounced for non-exposed banks.

[31]There is a large literature on increased government bond holdings by peripheral banks during the crisis. Angelini et al. (2014) suggest that the trend is caused by the general pattern of renationalization and a temporary precautionary liquidity holding following the 3-year LTRO. Other papers attribute the observed pattern to risk-shifting (Acharya and Steffen (2015), Crosignani (2015), and Drechsler et al. (forthcoming)), moral suasion (Ivashina and Becker (2014) and De Marco and Macchiavelli (2015)), or the interplay between regulator and a common central bank (Uhlig (2013)) .

The evidence is consistent with our previous findings as exposed banks use LTRO funds to increase credit supply more compared to non-exposed banks. The large government bond holding increase shown in the figure is consistent with Crosignani et al. (2015), who find a large increase in government bond holdings by Portuguese banks during the LTRO allotments. The authors suggest that peripheral banks, between December 2011 and February 2012, engage in a "collateral trade" by purchasing high yield domestic government bonds that are then pledged at the second LTRO allotment. There might be several motives behind this portfolio choice, ranging from risk-taking to a precautionary hoarding of liquidity.[32]

5 Firm-Level Credit and Aggregate Impact

In Section 3, we established the following facts: (i) there is a credit supply contraction during the run and a credit supply expansion during the intervention periods, (ii) banks reduce credit supply to all firms, except small and risky firms, during the run period, and (iii) increase credit supply to all firms in the intervention period. We now examine which firms benefit the most from the intervention and which firms are hit the most during the run. We do so by looking at the dynamic of total firm credit, namely the credit drawn from all sources (term loans, revolving credit lines, and loans backed by account receivables). In particular, we check whether during the run, firms are able to substitute away from exposed lenders to non-exposed lenders. Similarly, during the intervention period, an increased credit supply might not be followed by an increase in firm total firm borrowing.

We first analyze the cross-section of firms by collapsing our dataset at the firm-time level. For each firm, we compute the indirect exposure, through its banking relationships, to the

[32] Angelini et al. (2014) stresses that "banks needed to temporarily invest the funds acquired from the Eurosystem via the three-year LTROs."

foreign wholesale market in June 2011. Formally, the exposure of firm i is given by the weighted average of its banks' exposures, where the weights are given by the total credit drawn from each bank in June 2011. For each firm i, we compute:

$$\widetilde{Exposure}_{i,Jun11} = \frac{\sum_{j \in \mathcal{R}^i} Drawn_{j,Jun11} Exposure_{j,Jun11}}{\sum_{j \in \mathcal{R}^i} Drawn_{j,Jun11}} \tag{4}$$

where $\mathcal{R}^i$ is the subset of banks that have a relationship with firm i in June 2011. We use this measure to analyze (i) the effect of the run and the intervention on bank total credit and (ii) the effect of the intervention on firm profitability, risk, and investments.

5.1 Effect on Total Firm Credit

First, we examine whether firms are able to avoid the credit contraction during the run by substituting the reduced credit from affected banks with credit from less affected banks. To clarify what we mean by credit substitution, consider the following example. Firm F borrows from bank B1 and bank B2 before the run. The former is exposed to the run. The latter is not exposed. Even if bank B1 reduces its credit supply to firm F, it might still be the case that firm F is able to "undo" the credit contraction by borrowing more from B2 or starting a new relationship with a new bank. By looking at *total* firm credit (extended by all banks), we can check whether this substitution takes place during the run.

Second, we examine whether the increased credit supply during the intervention period corresponds an increased debt at the firm level. It might be the case that firms do not take advantage of the bank credit supply expansion by not expanding their total borrowing. We use the following specifications to address these two questions:

$$\begin{aligned} \Delta Log(Drawn_{it}) = \alpha + \beta_1 \widetilde{Exposure}_{i,Jun11} \times \mathbb{I}_{Run} + \beta_2 \widetilde{Exposure}_{i,Jun11} \times \mathbb{I}_{Interv} \\ + \phi' \Gamma_{it} + \eta_t + \chi_i + \epsilon_{it} \end{aligned} \tag{5}$$

where the dependent variable is the change in the (stock of) total firm i credit at time t, $Exposure_i$ is the indirect exposure of firm i to the foreign wholesale interbank market in June 2011 defined in (4), *Run* and *Intervention* are the usual time dummies, and $\eta_{province,i}$ and $\chi_{industry,i}$ are province and industry fixed effects, respectively.[33] We also saturate the regression with firm-level controls Γ_{it} ($Size$, ROE, $CAPEX$, $Leverage$, $EBITDA$), including their interaction with the two time dummy variables.

Table 8 shows the results. The negative effect of the run on firm credit is stronger for smaller and less profitable firms. Large and highly profitable firms do not suffer from the run. Taken together, these results suggest that firms are unable to completely undo the credit contraction and are therefore impacted by the foreign wholesale market run. The ECB intervention has a positive impact on firm credit regardless of the chosen firm level subsample cut. Interestingly, large and low risk firms seem to benefit from the intervention the most as their total credit increases the most during the *intervention* period.

5.2 Aggregate Impact

We next examine the aggregate impact of the intervention. We use a counterfactual exercise to estimate what the drop in credit would have been from March 2012 to December 2012 if the ECB had not offered the two LTRO allotments.[34] We proceed in five steps. First, we estimate the firm-time fixed effects $\hat{\mu}_{it}$ from our baseline regression (1). By capturing all observed and unobserved firm heterogeneity, these fixed effects effectively capture borrowers credit demand. Second, we compute the firm-level *indirect* exposure to the June 2011-November 2011 funding shock using (4). In this way, we obtain both firm demand and pre-run exposure

[33] In our sample, province fixed effects are based on 111 Italian provinces and industry fixed effects are based on 86 industries.

[34] See Chodorow-Reich (2014b) for a similar counterfactual exercise.

	$\Delta CREDIT$ (Drawn)				
$\mathbb{I}_{Run} \times \widetilde{Exposure}$	-0.701***	-0.563	-0.671***	-0.707***	-0.700***
	(0.159)	(0.492)	(0.172)	(0.158)	(0.159)
$\mathbb{I}_{Interv} \times \widetilde{Exposure}$	0.812***	0.988*	0.781***	0.812***	0.811***
	(0.190)	(0.575)	(0.202)	(0.196)	(0.190)
$\mathbb{I}_{Run} \times \widetilde{Exposure}_{Jun11} \times Size$		-1.854			
		(6.846)			
$\mathbb{I}_{Interv} \times \widetilde{Exposure} \times Size$		-2.381			
		(7.595)			
$\mathbb{I}_{Run} \times \widetilde{Exposure} \times Profitability$			-0.492		
			(0.382)		
$\mathbb{I}_{Interv} \times \widetilde{Exposure} \times Profitability$			0.492		
			(0.331)		
$\mathbb{I}_{Run} \times \widetilde{Exposure} \times LEV$				0.097	
				(0.123)	
$\mathbb{I}_{Interv} \times \widetilde{Exposure} \times LEV$				-0.012	
				(0.251)	
$\mathbb{I}_{Run} \times \widetilde{Exposure} \times Risky$					0.552***
					(0.191)
$\mathbb{I}_{Interv} \times \widetilde{Exposure} \times Risky$					-0.283**
					(0.137)
Time FE	✓	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓	✓
Observations	625,509	625,509	625,509	625,509	625,509
R-squared	0.260	0.260	0.260	0.260	0.260

Table 8: Firm-Level Effects, Credit Substitution. This table presents the results from specification (5), also augmented to include triple interactions with firm balance sheet characteristics. The dependent variable is the difference in log (stock of) total credit. Total credit includes all sources, namely drawn credit from revolving credit lines and loans backed by account receivables and term loans. $\widetilde{Exposure}$ is the firm indirect exposure to the foreign wholesale market in June 2011, divided by assets. $\mathbb{I}_{Run}$ is a dummy equal to one in the *run* and *intervention* periods. $\mathbb{I}_{Interv}$ is a dummy equal to one in the *intervention* period. The *normal* period runs from December 2010 to June 2011. The *run* period runs from June 2011 to December 2011. The *intervention* period runs from December 2011 to June 2012. Firm characteristics are measured in December 2010 and defined as follows: $Size$ is log of total assets; $Profitability$ is EBITDA; LEV is firm leverage; *Risky* is a dummy equal to one if the firm is considered risky based on the Z-score greater or equal than 5 (range 1-9). The firms in the sample have at least two credit lines with two separate banks at any given time t. Standard errors double clustered at the main bank level (as of June 2011) in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

to the wholesale market shock. Third, we plug the stored firm-time fixed effects into the firm-level equation and estimate:

$$\Delta Log(Credit_{it}) = \alpha + \beta_1 Exposure_i \times Run_t + \beta_2 Exposure_i \times Intervention_t + \hat{\mu}_{it} + \epsilon_{it}$$

where (i) the dependent variable is credit granted aggregated at the firm level, (ii) $Exposure_i$ is the firm-level indirect exposure in June 2011 to the foreign wholesale market, and (iii) *Intervention* and *Run* are our standard dummy variables. Fourth, we use the estimated regression coefficients and average exposures to the shock to predict the change in firm loan growth. Finally, we aggregate up at the period-level using a weighted avarege of firm-level loan growths, where the weights are given by firm-level granted credit in December 2012.

We then compare, in a partial equilibrium setting, the world with no ECB intervention to the world with LTROs. We obtain the former by simply setting $\beta_2 = 0$ in the last predictive regression. Of course, the exercise is subject to all caveats associated with a partial equilibrim example. The underlying assumption is that, absent the ECB intervention, the supply of credit granted would have decreased at the same rate during the *run* period. Thus, we find that the LTRO had a positive effect on credit supply, increasing it by 2%. The effect is quantitatively large: without the intervention, according to our partial equilibrium exercise, the credit supply would have contracted by 8.6% in the *intervention* period, instead of the observed 6.6%.

6 Conclusion

In this paper, we analyze the transmission of central bank liquidity injections on bank credit supply. In particular, we study the impact of the ECB December 2011 3-year LTRO on Italian bank credit supply. We show that the banks that experience a foreign wholesale market run before the intervention (i) reduce their credit supply during the period of funding

stress and (ii) expand their credit supply once the ECB injects liquidity into the system. Taking advantage of the Italian credit registry, we control for borrower (firm) observed and unobserved heterogeneity by comparing how the same firm's loan growth from one bank changes relative to another more affected bank. We find that the 3-year LTRO had a positive effect on credit supply in Italy, increasing it by 2%.

We then link the dynamics of bank credit supply with the ECB liquidity uptakes using a regulatory change that allows us to identify uptakes driven by the run. We show that banks that have a higher exposure to the foreign wholesale market erode their collateral in order to replace their missing funding. These banks therefore have scarce collateral at the time of the LTRO intervention, thus they access the costly government scheme that allows them to create additional collateral. We find that the transmission of LTRO to lending supply initially documented is fully driven by the uptakes backed by this newly created collateral.

The contribution of our paper is twofold. First, we examine how a central bank can counter a credit contraction following a negative shock. Most existing papers study, *in isolation*, the negative effect of funding shocks or the positive effects of accommodative monetary policy. We find that a central bank can counter a credit contraction by providing long-term liquidity to banks in exchange for collateral.

Second, we inform policy regarding the role of collateral in the transmission of central bank liquidity provisions. We show that banks that need the liquidity injection the most are those that are mechanically excluded from accessing the central bank liquidity, since they lack the necessary collateral. In this sense, our results indicate that a temporary relaxation of collateral requirements might be instrumental for well-functioning monetary policy during bad times.

By stressing the role of collateral in the transmission of monetary policy, our findings open new research questions. One avenue is evaluating if and to what extent collateral availability and eligibility distort bank portfolio choice. If collateral scarcity causes banks to choose projects that they would have not funded otherwise, the central bank collateral fremework

might have an effect on asset prices. Anticipating this mechanism, central banks might be able to influence bank portfolio choice and asset prices by changing eligibility requirements and haircuts.

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Appendix A Specification

In this section, we consider the following simplified version of (1):

$$y_{jt} = \beta_0 + \beta_1 T_j + \beta_2 \mathbb{I}_{Run} + \beta_3 T_j \times \mathbb{I}_{Run} + \beta_4 \mathbb{I}_{Interv} + \beta_5 T_j \times \mathbb{I}_{Interv} + \epsilon_{it} \tag{A1}$$

where j is a bank and t is a date. T_j is a treatment dummy equal to one for the treated group. There are three periods. The dummy variable $\mathbb{I}_{Run}$ is equal to one in the second and third period. The dummy variable $\mathbb{I}_{Interv}$ is equal to one in the last period.

Claim. The coefficient β_3 captures the difference in y_{it} for the treated group during the second period relative to control group during the first period. The coefficient β_5 captures the difference in y_{it} for the treated group during the third period relative to control group during the second period.

$$\begin{aligned}\beta_3 =& E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 1) - E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 1) \\ & - \big(E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 0) - E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 0)\big) \\ \beta_5 =& E(y_{jt}|Run_t = 1, Intervention_t = 1, T_j = 1) - E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 1) \\ & - \big(E(y_{jt}|Run_t = 1, Intervention_t = 1, T_j = 0) - E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 0)\big)\end{aligned}$$

Proof. Using (A1), we can compute the following conditional expectations

$$\begin{aligned}&E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 0) = \beta_0 \\ &E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 1) = \beta_0 + \beta_1 \\ &E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 0) = \beta_0 + \beta_2 \\ &E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 1) = \beta_0 + \beta_1 + \beta_2 + \beta_3 \\ &E(y_{jt}|Run_t = 1, Intervention_t = 1, T_j = 0) = \beta_0 + \beta_2 + \beta_4 \\ &E(y_{jt}|Run_t = 1, Intervention_t = 1, T_j = 1) = \beta_0 + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5\end{aligned}$$

Hence,

$$\begin{aligned}&E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 1) - E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 1) \\ &- \big(E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 0) - E(y_{jt}|Run_t = 0, Intervention_t = 0, T_j = 0)\big) = \beta_3 \\ &E(y_{jt}|Run_t = 1, Intervention_t = 1, T_j = 1) - E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 1) \\ &- \big(E(y_{jt}|Run_t = 1, Intervention_t = 1, T_j = 0) - E(y_{jt}|Run_t = 1, Intervention_t = 0, T_j = 0)\big) = \beta_5\end{aligned}$$

□

Appendix B Additional Figures

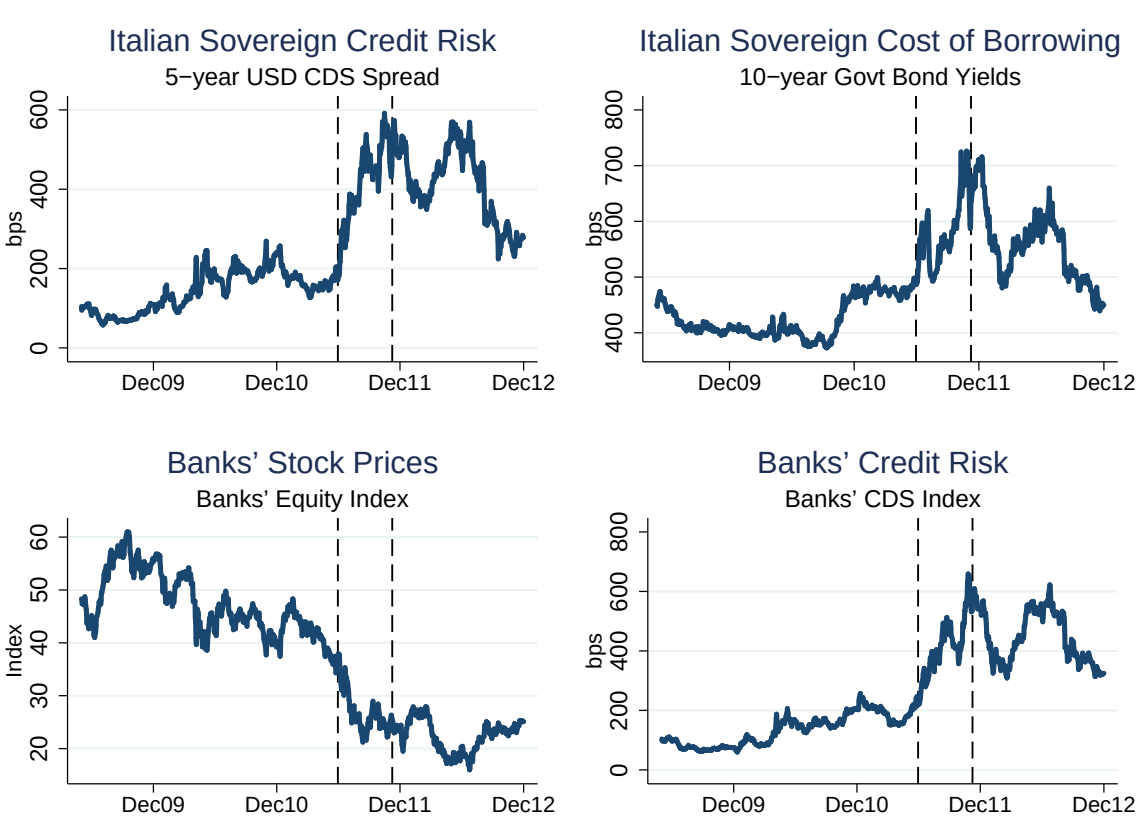

Figure B.1: Italian Bank and Sovereign Credit Risk. The top right left figure shows the Italian Sovereign 5-year USD-denominated CDS spread. The top right figure shows the Italian 10-year government bond yield. The bottom left figure shows Italian banks' equity prices (MSCI Italian Financials Index). The bottom right figure shows mean Italian banks' CDS spread using data on six major banks with CDS spread available on Bloomberg for the entire sample. The two dashed line correspond to June 2011 and November 2011. Souce: Bloomberg.

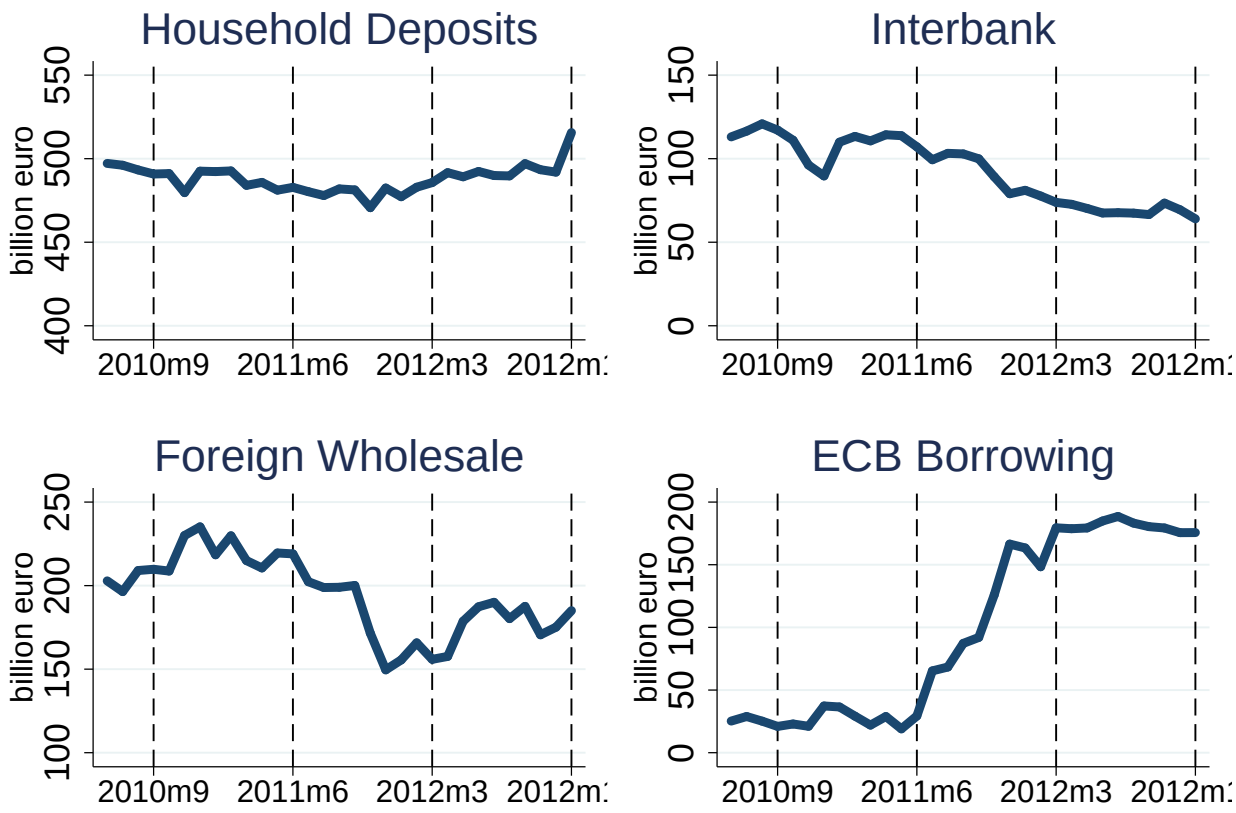

Figure B.2: Bank Funding Sources. This figure shows the composition of bank funding during the sample period. The dashed line correspond to June 2011, March 2012, and December 2012. They identify the three *normal*, *run*, *intervention* periods. The four panel show, respectively, total household deposits, total interbank, foreign wholesale (foreign deposits and centrally cleared repurchase agreements), and borrowing from the European Central Bank. Quantities are in billion €. Source: Supervisory and Statistical Reports at the Bank of Italy.

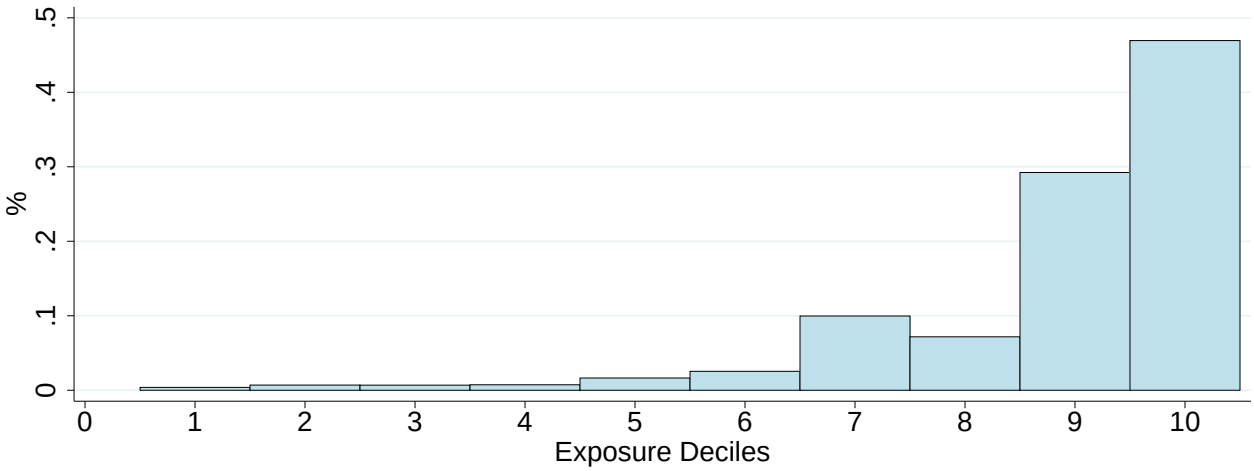

Figure B.3: June 2011 Foreign Wholesale Market Exposure and Loans to Firms. This bar chart shows the correlation between bank-level share of total loans to firms funded and exposure to the foreign wholesale market. The x-axis groups banks in ten deciles according to their exposure to the foreign wholesale market in June 2011. Each bar measures the share of total credit to firms funded by banks in each decile. Exposure deciles are delimited by p(10)=0.000%, p(20)=0.027%, p(30)=0.108%, p(40)=0.207%, p(50)=0.750%, p(60)=1.476%, p(70)=2.737%, p(80)=4.559%, and p(90)=7.567%. The exposure is defined as the sum of bank exposures to (i) foreign deposits (e.g., commercial paper and certificates of deposit held by U.S. money market funds) and (ii) centrally (Eurozone) cleared repurchase agreements, divided by total assets.

Appendix C Additional Tables

Panel A Exposed Banks		Jun10	Dec10	Jun11	Dec11	Jun12	Dec12
Size	€bn	71.94	70.65	70.51	71.03	73.03	74.31
Leverage	units	13.41	13.52	13.32	13.29	14.23	14.20
Tier 1 Ratio	units	10.50	10.62	10.86	11.44	11.56	11.58
RWA	%Assets	68.9%	68.2%	67.3%	65.8%	60.5%	58.3%
Credit to Households	%Assets	16.5%	17.0%	17.2%	17.0%	16.0%	15.7%
Credit to Firms	%Assets	41.4%	41.5%	41.7%	40.3%	37.8%	36.7%
Securities	%Assets	17.0%	16.9%	16.6%	18.3%	23.9%	23.8%
Government Bonds	%Assets	7.7%	8.0%	8.0%	10.2%	16.1%	17.6%
Cash Reserves	%Assets	0.4%	0.4%	0.4%	0.4%	0.4%	0.5%
ROA	Profits/Assets	0.24%	0.46%	0.26%	0.15%	0.20%	0.06%
Central Bank Borr	%Assets	1.50%	3.15%	3.16%	8.25%	10.95%	10.54%
Household Dep	%Assets	26.2%	25.3%	24.7%	24.3%	24.1%	24.9%
Interbank Borr	%Assets	6.3%	5.3%	5.5%	4.1%	3.9%	3.1%

Panel B Non-Exposed Banks		Jun10	Dec10	Jun11	Dec11	Jun12	Dec12
Size	€bn	1.71	1.77	1.82	1.83	1.96	2.08
Leverage	units	10.40	11.06	11.07	11.19	12.21	12.74
Tier 1 Ratio	units	27.72	19.81	17.89	16.44	16.02	15.31
RWA	%Assets	69.7%	69.9%	69.2%	69.8%	63.9%	62.7%
Credit to Households	%Assets	19.8%	20.8%	20.4%	20.4%	18.9%	18.1%
Credit to Firms	%Assets	42.0%	43.8%	44.9%	46.3%	43.1%	42.5%
Securities	%Assets	17.8%	16.8%	16.0%	16.2%	24.5%	23.7%
Government Bonds	%Assets	10.3%	10.0%	10.1%	10.7%	17.9%	17.8%
Cash Reserves	%Assets	0.5%	0.6%	0.6%	0.5%	0.5%	0.5%
ROA	Profits/Ass	0.05%	0.05%	0.02%	-0.06%	0.09%	0.04%
Central Bank Borr	%Assets	0.18%	0.92%	1.38%	3.24%	11.24%	11.55%
Household Dep	%Assets	39.9%	38.9%	37.0%	36.4%	34.6%	34.5%
Interbank Borr	%Assets	1.6%	2.6%	2.7%	6.0%	5.1%	4.9%

Table C.1: Additional Summary Statistics, Bank Characteristics, Exposed and Non-exposed Banks. This table shows cross-sectional means of selected balance sheet items during the sample period. The top panel (bottom panel) shows means for the subsample of exposed (non-exposed) banks. Exposed (Non-exposed) banks have a June 2011 exposure to the foreign wholesale market (above) below median. This table extends the top panel of Table 1 to subsample quartiles.

Firm Characteristics	Dec2010	Dec2011	Dec2012
Q1			
ROE	-0.97	-1.77	-3.30
EBITDA	2.20	1.78	0.86
Leverage	37.94	38.46	35.41
CAPEX	0.20	0.19	0.12
Tot. Debt	434	443	424
Fin. Debt	140	150	145
Size	652	665	650
Q2			
ROE	4.29	3.85	3.51
EBITDA	6.22	5.90	5.27
Leverage	67.85	68.56	66.82
CAPEX	1.44	1.35	1.03
Tot. Debt	1,038	1,064	1,027
Fin. Debt	449	469	457
Size	1,533	1,553	1,523
Q3			
ROE	17.73	17.39	16.87
EBITDA	11.42	11.07	10.37
Leverage	87.25	87.89	87.47
CAPEX	5.69	5.28	4.29
Tot. Debt	2,757	2,845	2,768
Fin. Debt	1,432	1,491	1,462
Size	4,058	4,099	4,025
Mean			
ROE	0.27	-1.57	2.10
EBITDA	6.83	5.06	3.04
Leverage	61.05	62.14	61.76
CAPEX	135.17	41.67	30.97
Tot. Debt	6,016	6,325	6,288
Fin. Debt	3,556	3,730	3,751
Size	9,226	9,299	9,312

Table C.2: Summary Statistics, Firms. This table shows firm summary statistics. The four panels show the first quartile, the median, the third quartile, and the mean, respectively. Firm characteristics include ROE, EBITDA, leverage, CAPEX, total debt, financial debt, and size.

	Mean (%Assets)	**p(25)** (%Assets)	**p(50)** (%Assets)	**p(75)** (%Assets)	σ (%)	**Sum** (€bn)	**No.** (units)
Balance Nov11	5.9%	3.0%	5.5%	8.2%	42.3%	127.0	49
LTRO							
Total Uptake	10.9%	6.0%	9.9%	15.5%	33.9%	170.1	72
New Borrowing	7.9%	3.5%	6.1%	10.4%	34.4%	54.2	72
LTRO1							
Total Uptake	3.2%	0.0%	2.4%	4.9%	34.3%	87.3	47
New Borrowing	1.4%	0.0%	0.5%	2.9%	34.3%	39.8	47
LTRO2							
Total Uptake	7.7%	3.4%	5.5%	9.7%	34.1%	82.8	72
New Borrowing	6.5%	2.0%	4.1%	9.1%	34.6%	14.4	72

Table C.3: Summary Statistics: Borrowing From LTRO. This table shows summary statistics of LTRO uptakes by the banks in our sample. Total uptake is defined as the total LTRO uptake. New borrowing is defined as the change in the total exposure to ECB borrowing around the LTRO allotments. LTRO, LTRO1, and LTRO2 correspond to the the sum of the two allotments, the first allotment, and the second allotment, respectively. The first line shows the total borrowing at ECB in November 2011, before the first LTRO allotment. The last column shows the number of banks taking advantage of the facility.

		Pledged Government Bonds	Available Government Bonds	Central Bank Borrowing	Haircut Adjusted ECB Collateral
Full Sample	Jun11	4.4%	3.9%	2.2%	5.7%
	Nov11	6.7%	3.6%	4.2%	4.7%
Exposure Q1	Jun11	3.4%	6.1%	1.5%	7.7%
	Nov11	4.6%	5.6%	1.8%	6.3%
Exposure Q2	Jun11	3.9%	4.2%	1.0%	6.0%
	Nov11	6.3%	3.6%	2.7%	5.2%
Exposure Q3	Jun11	4.6%	3.3%	2.7%	5.5%
	Nov11	6.9%	3.2%	4.3%	4.4%
Exposure Q4	Jun11	5.3%	2.1%	3.3%	3.7%
	Nov11	9.1%	2.0%	8.0%	2.8%

Table C.4: Evolution of Central Bank Collateral. This table shows summary statistics of (i) stock of available (non-pledged) government bonds, (ii) stock of pledged government bonds, and (iii) central bank borrowing, in June 2011 and November 2011. The top panel shows full sample means. The bottom four panels show subsample means for four subsamples based on banks' exposure to foreign wholesale funding in June 2011. The latter is defined as foreign wholesale funding divided by assets. Q1 (Q4) is the subsample with lowest (highest) exposure to foreign wholesale funding.

	Mean (%Assets)	**p(25)** (%Assets)	**p(50)** (%Assets)	**p(75)** (%Assets)	σ (%)	**Sum** (€bn)	**No. Banks** (units)
Collateral Creation	5.0%	3.1%	5.4%	6.4%	55.8%	68.9	27

Table C.5: Collateral Creation. This table shows summary statistics regarding collateral creation using Government Guaranteed Bank Bonds.