Surviving the perfect storm: the role of the lender of last resort *

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Abstract

When banks are hit by a severe liquidity shock, central banks have a key role as lenders of last resort. Despite the well-established importance of this mechanism, there is scarce empirical evidence that allows to explore this key role of central banks. We are able to explore a unique setting in which banks suddenly lose access to market funding due to contagion fears, at the onset of the euro area sovereign debt crisis. Using monthly data at the loan, bank and firm level, we are able to test the role of the central bank in a scenario of imminent collapse. We find that the liquidity obtained from the central bank played a critical role in avoiding the materialization of such a scenario.

JEL Codes: E44, E5, G21.

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1 Introduction

One of the critical functions of central banks is to act as lenders of last resort. When liquidity suddenly dries up, the central bank should stand ready to supply liquidity to distressed banks, as long as their solvency is not in jeopardy (Repullo, 2005, and Rochet and Vives, 2004). Despite this critical role, there is scarce empirical evidence on this topic. In this paper, we explore a unique event of large scale that might be the perfect lab to assess the role of the lender of last resort in avoiding the collapse of a banking system.

We focus on a large unanticipated shock that hit the Portuguese banking system in the early days of the sovereign debt crisis in the euro area. Specifically, in May 2010, Portuguese banks suddenly lost access to international medium and long term wholesale debt markets, which represented an important source of their funding. This sudden stop scenario was mainly linked to investors' concerns on contagion from the sovereign crisis that was then emerging in Greece. In this context, Portuguese banks escalated their recourse to Eurosystem[1] monetary operations, which increased by around 20 p.p. of GDP in just a few months. Despite this large scale sudden stop, there were no apparent implications in terms of aggregate credit conditions. Against this background, we investigate the role of the Eurosystem in counterbalancing the adverse and unexpected liquidity shock that hit the Portuguese banking system and in preventing its transmission to the credit channel. Overall, we consider that given the significant size of the ECB's interventions, it is important to assess their impact on the banking system and, ultimately, on the economy.

The empirical analysis takes advantage of a unique combination of detailed and extensive datasets available for the Portuguese economy. The main dataset used is the Portuguese Central Credit Register (CRC), which has monthly data on virtually all bank loans granted by Portuguese financial institutions. We focus on loans to non-financial corporations, and merge this information with data on the balance sheet and income statements of the entire universe of firms. Further, we collect monthly information on banks' liquidity, capital and balance sheet items, as well as on their holdings of Portuguese government bonds. Finally, we also gather bank-level data on the recourse to monetary policy operations and standing facilities, the collateral pool and reserve requirements compliance.

Ensuring a proper identification of the role of the enhanced liquidity provision by the ECB raises significant challenges. In this respect, several features of the data help in the identification. First, the liquidity shock was arguably exogenous and unanticipated. Second, there was high heterogeneity in the individual banks' recourse to the Eurosystem, both before and after the liquidity shock. In this respect, exploring the heterogeneity at the

[1] Throughout the paper, we used interchangeably the terms ECB and Eurosystem with same meaning.

micro level is helpful in the identification of the main transmission channels. Third, the richness of the data allows a careful identification of demand and supply in the loan market. In particular, we select only firms that have a relationship with more than one bank and employ firm fixed-effects estimation in order to control for firm-specific loan demand effects (Khwaja and Mian, 2008). Further, bank and firm variables are included at their levels prior to the liquidity shock, in order to mitigate endogenous effects. Finally, in order to address other sources of endogeneity concerns, namely regarding the recourse to Eurosystem operations, we also follow an instrumental variables approach. Several instruments are considered, including the amount of assets eligible to Eurosystem operations that are not allocated to the collateral pool, and the dependence of banks on international funding markets prior to the shock occurring. With these identification strategies, we are able to assess the effect of the expanded liquidity provision on banks' loan supply to non-financial corporations in a sudden stop scenario.

Our results show that access to ECB funding was essential in avoiding a collapse in Portuguese credit markets. Despite the sudden loss of access to wholesale markets, the virtually unlimited access to central bank funding helped banks to continue to provide funding to the real economy. We are not able to find any evidence of major disruptions in loans granted to firms.

Taking a bird's eye view on the balance sheet of banks, we observe that there was not any sizeable changes in banks's loan book, capital or loan-to-deposit ratios. The basic intermediation role of banks was unaffected, at least in the short run, by this shock of unprecedented magnitude.

Of course not all banks were affected equally by this shock, as their starting points in terms of liquidity and capital played an important role. We find that banks with better liquidity positions were able to channel more ECB funding to the financing of non-financial firms. In contrast, larger banks and the banks with higher capital ratios granted less credit than other banks which used similar amounts of central bank funding.

Though many things remained surprisingly unchanged after this unprecedented shock, banks' balance sheets were not unscratched. The increase in ECB funding during this period largely surpassed the liabilities that needed to be refinanced. This lead to a (temporary) expansion of banks' balance sheets. We show that at least part of these excess liquidity was channeled to an increase in holdings of domestic sovereign bonds. This is consistent with the idea that there might have been some financial repression in this period, with sovereigns in distress encouraging banks to buy their debt (Becker and Ivashina, 2014).

Finally, to clearly establish the role of the lender of last resort *on banks balance sheet* in this turbulent period, we design a simple counterfactual analysis. The main idea is to

show what could have happened to banks' assets if there was not any alternative source of funding when access to wholesale markets disappeared in the spring of 2010. Given the strong dependence of the largest Portuguese banks on market funding, we show that a collapse in credit would be unavoidable without the support of a lender of last resort.

We hope to offer a valuable contribution to the literature, as the empirical evidence on the role of the lender of last resort is almost inexistent, with a notable exception being Drechsler et al. (2013). These authors use bank-level data on ECB borrowing and find that euro area banks used this liquidity to engage in risk-shifting strategies, rather than to lend to the real economy. In contrast to the scarce empirical evidence, there is an extensive theoretical literature on the role of the lender of last resort, with an emphasis on potentially pervasive moral hazard problems that arise out of this insurance mechanism (Freixas et al, 2004, Gorton and Huang, 2004, Ratnovski, 2009, Rochet and Tirole, 1996, Rochet and Vives, 2004, Wagner, 2007). More generally, our study is also framed in the flourishing recent line of research on the impact of unconventional measures, in particular using micro data (Andrade et al., 2014, Acharya and Mora, 2014, Chodorow-Reich, 2014, Cantero-Saiz et al, 2014, Garcia-Posada and Marchetti, 2015).

This paper is organized as follows. In Section 2 we discuss the role of a central bank as a lender of last resort, providing also a timeline of the main events in the period being analyzed. In Section 3 we describe the data used and in Section 4 we present an overview of what happened with banks during this unique period. In Section 5 we use loan level data to examine the role of access to central bank funding in corporate lending during this period of near-collapse of the financial system. In Section 6 we go beyond the effects on credit, by looking at several dimensions of banks' balance sheets. This allows us to understand how this large and unexpected shock affected the structure of banks' assets and liabilities. In Section 7 we take an additional step in establishing clearly the role of the lender of last resort in avoiding a collapse of the banking system, by attempting to design a counterfactual scenario. In Section 8 we summarize our main findings.

2 The role of a central bank under a sudden stop scenario

Bagehot (1873) was amongst the first to acknowledge the role of the lender of last resort, arguing that "theory suggests, and experience proves, that in a panic the holders of the ultimate bank reserve (whether one bank or many) should lend to all that bring good securities quickly, freely, and readily. By that policy they allay a panic; by every other policy

they intensify it." Since then, the consensus has been to lend freely, usually at penalty rates and against good collateral, to all solvent but illiquid banks.

However, the lender of last resort generates an intrinsic moral hazard problem, as discussed by Freixas et al, 2004, Gorton and Huang, 2004, Ratnovski, 2009, Rochet and Tirole, 1996, Rochet and Vives, 2004, Wagner, 2007. This mechanism has to be credible ex-ante to prevent crises. But if the mechanism is in fact credible, banks will know they will be helped out if they face severe difficulties, thus having perverse incentives to engage in excessive risk-taking behaviors. For instance, Gonzales-Eiras (2004) finds that banks' holdings of liquid assets decrease when there is a lender of last resort, using a natural experiment in Argentina. This moral hazard problem is further aggravated by systemic behavior induced by collective risk taking strategies, in which banks believe that the likelihood of an intervention by the lender of last resort may become more likely (Fahri and Tirole, 2012).

Despite the extensive theoretical underpinnings on the role of the lender of last resort, to the best of our knowledge, the only paper empirically looking at the role of central banks as lender of last resort during the global financial crisis is Drechsler et al. (2013). Using weekly data on bank-level borrowing from the ECB, these authors find that euro area banks used central bank funding to invest in high-yield sovereign debt. This risk-shifting behavior was stronger for weakly-capitalized banks. These findings are inconsistent with the classical predictions of the lender of last resort theory, according to which banks borrow from the lender of last resort to avoid fire sales of their existing asset holdings. This should allow banks to continue lending to the economy, thereby preventing a credit crunch.

In this paper, we are able to perform a more targeted test of the role of the lender of last resort in a crisis setting. Since the early days of the global financial crisis, the ECB, together with central banks worldwide, actively intervened to restore the transmission of monetary policy and fulfil its mandate. This included not only a series of policy interest rate cuts, but also a large set of unconventional monetary policy measures. In the fall of 2008, the ECB adopted a fixed rate full allotment policy at its regular refinancing operations, ensuring that all the liquidity needs of banks were met at a fixed interest rate, as long as banks had enough eligible collateral to pledge. Around the same time, the list of assets eligible as collateral was expanded, with several increments in the difficult period that would follow. To some extent, we might argue that in this new setting, the ECB's role as a lender of last resort was significantly expanded[2]. During this period, the ECB also implemented longer-term refinancing operations (with maturities up to one year), foreign exchange operations and a covered bond purchase programme.

[2]The Eurosystem has an ultimate line of defense, labelled as emergency liquidity assistance (ELA). In these operations, the collateral accepted is significantly broader than in regular monetary policy operations. Data on ELAs is confidential to avoid sitgma effects.

These measures implied a significant expansion of the ECB balance sheet. However, Portuguese banks recorded only a mild increase in their access to ECB funding. Indeed, Portuguese banks were not hardly hit by the global financial crisis that followed the collapse of Lehman Brothers, as their exposure to subprime markets and, more generally, to US markets, was residual. Some constraints in access to interbank funding during this period were easily accommodated with occasional access to monetary policy operations and to the issuance of bonds with government guarantees. In turn, loan flows were unaffected during this period, with credit growth rates remaining significantly above those of the euro area.

This relatively benign scenario while the global financial system was in distress suffered a blow in the Spring of 2010. Suddenly, Portuguese banks entirely lost access to funding in international wholesale debt markets[3]. This sudden stop scenario was not due to intrinsic fragilities in the Portuguese banking system. Instead, it reflected the environment of heightened uncertainty in the beginning of the euro area crisis, when investors were wary of potential contagion from Greece. This sudden loss of access to markets was sizeable enough to compromise the survival of many Portuguese banks, which operated with relatively high loan-to-deposit ratios [around 190% at end-2009]. However, despite the high dependence on access to wholesale markets, when we look at credit growth during this period, it seems that nothing happened. The answer to this apparent puzzle lies in the lender of last resort support by the ECB. The unconventional measures adopted by the ECB early in the crisis allowed Portuguese banks to easily substitute market funding by ECB loans. At the same time, the ECB did not implement any new monetary policy measure and the Eurosystem excess liquidity remained broadly stable. In just a few months, the recourse of Portuguese banks to the Eurosystem increased by an impressive 20 p.p. of GDP. The evolution of this variable clearly illustrates the unanticipated nature of this shock (Figure 1). If banks were gradually getting into distress, we would expect a gradual increase in this variable over a few months. However, access to Eurosystem funding clearly spiked in May 2010.

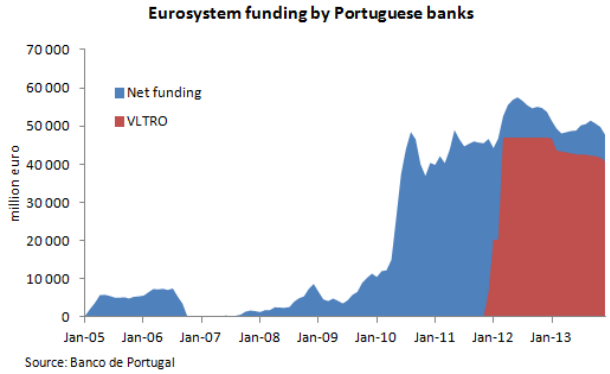
Against this background, in this paper we explore this unique setting to empirically assess the role of the lender of last resort in a sudden stop scenario. Our findings will show that the lender of last resort played a key role in allowing banks to survive the perfect storm.

3 Data

We collect monthly data from January 2005 to December 2013 from several datasets. The main dataset has bank loan level data from the Portuguese Central Credit Register (CRC),

[3] "From May 2010 on, Portuguese banks lost access to international medium and long term wholesale debt markets." Financial Stability Report Banco de Portugal, May 2012

Figure 1: Eurosystem funding



which is a database managed by Banco de Portugal. The CRC covers virtually all bank loans granted in Portugal (all financial institutions granting credit in Portugal are required to, on a monthly basis, report to the CRC all loans above 50 euros). We consider only loans granted to non-financial corporations. All financial institutions are allowed to consult information on their current and prospective borrowers, with their previous consent, thus making the CRC a key information-sharing mechanism between banks. The CRC has information on the type of loan, the debtor and the amount, while also including information on loan defaults and renegotiations, as well as potential credit liabilities associated with irrevocable commitments.

The data on loans is merged with data on banks' characteristics coming from supervisory balance sheet data. There are 44 credit institutions in our database, of which 28 are banks, 9 are branches of credit institutions with head office in the EU, 3 are factoring institutions, 2 are savings banks ("*caixa económica*") and 2 are mutual agricultural credit banks ("*caixas de crédito agrícola mútuo*"). We restrict the sample to the banks that were counterparties eligible to participate in Eurosystem operations, which leaves us with 29 banks. All institutions report monthly balance sheet data, with the exception of the branches of credit institutions with head office in the EU, which report quarterly. For these, we consider data at end of quarter for the missing months. We also collect monthly data on banks' detailed liquidity reports. These reports include detailed information for banks' assets and liabilities in several maturity brackets, thereby allowing to compute liquidity gaps between assets and liabilities in different time horizons. The information included in these reports also allows to identify the value of eligible assets for Eurosystem operations in banks' balance sheets (including those that are not currently part of the collateral pool).

In order to control for firms' characteristics, we also used data on firms balance sheet and income statements reported under *Informação Empresarial Simplificada* (*IES*). This data-

base covers the entire universe of Portuguese non-financial corporations, given it mandatory nature. The frequency of the data is annual.

Given the nature of the unconventional monetary policy measures, it is essential to gather data on policy implementation. We collect data at the Eurosystem level, publicly available at the ECB website, on liquidity provided (or absorbed) in each type of operation, on reserve requirements and on current accounts and on the asset purchase programmes. More importantly, we also collect data at the bank-level on the recourse to Eurosystem liquidity by type of operation (both liquidity provision and absorption), on reserve requirements and current accounts, and on the pool of eligible assets to refinancing operations.

Finally, we also collect data on banks' holdings of Portuguese government debt during this period, given its large increase and its relevance in the context of the sovereign debt crisis.

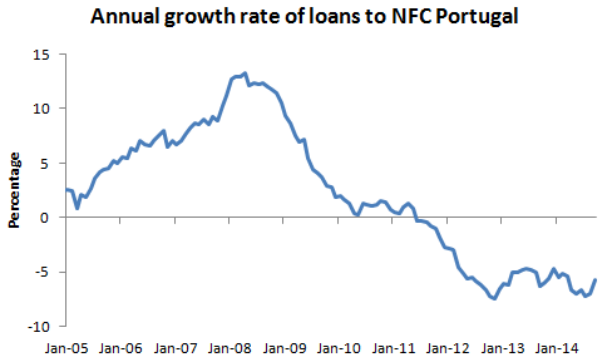
Table 1 summarizes the variables used in the paper.

Table 1: Descriptive statistics of the variables used in the analysis

Variable	T	Obs	Mean	Std. Dev.	Min	Max
Ln(assets)_i	March 2010	270403	24.3075	1.0891	18.4532	25.3654
Liq ratio_i	March 2010	270403	16.5384	7.6129	2.4341	89.1657
Solv ratio_i	March 2010	270403	9.3323	11.8556	-39.84	35.25
ECB fund_i	March 2010	270403	3.0017	2.3951	-4.5328	30.4544
LTD_i	March 2010	270403	171.9899	74.8216	0	2777.374
liq gap_i	March 2010	270403	-3.2550	6.1422	-54.3318	100.3576
collateral_i	March 2010	270403	0.1094	0.0608	0	0.5517
securities_i	March 2010	270403	1.16e+10	9.45e+09	0	2.59e+10
$\Delta\text{ECB fund}_i$	Mar-Aug 2010	251794	6.7061	5.4532	-1.1761	14.9227
Δloans_{ij}	Mar-Dec 2010	227209	-0.1126	0.7959	-11.4379	11.0735
$\Delta\text{loans + lines}_{ij}$	Mar-Dec 2010	203383	-0.1127	0.9026	-11.4359	10.2320
$\Delta\text{ln(assets)}_i$	Mar-Dec 2010	240574	0.0171	0.1163	-0.4724	0.5370
$\Delta\text{PT bonds}_i$	Mar-Dec 2010	239520	5.5442	12.6211	-14.0488	70.7718
ΔLTD_i	Mar-Dec 2010	240574	-2.1246	32.6544	-148.4666	227.6408
$\Delta\text{securities}_i$	Mar-Dec 2010	232065	-0.2182	0.5214	-2.0207	0.9351

The index i stands for bank and the index j stands for firm. T is the moment in time to which the statistics refer. Variables description: Ln(assets) is the logarithm of the total assets of the bank. Liq ratio is the amount of liquid assets (cash, loans and advances to credit institutions and other loans and advances) over total assets. Solv ratio is the prudential total capital ratio. ECB fund is the total amount of liquidity provided net of liquidity deposited at the Eurosystem over total assets of the bank. LTD is the loan-to-deposit ratio of the bank. Liq gap is the difference between liquid assets and liabilities with maturity between 1 and 3 months as a percentage of stable funding. Collateral is the amount of reported assets in the bank's balance sheet eligible for Eurosystem operations but not allocated to the collateral pool. Loans are the total amount of effective loans granted by the bank to the borrower. Loans + lines are the loans including unused credit lines. PT bonds is the amount (book-value) of Portuguese government bonds held by the bank.

Figure 2: Loan growth



4 What happened at the bank level?

The use of loan level data is a key source of identification, as discussed above, as it allows us to perfectly control for changes in loan demand. Nevertheless, before we explore that information in detail, it may be interesting to have an overview of what happened during this period at the bank level.

Figure 1 illustrates the sharp increase in access to Eurosystem funding in the Spring of 2010. After the collapse of Lehman Brother, in September 2008, there was only a mild and temporary increase in access to these operations. This contrasts strikingly with what happened in 2010. Between March and August, the increase in these operations represented around 20 p.p. of GDP.

Figure 2 depicts the annual growth rate of loans to non-financial corporations in Portugal. Despite the huge shock on banks' funding, loan growth rates remained broadly unchanged during this period. Only more than one year later, after the request for financial assistance by the Portuguese government, loan growth rates started to get into negative territory.

Something worth noting is the substantial heterogeneity between banks. Figure 3 shows that even though the average loan-to-deposit ratio was relatively high, suggesting a strong reliance on access to wholesale debt markets, there is a lot of dispersion in this measure. This was possibly reflected in the wide variation in access to ECB funding depicted in Figure 4. However, despite the remarkable heterogeneity on the way the shock was felt and on the banks' reaction, loan growth rates were very concentrated around zero during this period (Figure 5).

Figure 3: Empirical distribution of the loan-to-deposit ratio (March 2010)

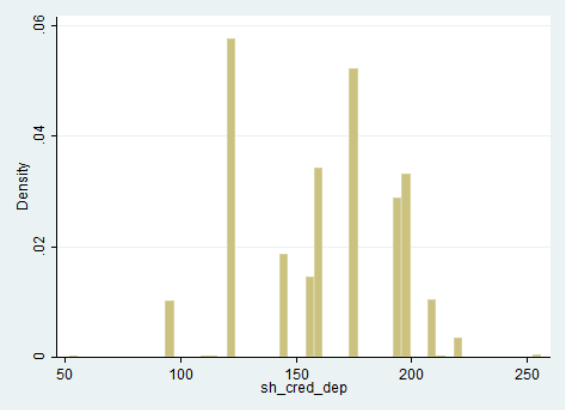


Figure 4: Empirical distribution of the change in access to Eurosystem funding (March-August 2010)

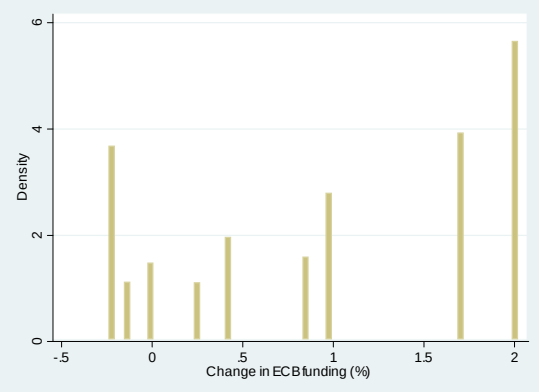
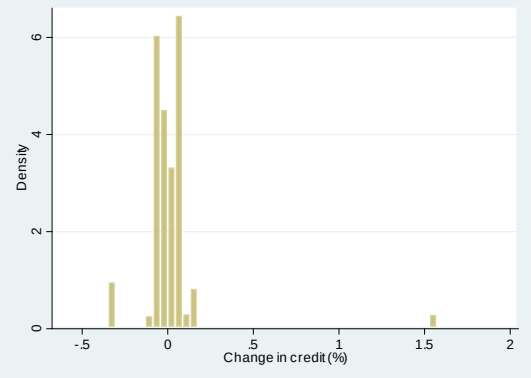


Figure 5: Empirical distribution of the loan growth rate (March-September 2010)



5 Loan level evidence on the role of the lender of last resort

5.1 Identification strategy

Ensuring a proper identification strategy is key in any empirical work hoping to establish a causality relationship between variables. This issue is even more challenging in a crisis environment, in which many things may be happening simultaneously. We try to explore the richness of the dataset available to maximize the potential provided by the quasi-natural experiment setting that we are examining.

Indeed, the nature of the shock itself helps to create the perfect lab to examine the role of the lender of last resort. The sudden loss of access to wholesale markets by Portuguese banks was largely unexpected, reflecting a sudden rise in investors' risk aversion, amidst growing concerns on the spreading of the sovereign debt crisis hitting Greece to other vulnerable euro area countries. Given the fragilities on the fiscal and economic situation of the Portuguese economy in that period, investors perceived Portugal to be the next "victim". These concerns actually materialized, with the government asking for international financial assistance one year later. Another important aspect to consider is that the ECB did not take any specific action as a reaction to these events. Portuguese banks were able to benefit from a safety net that had been created throughout the previous years, including the fixed rate full allotment setting and the extended list of eligible collateral.

For identification purposes, it is also worth noting the heterogeneity within Portuguese banks. Their situation diverged significantly in terms of their recourse to the Eurosystem, both before and after the liquidity shock. Moreover, banks' dependence on wholesale markets was also heterogenous, meaning that banks were hit differently by this shock. The same can be said for liquidity and capital buffers. In this respect, exploring the heterogeneity at the micro level is helpful in the identification of the main transmission channels.

Finally, the richness of the data allows for a careful identification of demand and supply in the loan market. Though exploring this event using bank level data would allow to establish some relationships between access to ECB funding and credit dynamics, it is important to note that at this level it is not possible to control for changes in the demand for bank loans. However, given that we have loan level data, we are able to select only firms that have a relationship with more than one bank. This selection, together with firm fixed-effects estimation, allows to control for firm-specific loan demand effects (Khwaja and Mian, 2008).

Importantly, to further mitigate endogeneity concerns, all bank and firm variables are included at their levels prior to the liquidity shock.

Our baseline specification is:

$$loan\_growth_{ijt} = c + \alpha_i + \beta \Delta ECB\_funding_{jt-4} + \delta X_{jt-9} + \varepsilon_{ijt}$$

where $loan\_growth_{ijt}$ refers to the log change of loans between March 2010 and December 2010 granted by bank j to firm i. This variable considers the total exposure of a bank to a firm, i.e. it includes unused credit lines. $\Delta ECB\_funding_{jt-4}$ is the change in ECB funding as a percentage of banks' assets between March 2010 and August 2010. Finally, X_{jt-9} are a set of bank controls measured at March 2010, to mitigate endogeneity concerns.

With this identification strategy, we are able to assess the effect of the expanded liquidity provision on banks' loan supply to non-financial corporations in a sudden stop scenario.

5.2 Testing the perfect lab

Table 2 shows the results of the empirical strategy discussed above. We begin by running the regressions without controlling for bank characteristics. In the first column we show the results without firm-fixed effects, while in the second column these are included, thereby allowing to capture all dimensions related to firm demand. In the third column we control for a number of bank characteristics, namely total assets, the liquidity ratio and the solvency ratio. In the fourth column we consider the same specification, but using a slightly modified version of the dependent variable, i.e., loan growth excluding unused credit lines.

The effect of the increase of access to ECB funding on firm loan growth is not statistically significant in any of these specifications. This shows that despite the dramatic increase in this funding source (and of its heterogeneity between banks), loan flows to firms remained broadly unchanged. This result confirms the idea that the access to the lender of last resort was essential to avoid a credit crunch.

Interestingly, we find that better capitalized banks were able to grant more loans than other banks. The same happened for banks with more comfortable liquidity positions, though this evidence is much weaker.

Even though we do not find any statistically significant impact of access to ECB funding on loan growth across the board, it is possible that firms were affected in different ways. We explore this by running the regression presented in the third column of Table 2 for different firm size cohorts, i.e., micro, small, medium and large firms. The results are presented in Table 3. The effect of access to ECB funding is not significant to any firm size category, suggesting that there was not a credit crunch in any of these segments of corporate loans. In turn, the effect of bank capital seems to be more relevant for the smaller firms, while the liquidity ratio played an important role only for medium-sized firms.

Table 2: Results for the regressions at the loan level

	(1)		(2)		(3)		(4)	
ΔECB fund$_{it-4}$	-0.0001		0.001		-0.004		-0.006	
	0.004		0.004		0.004		0.006	
ECB fund $_{it-9}$					-0.005		-0.005	
					0.008		0.008	
Ln(assets) $_{it-9}$					-0.014		-0.016	
					0.017		0.020	
Liq ratio $_{it-9}$					0.004	*	0.004	
					0.002		0.003	
Solv ratio $_{it-9}$					0.007	***	0.007	***
					0.001		0.001	
Constant	-0.111	***	-0.119	***	0.132		0.198	
	0.038		0.041		0.371		0.433	
Unused credit lines	Y		Y		Y		N	
Clustered s.e.	bank		bank		bank		bank	
Firm FE	N		Y		Y		Y	
Banks	29		29		29		29	
Firms	-		114611		114611		108003	
N obs	224524		224524		224524		201154	
Prob > F	0.9710		0.8388		0.0000		0.0000	

Note: Dependent variable: Log change in loans between March and December 2010. All variables defined in Table 1.Second line values are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Another possibility that could be considered was that banks engaged in risk-shifting strategies, by providing loans to riskier borrowers. In Table 4 we show the results of running the baseline regression separately for good and bad quality firms, i.e., firms without or with defaults in the last two consecutive months. Again, we cannot find any statistically significant effect of the role of the ECB. The only noteworthy difference is that banks with more capital and liquidity seem to be more prone to risk-taking strategies in this period.

As shown above, there is substantial heterogeneity in the way banks were affected by the sudden loss of access to wholesale debt markets. As such, it is quite likely that there are important differences between banks. Our first approach is to search for differences based on bank size. The Portuguese banking system is highly concentrated, with the five largest banks having a 70% market share of the corporate loan market. When we run the regressions separately for these banks, we find some interesting differences (Table 5). For the largest banks, we find a statistically significant negative effect of access to ECB on loan growth. This means that, within these largest banks, those that used more intensively ECB

Table 3: Results for the regressions for different samples according to firm size

	Micro		Small		Medium		Large	
ΔECB fund$_{it-4}$	-0.005		-0.006		0.002		-0.006	
	0.005		0.005		0.004		0.008	
ECB fund $_{it-9}$	-0.010		-0.013		0.000		-0.001	
	0.008		0.008		0.008		0.014	
Ln(assets) $_{it-9}$	-0.028		-0.020		-0.000		0.010	
	0.019		0.020		0.022		0.039	
Liq ratio $_{it-9}$	0.004		0.003		0.006	***	0.002	
	0.003		0.002		0.001		0.003	
Solv ratio $_{it-9}$	0.006	***	0.006	***	0.004	***	0.003	*
	0.001		0.001		0.001		0.002	
Constant	0.521		0.370		-0.178		-0.336	
	0.423		0.478		0.541		0.984	
Banks	25		26		28		26	
Firms	65247		25410		4771		856	
N obs	109567		59722		17058		3798	
Prob > F	0.0000		0.0000		0.0000		0.1815	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. Regressions include always firm fixed effects. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

funds, as a percentage of their assets, actually granted less credit to firms. One possibility, to be explored, is that these banks used this funding to increase other assets. The most plausible candidate should be government bonds, given the possible financial repression in a period in which loss of access to markets of banks was preceded by the loss of access of the sovereign (Becker and Ivashina, 2014). In a way, access to central bank funding might have allowed some banks to smooth, to some extent, the effect of this shock on the government sector.

Another potentially relevant source of heterogeneity is bank capital. So far, there seems to be consistent evidence that better capitalized banks granted more credit to firms, during this period. To better explore the role of the lender of last resort for banks with different degrees of capitalization, we run additional sample splits based on this variable (Table 6). First, we consider banks in the first and fourth quartile of the distribution of capital ratios. Access to ECB funding played a similar role for both sets of banks, not being statistically significant. Second, we split the sample in a less extreme way, by considering banks below and above the median. In this case, we are able to find a statistically significant effect for

Table 4: Results for the regressions for different samples according to firm recent credit history

	Good		Bad	
ΔECB fund$_{it-4}$	-0.004		-0.007	
	0.004		0.006	
ECB fund $_{it-9}$	-0.009		0.009	
	0.008		0.013	
Ln(assets) $_{it-9}$	-0.019		0.007	
	0.020		0.029	
Liq ratio $_{it-9}$	0.003		0.008	***
	0.002		0.003	
Solv ratio $_{it-9}$	0.004	***	0.020	***
	0.001		0.001	
Constant	0.347		-0.734	
	0.472		0.682	
Banks	29		26	
Firms	95085		19660	
N obs	184567		39957	
Prob > F	0.0000		0.0000	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. Regressions include always firm fixed effects. Good firms are those without default in the current or past quarter. All other variables defined in Table 1. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

the better capitalized banks, which, like the largest banks, granted less credit when they used more intensively the ECB's facilities.

Given these interesting differences in terms of bank capital, it is also relevant to consider potential differences in terms of liquidity. Indeed, the shock we are analyzing was primarily a liquidity shock, affecting more substantially the banks that were more reliant on wholesale debt markets. To explore this, we run the regressions separately for banks with loan-to-deposit ratios in the first and forth quartiles of the distribution (Table 7). In this case, we are not able to find any statistical difference for the role of the ECB. Interestingly, the capital ratio only affects positively loan growth for the banks which depend less on access to markets, which were arguably less hit by the shock.

We perform a similar exercise for another measure of liquidity, the liquidity gap, which measures the mismatch between assets and liabilities in a horizon between 1 month and 3 months (Table 8).Again, the role of the ECB was similar for both bank groups.

Table 5: Results for the regressions for different samples according to bank size

	Big5		Others	
ΔECB fund$_{it-4}$	-0.005	***	-0.002	
	0.001		0.004	
ECB fund $_{it-9}$	0.001		0.007	
	0.002		0.006	
Ln(assets) $_{it-9}$			0.081	***
			0.025	
Liq ratio $_{it-9}$	0.013	***	0.001	
	0.001		0.001	
Solv ratio $_{it-9}$	0.015	***	0.007	***
	0.001		0.001	
Constant	-0.494	***	-2.013	***
	0.013		0.620	
Banks	5		24	
Firms	97276		55669	
N obs	149085		75439	
Prob > F	0.0000		0.0000	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. All variables defined in Table 1. Regressions include always firm fixed effects. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Finally, we test whether collateral availability lead to any differences (Table 9). Banks with less collateral available for ECB operations might have been more constrained in using this funding. Once more, the effect of ECB funding is not significant.

As such, even though the shock that hit banks in the Spring of 2010 was primarily a funding shock, none of the liquidity dimensions analyzed seems to have played a significant role.

Finally, to better explore the heterogeneity between banks and grasp potentially different effects of the access to ECB funding, we consider another specification such that:

$$loan\_growth_{ijt} =$$
$$c + \alpha_i + \beta \Delta ECB\_funding_{jt-4} + \delta \Delta ECB\_funding_{jt-4} * X_{jt-9} + \delta X_{jt-9} + \varepsilon_{ijt}$$

where δ captures differential effects of access to ECB funding depending on bank characteristics. The results for the interactions with the capital ratio, loan-to-deposit ratio, the liquidity gap and the eligible collateral are shown in Table 10. The only statistically significant result concerns the liquidity gap: banks with a larger liquidity buffer were able to grant more credit when they used ECB funding more intensively.

Table 6: Results for the regressions for different samples according to banks' capital ratio

	Below p25		Above p75		Below p50		Above p50	
ΔECB fund$_{it-4}$	0.002		-0.002		0.001		-0.020	***
	0.008		0.018		0.003		0.002	
ECB fund $_{it-9}$	0.004		-0.024		-0.007		0.003	
	0.021		0.015		0.007		0.002	
Ln(assets) $_{it-9}$	-0.006		0.191	**	-0.014		0.041	***
	0.034		0.073		0.011		0.011	
Liq ratio $_{it-9}$	0.006		0.014		0.007	***	0.000	
	0.004		0.015		0.001		0.001	
Solv ratio $_{it-9}$	0.006	***	0.117	***	0.006	***	0.012	
	0.001		0.008		0.001		0.012	
Constant	-0.142		-6.776	**	0.047		-1.105	***
	0.786		2.370		0.294		0.306	
Banks	14		7		17		12	
Firms	50850		64371		81413		78215	
N obs	64889		73910		122722		101802	
Prob > F	0.0000		0.0000		0.0000		0.0000	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. Regressions include always firm fixed effects. All variables defined in Table 1. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 7: Results for the regressions for different samples according to bank LTD ratio

	Low LTD		High LTD
ΔECB fund$_{it-4}$	0.004		-0.009
	0.039		0.009
ECB fund $_{it-9}$	-0.011		-0.001
	0.022		0.009
Ln(assets) $_{it-9}$	0.015		0.006
	0.072		0.024
Liq ratio $_{it-9}$	-0.006		0.009
	0.007		0.005
Solv ratio $_{it-9}$	0.007	***	0.015
	0.001		0.014
Constant	-0.343		-0.504
	1.760		0.657
Banks	11		14
Firms	51342		69284
N obs	62139		86161
Prob > F	0.0000		0.0000

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. All variables defined in Table 1. Regressions include always firm fixed effects. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 8: Results for the regressions for different samples according to bank 1- to 3-month liquidity gap

	Low liq gap		High liq gap	
ΔECB fund$_{it-4}$	-0.043		0.005	
	0.053		0.006	
ECB fund $_{it-9}$	0.038		-0.007	
	0.074		0.004	
Ln(assets) $_{it-9}$	0.156		-0.045	**
	0.193		0.018	
Liq ratio $_{it-9}$	0.009		-0.007	
	0.010		0.005	
Solv ratio $_{it-9}$	0.008	*	0.056	
	0.004		0.044	
Constant	-3.800		0.366	
	4.487		0.948	
Banks	12		12	
Firms	68705		55938	
N obs	86752		68193	
Prob > F	0.0000		0.0002	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. All variables defined in Table 1. Regressions include always firm fixed effects. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 9: Results for the regressions for different samples according to bank collateral availability to Eurosystem operations

	Low collat	High collat	
ΔECB fund$_{it-4}$	-0.033	0.006	
	0.052	0.004	
ECB fund $_{it-9}$	-0.210	0.007	
	0.404	0.005	
Ln(assets) $_{it-9}$	0.146	0.005	
	0.206	0.020	
Liq ratio $_{it-9}$	0.005	-0.004	
	0.00	0.004	
Solv ratio $_{it-9}$	0.002	-0.027	*
	0.008	0.014	
Constant	-3.510	0.056	
	4.715	0.577	
Banks	13	8	
Firms	36313	48173	
N obs	40617	54205	
Prob > F	0.0000	0.0012	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. All variables defined in Table 1. Regressions include always firm fixed effects. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 10: Results for the regressions interacting the recourse to Eurosystem funding with bank variables

	x_i = capital		x_i =LTD		x_i =liq gap		x_i =collat	
ΔECB fund$_{it-4}$	-0.002		0.002		0.001		-0.002	
	0.011		0.007		0.005		0.006	
ECB fund $_{it-9}$	-0.004		-0.004		-0.011		-0.003	
	0.009		0.007		0.008		0.009	
ΔECB fund$_{it-4} * x_{it-9}$	-0.000		-0.000		0.002	**	-0.018	
	0.000		0.000		0.001		0.025	
Ln(assets) $_{it-9}$	-0.012		-0.017		0.000		-0.016	
	0.021		0.017		0.014		0.018	
Liq ratio $_{it-9}$	0.004	*	0.004	*	0.005	**	0.004	*
	0.002		0.002		0.002		0.002	
Solv ratio $_{it-9}$	0.007	***	0.007	***	0.007	***	0.007	***
	0.001		0.001		0.001		0.001	
Constant	0.091		0.211		-0.193		0.172	
	0.490		0.391		0.313		0.398	
Banks	29		29		29		29	
Firms	114611		114611		114611		114611	
N obs	224524		224524		224524		224524	
Prob > F	0.0000		0.0000		0.0000		0.0000	

Note: Dependent variable: Log change in loans, including unused credit lines, between March and December 2010. All variables defined in Table 1. Regressions include always firm fixed effects. Second line values are the robust standard errors clustered at bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

6 Where did the money go?

All the evidence presented so far clearly establishes that loan growth remained virtually unaffected despite the sudden loss of access to markets and the massive increase in central bank funding that ensued. This shows that the ECB played a key supporting role in a scenario of near-collapse of the banking system. However, part of the story remains untold. The increase in ECB funding largely surpassed the amount of bank debt that needed to be refinanced in 2010, thus leading to a (temporary) expansion of banks' balance sheets. A natural question is thus where did the money go.

In this section, we use bank level data to understand the main dynamics behind these large shocks. More specifically, we try to understand what (if anything) changed on the left-hand side of banks' balance sheets. In order to do so, we estimate a linear regression model such that:

$$\Delta Y_{jt} = \alpha + \beta \Delta ECB\_funding_{jt-4} + \varepsilon_{jt}$$

where ΔY_{jt} refers to the change of several balance sheet items between March 2010 and December 2010 in bank j. These include total assets, total loans to firms (including unused lines of credit), the loan-to-deposit ratio, the capital ratio and holdings of domestic sovereign bonds as a percentage of total assets. $\Delta ECB\_funding_{jt-4}$ is the change in ECB funding in percentage of total assets between March 2010 and August 2010. We consider a time lag between our dependent and independent variables to allow for some time to reflect the changes in funding in the structure of the balance sheet.

Table 11 shows the results of this estimation. We find that despite the large increase in funding through the Eurosystem, the impact on banks' total assets was not statistically significant. The same can be told for loans and for the loan-to-deposit ratio. There is only a marginally positive effect on banks' capital ratios. In sum, the structure of banks' balance sheets did not suffer major changes despite the large and unexpected shock that hit the Portuguese banking system, thus showing that the Eurosystem liquidity provision through the fixed rate full allotment procedure fulfilled the role of lender of last resort and avoided a major collapse in the banking system.

However, there is one balance sheet item where we can find a statistically significant impact of the increase in access to ECB funding: banks that obtained more funds from the ECB increased more significantly their holdings of domestic sovereign bonds. These results are consistent with those of Drechsler et al (2013). Using weekly data on bank-level ECB borrowing, these authors find that euro area banks used central bank funding to invest in distressed sovereign debt instead of channeling funds to the real economy. This

result confirms the financial repression hypothesis presented by Becker and Ivashina (2014), who argue that during this period sovereigns in distress encouraged banks to buy their debt. We should recall that the Portuguese government also lost access to markets in the spring of 2010. As such, our results suggest that the ECB played a dual role as lender of last resort during this period: on one hand it allowed banks to maintain loan flows to the private sector, avoiding a collapse in credit markets, while on the other hand it allowed the distressed sovereign to refinance some of its maturing debt. Without this support, the consequences for the financial system and for the economy as a whole could have been dramatic.

Table 11: Results for the linear regression at the bank level

	$\Delta\ln(\text{assets})_{it}$	$\Delta\ln(\text{loans})_{it}$	ΔLTD_{it}	Δsolv_{it}	$\Delta\text{PT bonds}_{it}$
$\Delta\text{ECB fund}_{it-4}$	0.5123	-0.9035	73.763	27.832 *	1.9892 ***
	0.4249	0.8321	546.08	15.402	0.4572
Constant	-0.0169	0.0807	48.417	-3.1399 *	-0.0283
	0.0540	0.108	62.545	1.6506	0.0270
Banks	26	26	26	26	20
R^2	0.0385	0.0314	0.0006	0.1076	0.6843

Note: All variables defined in Table 1. Second line values are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

7 What if?

To grasp the consequences of what could have been the situation if there was not a lender of last resort available to provide support to an entire banking system hit by a large and unexpected shock, we attempt to derive a simple counterfactual scenario. The main idea is to understand what could have happened if there was not any alternative source of funding when access to wholesale debt markets suddenly evaporated in the spring of 2010.

To do that, we estimate the following panel regression with bank fixed-effects:

$$Y_{jt} = c + \alpha_j + \beta_1 securities_{jt-3} + \beta_2 X_{jt} + \beta_3 trend_t + \varepsilon_{jt} \quad (1)$$

where Y_{jt} refers to total loans and total assets of bank j in period t. The coefficient β_1 represents the impact on these bank variables from funding via wholesale markets (*securities*

refers to the amount outstanding of debt issued by banks in the previous quarter). X_{jt} is a vector of bank characteristics (including liquidity and capital ratios). We include a time trend in these regressions, and confirm that there is indeed a cointegration relationship between the variables. This trend can be related to common factors to Portuguese banks explaining their evolution prior to the crisis. In these regressions, we consider only the banks which issued securities at least once prior to 2010.

Tables 12 and 13 present our results, the first looking at the impact on loans to firms (including credit lines) and the second looking at the impact on banks' total assets. In the first two columns of each table we show the results of these estimations using data until 2009. We see that before the shock there was a strongly positive relationship between market funding and banks' loans and assets. Portuguese banks strongly relied on access to international debt markets to finance their activity. In column (2), we estimate the same regressions in the same period, but instead of considering the relationship between securities issued and banks' assets, we consider the sum of securities issues and ECB financing, which was very small at the time. Given this, the results are virtually unchanged.

In columns (3) and (4) we show the same regressions as in columns (1) and (2), but for the 2010-2011 period[4]. If our hypothesis is correct, we would expect the positive relationship between loans or assets and securities to break. However, this relationship should hold when we include ECB funding if this is a quasi-perfect substitute for the lost wholesale market funding. The results thus are strikingly different from those of the first period, confirming our hypothesis: the positive correlation between debt issuance and banks' assets entirely disappears. The coefficient is not statistically significant for total assets and is actually negative for loans. The more market debt outstanding banks had, the lower their stock of loans to firms during this period.

In the last column we consider the joint effect of securities issued and access to ECB funding. For loans we still obtain a negative coefficient. But when we look at the effect on total assets, we find a positive coefficient, showing that access to the lender of last resort was indeed critical to avoid a collapse in the banking system. This coefficient is smaller than those of columns (1) and (2), suggesting that ECB funding did not perfectly substitute securities issuance. The results on loans and on total assets suggest that the replacement of securities funding by ECB funding was likely used for other purposes than expanding loans to firms. However, it is important to note that in these regressions we are not controlling for demand effects, unlike what we did when using loan level data. As such, it is quite possible that this result is affected by a contraction of loan demand in a period of strong adjustment of expectations.

[4]If the estimation is done only for 2010, the results described below are generally consistent.

Another important hypothesis that should be tested is once again the existence of financial repression. In this way, we conduct a similar analysis on the holdings of Portuguese sovereign bonds by banks against banks' recourse to Eurosystem funding. The results are shown in Table 14. The first column shows the results for the period 2005-2009 and no correlation is found between the two variables. However, for the period 2010-2011 we observe a positive correlation between ECB funding and holdings of sovereign debt, thus providing further support to the financial repression hypothesis.

Table 12: Results for the panel regression at the bank level for the evolution of loans to non-financial firms

	2005-2009		2010-2011	
	(1)	(2)	(3)	(4)
$securities_{jt-3}$	0.5681 ***		-0.1077 **	
	0.0387		0.0421	
$(securities + ECB)_{jt-3}$		0.4821 ***		-0.1086 *
		0.0944		0.0618
Banks	26	19	24	19
N^o obs	1197	912	534	456
Prob > F	0.0000	0.0000	0.0175	0.1031

Note: All variables defined in Table 1. The estimated model is the one specified in equation (1). The coefficients on bank controls, the constant and the trend are omitted given the large values, as this is a regression on levels. The coefficients on bank controls are generally statistically non-significant, while the constant and the trend are significant. Nonetheless, the full results are available upon request. Second line values are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 13: Results for the panel regression at the bank level for the evolution of total assets

	2005-2009		2010-2011	
	(1)	(2)	(3)	(4)
$securities_{jt-3}$	1.6659 ***		0.0635	
	0.1337		0.1254	
$(securities + ECB)_{jt-3}$		1.4683 ***		0.3539 ***
		0.2275		0.0779
Banks	26	19	24	19
N^o obs	1197	912	534	456
Prob > F	0.0000	0.0000	0.4498	0.0018

Note: All variables defined in Table 1. The estimated model is the one specified in equation (1). The coefficients on bank controls, the constant and the trend are omitted given the large values, as this is a regression on levels. The coefficients on bank controls are generally statistically non-significant, while the constant and the trend are significant. Nonetheless, the full results are available upon request. Second line values are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 14: Results for the panel regression at the bank level for the evolution of Portuguese sovereign bond holdings

	2005-2009	2010-2011
$ECB\ funding_{jt-3}$	0.0661	0.7264 ***
	0.2275	0.1703
Banks	24	22
N^o obs	1063	483
Prob > F	0.1850	0.0009

Note: All variables defined in Table 1. The estimated model is equivalent to the one specified in equation (1). The coefficients on bank controls, the constant and the trend are omitted given the large values, as this is a regression on levels. Only the coefficients on the liquidity ratio and on the trend are statistically significant for the first period. Nonetheless, the full results are available upon request. Second line values are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

8 Concluding remarks

What happens when an entire banking system suddenly loses access to debt markets? At the very least, a credit crunch is likely to follow. More likely, the entire economy will be disrupted.

In the recent past, Portuguese banks went through an episode that could easily fit this description. In the early days of the euro sovereign debt crisis, when distress in Greece started to assume large-scale proportions, international investors suddenly became unwilling to provide funding to Portuguese banks, due to concerns about the sustainability of sovereign debt levels. Despite the magnitude of this shock, credit flows during this period were virtually unchanged. This is even more surprising when we consider that Portuguese banks were highly dependent on this type of funding, as their loan to deposit ratios were close to 190%.

The answer to this puzzle has one very obvious solution: the ECB monetary policy framework allowed banks to obtain all the liquidity they needed almost immediately and without major implications on funding costs.

In this paper, we argue that this perfect storm scenario is also the perfect setting to study empirically something that has been absent from the literature: the role of the lender of last resort. By exploring very detailed bank data, we are able to document the critical role of the central bank in avoiding the collapse of the financial system and, consequently, of the economy. We show that even though funding with the central bank increased dramatically over the course of a few months, credit flows to firms remained broadly stable. At the same time, banks were able to play an important role in the financing of the sovereign, who also lost access to markets in this period. Without the supporting role of the lender of last resort, a collapse of the banking system would possibly have been unavoidable.

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