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The design and transmission of central bank liquidity provisions ☆

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ABSTRACT

We analyze the role of loan maturity and collateral eligibility in the transmission of central bank liquidity provisions to banks following a wholesale funding dry-up. We analyze the transmission of the three-year LTRO, which substantially extended the ECB liquidity maturity, in Italy, where banks benefited from a government guarantee program that effectively relaxed the ECB collateral requirements. Combining the national credit register with banks securities holdings, we find that (i) the maturity extension supported banks' credit supply and (ii) banks used most liquidity to buy domestic government bonds and substitute missing wholesale funding, two possibly unstated goals of the intervention.

1. Introduction

During the recent financial crises in the United States, the United Kingdom, and Europe, central banks provided liquidity to banks to counter ongoing credit contractions.[1]

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[1] In the United States, the Term Asset-Backed Securities Loan Facility and the Term Auction Facility helped banks refinance their short-term debt. Outside the United States, the Bank of England Funding for Lending Scheme and the ECB Long Term Refinancing Operations provided

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These interventions are based on the observation that banks hold fewer liquid assets than liquid liabilities and are therefore vulnerable to funding dry-ups, which can induce them to engage in costly fire sales, reducing their credit supply. By providing liquidity, central banks can help banks support their credit supply. While the literature has made progress in linking liquidity support to credit supply, little is known about how central banks should design their liquidity provisions. A clear understanding of the role of specific design features, such as maturity of loans granted or collateral rules, is crucial for a better policy response and a clear understanding of underlying theoretical channels.

We contribute to this literature by analyzing the role of loan maturity and collateral eligibility in the transmission of the European Central Bank (ECB) collateralized liquidity provision to banks during the eurozone crisis. Our focus is the three-year Long-Term Refinancing Operations (LTRO) that had the stated goal to "support bank lending and liquidity in the euro area money markets."[2] We analyze the transmission through Italian banks, which, having experienced a sharp reduction of their foreign wholesale funding before the LTRO, provide a rare case of a dry-up followed by a liquidity provision.[3] The LTRO had two unique features: (i) it extended the maturity of ECB collateralized liquidity from a few months to three years and (ii) it relaxed, in the Italian context, the collateral requirements, thanks to a government guarantee program. In our analysis, we combine the national credit registry with supervisory data on bank security level holdings, obtaining a unique view of the two largest asset classes held by banks.

Our analysis provides two main findings. First, we find that the long maturity of central bank liquidity allowed banks hit by the dry-up to avoid a further deterioration of their credit supply to firms. Short-term liquidity provisions in place during the dry-up were indeed unable to stop the ongoing bank credit contraction. Note that, in a frictionless world, short- and long-term liquidity provisions are equivalent as banks can roll over short-term loans indefinitely. However, if future central bank accommodation is uncertain, short-term liquidity exposes banks to rollover risk, failing, in turn, to support credit supply. Second, we find that banks used most liquidity to buy domestic government bonds and substitute maturing bond financing, helping the stabilization of the banking sector and public debt markets, at the cost of exacerbating the banks-sovereign nexus.

We proceed in three steps. First, we track the time-series evolution of bank credit supply depending on banks' reliance on the foreign wholesale market. We disentangle demand and supply of credit, selecting firms that borrow from two or more banks and plugging firm fixed effects into our specifications. More specifically, we compare the stock of credit granted to the same firm by banks differentially exposed to the dry-up during (i) the "normal" period (December 2010 to June 2011), when funding markets are well functioning; (ii) the "dry-up" period (June 2011 to December 2011), when we observe the dry-up; and (iii) the "intervention" period (December 2011 to June 2012) after the LTRO. High-exposure banks (top decile of the distribution) reduced their credit supply about 0.9 percentage point more during the dry-up (on a baseline contraction of 2.2%) but 1.3 percentage point less after the LTRO compared with median-exposure banks. Our results are robust to the inclusion of bank-firm fixed effects and time-varying bank balance sheet variables, which control for the nonrandom composition of funding (exposed banks are larger and more levered). At the firm level, firms were unable to completely substitute missing credit from exposed banks with new credit from nonexposed banks during the dry-up and increased their total borrowing after the LTRO.

Second, we analyze the transmission channel. Given the two unique features of the LTRO, two channels might be at work. According to the "maturity extension channel," the long maturity of the LTRO helped banks restore their credit supply by reducing their rollover risk. This channel is relevant in our context as the continuation of the ECB's extraordinary monetary easing and the future of the euro were both uncertain in December 2011. According to the "collateral relaxation channel," the eligibility of new assets as collateral at the central bank helped banks restore their credit supply by facilitating access to the LTRO. This channel is relevant in our context as 60% of the LTRO uptake was backed by newly eligible collateral as banks took advantage of a government guarantee program to expand their borrowing capacity at the ECB. Exploiting banks' heterogeneity in short-term liabilities and in available ECB-eligible collateral, we find that the restoration of credit supply is driven by the maturity extension channel, consistent with the observation that banks borrowed freely from the ECB during the dry-up, but this short-term liquidity did not prevent them from reducing their credit supply. Banks' equity prices also support the maturity extension channel: within banks exposed to the dry-up, those more reliant on short-term funding underperformed less reliant banks during the dry-up, but this gap narrowed after the LTRO.

Third, we find that banks used most liquidity to buy domestic government bonds and to substitute expiring bonds, two potentially unstated goals of the policy. The effect on government bond holdings is intuitive as the LTRO allowed banks to engage in a profitable trade by buying high-yield securities financed through the cheap ECB loans. Domestic government bonds were particularly attractive for this trade as they had a high yield, carried a zero regulatory risk weight, and could be used to risk-shift and satisfy an eventual government moral suasion. Consistent with a causal effect of the LTRO, we find that banks substantially increased their domestic government bond holdings right after the policy, mostly purchasing government bonds that matched the maturity of the LTRO. Driven by the large share of bonds expiring in the first half of 2012, a

long-term funding to banks. See Di Maggio et al. (2020) and Krishnamurthy et al. (2018) for excellent analyses of central bank interventions during the recent crises in the United States and Europe.

[2] The announcement is available at www.ecb.europa.eu/press/pr/html/index.en.html.

[3] We observe a stark contraction of wholesale funding from June to December 2011, driven by foreign deposits (mainly U.S.-held certificates of deposit and commercial paper) and eurozone centrally cleared repurchase agreements.

period where wholesale markets were hard to tap, banks also used the LTRO to replace their maturing bonds.

Our results suggest that, of the € 170 billion borrowed, our sample banks used € 85 billion to buy government bonds, € 18 billion to restore credit supply, and € 64 billion to substitute missing wholesale funding, mostly in the form of bank bonds (€ 47 billion). The effect on credit supply is nevertheless sizable. In a counterfactual exercise, we find that, without the LTRO, private credit would have contracted 5.6% in the first half of 2012 instead of the observed 3.6%.

Our contribution is twofold. First, after documenting the well-established pass-through of bank negative funding shocks to credit supply (Khwaja and Mian, 2008; Paravisini, 2008; Chava and Purnanandam, 2011; Schnabl, 2012; Iyer et al., 2014), we show that a subsequent central bank liquidity provision, *if long term*, allows banks to avoid a further reduction of their credit supply. In particular, this type of intervention, related to the seminal lender of last resort literature (Bagehot, 1873), replenishes bank funding sources following a dry-up and is therefore inherently different from policies that affect the value of securities held by banks such as large-scale asset purchases (Di Maggio et al., 2020; Krishnamurthy and Vissing-Jorgensen, 2013; Chakraborty et al., 2020; Kandrac and Schlusche, forthcoming; Darmouni and Rodnyansky, 2017; Kurtzman et al., forthcoming) and policies like yield curve flattening (Foley-Fisher et al., 2016), indirect recapitalizations (Acharya et al., 2019), and negative rates (Di Maggio and Kacperczyk, 2017; Heider et al., 2019).[4] Our analysis also informs policy about the role of loan maturity and collateral rules (Choi and Santos, forthcoming; Cahn et al., 2020) for the transmission of central bank liquidity provisions during crises.

Second, we find that central bank liquidity is largely used to buy domestic government bonds. By jointly analyzing holdings of securities and loans to firms, the two largest asset classes held by banks, we add to the literature on the transmission of monetary policy through banks (Bernanke and Blinder, 1992; Stein, 1998; Kashyap and Stein, 2000), typically focused on credit to firms (Jimenez et al., 2012) or households (Di Maggio et al., 2017; Agarwal et al., 2018).[5]

Our findings also relate to the literature on the ECB's recent extraordinary policies (see Krishnamurthy et al. (2018) for an excellent overview), such as the Outright Monetary Transactions program, an announcement that triggered a sizable recapitalization of banks (Ferrando et al., 2018; Acharya et al., 2020; 2019), and the Security Markets Program (Eser and Schwaab, 2016; Koetter et al., 2017) and Corporate Sector Purchase Program (Abidi and Miquel-Flores, 2018; Arce et al., forthcoming; Grosse-Rueschkamp et al., 2019), two types of large-scale asset purchases.[6] More importantly, Daetz et al. (2018), Darracq-Paries and De Santis (2015), Alves et al. (2016), Andrade et al. (2019), and Garcia-Posada and Marchetti (2016) also analyze the LTRO. Compared with these papers, we contribute by (i) analyzing the role of loan maturity and collateral eligibility for the transmission of central bank liquidity, (ii) analyzing a setting with an ongoing funding dry-up, and (iii) jointly examining credit to firms and holdings of securities.[7]

The rest of the paper is structured as follows. Section 2 tracks the empirical setting. Section 3 documents the evolution of bank credit supply. Section 4 analyzes the LTRO transmission channel. Section 5 shows the effect of the LTRO on government bond holdings and banks' overall balance sheet. Section 6 presents some additional results. And, Section 7 concludes.

2. Setting and data

Our laboratory is Italy from December 2010 to June 2012. In this section, we describe the Italian macroeconomic environment during this period, show that Italian banks are hit by a wholesale funding dry-up in the six months before the LTRO, and describe our data set.

2.1. Macroeconomic picture

Sovereign yields of core and "peripheral" (Greece, Italy, Ireland, Portugal, Spain) eurozone countries first diverged in 2009, driven by concerns about the public debt sustainability of peripheral countries.

The crisis in Italy started in 2009 and can be divided into two phases. During the first phase, from 2009 to June 2011, Italian government bond prices fell 25% and sovereign CDS spreads doubled to reach 200 basis points as investors became 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 S&P downgraded the Greek debt to CCC and announcements of the involvement of the private sector in Greek debt restructuring led to contagion in Italy.

During the second phase, from June to December 2011, sovereign CDS spreads and bond yields started increasing very sharply, reaching record highs in November 2011.[8] As

[4] Large-scale asset purchases operate through banks by increasing the value of some of their assets (e.g., Treasury securities or mortgage-backed securities), which, in turn, causes banks to rebalance their portfolios. Similarly, announcements like Draghi's OMT speech can lead to indirect recapitalizations of weak banks (Acharya et al., 2019).

[5] Crosignani et al. (2020) and Peydró et al. (forthcoming) use security level data to analyze banks' holdings of eligible collateral during the LTRO and the role of bank capital for the risk-taking channel of monetary policy, respectively.

[6] See Garcia-de-Andoain et al. (2016), Casiraghi et al. (2013), and Szczerbowicz (2015) for broader analyses of ECB interventions. The pass-through of sovereign risk through banks is analyzed by Beltratti and Stulz (2019), Popov and van Horen (2015), De Marco (2019), Bottero et al. (2020), Bofondi et al. (2018), and Acharya et al. (2018).

[7] Alves et al. (2016), Andrade et al. (2019), and Garcia-Posada and Marchetti (2016) use credit registry data from Portugal, France, and Spain, respectively. Daetz et al. (2018) use eurozone syndicated loan data and Darracq-Paries and De Santis (2015) estimate a panel VAR.

[8] Greece was downgraded five times by the three main credit rating agencies in June and July. As shown in Bofondi et al. (2018), sovereign yields then also abruptly rose in Italy, as investors feared that Italy might have also been unable to repay its public debt. With sovereign yields rising, support for the Italian government fell, forcing Prime Minister Silvio Berlusconi to resign in favor of the technocratic government led by Mario

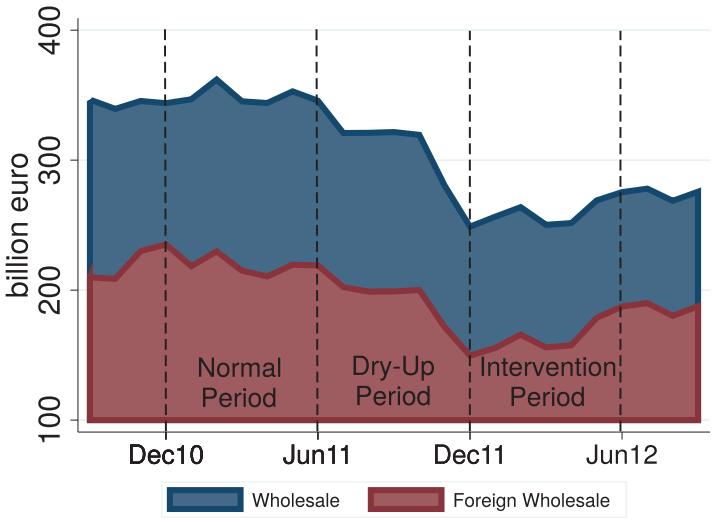

Fig. 1. Foreign wholesale funding dry-up. This plot shows the total wholesale market funding (foreign and domestic wholesale, excluding bond financing) and the foreign wholesale market funding of our sample banks. Our sample is presented in Section 2.3. The total wholesale funding corresponds to the sum of the blue and red areas. Quantities are in billion euro. Source: Bank of Italy. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

concerns about the solvency of the sovereign and its financial sector mounted, Italian banks experienced a dry-up of their wholesale funding, driven by withdrawals of foreign investors.

2.2. Bank funding during the crisis

During the first phase of the crisis, from January 2009 to June 2011, bank funding sources proved to be somewhat resilient. Retail funding increased slightly, whereas wholesale funding dropped by 3 percentage points of total assets. Short-term central bank liquidity partially substituted for this drop, reaching 2.2% of total assets in June 2011. In particular, in the first half of 2011, Italian banks could still count on stable funding from both retail deposits and wholesale markets.[9]

During the second phase, in the six months from June to December 2011, wholesale funding declined by 5 percentage points. This drain in funds was again offset by short-term central bank liquidity, which, at the end of 2011, represented 5.7% of total assets. This dry-up in wholesale funds, called a "quiet run" by Chernenko and Sunderam (2014), was driven by a sharp reduction in *foreign* funding, mainly certificates of deposits and commercial paper held by U.S. money market funds and eurozone centrally cleared repurchase agreements. In Fig. 1, we illustrate, for our sample banks described in Section 2.3, the € 97 billion drop in wholesale funding (equivalent to 3.6% of their size) driven by foreign withdrawals between June and December 2011. In Section 3.1, we show a substantial heterogeneity, in the cross-section of banks, behind this aggregate drop in wholesale funding. In December 2011, the ECB introduced the LTRO and the dry-up stopped.

The ECB had started providing extraordinary liquidity to banks as early as October 2008, when it switched to a "fixed-rate full-allotment" mode for its refinancing operations. In this new regime—still ongoing—eurozone banks can obtain unlimited liquidity from the central bank at a fixed rate as long as they pledge sufficient eligible collateral. The ECB applies a haircut on collateral that depends on the asset class, residual maturity, rating, and coupon structure of the pledged security. There is no limit on how much a bank can borrow, provided that it posts adequate collateral.[10]

The LTRO On December 8, 2011, the ECB increased its support of the eurozone banking sector even further, announcing the provision of two three-year maturity loans, the LTRO, 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." As pointed out by many commentators, the LTRO also likely had the implicit goals of (i) helping eurozone banks that had a substantial bond refinancing need in the first half of 2012 (€ 43 billion for our sample banks) and (ii) supporting the public debt markets of peripheral eurozone countries.[11]

Monti. In Fig. B.1 in the Appendix, we show the time-series evolution of various macroeconomic variables around this time.

[9] The issuance of bonds by Italian banks was particularly strong in the first half of 2011. By July 2011, Italian banks' bond issuance was greater than the volume of bonds maturing in the whole of 2011 (Bank of Italy, 2011b).

[10] Eligible collateral includes government and regional bonds, covered bonds, corporate bonds, asset-backed securities, 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.

[11] Referring to the LTRO, French President Nicolas Sarkozy stated: "This means that each state can turn to its banks, which will have liquidity at their disposal" (*Financial Times*; December 14, 2011). For an analysis of the effect of the LTRO on eurozone peripheral sovereign markets, see Crosignani et al. (2020). Bank of Italy (2012a) states that one of the goals of the LTRO was to "alleviate the funding difficulties of banks caused by

While the interest rate and the haircuts did not change from previous standing operations, the LTRO had two distinctive features compared with preexisting liquidity facilities available to Italian banks.[12] The first feature is the three-year maturity. With the exception of a one-year loan allotted in October 2011, previous facilities had a maturity ranging from one week to six months.[13] The second feature, unique to the Italian setting, is a de facto relaxation of the collateral requirement. Right after the LTRO announcement, the Italian government offered banks a guarantee on securities *otherwise ineligible* at the ECB, secured by paying a fee. As the ECB accepts all government-guaranteed assets as collateral, the program effectively gave banks a technology to "manufacture" ECB-eligible collateral and therefore increase their borrowing capacity at the ECB, consistent with an implicit coordination between the fiscal and monetary authorities.[14]

Almost all Italian banks that are usually counterparties of the ECB open market operations tapped the LTRO.[15] Our sample banks obtained € 170 billion (€ 181.5 billion if we also include foreign branches and subsidiaries of Italian banks), consisting of € 87.3 billion at LTRO1 and € 82.7 billion at LTRO2. Sixty percent of the LTRO uptake was backed by newly created eligible collateral. It is an economically large quantity, as the mean uptake was 10.9% of total assets.[16] This large uptake is not surprising: the long-term LTRO liquidity was an opportunity not to be missed for banks, as its interest rate and haircuts were generally more attractive, especially in peripheral countries like Italy, than those available in the private market.[17]

2.3. Data

In this section, we describe the data set construction. Our unit of observation is at the (i, j, s, t) level, where i is a firm, j is a bank, s is a security, and t is a date. Data on banks refer to the banking group level, consolidated at the national level. We combine information from various sources.

First, at the (i, j, t) firm-bank-period level, we obtain data on all outstanding loans with a balance 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 data set is extremely high, as banks are 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 (most of them biannually) and detailed information on bank funding. In particular, we observe funding by asset class and maturity, including LTRO borrowing. The source is the Supervisory and Statistical Reports submitted by intermediaries to the Bank of Italy.

Third, at the (s, j, t) security-bank-period level, we observe holdings of each marketable security held by Italian banks from the Supervisory Reports. We also observe time-invariant information (e.g., issuer) from Datastream, whether the security is ECB-eligible collateral and its haircut at LTRO from the ECB, and whether it is pledged (at the ECB or in the private market) or available.

Fourth, at the (i, t) firm-period level, we have information on firms' characteristics from end-of-year balance sheet data and profitability ratios from official firm reports available from the Italian Chamber of Commerce (CebiCerved database).

Our final data set is obtained by merging all data sources and focusing on a large sample of banks. First, given our focus on the transmission of a monetary policy intervention, we select the sample of 115 banks that are counterparties of the Bank of Italy at least once in the sample period. Second, we exclude 11 foreign banks (branches and subsidiaries) operating in Italy, as we only observe the liquidity provisions that banks obtained from the ECB through the Bank of Italy and not their total ECB borrowing, which is likely much larger. Third, we exclude 19 mutual banks and their central institutes, as in most cases the latter tapped the ECB liquidity and then redistributed funds among the former, but we do not observe the allocation of liquidity among affiliated banks. Fourth, we exclude four banks involved in extraordinary administration procedures around the time of the LTRO, as their

the sovereign debt tensions and aggravated by the large volume of bank bonds maturing in the first half of 2012."

[12] The interest rate on the LTRO is the average rate of the regular main refinancing operations over the life of the operation, to be neutral compared with preexisting short-term loans. The regulatory treatment of long-term and short-term loans from the ECB is also equivalent. Banks had the option of repaying the LTRO loans after one year. No other major changes were made on the haircuts or eligibility of collateral securities, with the exception of selected asset-backed securities (ABS). In December 2011, the ECB started accepting ABS with a second-best rating of at least "single A" (see Van Bekkum et al. (2018)). The ECB also allowed national central banks to temporarily accept selected bank loans ("additional credit claims") in addition to those eligible before the intervention, but this change was implemented only in July 2013 by the Bank of Italy.

[13] The maturity of ECB liquidity facilities is usually between one week and three months. During the crisis, the ECB adopted extraordinary 6- and 12-month operations (April 2010, May 2010, and August 2011).

[14] Banks could obtain the government guarantee on zero-coupon, senior, unsecured, euro-denominated bank bonds. 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 allow the bonds to go to the market or to investors, but keep them on the asset side of the balance sheet. Paying a fee to the Treasury, banks could then obtain a government guarantee on these newly created bonds (called Government Guaranteed Bank Bonds) so that they became eligible to be pledged at the LTRO. In the Online Appendix, we provide a detailed description of this government guarantee program as well as anecdotal evidence on its rationale and use by banks. Using our security level data set, we confirm that these government-guaranteed securities are used as collateral at the ECB.

[15] All banks have access to the ECB, but very small banks are not typically counterparties of ECB open market operations. Even if the costs (e.g., fees) of accessing the ECB are very low, these small institutions lack the know-how and IT infrastructure to deal with ECB operations.

[16] The median uptake was 9.7% of total assets. More than 95% of banks that are usually counterparties of the ECB's open market operations borrowed at the LTRO. For more descriptive statistics, see Bank of Italy (2012b).

[17] Consistent with ECB liquidity being particularly attractive in the eurozone periphery, approximately two-thirds of the total LTRO liquidity was allotted to Italian and Spanish banks. Banks located in core countries could, in general, obtain cheaper funding in private markets. See Drechsler et al. (2016) for a discussion of the ECB subsidy.

Table 1
Summary statistics: bank characteristics and credit growth. The top panel shows cross-sectional means of selected balance sheet characteristics from June 2010 to December 2012. The bottom panel shows changes (difference in log stocks) in (i) total credit on term loans and drawn from revolving credit lines and loans backed by account receivables and (ii) total credit on term loans and committed on revolving credit lines and loans backed by account receivables. Source: Bank of Italy.

Bank-level		Jun10	Dec10	Jun11	Dec11	Jun12	Dec12
Total assets	€ billions	37.3	36.7	36.6	36.4	37.5	37.7
Leverage	Units	11.9	12.3	12.2	12.2	13.2	13.5
Tier 1 ratio	Units	19.0	15.2	14.3	13.9	13.8	13.4
Risk-weighted assets	%Assets	69.3	69.0	68.3	67.8	62.2	60.5
Nonperforming loans	%Loans	8.2	8.5	9.1	9.9	11.7	12.7
Private credit	%Assets	59.5	62.8	65.2	66.8	67.6	69.4
Credit to households	%Assets	16.3	17.5	18.2	18.7	19.2	19.9
Credit to firms	%Assets	38.4	40.5	42.2	43.4	43.6	44.6
Securities	%Assets	17.4	16.9	16.3	17.3	24.2	23.7
Government bonds	%Assets	5.6	6.5	8.0	9.1	16.6	19.6
Cash reserves	%Assets	0.4	0.5	0.5	0.5	0.4	0.5
ROA	%Assets	0.1	0.3	0.1	0.0	0.1	0.1
Central bank borrowing	%Assets	0.9	2.0	2.2	5.7	12.5	13.5
Household deposits	%Assets	33.0	32.0	30.8	30.3	29.3	29.8
Wholesale funding	%Assets	8.1	8.5	8.4	7.7	8.0	8.5
Bond financing	%Assets	18.6	18.5	19.2	18.0	16.3	14.8

Loan-level	Loan type	Dec10–Jun11	Jun11–Dec11	Dec11–Jun12
ΔCreditDrawn	All types	6.2%	−2.1%	−3.1%
ΔCreditGranted	All types	4.7%	−2.2%	−3.6%

credit policies are likely to have very small discretion margins. Fifth, we exclude seven banks that specialize in specific activities such as wealth or nonperforming loans management. Our final sample consists of 74 banking groups ("banks"), equivalent to about 70% of total assets of banks operating in Italy in June 2011.

In the top panel of Table 1, we show bank level summary statistics at six dates around the introduction of the LTRO. Two features stand out: (i) two jumps in central bank borrowing around the two LTRO allotments (December 2011 and February 2012) and (ii) a stark increase in holdings of securities, driven by government bonds, between December 2011 and June 2012. In Table 5, we discuss the effect of the LTRO on banks' balance sheet composition, mostly focusing on holdings of government bonds. In the bottom panel, we show changes in credit to firms, where credit is the sum of term loans, revolving credit lines, and loans backed by account receivables. We report separately credit drawn and credit granted (committed). Changes in both credit granted and drawn are large and negative after June 2011, when Italian banks were hit by the dry-up.[18]

3. Bank credit supply during the dry-up and the LTRO

In this section, we document the evolution of bank credit supply for banks differentially exposed to the foreign wholesale dry-up. We isolate bank credit supply by restricting our sample to the large number of firms that borrow, in any given period, from two or more banks and then comparing changes in credit from different banks *within* firms (Khwaja and Mian, 2008).[19] In Section 3.1, we present our measure of bank exposure to the dry-up. In Section 3.2, we show that more exposed banks reduced their credit supply during the dry-up, but restored it after the LTRO.

3.1. Exposure to the wholesale funding dry-up

We use banks' reliance on the foreign wholesale funding in June 2011 as a measure of bank exposure to the June–December 2011 dry-up. The intuition is that banks with high exposure to the foreign wholesale funding are more affected by the dry-up than less exposed banks. In the Online Appendix, we validate this measure by showing that the exposure to the foreign wholesale market in June 2011 explains the June–December 2011 dry-up, controlling

[18] The time-series evolution of Italian banks' aggregate credit growth by Italian banks to domestic nonfinancial companies is publicly available at the statistical database at www.bancaditalia.it. Credit growth collapsed from above 10% year-over-year before the collapse of Lehman to around 0% year-over-year at the end of 2009. At the beginning of 2010, credit growth started increasing again and stabilized at around 5% year-over-year in the first half of 2011. In the fall of 2011 (during our dry-up period), credit growth collapsed until the summer of 2012 and then kept falling more gradually, reaching record lows in the fall of 2013. In sum, while the first signs of the sovereign crisis were evident at the end of 2010, the deterioration of credit growth accelerated dramatically in the fall of 2011 during the dry-up.

[19] Our sample includes approximately 1.4 million observations at any given date. In most of our analysis, we focus on firms with multiple relationships. We make sure that this subsample, which includes approximately 0.7 million observations (275,000 unique firms) at any given time, is comparable to the full sample. Approximately 170,000 firms have two relationships at any given date, 60,000 have three relationships, 24,000 have four relationships, and 21,000 have five or more relationships. See Ongena and Smith (2000) for a discussion of multiple relationships in Italy.

Table 2
Summary statistics for exposed and non-exposed banks. This table shows June 2011 bank summary statistics (subsample medians) for exposed and nonexposed banks. The last column shows the Imbens and Wooldridge (2009) normalized difference. Exposed (nonexposed) banks have exposure to the foreign wholesale market above (below) the median in June 2011. Source: Bank of Italy.

Balance-Sheet Item	Unit	Exposed banks	Non-exposed banks	Normalized difference
Total assets	€ billions	11.0	1.3	0.38
Leverage	Units	13.2	10.8	0.37
Tier 1 ratio	Units	9.1	11.4	−0.30
Risk-weighted assets	%Assets	71.2	68.0	−0.09
Nonperforming loans	%Loans	8.6	8.7	−0.21
Private credit	%Assets	68.9	70.1	−0.14
Credit to households	%Assets	17.1	20.0	−0.24
Credit to firms	%Assets	43.7	47.0	−0.13
Secusrities	%Assets	14.2	14.0	0.04
Government bonds	%Assets	7.1	6.2	−0.10
Cash reserves	%Assets	0.4	0.5	−0.36
ROA	%Assets	0.2	0.1	0.52
Central bank borrowing	%Assets	1.8	0.0	0.37
Household deposits	%Assets	24.7	34.9	−0.66
Wholesale funding	%Assets	12.2	1.6	1.22
Bond financing	%Assets	22.8	20.2	0.07

for other bank characteristics (our "first stage").[20] We define bank j's exposure as the foreign wholesale funding normalized by total assets in June 2011, just before the dry-up:

$$Exposure_{j,Jun11} = \frac{ForeignWholesale_{j,Jun11}}{TotalAssets_{j,Jun11}}, \quad (1)$$

where $ForeignWholesale$ is the sum of foreign deposits (mainly commercial paper and certificates of deposit held by U.S. money market funds) and eurozone centrally cleared repurchase agreements. Approximately half of our sample banks have a small exposure, below 1%. However, banks with exposure above 5% are quantitatively important, as they hold 75% of total credit to firms.[21]

Of course, banks' funding mix in June 2011 is correlated with other observable and unobservable characteristics of banks. In Table 2, we show bank summary statistics for exposed (above median exposure) and nonexposed (below median exposure) banks in June 2011. Exposed banks tend to be larger, more levered, and less reliant on household deposits than non-exposed banks. This correlation is intuitive. On the one hand, large banks obtain a sizable amount of funding through wholesale markets and very large banks, in particular, have a nonnegligible share of total funding coming from foreigners.[22] On the other hand, small banks are usually present in local markets, where they have a large and stable household deposit base. As will become clear from our main specification, we include bank balance sheet controls as well as stringent fixed effects to tackle the potential omitted variable bias originating from these differences in observables. In particular, we include a nonlinear control for bank size to confirm that our results are not driven by size.

From an empirical standpoint, our choice to use banks' exposure to foreign wholesale funding as a source of heterogeneity is motivated by the endogenous nature of LTRO borrowing. More specifically, banks can *choose* how much to borrow long-term at the LTRO. Hence, were we to use the heterogeneity of banks' LTRO borrowing as a source of variation, we would likely capture other bank characteristics and our results would suffer from an omitted variable bias.[23] In Fig. 2, we show that bank uptake of LTRO liquidity and bank exposure to the dry-up are uncorrelated: banks tap liquidity for approximately 10% of total assets, *regardless* of their exposure to the dry-up. In particular, we divide banks into quartiles according to their exposure to the dry-up (x-axis) and show that their LTRO uptake, normalized by total assets (y-axis), is unrelated to the exposure to the dry-up.

From a theoretical standpoint, our choice to use banks' exposure to foreign wholesale funding as a source of het-

[20] In the Online Appendix, we also show, nonparametrically, that banks more exposed to the dry-up (above median exposure) experienced a reduction of their wholesale funding while less exposed banks (below median exposure) did not change their wholesale funding during the dry-up. Consistent with ECB short-term liquidity substituting for the missing wholesale funding, the evolution of total assets of more and less exposed banks is similar.

[21] The 10th, 30th, 50th, 70th, and 90th percentiles of the distribution of the exposure variable are 0.0%, 0.1%, 0.8%, 2.7%, and 7.6%, respectively. In the Online Appendix, we show the distribution of banks' exposure to the dry-up.

[22] There is ample evidence that very large banks were hit by a shock in the second half of 2011 because of their exposure to the foreign wholesale funding dry-up. Bank of Italy (2012b) acknowledges that "foreign fund raising is the almost exclusive preserve of the bigger banks." In its description of the dry-up, Bank of Italy (2012a) states that "the contraction in funding was especially pronounced for large banks. The funding of the five largest banking groups shrank by 5.5 per cent in the twelve months ending in November, mainly owing to the fall in non-residents' deposits and overnight deposits." Finally, Bank of Italy (2011a) states that "the largest banks were more affected by the turmoil generated by the sovereign debt crisis, mainly because they make greater recourse to international markets for wholesale funding."

[23] The existing papers on the LTRO transmission simply use banks' endogenous uptake of ECB liquidity as a source of variation (Andrade et al., 2019; Daetz et al., 2018; Alves et al., 2016; Garcia-Posada and Marchetti, 2016).

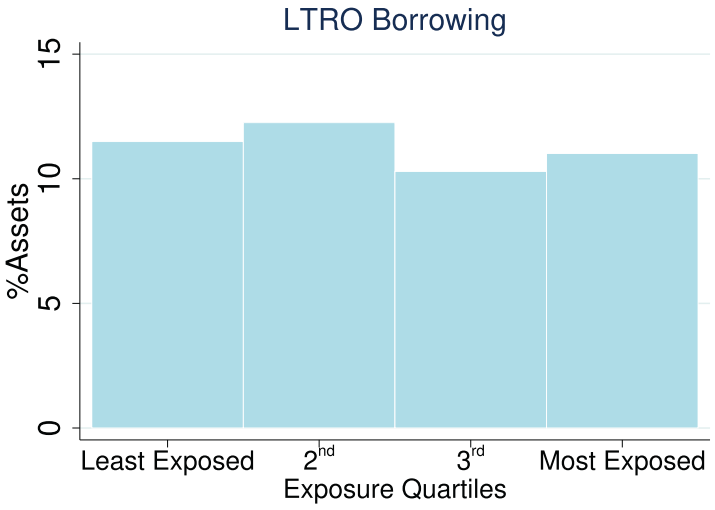

Fig. 2. LTRO uptakes by bank exposure quartile. This histogram shows, for each dry-up exposure quartile, mean LTRO uptakes, normalized by assets in June 2011. Banks are divided into quartiles according to their exposure to the foreign wholesale market in June 2011. Source: Bank of Italy.

erogeneity closely follows the theory of wholesale market dry-ups. Dry-ups are the result of asymmetric information, as borrowers know more than lenders about their own financial health than lenders. In an economy populated by only uninformed lenders, following a shock, lenders become concerned about the quality of borrowers and interest rates go up for *all* borrowers. High-quality borrowers then self-select out of the market, causing uninformed lenders to stop lending to *all* borrowers (Akerlof, 1970). However, if there are some informed lenders in the economy, they will stop lending to low-quality borrowers (Gorton and Pennacchi, 1990; Calomiris and Kahn, 1991). To isolate the correlation between the exposure to the dry-up and bank credit supply, we include a set of control variables that capture bank vulnerability (leverage, tier 1 ratio, nonperforming loans ratio, ROA), therefore controlling for the potential selective withdrawals of informed lenders.[24]

3.2. Funding dry-ups and the evolution of bank credit supply

Following the timing suggested by Fig. 1, we compare three periods: (i) the *normal* period, from December 2010 to June 2011, when funding markets are well functioning; (ii) the *dry-up* period, from June 2011 to December 2011, when we observe a dry-up in the foreign wholesale market; and (iii) the *intervention* period, from December 2011 to June 2012, after the LTRO.[25]

We use a difference-in-differences specification to demonstrate the evolution of bank credit supply during the dry-up and intervention periods. In particular, we (i) compare the stock of credit granted by bank j to firm i in the dry-up period to the same (i, j) stock of credit granted in the normal period, and (ii) compare the stock of credit granted by j to i in the intervention period to the same (i, j) stock of credit granted in the dry-up period.[26] More specifically, we estimate the following model:

$$\begin{aligned}\Delta CreditGranted_{ijt} &= \alpha + \beta_1 Exposure_{j,Jun11} \times \mathbb{I}_{DU,LTRO} \\ &+ \beta_2 Exposure_{j,Jun11} \times \mathbb{I}_{LTRO} + \mu_{it} + \gamma_{ij} + \phi' X_{ijt} + \epsilon_{ijt},\end{aligned} \tag{2}$$

where observations are at the (i, j, t) firm-bank-period level. We use the four dates that delimit the normal period, the dry-up period, and the intervention period: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 firm i at time t.[27] $Exposure_{Jun11}$ is bank j's exposure to the foreign wholesale market in June 2011, defined in (1). $\mathbb{I}_{DU,LTRO}$ is a dummy equal to one in the dry-up and the intervention periods and $\mathbb{I}_{LTRO}$ is a dummy equal to one in the intervention period only. We add bank-firm fixed effects to absorb any bank-firm time-invariant characteristics, including any time-invariant bank characteristic. We also plug in firm-time fixed effects to control for both observable and unobservable firm heterogeneity, crucially capturing firm demand for credit at time t.

Intuitively, as in a standard difference-in-differences setting, β_1 captures the difference in credit growth between more exposed and less exposed banks during the dry-up period relative to the normal period. Similarly, β_2 captures the difference in credit growth between more exposed and less exposed banks during the intervention period relative to the dry-up period.[28] We rely on two identification assumptions: (i) exposed banks would have

[24] Perignon et al. (2018) show that in the European market from 2008 to 2014 dry-ups are consistent with theories featuring informed and uninformed lenders reacting to a deterioration in the quality of borrowers.

[25] We end the sample in June 2012 to avoid overlapping with the July 2012 Draghi OMT announcement.

[26] By stacking two diff-in-diff specifications, we estimate the time-invariant fixed effects on the entire sample period.

[27] Credit granted includes drawn and undrawn credit. In line with empirical studies that use credit registry data, we use credit granted as our dependent variable, as credit drawn is more likely to be driven by firm demand.

[28] In the Online Appendix, we prove this claim analytically.

behaved like nonexposed banks during the dry-up period in the absence of the dry-up, and (ii) exposed banks would have behaved like nonexposed banks during the intervention period in the absence of the LTRO.[29]

Given that bank exposure is not randomly assigned to banks, we ensure that our results are robust to the inclusion of key balance sheet characteristics *interacted* with the two time dummies.[30] These characteristics are leverage, return on assets, tier 1 ratio, nonperforming loans ratio, and a nonlinear control for bank size. This nonlinear control is particularly important as very large banks (i) have a high exposure to the dry-up and (ii) account for a very large share of our borrower-bank level observations. More specifically, given that the largest five banking groups originate 60.2% of our loans and are among the top-ten most exposed banks, we include a variable equal to banks' total assets for the largest five banking groups and equal to zero for all other banks.[31]

Finally, we add firm-bank relationship variables (vector X) to control for specific characteristics of the bank-firm credit relationships that might change over time. 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 to committed credit (measuring how close firm i is to exhausting its borrowing capacity from bank j), and (iii) the share of overdraft credit by firm i with respect to bank j (measuring the extent of an eventual overborrowing).

In Table 3, we show the estimation results, progressively saturating our specification with fixed effects and controls. In columns (1) and (2), we include time and bank fixed effects. The sample is the only difference between the two columns, as column (2) only includes firms that have multiple relationships. In column (3), we include firm-time fixed effects to control for firm time-varying credit demand. These estimation results show a negative effect of the dry-up and a positive effect of the intervention on bank credit supply. The estimated coefficients are stable, suggesting that (i) the subsample of firms with multiple relationships is comparable to the full sample and (ii) firms borrowing from exposed banks do not systematically demand more or less credit during the dry-up and more or less credit during the intervention period compared to less exposed banks. In other words, firm demand does not seem to be a major identification concern in this setting.

In column (4), we include the relationship control variables to account for time-varying bank-firm relationship characteristics. In column (5), we include the more stringent bank-firm fixed effects to exploit the variation within the same firm-bank pair over time, thereby controlling for any time-invariant relationship characteristics. Again, affected banks' credit supply contraction during the dry-up relative to unaffected banks is offset by an increase after the LTRO.[32]

In column (6), we saturate the specification with bank balance sheet characteristics *interacted* with the two time dummies. Again, we confirm that banks with a large exposure to the foreign wholesale market reduce their credit supply more during the dry-up, but less during the intervention period, compared with less exposed banks.[33] The estimates of the balance sheet controls suggest that banks with better regulatory capital reduce their credit supply less than those with worse regulatory capital and the intervention might have also helped banks holding low-quality assets.

The effects are economically significant. During the dry-up, on a baseline credit contraction of 2.2%, credit granted by high-exposure banks (top decile of the exposure distribution) grew about 0.9 percentage points less than credit granted by the median-exposure bank. However, during the intervention period, we observe an offsetting credit supply expansion equivalent to 1.3 percentage points, on a baseline credit contraction of 3.6%. In Section 6.2, we aggregate these estimation results and find, in a counterfactual exercise, that, without the LTRO, private credit would have contracted 5.6% in the first half of 2012 instead of the observed 3.6%. In the next section, we analyze the transmission mechanism and document a substantial heterogeneity in these effects.

4. Transmission channel

In the previous section, we have shown that banks reduced their credit supply during the dry-up and restored it after the LTRO. Given the two unique features of the LTRO, two transmission channels might be at work: the "maturity extension channel" and the "collateral relaxation channel."

According to the maturity extension channel, banks restore their credit supply when, in an environment where future central bank accommodation is uncertain, the central bank extends the maturity of its liquidity provision. In a frictionless world with no uncertainty, short- and long-term central bank liquidity provisions are equivalent as banks can roll over short-term loans indefinitely. However, if future central bank accommodation is uncertain, short-term liquidity exposes banks to rollover risk, potentially failing to counter an ongoing credit supply contraction.

[29] In Fig. B.2, we show the evolution of our outcome variable for above and below median exposure banks.

[30] We choose these balance sheet characteristics based on the difference in observables highlighted in Table 2 and concerns about potential omitted variables. In the Online Appendix, we show the evolution of several bank balance sheet variables, including pre-trends starting in June 2010, for exposed and non-exposed banks.

[31] With the inclusion of this "treatment intensity" dummy, we control for a potential omitted variable bias driven by large banks. In Table A.1, we show that our results are robust to alternative nonlinear controls for large banks. In columns (1)–(3), we find that our coefficients of interest are significant and stable in magnitude if we use a variable based on the two, three, and eight largest banks, respectively. In columns (4)–(5), we find that, within the subsample of low-exposure banks, there is no effect of bank size on our outcome variable, further suggesting that the our results are not driven by size.

[32] While, with bank fixed effects, the sample includes firms that have multiple relationships at each date t, with bank-firm fixed effects the sample includes only observations about the *same* bank-firm relationship over time.

[33] Table OA.2 shows that our coefficients of interest are stable and significant as we progressively saturate the specification with bank controls, suggesting that column (6) is not an estimate of an overfitted model.

Table 3
Bank credit supply during the dry-Up and the intervention periods. This table presents the results from specification (2). 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. $\mathbb{I}_{DU,LTRO}$ is a dummy equal to one in the dry-up and intervention periods. $\mathbb{I}_{LTRO}$ is a dummy equal to one in the intervention period. The normal period runs from December 2010 to June 2011. The dry-up 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 firm *i* and bank *j*. *LEV* is leverage, *ROA* is return on assets, *T1R* is the tier 1 ratio, *NPL* is nonperforming loans ratio, and *Large* is a variable equal to bank total assets if the bank is one of the five largest banks and zero otherwise. Standard errors double-clustered at the bank and firm level are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bank of Italy.

LHS=$\Delta CreditGranted$	(1)	(2)	(3)	(4)	(5)	(6)
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO}$	−0.092**	−0.127***	−0.129***	−0.128***	−0.132***	−0.104***
	(0.041)	(0.045)	(0.037)	(0.037)	(0.040)	(0.032)
$Exposure_{Jun11} \times \mathbb{I}_{LTRO}$	0.212***	0.247***	0.251***	0.245***	0.172***	0.141***
	(0.054)	(0.061)	(0.044)	(0.043)	(0.043)	(0.052)
Share				−0.002***	−0.026***	−0.026***
				(0.000)	(0.001)	(0.001)
Overdraft				0.068***	0.251***	0.250***
				(0.003)	(0.027)	(0.026)
Drawn/Granted				0.052	0.252	0.250
				(0.032)	(0.223)	(0.219)
$LEV_{Jun11} \times \mathbb{I}_{DU,LTRO}$						0.144
						(0.183)
$LEV_{Jun11} \times \mathbb{I}_{LTRO}$						0.210
						(0.138)
$ROA_{Jun11} \times \mathbb{I}_{DU,LTRO}$						−0.031
						(0.024)
$ROA_{Jun11} \times \mathbb{I}_{LTRO}$						0.072
						(0.055)
$T1R_{Jun11} \times \mathbb{I}_{DU,LTRO}$						0.386**
						(0.158)
$T1R_{Jun11} \times \mathbb{I}_{LTRO}$						0.409***
						(0.140)
$NPL_{Jun11} \times \mathbb{I}_{DU,LTRO}$						−0.285
						(0.196)
$NPL_{Jun11} \times \mathbb{I}_{LTRO}$						0.335**
						(0.164)
$Large \times \mathbb{I}_{DU,LTRO}$						−0.013
						(0.013)
$Large \times \mathbb{I}_{LTRO}$						−0.019
						(0.025)
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

This friction is likely at work in our context as the continuation of the extraordinary monetary easing by the ECB (full allotment procedure) and the future of the eurozone were both uncertain in late 2011.

According to the collateral relaxation channel, banks restore their credit supply when new assets become eligible as collateral at the central bank. Given that banks need to pledge collateral in order to obtain a central bank loan, banks with scarce collateral are mechanically constrained as to how much they can borrow from the central bank. This constraint is relaxed if the set of assets eligible to be pledged at the central bank is expanded. In our context, 60% of the LTRO uptake was backed by newly eligible collateral as banks took advantage of the government guarantee program to expand their borrowing capacity at the ECB.

In Sections 4.1 and 4.2, we attempt to disentangle these channels using additional sources of bank level variation coming from balance sheet characteristics and market data, respectively.

4.1. Evidence from balance sheets

In this section, we attempt to disentangle the two transmission channels by exploiting two sources of bank level heterogeneity. We measure banks' exposure to the maturity extension channel using bank short-term liabilities (less than three-year residual maturity) as a share

of total assets, as of December 2011. The intuition is that banks more reliant on short-term funding might have benefited more from the LTRO maturity extension feature compared to banks less reliant on short-term funding. We measure banks' exposure to the collateral relaxation channel using bank ECB-eligible available collateral as a share of total ECB-eligible collateral, as of December 2011. The intuition is that banks with scarce collateral might have benefited more from the LTRO collateral relaxation feature compared to banks with more available collateral.

We estimate the following triple-interaction model:

$$\begin{aligned}\Delta CreditGranted_{ijt} &= \alpha + \beta_1 HighExposure_j \times \mathbb{I}_{LTRO} \times Z_j \\ &+ \beta_2 Z_j \times \mathbb{I}_{LTRO} + \beta_3 HighExposure_j \times \mathbb{I}_{DU,LTRO} \\ &+ \beta_4 HighExposure_j \times \mathbb{I}_{LTRO} + \mu_{it} + \gamma_{ij} + \phi' X_{ijt} + \epsilon_{ijt},\end{aligned} \tag{3}$$

where *HighExposure* is a dummy equal to one for banks that have above median exposure to the dry-up and the vector Z is either banks' exposure to the maturity extension channel (*MEC*) or banks' exposure to the collateral channel (*CRC*).[34] Finally, following our baseline model (2), we include firm-time fixed effects, bank-firm fixed effects, and, in our most conservative specification, a set of bank level controls interacted with the time dummies. This specification allows us to check whether the correlation between bank exposure to the dry-up and bank credit supply varies according to the exposure to the maturity extension channel and the collateral relaxation channel.

We show the estimation results in Table 4. In column (1), the variable *MEC* captures the maturity extension channel. The estimated triple interaction term suggests that the maturity extension channel drives the restoration of credit supply by high-exposure banks after the LTRO. The estimated $\beta_1 + \beta_2$ suggests that the maturity extension channel per se is not driving the increase in credit supply. In column (2), the variable *CRC* captures the collateral extension channel. Based on the estimated coefficients, we do not find an effect of the collateral relaxation channel on bank credit supply. In column (3), we include, in a "horse-race" specification, both *MEC* and *CRC* and confirm the importance of the maturity extension channel. In the last two columns, we include the bank level controls used in column (6) of Table 3 interacted with the two time dummies: we include the nonlinear control for bank size in column (4) and add all other control variables in column (5). The estimated coefficients β_1 and β_2 are stable and significant.

These results suggest that the increase in bank credit supply after the LTRO is driven by the maturity extension channel. Based on the estimates of column (3), within banks more affected by the dry-up, banks more exposed to the maturity extension channel increased their credit supply about 1.2 percentage points more than less exposed banks (top versus bottom quartile of the exposure distribution). These findings are consistent with the observation that, during the dry-up, banks had abundant collateral and borrowed freely from the central bank, but this short-term maturity provision did not prevent them from reducing credit to firms, likely because of the uncertainty about the ECB's role as a liquidity provider in the future. The large availability of collateral during the dry-up might explain why our measure of the collateral relaxation channel is not correlated with the restoration of credit supply. While the government guarantee likely helped some collateral-constrained banks access the LTRO, collateral scarcity did not cause banks to reduce their credit supply during the dry-up and, consequently, restore their credit supply after the LTRO.

[34] We interact the continuous variables *MEC* and *CRC* with the dummy *HighExposure*. As discussed in Section 3.1, the median split is purely driven by data, as approximately half of our sample banks have a negligible exposure to the dry-up. The interaction with a dummy variable also makes the estimated coefficients easier to interpret.

4.2. Evidence from market data

Using market data, we provide additional evidence supporting the maturity extension channel in this section. We obtain equity prices for 14 of our sample banks from FactSet.[35] In Fig. 3, we show the time-series evolution of equity prices for various subsamples of banks.

The first panel shows evidence supporting our identification strategy. The figure shows the evolution of stock prices for banks exposed and nonexposed to the dry-up, respectively. We observe that (i) exposed banks started to underperform non exposed banks in mid-2011 and (ii) both groups of banks experienced an increase in stock price around the LTRO announcement in December 2011. In sum, this figure supports the parallel trend assumption before the dry-up and provides additional evidence suggesting that the dry-up is an economically meaningful shock.

The second and third panels show evidence supporting the maturity extension channel. These panels show the evolution of stock prices for exposed banks only. The second panel splits exposed banks in two groups based on their reliance on short-term funding. The third panel splits exposed banks in two groups based on their collateral availability. We observe that, within exposed banks, (i) banks more reliant on short-term funding underperformed banks less reliant on short-term funding during the dry-up, but this gap narrowed after the LTRO, and (ii) banks with high- and low-collateral availability performed similarly during the dry-up and LTRO periods.

5. Government bonds and use of LTRO liquidity

We've shown that banks exposed to the dry-up restored their credit supply in the first half of 2012, consistent with a maturity extension channel of the LTRO. In this section, we analyze banks' other use of LTRO liquidity. Motivated by the sizable increase in government bond holdings shown in Table 1, we analyze banks' holdings of government bonds in Section 5.1. Motivated by the large bond financing rollover need (€ 43 billion by our sample banks) in the first half of 2012, we analyze whether banks used the LTRO to roll over bond financing in Section 5.2.

[35] We focus our analysis on equity prices because of limited market data available for CDS and bonds.

Table 4
Bank credit supply during the LTRO period, transmission channel, balance sheet heterogeneity. This table presents the results from specification (3). The dependent variable is the difference in log (stock of) credit granted. *HighExposure* is a dummy equal to one for banks that have above median exposure to the dry-up according to $Exposure_{Jun11}$. $\mathbb{I}_{DU,LTRO}$ is a dummy equal to one in the dry-up and intervention periods. $\mathbb{I}_{LTRO}$ is a dummy equal to one in the intervention period. The normal period runs from December 2010 to June 2011. The dry-up period runs from June 2011 to December 2011. The intervention period runs from December 2011 to June 2012. *MEC* is the bank level short-term liabilities (less than three-year residual maturity) as a share of total assets, measured in December 2011. *CRC* is the bank level ECB-eligible available collateral as a share of total ECB-eligible collateral, measured in December 2011. The following relationships controls are included in the estimation but omitted from the output brevity: *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*, and *Overdraft* is the share of overdraft credit between firm *i* and bank *j*. The following bank level controls, interacted with $\mathbb{I}_{LTRO}$, are included in the estimation in column (5) but omitted from the output brevity: *LEV* is leverage, *ROA* is return on assets, *T1R* is the tier 1 ratio, *NPL* is nonperforming loans ratio. The variable *Large* is included in the estimation in columns (4)–(5) but omitted from the output brevity. *Large* is a variable equal to bank total assets if the bank is one of the five largest banks and zero otherwise. Standard errors double-clustered at the bank and firm level are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bank of Italy.

LHS=$\Delta CreditGranted$	(1)	(2)	(3)	(4)	(5)
$HighExposure \times MEC \times \mathbb{I}_{LTRO}$	0.078***		0.082***	0.079***	0.117*
	(0.027)		(0.029)	(0.029)	(0.067)
$MEC \times \mathbb{I}_{LTRO}$	−0.074***		−0.078***	−0.078***	−0.109*
	(0.027)		(0.029)	(0.027)	(0.065)
$HighExposure \times CRC \times \mathbb{I}_{LTRO}$		−0.028	−0.025		
		(0.044)	(0.037)		
$CRC \times \mathbb{I}_{LTRO}$		−0.009	−0.011		
		(0.030)	(0.018)		
$HighExposure \times \mathbb{I}_{DU,LTRO}$	−0.043***	−0.050***	−0.043***	−0.033***	−0.042***
	(0.005)	(0.007)	(0.005)	(0.006)	(0.010)
$HighExposure \times \mathbb{I}_{LTRO}$	−0.054***	−0.015	−0.055***	−0.064***	−0.079**
	(0.013)	(0.014)	(0.018)	(0.014)	(0.036)
Firm-time FE	✓	✓	✓	✓	✓
Bank-firm FE	✓	✓	✓	✓	✓
Relationship controls	✓	✓	✓	✓	✓
Control for bank size				✓	✓
Other bank controls					✓
Observations	2,135,929	2,171,749	2,135,929	2,135,929	2,135,929
R-squared	0.701	0.701	0.701	0.702	0.702

5.1. Holdings of government bonds

In Fig. 4, we show that government bond holdings, normalized by total assets in June 2011, jump from below 10% to more than 15% after the LTRO.[36] More than half of the purchases were concentrated in bonds maturing in a two-year window around the LTRO maturity.

The LTRO allowed banks to engage in a profitable trade by buying high-yield securities financed through the cheap (roughly 1% rate) LTRO loans. This trade was particularly attractive if implemented through domestic government bonds. Since they're euro-denominated, domestic government bonds carry a zero regulatory risk weight. Moreover, during this period, domestic government bonds had a high yield, and, compared with other (nondomestic) high-yield eurozone bonds, could be used to risk-shift and satisfy an eventual government moral suasion.[37]

The two unique features of the LTRO, the maturity extension and the relaxation of collateral requirements, might again explain why banks did not engage in this trade as much before the LTRO. The collateral relaxation might have helped banks with scarce available collateral willing to engage in this trade access the ECB liquidity. The maturity extension might have helped banks minimize the funding liquidity risk of this trade. Before the LTRO, banks that wanted to use ECB liquidity to buy government bonds were exposed to funding liquidity risk as they had to frequently roll over with the ECB the funding leg of their trade. As shown in Crosignani et al. (2020) in the context of Portugal, as the ECB extended the maturity of its liquidity provision with the LTRO, banks bought domestic government bonds matching the LTRO maturity. This trade lowered sovereign yields supporting, in turn, the sovereign debt capacity, a likely unstated objective of the policy.

[36] Given that we observe total assets at a semi-annual frequency, we normalize holdings by total assets as of June 2011. The jump in holdings shown in the plot is not driven by a change in total assets around the LTRO.

[37] A large literature attributes the increased government bond holdings to risk-shifting (Acharya and Steffen, 2015; Drechsler et al., 2016), moral suasion (Ivashina and Becker, 2018; Ongena et al., 2019; De Marco and Macchiavelli, 2017), a combination of the two (Altavilla et al., 2017; Horvath et al., 2015), precautionary motives (Angelini et al., 2014), or the interplay between a regulator and a common central bank (Uhlig, 2013).

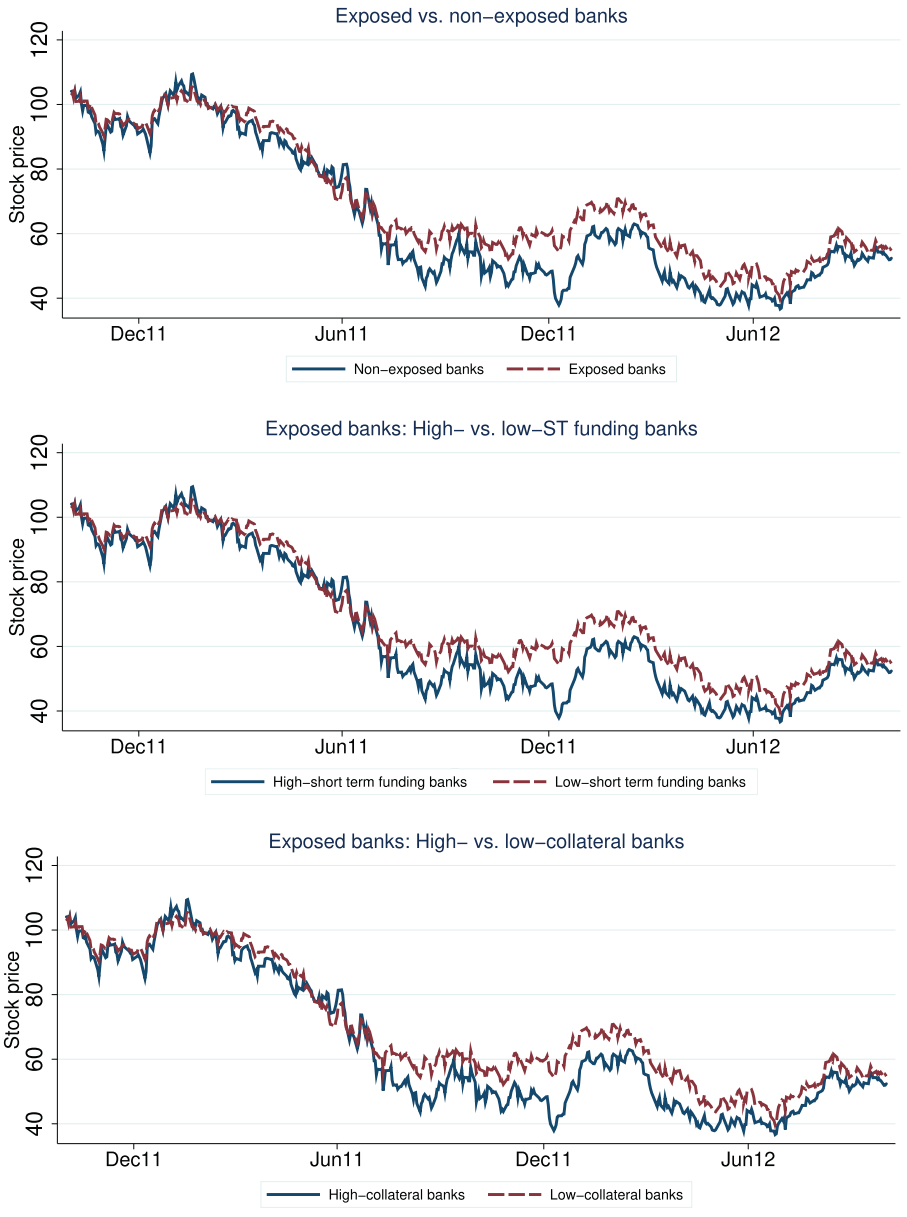

Fig. 3. Bank stock price. This figure shows the time-series evolution of banks' equity prices. Equity prices are normalized at 100 on March 1, 2011. The first panel shows mean normalized equity prices for exposed and nonexposed banks. The second panel shows mean normalized equity prices for exposed banks with high short-term debt (above median *MEC* within exposed banks) and exposed banks with low short-term debt (below median *MEC* within exposed banks). The third panel shows stock prices for banks with high collateral availability (above median *CRC* within exposed banks) and low collateral availability (below median *CRC* within exposed banks). Exposed banks are banks in the top quartile of the exposure distribution. Given that equity prices are available for the largest banks, defining exposed and non exposed banks based on the median would leave us with no non-exposed banks. Source: Bank of Italy, FactSet.

We analyze the mechanism driving the increase in government bond holdings by estimating the following specification in the cross-section of banks:

$$Govt_{jt} = \alpha + \beta\Gamma_j \times \mathbb{I}_{LTRO} + \eta_t + \gamma_j + \epsilon_{jt}, \quad (4)$$

where the unit of observation is at the bank-month level and the sample period runs from June 2011 to June 2012. The independent variables in the vector Γ include (i) banks' balance sheet characteristics measured in December 2011 (leverage, return on assets, tier 1 ratio, nonperforming loans ratio, log(assets)), (ii) the collateral availability variable *CRC*, (iii) the exposure to the dry-up defined in (1), and (iv) bank bonds expiring shortly after the LTRO. This last variable is motivated by the large rollover need of Italian banks after the LTRO: € 43 billion for our sample banks in the first half of 2012. All these variables are interacted with the time dummy $\mathbb{I}_{LTRO}$, which is equal to one in the intervention period. The specification also includes bank and month fixed effects.

Table 5
Effect on holdings of government bonds. This table presents the results from specification (4). The dependent variables are holdings of government bonds in columns (1)–(3), holdings of domestic and peripheral nondomestic (Greece, Ireland, Portugal, Spain) government bonds in columns (4)–(5), and holdings of government bonds (i) with a residual maturity greater than five years, (ii) with a residual maturity between one and five years, and (iii) with a residual maturity shorter than one year, respectively, in columns (6)–(8). All dependent variables are normalized by total assets in June 2011. The independent variables are available ECB-eligible collateral divided by total collateral, leverage, return on assets, tier 1 ratio, nonperforming loans ratio, and log(assets), measured in December 2011, and the exposure to the dry-up defined in (1). $Bonds^{1y}$, $Bonds^{6mo}$, $Bonds^{3mo}$ are bank bonds maturing in the one-year, six-month, and three-month period after the LTRO, normalized by total assets, respectively. All independent variables are interacted with the $\mathbb{I}_{LTRO}$ time dummy, equal to one, in the intervention period. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bank of Italy, Bloomberg, Datastream.

	$Govt$	$Govt$	$Govt$	$Govt^{Dom}$	$Govt^{GIPS}$	$Govt^{LT}$	$Govt^{MT}$	$Govt^{ST}$
$Bonds^{1y} \times \mathbb{I}_{LTRO}$	−0.553**			−0.566**	0.005	0.044	−0.434**	−0.164
	(0.256)			(0.258)	(0.007)	(0.051)	(0.195)	(0.112)
$Bonds^{6mo} \times \mathbb{I}_{LTRO}$		−0.910**						
		(0.409)						
$Bonds^{3mo} \times \mathbb{I}_{LTRO}$			−1.035**					
			(0.510)					
$CRC \times \mathbb{I}_{LTRO}$	0.008	−0.002	0.003	0.013	−0.001	0.015	−0.039	0.032
	(0.042)	(0.042)	(0.043)	(0.043)	(0.001)	(0.009)	(0.040)	(0.029)
$LEV \times \mathbb{I}_{LTRO}$	0.004	0.004	0.004	0.004	−0.000	−0.000	0.002	0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.000)	(0.001)	(0.002)	(0.002)
$ROA \times \mathbb{I}_{LTRO}$	0.534	0.605	0.637	0.459	−0.055	−0.316*	0.090	0.759
	(2.036)	(2.078)	(2.075)	(2.117)	(0.069)	(0.166)	(1.197)	(0.931)
$T1R \times \mathbb{I}_{LTRO}$	0.001	0.001	0.001	0.001	−0.000	−0.000	0.001*	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
$NPL \times \mathbb{I}_{LTRO}$	−0.310**	−0.308**	−0.322**	−0.307*	0.002	0.013	−0.170	−0.153**
	(0.153)	(0.150)	(0.158)	(0.154)	(0.003)	(0.030)	(0.105)	(0.075)
$Size \times \mathbb{I}_{LTRO}$	−0.009	−0.010*	−0.009*	−0.009	0.000	−0.001	−0.010**	0.001
	(0.006)	(0.006)	(0.005)	(0.006)	(0.000)	(0.001)	(0.004)	(0.002)
$Exposure \times \mathbb{I}_{LTRO}$	−0.333	−0.304	−0.292	−0.315	−0.016	−0.018	−0.272	−0.043
	(0.352)	(0.348)	(0.346)	(0.373)	(0.022)	(0.042)	(0.225)	(0.165)
Bank FE	✓	✓	✓	✓	✓	✓	✓	✓
Time FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	949	949	949	949	949	949	949	949
R-squared	0.859	0.859	0.857	0.850	0.894	0.783	0.836	0.767

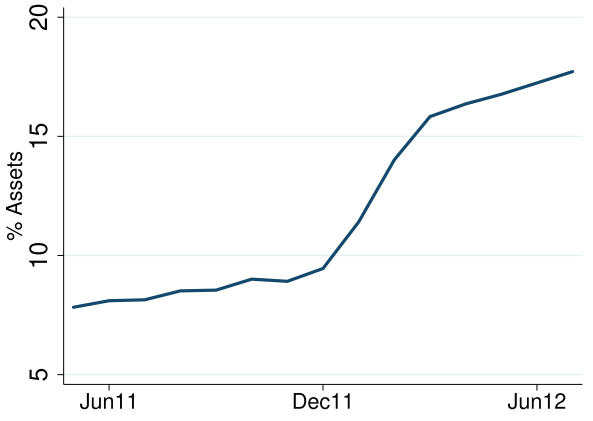

Fig. 4. Bank government bond holdings. This figure shows the evolution of bank government bond holdings (sample mean), normalized by total assets in June 2011. Source: Bank of Italy, Datastream.

We show the estimation results in Table 5. In columns (1)–(3), the dependent variable is holdings of government bonds normalized by assets and $Bonds^{1y}$, $Bonds^{6mo}$, $Bonds^{3mo}$ are bank bonds maturing in the one-year, six-month, and three-month period after the LTRO, normalized by total assets, respectively. The estimated coefficients, monotonic in banks' bond rollover need, suggest that banks with a higher bond rollover need increased their government bond holdings less after the LTRO compared with banks with a lower rollover need. In columns (4)–(5), the dependent variables are holdings of domestic and peripheral nondomestic (Greece, Ireland, Portugal, Spain) government bonds normalized by total assets, respectively. The estimated coefficients suggest that domestic government bonds drive the correlation in column (1), consistent with the persistently high home bias of Italian banks in their government bond portfolio.[38]

In the last three columns, the dependent variables are (i) holdings of government bonds with a residual maturity greater than five years ($Govt^{LT}$), (ii) holdings of government bonds with a residual maturity between one and five years, i.e. in a two-year window around the LTRO maturity, ($Govt^{MT}$), and (iii) holdings of government bonds with a residual maturity shorter than one year ($Govt^{ST}$). Together with the fact that banks mostly purchased government bonds maturing around the LTRO maturity date, the estimated coefficients suggest that banks, especially those without a large bond rollover need, exploited an attractive trading opportunity. The long maturity of the LTRO liquidity provision helped banks minimize the risk of this trade.

[38] Our sample banks display a large home bias in their government bond portfolio, even before the LTRO. In June 2011, the share of domestic securities in banks' government bond portfolio was 94%.

The purchases of government bonds turned out to be very profitable for banks. Calculating the income by subtracting the LTRO rate from the mean sovereign yields for the three maturity categories above, we find that banks' purchases generated € 4.2 billion in profits. The steepening of the sovereign yield curve right after the LTRO (lower short-term yields) is consistent with an effect of banks' purchases on prices. Using nonperipheral yields for comparison, we find that, without the LTRO, Italian short-term (less than five-year) sovereign yields would have been 60 basis points higher.[39]

5.2. Other use of LTRO liquidity

In this section, we analyze how banks allocated the € 170 billion borrowed at the LTRO.

We have shown that banks increased their holdings of domestic government bonds after the LTRO and banks exposed to the dry-up restored their credit supply after the LTRO. We aggregate our findings by regressing these outcome variables on the actual LTRO uptake for banks with high and low exposure to the dry-up. With the usual caveats of a partial equilibrium exercise, we find that our sample banks, of the € 170 billion borrowed at the LTRO, invested € 18 billion in credit to firms and € 85 billion in domestic government bonds from December 2011 to June 2012.[40] By analyzing the aggregate banks' balance sheet, we find that banks used the remaining portion of LTRO liquidity to substitute missing wholesale funding sources. In particular, in the first half of 2012, (i) bond financing, stable before the LTRO, decreases by around € 47 billion, exactly the amount of bonds maturing in that period, (ii) other wholesale funding sources decrease by another € 17 billion, and (iii) total assets remained unchanged.

Our results suggest that of the € 170 billion liquidity allotted by the LTRO, banks used € 85 billion to buy government bonds, € 18 billion to restore private credit supply, and € 64 billion to substitute missing wholesale funding, mostly in the form of bank bonds (€ 47 billion). The results in this section suggest that the LTRO and the debt guarantee program likely helped banks purchase government bonds and substitute their bond financing, pointing to an implicit coordination between the fiscal and the monetary authorities. We calculate that banks saved around € 720 million, thanks to the government guarantee.[41]

6. Additional results

In this section, we present additional results. In Section 6.1, we show how the effects on credit vary across firms. In Section 6.2, we analyze firm borrowing and conduct a counterfactual exercise.

6.1. Credit supply across firms

In this section, we check whether the effect of the dry-up and the effect of the central bank intervention on bank credit supply vary across firms. In particular, we ask vis-à-vis which firms more exposed banks reduced first and increased after their credit supply the most, compared with less exposed banks. To this end, we exploit firm level information on profitability (EBITDA), size, leverage, and credit risk (Z-score). We re-run our most conservative baseline specification, interacting our two key interaction terms with firm characteristics, measured in December 2010.[42]

We show the estimation results in Table 6. Again, we report our baseline specification in column (1), as a reference. In columns (2) through (5), we include the triple interaction terms, demeaned for ease of interpretation. For example, in column (2), we ask whether the effect of the dry-up and the effect of the intervention on credit supply change 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 a firm riskiness dummy. The firm-bank and the time-firm double interactions are absorbed by the fixed effects.

We find that, holding the exposure to the dry-up constant, the effect of the dry-up is stable across different firm characteristics, with the exception of risky clients, to which affected banks reduced their credit supply more compared with safer clients. However, holding the exposure to the dry-up constant, during the intervention period, more exposed banks increased their credit supply, especially to large, low-profitability, and risky firms, compared to less exposed banks.

6.2. Effect on firm borrowing

In this section, we analyze total firm borrowing, collapsing our bank-firm data set at the firm level. For each firm, we compute the *indirect* exposure to the dry-up based on its banking relationships. Formally, the indirect

[39] More formally, we follow Crosignani et al. (2020) and estimate the specification $y_{it}^{m} = \alpha + \beta_{(m)} Post_t \times IT_i + \eta_i + \delta_t + \epsilon_{it}$, where the dependent variable is the sovereign yield of country i at day t and maturity m, IT is a dummy equal to one for Italy and zero for the control countries (AT, BE, CY, DE, FI, FR, NL, SK, SL), and η and δ are country and day fixed effects. The sample period runs daily from November 29, 2011 to December 19, 2011 and *Post* is equal to one from December 8, 2011. Counterfactual yields are obtained setting the estimated $\beta^{(m)}$ equal to zero and then averaging in the three maturity groups over the period from December 8, 2011 to May 30, 2012.

[40] The magnitude of government bonds is consistent with the change in holdings from December 2011 to June 2012. More exposed banks invested, for every euro borrowed at the LTRO, € 0.10 in credit to firms and € 0.45 in government bonds. Less exposed banks purchased public debt almost exclusively, investing € 0.91 in government bonds for every euro borrowed at the LTRO. In the Online Appendix, we show the estimation results behind these claims.

[41] We calculate the savings induced by the guarantee program as the weighted average of pre-LTRO return on bonds and on foreign wholesale funding (2.7%) minus the government fee minus the LTRO rate, times the usage of the guarantee.

[42] We lose 45% of our observations by merging the firm level data set from Cebi-Cerved with bank-firm observations from the comprehensive national credit registry. However, we can still count on more than 1 million observations at any given date. As firm level characteristics are available at an annual frequency, we use firm characteristics measured in December 2010 (last observation before the dry-up). We present firm summary statistics in the Online Appendix.

Table 6
Bank credit supply across firms. This table presents results from specification (2) 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 defined in (1). $\mathbb{I}_{DU,LTRO}$ is a dummy equal to one in the dry-up and intervention periods. $\mathbb{I}_{LTRO}$ is a dummy equal to one in the intervention period. The normal period runs from December 2010 to June 2011. The dry-up 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 firm i with respect to bank j), bank characteristics in June 2011 (leverage, return on assets, tier 1 ratio, nonperforming loans ratio, and a variable equal to bank total assets if the bank is one of the five largest banks and zero otherwise) interacted with the two time dummies. Firm characteristics are measured in December 2010, *FirmSize* is log of total assets, $FirmProfitability$ is EBITDA, *FirmLeverage* is firm leverage, and *FirmRisky* is a dummy equal to one if the firm is considered risky based on a Z-score greater or equal to 5 (range 1–9). We do not observe the continuous Z-score variable and are therefore forced to use a dummy variable to measure firm risk. The triple interaction terms are demeaned for ease of interpretation. Standard errors are double-clustered at the bank and firm level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bank of Italy, Cebi-Cerved Database.

LHS=$\Delta CreditGranted$	(1)	(2)	(3)	(4)	(5)
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO}$	−0.104***	−0.107***	−0.106***	−0.106***	−0.104**
	(0.032)	(0.036)	(0.040)	(0.040)	(0.040)
$Exposure_{Jun11} \times \mathbb{I}_{LTRO}$	0.141***	0.140***	0.153***	0.153***	0.150***
	(0.052)	(0.053)	(0.054)	(0.054)	(0.054)
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO} \times FirmSize$		−0.000			
		(0.019)			
$Exposure_{Jun11} \times \mathbb{I}_{LTRO} \times FirmSize$		0.034***			
		(0.011)			
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO} \times FirmProfitability$			0.057		
			(0.202)		
$Exposure_{Jun11} \times \mathbb{I}_{LTRO} \times FirmProfitability$			−0.335***		
			(0.112)		
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO} \times FirmLeverage$				−0.018	
				(0.021)	
$Exposure_{Jun11} \times \mathbb{I}_{LTRO} \times FirmLeverage$				0.012	
				(0.039)	
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO} \times FirmRisky$					−0.054**
					(0.027)
$Exposure_{Jun11} \times \mathbb{I}_{LTRO} \times FirmRisky$					0.072***
					(0.026)
Firm-time FE	✓	✓	✓	✓	✓
Bank-firm FE	✓	✓	✓	✓	✓
Bank controls (interacted with time dummies)	✓	✓	✓	✓	✓
Relationship 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

exposure of firm i is the weighted average of its banks' exposures to the dry-up, where the weights are given by the total credit drawn from each bank in June 2011:

$$\widetilde{Exposure}_{i,Jun11} = \frac{\sum_j Drawn_{ij,Jun11} Exposure_{j,Jun11}}{\sum_j Drawn_{ij,Jun11}}, \quad (5)$$

where $Exposure_{Jun11}$ is defined in (1). First, we examine the effect of the dry-up and the effect of the intervention on firm borrowing behavior. Second, we compute aggregate effects.

Firm borrowing We now ask (i) whether firms avoid the credit contraction by substituting the reduction in credit from more exposed banks with more credit from less exposed banks, and, similarly, (ii) whether firms subsequently expand their *total* borrowing following the increased credit supply during the LTRO period. We estimate the following model:

$$\Delta CreditDrawn_{it} = \alpha + \beta_1 \widetilde{Exposure}_{i,Jun11} \times \mathbb{I}_{DU,LTRO} + \beta_2 \widetilde{Exposure}_{i,Jun11} \times \mathbb{I}_{LTRO} + \psi' \Lambda_{it} + \phi' \Gamma_{it} + \eta_t + \chi_i + \epsilon_{it}, \quad (6)$$

where observations are at the (i,t) firm-period level. We use the four dates that delimit the normal period, the dry-up period, and the intervention period (December 2010, June 2011, December 2011, and June 2012). The dependent variable is the change in log (stock of) total firm i credit drawn at time t, and $\widetilde{Exposure}_i$ is the indirect exposure of firm i to the dry-up defined in (5).[43] $\mathbb{I}_{DU,LTRO}$ and $\mathbb{I}_{LTRO}$ are the usual time dummies, η are time fixed effects, and χ are firm fixed effects.

We saturate the regression with bank and firm level controls. Bank characteristics (vector Λ) include the indirect exposure of firm i to each balance sheet control used

[43] We now use credit drawn, and not granted, as a dependent variable. This choice is motivated by our goal of finding whether firms reacted to the credit contraction/expansion by changing their (potentially bank-specific) demand.

Table 7
Effect on firm borrowing. This table presents the results from specification (6). The dependent variable is the difference in log (stock of) total credit. Total credit includes drawn credit from revolving credit lines and loans backed by account receivables and term loans. $\widetilde{Exposure}$ is the firm's indirect exposure to the foreign wholesale defined in (5). $\mathbb{I}_{DU,LTRO}$ is a dummy equal to one in the dry-up and intervention periods. $\mathbb{I}_{LTRO}$ is a dummy equal to one in the intervention period. The normal period runs from December 2010 to June 2011. The dry-up 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: *FirmSize* is log of total assets; *FirmProfitability* is EBITDA, *FirmLEV* is firm leverage, and *FirmRisky* is a dummy equal to one if the firm is considered risky based on a Z-score greater than or equal to 5 (range 1–9). We do not observe the continuous Z-score variable and are therefore forced to use a dummy variable to measure firm risk. Estimated coefficients on double firm-time interactions and double bank-time interactions (with the exception of the exposure-time term) are included in the estimation, but omitted in this table. The firms in the sample have at least two credit lines with two separate banks at any given time t. The triple interaction terms are demeaned for ease of interpretation. Standard errors are double-clustered at the main bank level (calculated as of June 2011) in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bank of Italy, Cebi-Cerved Database.

LHS=$\Delta CreditGranted$	(1)	(2)	(3)	(4)	(5)
$\mathbb{I}_{DU,LTRO} \times \widetilde{Exposure}_{Jun11}$	−0.637***	−0.639***	−0.641***	−0.638***	−0.671***
	(0.167)	(0.168)	(0.166)	(0.167)	(0.165)
$\mathbb{I}_{LTRO} \times \widetilde{Exposure}_{Jun11}$	0.774***	0.771***	0.777***	0.774***	0.790***
	(0.189)	(0.187)	(0.188)	(0.189)	(0.188)
$\mathbb{I}_{DU,LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmSize_{Dec10}$		−0.019			
		(0.068)			
$\mathbb{I}_{LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmSize_{Dec10}$		−0.024			
		(0.077)			
$\mathbb{I}_{DU,LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmProfitability_{Dec10}$			−0.511		
			(0.383)		
$\mathbb{I}_{LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmProfitability_{Dec10}$			0.509		
			(0.340)		
$\mathbb{I}_{DU,LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmLeverage_{Dec10}$				0.094	
				(0.127)	
$\mathbb{I}_{LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmLeverage_{Dec10}$				−0.012	
				(0.250)	
$\mathbb{I}_{DU,LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmRisky_{Dec10}$					0.574***
					(0.205)
$\mathbb{I}_{LTRO} \times \widetilde{Exposure}_{Jun11} \times FirmRisky_{Dec10}$					−0.301**
					(0.140)
Time FE	✓	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓	✓
Bank-level controls Λ	✓	✓	✓	✓	✓
Firm-level controls Γ	✓	✓	✓	✓	✓
Observations	625,509	625,509	625,509	625,509	625,509
R-squared	0.260	0.260	0.260	0.260	0.260

in our baseline regression, following the definition illustrated in (5), interacted with the two time dummies. Firm characteristics (vector Γ) include the interaction between the two time dummies and a series of firm characteristics, namely size, profitability, leverage, and credit risk. As firm variables are available at an annual frequency, we use observations in December 2010.

We show the estimation results in Table 7. In the first column, we find that the firms more exposed to the dry-up reduced borrowing from banks during the dry-up and increased it during the intervention period compared with less exposed firms. These results suggest that (i) firms were unable to completely undo the credit contraction and were therefore affected by the wholesale funding dry-up, and (ii) the LTRO helped firms reaccess bank credit. The inability to substitute sources of funding during the credit contraction is consistent with the literature on "slow moving" capital and the literature on information frictions as borrowers left looking for a new lender are adversely selected, preventing a full reallocation of credit. In columns (2) through (5), we include triple interaction terms, demeaned for ease of interpretation, to ask which firms were able to at least partially undo the credit crunch and which types of firms benefited the most from the intervention. We find that the decline in credit the exposed firms experienced during the dry-up was milder for risky firms. Risky firms also benefited less from the increase in credit during the intervention period. Our findings are consistent with Ippolito et al. (2016), who show that financially constrained firms drive the increase in the drawdown following a negative shock hitting their lender bank.

Aggregate effect

We next examine the aggregate effect of the intervention on bank credit supply to firms. We use a counterfactual exercise to estimate the drop in credit that would have occurred from December 2011 to June 2012 if the ECB had not offered LTRO liquidity.

We proceed in five steps. First, we estimate the firm-time fixed effects $\hat{\mu}_{it}$ from our baseline specification (2). By capturing firm time-varying heterogeneity, these fixed

effects effectively capture borrowers' credit demand. Second, we compute the firm level *indirect* exposure to the dry-up using (5). Third, having obtained firm demand and firm exposure to the wholesale funding shock, we plug the stored firm-time fixed effects $\hat{\mu}$ into the firm level equation and estimate

$$\begin{aligned}\Delta CreditGranted_{it} = \alpha + \beta_1 \widetilde{Exposure}_{i,Jun11} \times \mathbb{I}_{DU,LTRO} \\ + \beta_2 \widetilde{Exposure}_{i,Jun11} \times \mathbb{I}_{LTRO} + \hat{\mu}_{it} + \psi' \Lambda_{it} \\ + \phi' \Gamma_{it} + \eta_t + \chi_i + \epsilon_{it}, \end{aligned} \tag{7}$$

where the only differences from (6) are the dependent variable (we now use credit *granted*) and the inclusion of the fixed effects $\hat{\mu}$ as an independent variable. Fourth, we use the coefficients estimated in (7) and average exposures to the dry-up to predict the change in firm loan growth. In the last step, we aggregate at the period level using a weighted average of firm level loan growth, where the weights are given by firm level granted credit in December 2011.

We then compare the world with no LTRO intervention with the world with LTRO intervention. We obtain the former by simply setting $\beta_2 = 0$ in the last predictive regression. Of course, this analysis is subject to all caveats associated with a partial equilibrium exercise. In particular, the underlying assumption is that, absent the ECB intervention, during the intervention period the supply of credit granted would have decreased at the same rate as the dry-up period. We find that the LTRO had a positive effect on credit supply, increasing it by 2%. The effect is quantitatively large: without the intervention, bank credit would have contracted 5.6% in the intervention period instead of the observed 3.6%.

7. Conclusion

There is substantial agreement that central banks should provide liquidity to banks during crises. However, there is little academic research to help policy makers design these interventions and, more generally, little is known about the transmission of central bank liquidity through banks in bad times. In this paper, we analyze the transmission of the ECB LTRO, which extended the maturity of ECB liquidity provision from a few months to three years, in the Italian context, where a government guarantee program effectively relaxed the central bank collateral eligibility rules. In this setting, which also provides a rare case of a bank funding dry-up followed by a central bank liquidity provision, we combine the Italian national credit registry with bank security level holdings.

Our findings can be summarized as follows. First, by providing *long-term* liquidity, central banks help banks support their credit supply. In the presence of uncertainty about the future role of the central bank as a liquidity provider, short-term liquidity is ineffective at stopping an ongoing credit contraction. Second, banks use most liquidity to buy domestic government bonds and substitute maturing bond financing. In the context of the LTRO, these effects likely helped the stabilization of the banking sector and public debt markets, likely unstated goals of the policy.

Our results inform the theory and practice of central bank liquidity provisions during crises. We show that the design of the liquidity provision matters for its transmission. In particular, the maturity at which the central bank lends to banks, a usually overlooked feature of liquidity provisions, plays a key role. Of course, the benefits of a longer maturity, and the relaxation of collateral eligibility rules, should be weighed against the costs in terms of ex ante moral hazard. We believe these are promising areas for future research.

Appendix A. Additional tables

Table A.1
Bank credit supply during the dry-up and the intervention periods: robustness. This table presents the results from specification (2). 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. $\mathbb{I}_{DU,LTRO}$ is a dummy equal to one in the dry-up and intervention periods. $\mathbb{I}_{LTRO}$ is a dummy equal to one in the intervention period. The normal period runs from December 2010 to June 2011. The dry-up period runs from June 2011 to December 2011. The intervention period runs from December 2011 to June 2012. These three relationships controls are included in the estimation but omitted from the output brevity: *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 firm i and bank j. These bank balance sheet controls are included in the estimation but omitted from the output brevity: *LEV* is leverage, *ROA* is return on assets, *T1R* is the tier 1 ratio, and *NPL* is nonperforming loans ratio. $Large^{500}$ is a variable equal to bank total assets if the bank is one of the two largest banks (assets above € 500 billion) and zero otherwise, $Large^{200}$ is a variable equal to bank total assets if the bank is one of the three largest banks (assets above € 200 billion) and zero otherwise. $Large^{50}$ is a variable equal to bank total assets if the bank is one of the eight largest banks (assets above € 50 billion) and zero otherwise. Standard errors double-clustered at the bank and firm level are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: Bank of Italy.

LHS=$\Delta CreditGranted$	(1)	(2)	(3)	(4)	(5)
$Exposure_{Jun11} \times \mathbb{I}_{DU,LTRO}$	−0.119***	−0.118***	−0.103***		
	(0.032)	(0.035)	(0.032)		
$Exposure_{Jun11} \times \mathbb{I}_{LTRO}$	0.119**	0.113*	0.136**		
	(0.049)	(0.057)	(0.052)		
$Large^{500} \times \mathbb{I}_{DU,LTRO}$	−0.003				
	(0.015)				
$Large^{500} \times \mathbb{I}_{LTRO}$	−0.001				
	(0.023)				
$Large^{200} \times \mathbb{I}_{DU,LTRO}$		−0.001			
		(0.018)			
$Large^{200} \times \mathbb{I}_{LTRO}$		0.005			
		(0.025)			
$Large^{50} \times \mathbb{I}_{DU,LTRO}$			−0.014		
			(0.013)		
$Large^{50} \times \mathbb{I}_{LTRO}$			−0.016		
s			(0.026)		
$Log(Assets)_{Jun11} \times \mathbb{I}_{DU,LTRO}$				−0.002	
				(0.009)	
$Log(Assets)_{Jun11} \times \mathbb{I}_{LTRO}$				−0.002	
				(0.011)	
$Assets_{Jun11} \times \mathbb{I}_{DU,LTRO}$					−1.495
					(3.333)
$Assets_{Jun11} \times \mathbb{I}_{LTRO}$					3.688
					(4.315)
Firm-time FE	✓	✓	✓	✓	✓
Bank-firm FE	✓	✓	✓	✓	✓
Relationship controls	✓	✓	✓	✓	✓
Bank balance-sheet controls	✓	✓	✓	✓	✓
Sample banks	Full	Full	Full	Low-expos.	Low-expos.
Observations	2,171,749	2,171,749	2,171,749	12,367	12,367
R-squared	0.701	0.701	0.701	0.685	0.685

Appendix B. Additional figures

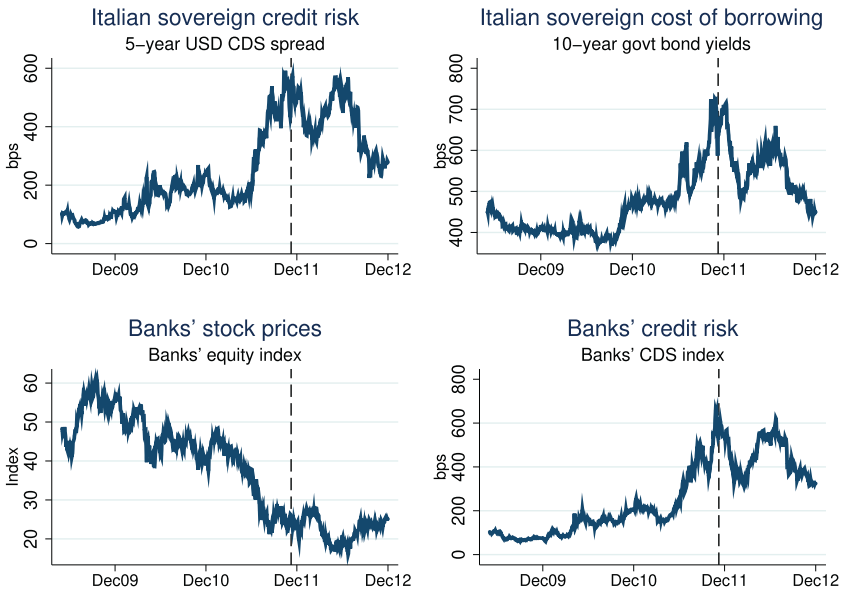

Fig. B.1. Italian bank and sovereign credit risk. The top left figure shows the Italian sovereign five-year, USD-denominated CDS spread. The top right figure shows the Italian ten-year government bond yield. The bottom left figure shows Italian banks' equity prices (MSCI Italian Financials Index). The bottom right figure shows Italian banks' CDS spread using data on the six major banks with CDS spreads available on Bloomberg for the entire sample. The vertical dashed line corresponds to the LTRO announcement on December 8, 2011. Source: Bloomberg.

Fig. B.2. Outcome variable: Time-series evolution. This figure shows the difference in the time-series evolution of our outcome variable for exposed (above median exposure) and nonexposed (below median exposure) banks during the normal period, dry-up period, and intervention period. Source: Bank of Italy.

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