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A small open economy before and during the crisis: the importance of banks, asset markets and monetary policy

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Abstract

It is widely accepted that there are welfare benefits from financial integration via risk sharing of idiosyncratic shocks. However, evidence suggests that aggregate shocks are preponderant in explaining business cycles, at least in the US and the euro area. This thesis discusses this idea, both theoretically and empirically, in the background of the euro area before and after the Great Recession. There are welfare gains for a SOE of financial integration, even when faced with aggregate shocks. A sudden stop scenario is thus more relevant for this SOE, but can be counteracted with monetary policy intervention in the affected markets.

Keywords: monetary policy, banking, financial crisis, euro area

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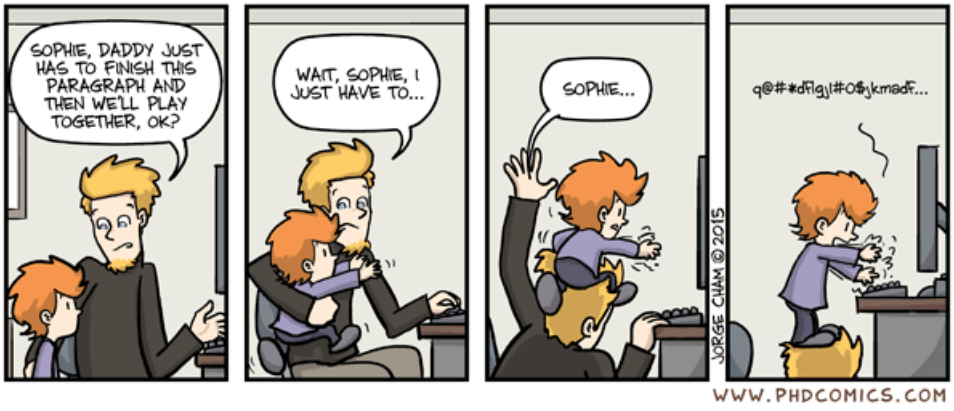

This thesis is still a building up creature like a toddler and was accompannied by toddlers. And just like a toddler, it needed the help of many people to grow up. First and foremost, I have to thank my supervisor, Isabel Horta Correia, for all the ideas, suggestions and discussions, understanding and encoragement. Your deep understanding and knowledge of economics, your easiness in transmisting ideas and the ability to always focus on the most relevant issues always left me amazed and made you the best advisor I could possible have had. A second very special thanks goes to Diana Bonfim. You were much more than a co-author, you were almost a co-supervisor and specially a very good friend. I constantly admire your efficiency and calm. For sure, none of this had been possible without you. This thesis is literally the result of the work of several people. I have also to thank to my co-authors Nuno Alves and Bernardino Adão, for your bright ideas, suggestions and fruitful discussions. Thank you for letting me work with you and learn from you.

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Contents

Introduction

The Great Recession of the last decade has motivated a huge amount of work in the economic literature. Several authors have been trying to include financial factors in macroeconomic models, the study of the behaviour of banks and their interaction with the business cycle has flourished and many others have worked on the policy responses and limitations, in particular of monetary policy. This dissertation falls into this general line of work, with a focus on the euro area, on monetary policy and its transmission in the euro area via financial intermediaries. Monetary policy influences banks financing costs directly, via monetary policy implementation instruments, as shown in chapter 3, and indirectly via the credit, the expectations and the risk-taking channels (chapter 1). It is currently more widely accepted that, when facing a large shock that impacts the functioning of financial markets, in particular money and debt markets, and increases systemic risk and the probability of runs, the central bank should intervene. With complete markets, it should be enough to respond to aggregate shocks (Allen & Gale 2004, Goodfriend & King 1988). The justification to intervene in response to idiosyncratic shocks implies that there is some friction, such as limited market participation (Allen *et al.* 2009, Acharya *et al.* 2012). During the crisis, it seems likely that there were idiosyncratic shocks that, in the absence of complete markets, had aggregate effects and justified central bank intervention in the style of lender-of-last-resort, such as the fixed-rate full allotment procedure by the ECB.

The first chapter, written in co-authorship with Diana Bonfim, is an empirical study on the risk-taking channel of monetary policy applied to Portugal.[1] In an

[1]This article is published, see Bonfim & Soares (2018).

environment of low policy interest rates, the incentive for banks to take more risk into their balance sheets increases. Other studies have found a negative relationship between the level of monetary policy interest rates and bank risk-taking (Dell'Ariccia *et al.* 2017, Gaggl & Valderrama 2011, Ioannidou *et al.* 2015, Jiménez *et al.* 2014, Morais *et al.* 2015). We contribute to the literature by examining the mechanisms through which the channel may work in different ways, by exploring detailed bank and borrower information to look at loan origination and performance over time. Crucial to our work is the identification strategy, that relies in the fact that monetary policy decisions can be considered as fully exogenous during the period analyzed (1999-2007). The influence of Portuguese financial and economic conditions on the decisions taken by the ECB should be negligible. Our results partly support the existence of a risk-taking channel. When monetary policy interest rates are lower, banks are more likely to lend to ex-ante riskier borrowers. However, the average exposure to existing risky borrowers does not increase. In other words, we find results in favor of an effect at the extensive margin of credit concession, but not for the intensive margin. When we track loan performance over time, we see that loans granted when monetary policy rates were low are not generally more likely to default ex-post. However, one crucial exception occurs when interest rates increase after having been low for a long period. In this case, loans granted in low interest rates periods are significantly more likely to default when monetary policy tightens due to sudden changes in expectations. This result may be specially relevant for supervisors and other policymakers when interest rates increase after prolonged periods of loose monetary conditions.

The second chapter, written in co-authorship with Nuno Alves and Diana Bonfim, focus on a 'natural experiment' that documents the role of the ECB as lender of last resort. In May 2010 Portuguese banks suddenly lost access to international medium and long-term wholesale debt markets, which was an important source of their funding. This sudden stop scenario was mainly linked to investors' concerns about contagion from the sovereign crisis that was then emerging in Greece. Thus, this was a large, exogenous and non-expected shock. Portuguese banks then escalated their recourse to Eurosystem monetary operations, which increased by 20% 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 ECB in counterbalancing the adverse and unexpected liquidity shock that hit the Portuguese banking system. To do so, we explore the heterogeneity across banks' loans to non-financial corporations, controlling for information on banks' balance sheet, regulatory reports and recourse to monetary policy instruments. 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. Based on past regularities, that show 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. Surprisingly, the increase in ECB funding during this period largely surpassed the liabilities that needed to be refinanced. We show that at least part of the excess liquidity created was channeled to an increase in holdings of domestic sovereign bonds, consistent with the idea of financial repression during this period, with sovereigns in distress encouraging banks to buy their debt (Becker & Ivashina 2014, Ongena *et al.* 2016).

The third chapter extends the analysis of the policy response to the financial crisis to the interbank money market. The financial crisis began in 2007 as a disruption in money markets, that used to constitute the first step in monetary policy implementation. During the following years, these markets remained impaired, justifying many of the monetary policy measured taken, expecially in the early years. My aim is to evaluate the measures taken and their effectiveness. To such end, I use data on overnight interbank transactions, identified from data from the TARGET payment systems managed by the Banco de Portugal, using an algorithm similar to Furfine (1999). Overnight transactions represent the large share of the turnover in the unsecured money market of the euro area (ECB 2012) and is the most relevant segment for monetary policy analysis. This data is merged with banks' balance sheet variables. I find that the measures, namely the fixed-rate full allotment procedure and the excess liquidity created, were effective in reducing interest rates in

the market, but the impact on market activity was negative. Indeed, following the increased intermediation by the central bank, market activity was reduced, both in terms of access to the market and volume traded. I also find that the overnight market seems to already respond to risk considerations, by imposing higher interest rates to banks with lower solvability or liquidity ratios. The results also seem to confirm the idea of a significant market segmentation across euro area jurisdictions following the sovereign debt crisis, with Portuguese banks being penalized and seeing the impact of policy measures substantially reduced.

The fourth chapter, written in co-authorship with Bernardino Adão, asks whether there are welfare gains for a small open economy from belonging to a monetary union even when faced with large negative aggregate shocks. It is well known that countries would benefit from financial integration when hit by idiosyncratic shocks. However, when evaluating the gains to a country like Portugal of belonging to the Monetary Union, and participating in the more integrated assets markets that the common currency and monetary policy back, the evidence supports the hypothesis that a large share of output volatility is not due to individual shocks but instead to common shocks. This paper explores one mechanism that can support the advantage of staying inside the union even in this case for a SOE. We introduce heterogeneity at the country level and show that, despite aggregate and distributional effects from common shocks when countries are perfectly integrated, quantitatively the aggregate effect is not significant. Nonetheless, the distributional effect is quantitatively significant for the SOE, meaning that for these economies there is a clear advantage due to a risk sharing mechanism. The source for these effect is the difference in the parameters that govern the risk aversion/intertemporal substitution across economies. Using evidence that corroborates the usual perception, a very simple general equilibrium model is calibrated and simulated to evaluate the question above.

Chapter 1

The risk-taking channel of monetary policy: exploring all avenues

Abstract

The literature on the risk-taking channel of monetary policy grew quickly, leading to scattered evidence. We examine this channel through different angles, exploring detailed information on loan origination and performance. Ex-ante riskier borrowers receive more funding at the extensive margin when interest rates are lower. Ex-post performance is independent of the level of interest rates at origination. Still, loans granted in periods of very low and stable interest rates show higher default rates once interest rates start to increase. Risk-taking is stronger among banks with lower capital ratios, suggesting that this channel may be linked to managerial incentives for risk-shifting.

JEL Codes: E44, E5, G21.

Keywords: risk-taking channel, monetary policy transmission, credit risk.

[0]This is joint work with Diana Bonfim.

[0]The views expressed in this paper are those of the authors and do not reflect the views of the Banco de Portugal or the Eurosystem.

1.1 Introduction

Since the onset of the financial crisis, there has been an increasing interest on the links between the financial system and monetary policy. One of the recent avenues of research has focused on the transmission of monetary policy through banks' risk-taking behavior, usually labeled as the risk-taking channel (Shin & Adrian (2008), Adrian & Shin (2010), Adrian & Song Shin (2010), Jiménez *et al.* (2014)). The basic idea is that in an environment of low policy interest rates, the incentive for banks to take more risk into their balance sheets increases. In the last few years, the literature on this channel has flourished (Dell'Ariccia *et al.* (2017), Delis *et al.* (2017), Morais *et al.* (2015), Paligorova & Santos (2017)). Several authors have found a negative relationship between the level of monetary policy interest rates and bank risk-taking. Generally, the results suggest that, in the short-run, lower policy interest rates decrease the total credit risk of the banking sector, since the impact via the increase in borrowers' repayment capacity for outstanding loans is more significant. However, in the medium-term, the higher risk-taking may eventually materialize in a deterioration of banks' asset quality, especially when a period of low policy interest rates is followed by a recession or by a severe monetary policy contraction.

The existence of a risk-taking channel is thus well-documented. However, given the fast expansion of this literature during a very short period, the available evidence is scattered and anchored on many different methodologies, datasets and definitions. Our goal in this paper is to examine how this channel works through different angles. To do so, we explore detailed bank and borrower information to look at loan origination and performance over time. We use a loan level Portuguese dataset with universal coverage on loan, firm and bank information to provide a thorough and comprehensive assessment of the different ways through which the risk-taking channel of monetary policy may operate.

This allows us to obtain consistent answers to many of the questions previously addressed in the literature on this topic, while also addressing new ones. We first test whether the risk-taking channel exists when we consider the ex-ante riskiness

of borrowers. This allows us to understand if banks were making risky choices based on observable firm characteristics. We consider different risk measures and different lending choices. We also test the impact of the level of policy rates at the moment loans are granted on ex-post risk. Further, we test whether loans granted when rates are low and stable are more sensitive to a tightening in monetary policy, thus assessing the role of banks' expectations on risk-taking behaviors. Moreover, the richness of our dataset allows us to explore the heterogeneity underlying the different ways in which the risk-taking channel operates, taking into account the role of firm and, more importantly, bank characteristics. This allows us to improve the link between theoretical and empirical evidence on the transmission of monetary policy through the risk-taking channel.

Testing all of these hypotheses requires an adequate identification strategy. It is possible to argue that there may be common (unobservable) effects that simultaneously influence the monetary policy stance and banks' risk-taking decisions. If that is the case, it is not possible to infer causality, thereby hindering the correct identification of the risk-taking channel. Our setup overcomes this challenging identification problem given that monetary policy decisions can be considered as fully exogenous during the period analyzed (1999-2007). The influence of Portuguese monetary and economic conditions on the decisions taken by the ECB should be negligible. This is the same argument used by Jiménez *et al.* (2012), Jiménez *et al.* (2014) and, to some extent, by Ioannidou *et al.* (2015) and Geršl *et al.* (2015).

Our empirical results partly support the existence of a risk-taking channel. When monetary policy interest rates are lower, banks are more likely to lend to ex-ante riskier borrowers. However, the average exposure to existing risky borrowers does not increase. In other words, we find results for the extensive margin, but not for the intensive margin. When we track loan performance over time, we see that loans granted when monetary policy rates were low are not generally more likely to default ex-post. However, one crucial exception occurs when interest rates increase after having been low for a long period. In this case, loans granted in low interest rates periods are significantly more likely to default when monetary policy tightens due to

sudden changes in expectations. This result may be specially relevant for supervisors and other policymakers when interest rates increase after prolonged periods of loose monetary conditions.

Regarding bank heterogeneity, we find that risk-taking behaviors are stronger for banks with less capital. There is evidence that banks closer to minimum regulatory ratios take more risk because they do not fully internalize the potential consequences of the risks taken (Jiménez *et al.* (2014), Diamond & Rajan (2012)). Though less consistently, we also find some evidence that banks with larger liquidity buffers are more prone to risk-taking behaviors. Taking the results for liquidity and capital together, we are able to conclude that risk-taking behaviors in a low interest rate environment may be associated with poor managerial incentives, which encourage risk-shifting strategies (Acharya & Naqvi (2012), Altunbas *et al.* (2010)). Indeed, banks with more liquidity have more incentives to engage in risk-shifting when interest rates are lower, given that liquid assets usually offer null or very small remunerations. In a low interest rate environment, banks with many liquid assets may divert some of these resources to grant riskier loans, in a search for yield strategy.

In sum, our paper contributes to the expanding empirical literature on the risk-taking channel of monetary policy by looking simultaneously at different dimensions of the transmission mechanism. By exploring a rich and detailed dataset, with loan, firm and bank information, and by taking advantage of a quasi-experimental setting in which monetary policy decisions can be considered as fully exogenous, we explore the effect of interest rates on banks' risk-taking behaviors through different angles. As such, the paper offers an encompassing analysis of the risk-taking channel, thereby helping to bring some consistency to this fast growing literature, while providing additional evidence supporting the existence of the channel.

The paper is organized as follows: In section 2 we briefly summarize the theoretical and empirical discussions in the literature on the risk-taking channel. Section 3 describes the dataset used and section 4 details the identification strategy and methodologies followed. In sections 5 and 6, we present our main results. The anal-

ysis is built around two blocks. First, in section 5, we assess the risk-taking channel at the moment a lending decision is taken, both at the extensive and intensive margins. We focus on the effects of policy interest rates on lending by testing two hypotheses: (1) Do riskier firms get more credit when policy rates are lower? (section 5.1) and (2) Are riskier firms more likely than other firms to obtain a loan when interest rates decrease? (section 5.2). Second, in section 6, we assess the risk-taking channel through ex-post changes in loan portfolio quality. Again, two hypotheses are tested: (1) Does the level of the policy rate when loans are granted influence the (ex-post) probability of default? (section 6.1) and (2) Are loans granted when policy rates are low and stable more likely to default when interest rates increase? (section 6.2). Section 7 summarizes our main findings.

1.2 An overview of the literature

The theoretical research on the risk-taking channel has been expanding significantly during the last few years (Adrian & Shin (2010), Adrian & Song Shin (2010), Shin & Adrian (2008), Afanasyeva & Guntner (2015), Borio & Zhu (2012), Cesa-Bianchi & Rebucci (2017), DellAriccia *et al.* (2011), Nicoló *et al.* (2010), González-Aguado & Suarez (2015), Morris & Shin (2015)). These authors have identified some mechanisms through which this channel operates. One of these mechanisms is the search for yield, which occurs mainly through the asset side of financial institutions' balance sheet. A decrease in policy rates decreases their portfolio income and then decreases the incentive to monitor, or similarly, increases search for yield and then risk-taking (DellAriccia *et al.* 2011).

The risk-taking channel may also operate through risk-shifting, occurring mainly via the liability side of financial institutions' balance sheet. A decrease in policy rates decreases the cost of banks' liabilities. Given the evidence that banks target a leverage ratio (Adrian & Shin (2010), Adrian & Song Shin (2010), Shin & Adrian (2008), Bruno & Shin (2015)), they get back to their target by increasing market funding, especially in shorter maturities, and by expanding credit to cover riskier

projects. Both changes imply an increase in the risk banks assume (DellAriccia *et al.* (2011), Valencia (2014)). This mechanism reinforces itself, since banks increase demand for assets, increasing their price and consequently further expanding their balance sheet and increasing their leverage. Moreover, a prolonged period of low interest rates can affect asset and collateral valuations, as it is associated with lower market volatility, thus reducing risk perception (Gambacorta 2009).

Other authors highlight a distortion of incentives in an environment of very low interest rates. In Acharya & Naqvi (2012), an agency problem between the bank manager and the principal induces the bank manager to take excessive risk when the bank is awash with liquidity. This usually occurs in situations of high macroeconomic risk, when the central bank tends to loosen its monetary policy.

During the last few years, there were several relevant empirical contributions to the literature on the risk-taking channel, most of them finding evidence in favor of the existence of this channel. One important strand of the literature uses loan-level datasets on individual countries (Dell'Ariccia *et al.* (2017), Gaggl & Valderrama (2011), Ioannidou *et al.* (2015), Jiménez *et al.* (2014) and Morais *et al.* (2015)). Other authors use less granular data, at the bank or country level (Altunbas *et al.* (2010), Angeloni *et al.* (2015), Bruno & Shin (2015), Maddaloni & Peydró (2011), Paligorova & Santos (2017)). Generally, these studies find a negative relationship between the level of policy rates and the risk of the loan portfolio of the banks. However, the evidence for the US seems to be milder. For instance, Delis *et al.* (2017) find that low policy rates decrease the risk of banks' loan portfolios in the short-term but significantly increase it in the medium run, while Buch *et al.* (2014) do not find favorable evidence for the overall banking system, finding however important differences between different types of banks.

Available empirical evidence suggests that there is some heterogeneity in bank risk-taking behaviors, in line with agency theories (Stein & Kashyap (2000), Freixas & Rochet (2008)). Indeed, there seems to be some evidence that the risk-taking channel is stronger for poorly capitalized banks (Jiménez *et al.* (2014), Dell'Ariccia *et al.* (2017), Delis *et al.* (2017), Ioannidou *et al.* (2015)) for banks with less liquidity

(Brissimis & Delis 2010) and for smaller banks (Buch *et al.* 2014). Altunbas *et al.* (2010) also find that banks more involved in non-traditional banking activities take more risk. Finally, Maddaloni & Peydró (2011) find evidence of agency problems in excessive risk-taking, given that the impact of low monetary policy rates on lending standards is amplified when supervision standards for bank capital are weaker.

Financial innovation also seems to impact on banks' lending standards. Maddaloni & Peydró (2011) find that securitization leads to softer lending standards in both the euro area and the US, amplifying the effects coming from low policy rates (Delis & Kouretas 2011).

Our paper contributes to the expanding empirical literature on the risk-taking channel of monetary policy by looking at the risk-taking channel through different angles. By exploring a rich and detailed dataset and by taking advantage of the exogeneity of monetary policy decisions, we test the effect of policy rates on banks' risk-taking behaviors. We do this through several different perspectives, thereby providing a thorough analysis of this transmission channel. In line with most literature, our results support the existence of a risk-taking channel along some dimensions and especially for banks with less capital.

1.3 Data

We collect data for the period between 1999 and 2007. As discussed below, the identification strategy relies on the exogeneity of monetary policy, thus we only use data for the period after Portugal joined the euro area. We chose to use data only up to 2007 since the transmission of monetary policy has been severely impaired by the global financial crisis (and, more importantly, by the euro area sovereign crisis). As such, we want to test the existence of a risk-taking channel of monetary policy in "normal" conditions exploiting the exogeneity of the interest rates set by the ECB Governing Council. The period under analysis allows us to cover a full business cycle.

The most important data source is the Portuguese Central Credit Register

(CRC), which is a database managed by Banco de Portugal, covering virtually all bank loans granted in Portugal (all financial institutions granting credit in Portugal are required to report on a monthly basis all loans granted above 50 euros). The register includes outstanding loans to firms, as well as potential credit liabilities associated with irrevocable commitments. 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.

To address our research question, we have to identify episodes of default. We consider that there is a default when a loan is overdue or in litigation during an entire semester. This avoids mining the data with very short-lived episodes, possibly related to reporting errors or problems in bank payments, for instance.

We also use information on banks' characteristics coming from supervisory quarterly balance sheet data. From all monetary financial institutions with activity during at least one year between 1999 and 2007, we select institutions with a market share of at least 0.1 per cent in the corporate loan market. After this selection, we have a sample of 52 credit institutions: 30 banks, 10 mutual agricultural credit banks ("*caixas de crédito agrícola mútuo*"), 1 savings bank ("*caixa económica*") and 11 branches of credit institutions with head office in the EU.

Our unit of observation is a firm-bank relationship in a given quarter. We consider that there is a new loan when there is an increase in the amount of credit granted by a bank to a firm or when there is a new firm-bank relationship.[1] Using quarterly data for the period 1999-2007, we have almost 12 million observations, representing 933,611 different firm-bank relationships. Default episodes account for 8 per cent of total observations. On average, each firm has a relationship with three banks and has credit history for 24 quarters.[2] The average amount of each firm's

[1] Unlike Jiménez *et al.* (2012) and Jiménez *et al.* (2014), we do not have individual loans data, i.e., we cannot exactly identify when a new loan contract is established or when an old one matures. Nevertheless, we consider that the relevant unit of analysis would still be the relationship between the bank and the firm and not strictly the loan contract.

[2] To compute the duration of credit histories we used data since 1995.

loan per bank is around 234 thousand euros, thus suggesting that we are dealing mainly with micro and small enterprises.

Table 1.1 presents the definitions of all the explanatory variables considered in the analysis, as well as some descriptive statistics. As discussed below, our analysis relies on different methodologies to look at different dimensions of the risk-taking channel. Depending on the methodology being used, we can use different measures of borrower's credit quality: having recent default history (for two consecutive quarters) (*bad_hist*), currently being in default with that specific bank (*D_default_bank*) or obtaining a loan for the first time ever (*new_bor*). For robustness, we considered different measures of credit quality (currently being in default in any loan, being in default for 4 consecutive quarters or for 4 consecutive years or having a default in the future) and the results remain broadly robust.

Table 1.1: Variables description and descriptive statistics

	Description	Unit	Obs	Mean	Std. Dev.	Min	Max
Dependent variables							
loan_growth	Change in the log of loan amount relative to the previous quarter (at firm-bank level)	%	8 667 766	-0.038	1.441	-46.010	46.212
loan_growth_cl	Change in the log of loan amount including unused credit lines relative to the previous quarter (at firm-bank level)	%	9 932 343	-0.031	0.985	-48.470	47.801
bad_hist	Dummy =1 if the borrower has overdue credit in the current and in the previous quarter; = 0 otherwise	{0,1}	11 772 002	0.112	0.316	0	1
new_bor	Dummy =1 if it is a first-time borrower; = 0 otherwise	{0,1}	11 772 002	0.018	0.133	0	1
D_default_bank	Dummy =1 if the borrower has overdue credit in the current quarter with the bank; = 0 otherwise	{0,1}	11 772 002	0.080	0.271	0	1
new_loan	Dummy =1 if there is an increase in loan amount or a new bank relationship is created; = 0 otherwise	{0,1}	11 772 002	0.305	0.461	0	1
new_loan_cl	Dummy =1 if there is an increase in loan amount including unused credit lines or a new bank relationship is created; = 0 otherwise	{0,1}	11 772 002	0.286	0.452	0	1
Independent variables							
Monetary Policy Rates							
i ECB eoq	ECB main refinancing rate at the end of the quarter	%	11 772 002	2.978	0.885	2	4.75
Taylor residual	Residuals for Portugal of a panel-data Taylor rule with 10 euro area countries (AT, BE, DE, ES, FI, FR, IE, IT, NL, PT) against contemporaneous GDP growth and inflation	p.p.	11 552 445	-0.108	0.665	-1.553	1.203
Differences-in-differences							
treatment	Dummy = 1 for firm-bank relationships with a new loan granted between Jan-05 and Sep-05; = 0 for firm-bank relationships with a new loan granted between Oct-05 and Mar-06	{0,1}	2 112 930	0.412	0.492	0	1
after t	Dummy =1 after the low interest rate period (from 2006Q1 onwards)	{0,1}	11 772 002	0.263	0.440	0	1
Bank characteristics							
ln(assets)	Logarithm of the total assets of the bank	ln(EUR)	11 536 811	23.419	1.662	16.70	25.19
liq ratio	The amount of liquid assets over total assets.[a]	%	11 536 811	18.475	10.809	0.00	82.87
rel npl/assets	Difference between the bank ratio of non performing loans over total assets and the average ratio for all banks	%	11 536 811	-1.953	2.250	-3.79	22.55
capital_ratio	Equity capital over total assets	%	11 432 772	4.819	2.462	0.07	37.99
savings	Dummy = 1 if the bank is a saving bank; = 0 otherwise	{0,1}	11 772 002	0.033	0.179	0	1
CCAM	Dummy = 1 if the bank is a mutual agricultural credit bank; = 0 otherwise	{0,1}	11 772 002	0.023	0.150	0	1
ICUE	Dummy = 1 if the bank is a branch of a credit institution with head office in the EU; = 0 otherwise	{0,1}	11 772 002	0.037	0.189	0	1
M&A	Dummy = 1 if the bank is involved in a merger in that quarter; = 0 otherwise	{0,1}	11 772 002	0.051	0.220	0	1
IAS	Dummy = 1 for the quarter when the bank switched from the old accounting standards to the IAS	{0,1}	11 772 002	0.032	0.175	0	1
Borrower characteristics							
#rel	Number of bank relationships of the firm	integer	11 772 002	3.057	2.424	1	38
credit	The total amount of credit of the firm	EUR	11 772 002	1 040 303	12 800 000	0	4 520 000 000
age	Number of quarters that the firm has credit	integer	11 772 002	23.785	13.510	0	51
loan	Total credit granted by the bank to the borrower	EUR	11 772 002	234 358	4 398 536	0	4 520 000 000
loan_cl	Total credit including unused credit lines granted by the bank to the borrower	EUR	11 772 002	313 461	5 086 170	0	4 520 000 000
Cred_LT_prop	Share of long term credit on the sum of short and long-term credit	%	10 222 954	48.769	39.713	0	100
sectoral dummies	Dummies for economic sectors based on 2 digit NACE codes (66 sectors)	{0,1}					
Macro controls							
GDP PT	Portuguese real GDP y-o-y quarterly growth rate	%	11 772 002	1.612	1.592	-1.90	5.10
inflation PT	Quarterly inflation rate (HICP)	%	11 772 002	2.926	0.702	1.90	4.40
trend	Time trend	integer	11 772 002	20.191	10.101	1.00	36.00

[a] Included in liquid assets: cash, balances with the central bank, loans and advances to credit institutions, loans and advances to the public sector, gold and other precious metals for the old accounting standards; cash, loans and advances to credit institutions and other loans and advances for the IAS.

We analyze lending at the intensive margin using two different quarterly firm-bank loan growth measures: the log change in loans (*loan_growth*) and the log change in loans including the unused amount of committed credit lines (*loan_growth_cl*). To study the extensive margin, we consider two dummy variables that take the value one if i) there is an increase in loan exposure (*new_loan*) or ii) if there is a new lending relationship (*new_bor*). In both cases we consider an alternative definition that takes into account unused committed credit lines (*new_loan_cl* and *new_bor_cl*, respectively).

The most relevant explanatory variable for our analysis is the monetary policy interest rate, defined as the ECB main refinancing rate at the end of each quarter. In addition to this, we also consider a Taylor rule residual to capture the stance of monetary policy. This is calculated as the residual for Portugal from a panel-data Taylor rule estimated for ten euro area countries along the lines of Maddaloni & Peydró (2011). Figure 1.1 shows the evolution of the two main explanatory variables. We also considered the quarterly average of the ECB main refinancing rate and of the EONIA, and the results are robust.

We also control for a broad set of bank and firm characteristics. Regarding bank characteristics, we control for bank size (*ln(assets)*), liquidity (defined as liquid assets as a percentage of total assets - *liq ratio*), credit quality (the non-performing loans ratio of the bank relative to the ratio for the entire banking sector – *rel npl/assets*) and solvency (*capital_ratio*). We also control for the bank type (deposit taking financial institution, *savings* bank, agricultural cooperative banks (*CCAM*) and subsidiaries from EU countries (*ICUE*)), for mergers and acquisitions (*M&A*) and for the change to International Accounting Standards (*IAS*). Borrower characteristics are based on the information available in the CRC: number of bank relationships (*#rel*), total amount of credit granted to the firm (*credit*), number of quarters with credit history (*age*), loan size (*loan*) and share of long term credit that the firm holds (*Credit_LT_prop*). We also control for firms' business sector using 2-digit NACE codes.[3] Finally, we include macroeconomic controls (*GDP* and *inflation* for

[3]This information is compiled with information from a dataset on firms (*Informação Empresarial Simplificada*).

Portugal) and a time trend.

1.4 Identification strategy and methodology

Our primary objective is to test the existence of a risk-taking channel in a bank-based financial system. In other words, we want to assess whether banks grant riskier credit when policy interest rates are lower. Taken at face value, this would mean regressing variables that capture bank risk-taking on interest rates. However, to correctly identify the causal effect of monetary policy on bank risk-taking, monetary policy decisions need to be exogenous. Otherwise, it is possible that there are (omitted) variables that simultaneously affect monetary policy and bank risk-taking decisions. Our setup allows us to avoid this potentially serious endogeneity problem, as monetary policy is fully exogenous during the period analyzed. Portugal is a small open economy that joined the euro area in 1999. The impact of macroeconomic and financial conditions specific to the Portuguese economy on euro area interest rates should be negligible. Moreover, the correlation of the Portuguese economic cycle with that of the euro area was relatively low. For instance, the correlation for inflation, which is at the core of the primary objective of the ECB, was 0.3 during the sample period. Euro area monetary policy can thus be considered exogenous, allowing for the correct identification of this causal effect. This is the same argument used by Jiménez *et al.* (2012) and Jiménez *et al.* (2014) and, to some extent, by Ioannidou *et al.* (2015) and Geršl *et al.* (2015). Indeed, this article follows to some extent part of their empirical strategy but includes additional layers of analysis, with the objective of testing from different perspectives whether there is a risk-taking channel.

Our methodological strategy is anchored in two blocks. In the first block, we assess the risk-taking channel at the intensive and extensive margins using ex-ante information. In other words, we assess loan growth to risky borrowers and the probability of granting new loans to these borrowers, respectively. As such, we focus on the effects of policy interest rates on lending by testing two hypotheses: (1)

Do riskier firms get more credit when policy rates are lower? (section 5.1) and (2) Are riskier firms more likely than other firms to obtain a loan when interest rates decrease? (section 5.2). To answer the first question, we run the following panel regression:

$$loan\_growth_{ijt} = c_{ij} + \alpha i_{t-1}^{ECB} \times bad\_hist_{it-1} + \beta i_{t-1}^{ECB} + \gamma bad\_hist_{it-1} + \delta' X_{ijt-1} + \varepsilon_{ijt} \tag{1.1}$$

Where the index i stands for firm, the index j stands for bank and the index t for quarter. We include firm-bank fixed effects (c_{ij}) and α is the main coefficient of interest, capturing the (additional) effect of the policy rate (i^{ECB} or *Taylor*) on the loan growth of firms with recent bad credit history (*bad_hist*). A negative α would provide evidence in favor of the risk-taking channel. The vector of controls X_{ij} includes the bank and firm characteristics and macro conditions described in section 3.

In order to test the second hypothesis, we use discrete choice models to assess the probability of borrowers with recent episodes of default or no credit history being granted loans[4]. The following probit model is estimated:

$$\Pr\left(risky_{it} = 1 | new\_loan_{ijt} = 1\right) = \Phi\left(\alpha i_{t-1}^{ECB} + \delta' X_{ijt-1} + \varepsilon_{ijt}\right) \tag{1.2}$$

This approach allows us to test whether banks grant more loans to risky borrowers during periods of lower policy interest rates. Our dependent variable takes the value one when a new loan is granted to a borrower defined as risky (and zero when a new loan is granted to any other borrower). A negative α would imply that when policy rates are lower (or when monetary policy stance is more accomodative than what is foreseen in a Taylor rule), it is more likely to grant a new loan to a riskier borrower. We consider two definitions of risky borrowers: when borrowers

[4]Granting loans to borrowers with limited historical data increases the expected profitability of banks, while fostering innovation, as shown by Thakor (2012). However, it also increases the risk held by banks.

are in default with any bank in the last two quarters (*bad_hist*) or when borrowers obtain a loan for the first time (*new_bor*).

Positive answers to the above two questions would mean that there is more expansion of credit to riskier borrowers when interest rates are lower. But will the ex-ante risky borrowers reveal themselves as riskier ex-post? What is the impact in the overall risk assumed by banks and, in the end, what are the consequences in terms of financial stability? Based on previous evidence that shows that firms that have defaulted are more likely to default in the future (Bonfim *et al.* 2012), we assess the ex-post performance of the loans granted during periods of low interest rates. Again, two hypotheses are tested here: (1) Does the level of the policy rate when loans are granted influence the (ex-post) probability of default? (section 6.1) and (2) Are loans granted when policy rates are low and stable more likely to default when interest rates increase? (section 6.2).

In order to test the first hypothesis, we use duration analysis to assess the impact of monetary policy rates when loans are granted on the time until a firm defaults. We model the hazard rate of the loans granted to the firms, considering that the failure event is the occurrence of default. The hazard function is defined as the instantaneous probability of a firm defaulting on the bank, conditional on having no default up to time t. The time at risk is defined as the time elapsed between the moment a new loan is granted and the moment the firm (eventually) defaults with that bank. Taking into account the shape of the hazard function of the sample, we estimate a parametric model with a Weibull distribution, which allows for a monotonic hazard function, i.e., the hazard rate either increases or decreases over time according to the Weibull distribution parameter. In this estimation, p is the distribution parameter that indicates whether the Weibull hazard function is monotonically increasing ($p > 1$) or decreasing ($p < 1$). The following Weibull hazard function is estimated:

$$h_{ij}(t) = p \exp\left(\alpha i_{\tau-1}^{ECB} + \gamma bad\_hist_{i\tau-1} + \delta' X_{ij\tau-1}\right) t^{p-1} \tag{1.3}$$

where again we could interpret a negative α as an indication of a risk-taking

channel at work. The explanatory variables are considered at the moment the loan was granted (τ).

For the second hypothesis, we use a differences-in-differences (DID) analysis, where we define the loans "treated" as the ones that were granted during a period of low interest rates ($treatment_{ijt} = 1$). We want to understand if these loans are relatively more likely to default once interest rates start to increase ($after\_t_t = 1$), revealing themselves as riskier ex-post. To be sure that the treatment and control groups are comparable we focus our analysis on a very short window: we consider that treated loans are those granted immediately before interest rates began to increase in December 2005, when interest rate expectations were still anchored at low levels (2005Q1 to 2005Q3). The loans in the control group are those granted in the period when interest rates were still low, but interest rate expectations had increased markedly, as illustrated in Figure 1.2 (2005Q4 to 2006Q1).

The ECB had kept monetary policy interest rates stable at 2% since June 2003. In December 2005, the ECB increased rates for the first time since October 2000. This was a minor 25 basis points upward revision in the interest rate, which was not immediately reflected in firms' borrowing costs, as shown in Figure 1.2. The tightening trend of monetary policy only became clear during 2006, with interest rates reaching 4.25% in the summer of 2007. As such, the effective interest rates set by banks on loans granted to firms between January 2005 and March 2006 were very similar, as shown in Figure 1.2. The borrowing costs of Portuguese non-financial corporations oscillated in a narrow interval between 4.7 and 5% during this period.

The main difference between the loans granted in January-September 2005 and those granted in October 2005-March 2006 relates to the level of interest rate *expectations*. The chart shows that market participants' expectations on future interest rates (proxied by the 6-month overnight interest rate swap) increased markedly in October 2005, decoupling from monetary policy rates and bank interest rates on loans to firms. This change in expectations was very sudden and was underpinned by a change in the communication of the ECB, signalling that monetary policy could be tightened in the near future.

Figure 1.1: ECB main refinancing rate and estimated Taylor residual for Portugal.

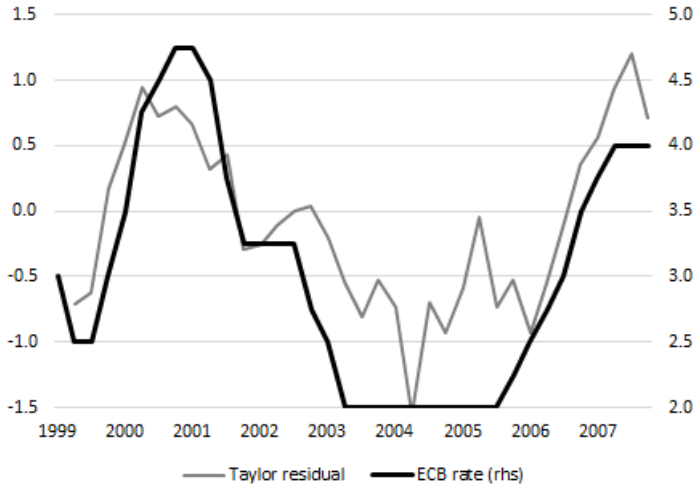
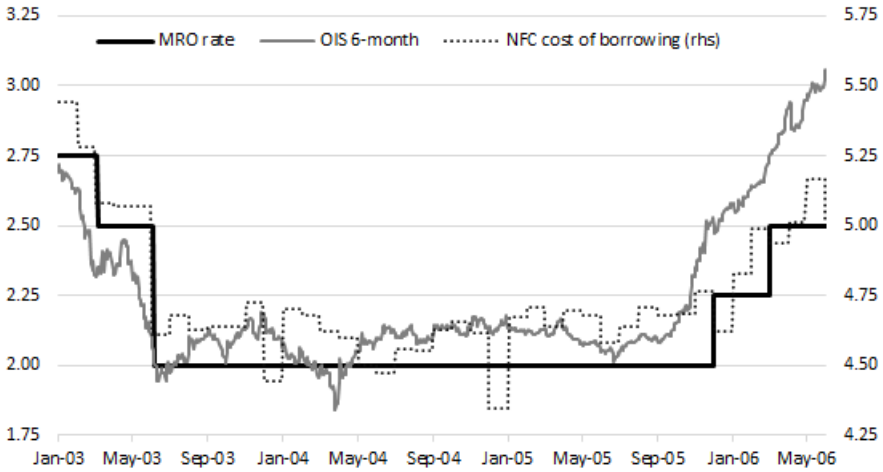


Figure 1.2: Euro area short-term interest rate expectations and non-financial firms' cost of borrowing in Portugal.



Note: The black line is the main refinancing rate (MRO) of the ECB. The gray line is the 6-month OIS (overnight interest rate swap) rate and can be read as the average expected overnight rate 6-months forward. The dotted line is the composite cost of borrowing to non-financial corporations (NFC) in Portugal as calculated by the ECB.
Source: Thomson Reuters and ECB MFI interest rate statistics.

This setting allows us to test the risk-taking channel in a unique scenario. With our DID approach, we are comparing loans granted with similar levels of prevailing interest rates, but with quite different expectations regarding future rates. We are thus able to test if banks adopted riskier behaviors when interest rates were low and were expected to remain so for the foreseeable future, compared to a situation in which rates were still low, but there was an emerging consensus that they would increase soon. Here we measure loan riskiness based on the likelihood of loan default in the period of monetary policy tightening, thus testing which borrowers were more sensitive to interest rate hikes. Our argument hinges on the idea that banks might have been less prudent in assessing borrowers' sensitivity to interest rate risk when interest rates are expected to remain low for some time.

We estimate the following equation:

$$\Pr\left(bad\_hist_{it}=1\right)=\Phi\left(\alpha treatment_{ijt}\times after_{t}+\gamma treatment_{ijt}+\beta after_{t}+\delta' X_{ijt-1}+\varepsilon_{ijt}\right) \tag{1.4}$$

In order to prove the existence of a risk-taking channel, we would need to find that loans granted when policy rates were low would have a higher probability of default when interest rates increase, which would imply a positive α.

One important dimension of our analysis is to understand which banks are more prone to risk-taking. To test this, we interact the risk-taking coefficient (α) with banks' liquidity, capital and total assets in all the approaches described above. Furthermore, for all identification strategies, we look separately at small and large firms and at small and large banks. This allows us to draw important insights about the role of bank and firm characteristics in the transmission of monetary policy through the risk-taking channel.

1.5 The risk-taking channel assessed with ex-ante information

1.5.1 Do riskier firms get more credit when policy rates are lower?

To answer this question, Table 1.2 presents the results of a panel regression with fixed effects on firm loan growth against the monetary policy rate, the recent credit history of the firm (*bad_hist*) and an interaction term between these two, controlling for bank and firm characteristics and macro conditions (equation 1.1). Given that borrowers' credit situation can be verified by any bank through the CRC, we consider that there is bad credit history when the firm is defaulting on any bank loan, i.e., not only on the bank offering the new loan.

Table 1.2: Risk-taking at the intensive margin: loan growth and interest rates

	Dependent variable: loan_growth											
									Small firms	Large firms	Small banks	Large banks
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
	S.e.	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*
i*bad_hist t-1	-0.018**	-0.018	0.001	0.001	-0.001	-0.001	0.001	-0.002	0.005	0.004	-0.003	0.002
	(0.009)	*(0.014)*	*(0.005)*	*(0.005)*	*(0.005)*	*(0.006)*	*(0.007)*	*(0.016)*	*(0.007)*	*(0.006)*	*(0.006)*	*(0.007)*
i*bad_hist t-1* liq_ratio t-1						0.000						
						(0.000)						
i*bad_hist t-1* capital_ratio t-1							-0.000					
							(0.001)					
i*bad_hist t-1* ln(assets) t-1								0.000				
								(0.001)				
i ECB eoq t-1	0.016	0.016	-0.006	-0.006	-0.008	-0.006	-0.006	-0.006	0.015	-0.019	0.024	-0.037
	(0.014)	*(0.018)*	*(0.030)*	*(0.030)*	*(0.025)*	*(0.030)*	*(0.031)*	*(0.030)*	*(0.044)*	*(0.019)*	*(0.045)*	*(0.038)*
bad_hist t-1	0.112***	0.112**	-0.026	-0.026	-0.023	-0.025	-0.026	-0.026	0.002	-0.055***	-0.015	-0.032
	(0.026)	*(0.051)*	*(0.016)*	*(0.016)*	*(0.014)*	*(0.016)*	*(0.015)*	*(0.016)*	*(0.021)*	*(0.013)*	*(0.018)*	*(0.023)*
liq_ratio t-1	-0.002***	-0.002	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	0.001
	(0.001)	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.002)*
capital_ratio t-1	0.003	0.003	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.000	-0.001	0.001
	(0.004)	*(0.005)*	*(0.003)*	*(0.003)*	*(0.002)*	*(0.003)*	*(0.003)*	*(0.003)*	*(0.003)*	*(0.004)*	*(0.001)*	*(0.013)*
ln(assets) t-1	0.139***	0.139**	0.038	0.038	0.037	0.038	0.038	0.038	0.003	0.046	-0.038**	0.147
	(0.043)	*(0.060)*	*(0.042)*	*(0.042)*	*(0.037)*	*(0.042)*	*(0.042)*	*(0.042)*	*(0.039)*	*(0.048)*	*(0.017)*	*(0.073)*
bank variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
borrower variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
unused credit lines	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
sectoral dummies	no	no	no	no	yes	no	no	no	no	no	no	no
macro variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
fixed effects	relationship	relationship	relationship	relationship	relationship	relationship	relationship	relationship	relationship	relationship	relationship	relationship
Clustered s.e.	quarter	quarter & bank	quarter & bank	quarter & bank & firm	quarter	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank
N obs.	6,427,685	6,427,685	6,927,838	6,927,838	5,919,775	6,927,838	6,927,838	6,927,838	2,690,267	904,414	2,568,837	4,359,001

Note: All variables defined in Table 1.1. Results of panel data regressions on the dependent variable loan_growth (or loan_growth_cl) defined as the quarterly growth (log difference) of the loan amount (or including unused credit lines) at the firm-bank level. Bank variables included and not reported: rel npl/assets, M&A and IAS. Borrower variables included and not reported: ln(1+#rel), ln(credit), ln(2+age), ln(1+loan) and Cred_LT_prop. Macro variables included and not reported: GDP PT (4 lags) and π PT. A constant and a quadratic trend are also included but their coefficients are not reported. Columns IX to XII report the results of the regression for sub-samples according to criteria defined in the top of the column. Small (large) firms proxied by the size of the total credit of the firm: Small firms are below the median, large firms are in the top-10 percentile. Large banks are the 5 largest banks in Portugal, representing around half of the total corporate loan market; small banks are the remaining ones. Multi-way clustering computed using reghdfe (Correia, 2017). For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

The coefficient on the interaction term $i * bad\_hist$ captures risk-taking. A negative coefficient would mean that when interest rates are lower, firms with a recent bad credit history show stronger loan growth than other firms. Looking across the several columns of Table 1.2, we find that this coefficient is generally non-significant, implying that, at the intensive margin, there seems to be no evidence of a risk-taking channel.

Let us analyze in more detail the different columns of Table 1.2. In the first column, we show the results of an estimation with relationship fixed effects, standard errors clustered at the quarter level, and bank, borrower and macroeconomic controls. Using this specification we find statistically significant results to support the risk-taking channel. Nevertheless, the result is not strong enough to survive an estimation with standard errors clustered at the quarter and bank level (instead of only at the quarter level), as shown in column II.

The same is true when we consider unused credit lines as part of our dependent variable. As mentioned before, in our ex-ante assessment of the risk-taking channel, we consider that there may be two ways to capture banks' increased exposure to a given firm. On one hand, we can consider, as in columns I and II, that the bank increases its exposure to the firm every time there is an increase in effective loan amounts. On the other hand, part of this effective loan amount increase may reflect the drawing down of credit lines by firms. As such, we consider that it might be important to also consider changes in the total exposure of a bank to a firm, including also the unused amount of committed credit lines. From column III onwards we consider this latter definition of the dependent variable.

In column IV, we impose an even more demanding structure on the data, setting a three-way multi-clustering of errors (quarter, bank and firm) and, as it would be expected, the no-significance result also shows up.[5] However, we consider that the most critical clustering level should be at the quarter and bank level and we adopt this throughout our analysis of the intensive margin.[6] The reason for this is

[5]We computed multi-way clustering following Correia (2017).

[6]The only exception are the results displayed in column V, where we have to go back to clustering only at the quarterly level when we add sectoral dummies, with the goal of better controlling for firm heterogeneity. The results remain non-significant when we do this.

that (i) monetary policy interest rates, which play a key role in our analysis, vary simultaneously for every bank and firm at a quarterly frequency (Petersen 2009), and (ii) banks' internal pratices and the relatively low number of banks in the Portuguese economy justify grouping the errors by bank.

In columns VI to VIII we add another layer of analysis. The goal is to understand if the risk-taking channel works differently depending on bank characteristics. To answer this question, we add a triple interaction term to the regressions. More specifically, we consider the interaction between monetary policy interest rates, the dummy for bad quality borrowers and banks' liquidity ratio (column VI), capital ratio (column VII), and log of total assets (column VIII), respectively. We cannot find any differential effect from these bank characteristics.

To better understand how the risk-taking channel works at the intensive margin, we estimate our regression separately for small and large firms (columns IX and X, respectively). Small firms are those below the median of the empirical distribution of total assets, while large firms are those in the 90th percentile. The results show no statistically significant interaction effects of the level of the interest rate and the credit history of the firm.

Finally, we run a similar exercise for bank size, estimating the regression separately for small and large banks (columns XI and XII, respectively), where the latter are the five largest banks (accounting for more than half of the corporate loan market). Again, no difference is to be mentioned and, contrary to some studies that find riskier behaviors by small banks (Buch *et al.* (2014), Stein & Kashyap (2000)), we do not find evidence of risk-taking at the intensive margin for all types of banks.

Until now, we focused our analysis on the coefficients associated with the identification of the risk-taking channel. However, the results concerning some of the remaining control variables deserve a few words. The effect of interest rates on loan growth at the firm level is generally not statistically significant when we also control for banks' risk-taking.

The coefficient on the *bad_hist* variable in columns I and II is somehow puzzling. It seems to suggest that borrowers with recent poor recent credit history

show stronger loan growth than other firms. Given that we are using relationship fixed effects, this is happening when firms get into distress. Using a similar dataset, Bonfim *et al.* (2012) showed that in Portugal firms regain access to credit very easily after default. These two results taken together might be supportive of the existence of evergreening (Peek & Rosengren 2005). Banks may be extending loans to distressed borrowers to avoid recording losses on their loans. However, it is important to note that this result is only obtained when using effective loan growth as the dependent variable. When we include total loan exposure growth, i.e., including unused credit lines (column III onwards), the coefficient is no longer significant. Therefore, this result seems to be more in line with the argument that firms tend to increase their funds by withdrawing on pre-existing commitments when they enter into default in a loan, in line with what Ivashina & Scharfstein (2010) find for the crisis period.

Using the residuals of a Taylor rule for the Portuguese economy as explanatory variable instead of the monetary policy interest rate does not change our conclusions. The results for our baseline regression with this alternative explanatory variable are presented in Table 1.3. In columns I and II we consider, respectively, loan growth without and with unused credit lines.

The interaction term between monetary policy and the credit history of the firm continues to be non-significant. The main difference relates to the *bad_hist* variable. We find that firms with a bad credit history indeed have a stronger effective loan growth, but a weaker potential loan growth. This reinforces the previous argument that firms make more use of pre-existing commitments when they enter distress, though this does not correspond to an increase of the exposure of the bank to that firm.

In sum, we find no consistent evidence of a risk-taking channel of monetary policy working at the intensive margin: the level of interest rates or the monetary policy stance do not seem to be relevant for the expansion of credit by banks to riskier firms.

Table 1.3: Risk-taking at the intensive margin: loan growth and Taylor residuals

	Dependent variable: loan_growth	
	I	II
	Coef.	Coef.
	S.e.	*S.e.*
Taylor*bad_hist t-1	-0.017	0.012
	(0.019)	*(0.011)*
Taylor residual t-1	0.008	0.001
	(0.010)	*(0.014)*
bad_hist t-1	0.058***	-0.023***
	(0.018)	*(0.005)*
liq_ratio t-1	-0.002	-0.000
	(0.001)	*(0.001)*
capital_ratio t-1	0.003	-0.000
	(0.004)	*(0.003)*
ln(assets) t-1	0.141**	0.035
	(0.058)	*(0.038)*
bank variables	yes	yes
borrower variables	yes	yes
unused credit lines	no	yes
sectoral dummies	no	no
macro variables	yes	yes
fixed effects	relationship	relationship
Clustered s.e.	quarter & bank	quarter & bank
N obs.	6,427,685	6,927,838

Note: All variables defined in Table 1.1. Results of panel data regressions on the dependent variable loan_growth (or loan_growth_cl) defined as the quarterly growth (log difference) of the loan amount (or including unused credit lines) at the firm-bank level. Bank variables included and not reported: rel npl/assets, M&A and IAS. Borrower variables included and not reported: ln(1+#rel), ln(credit), ln(2+age), ln(1+loan) and Cred_LT_prop. Macro variables included and not reported: GDP PT (4 lags) and π PT. A constant and a quadratic trend are also included but their coefficients are not reported. Multi-way clustering computed using reghdfe (Correia, 2017). For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

1.5.2 Are riskier firms more likely than other firms to obtain a loan when interest rates decrease?

In this section we consider the extensive margin of loan dynamics: are riskier firms more likely than other firms to get new loans when interest rates are lower? Our analysis is based on the estimation of discrete choice models for new bank loans. Given that a new loan is being granted, we evaluate the probability that the borrower has a recent bad credit history or has no credit history (equation 1.2). We are interested in studying how monetary policy rates in the quarter prior to loan origination influence the probability of granting loans to these higher risk borrowers.

Table 1.4 presents the results of the estimation for borrowers with recent default (*bad_hist*). Overall, we find that lower short-term interest rates increase the probability of banks granting a loan to a borrower with recent episodes of loan default vis--vis that of a healthy borrower, thus supporting the existence of a risk-taking channel at the extensive margin.[7]

[7]The absence of loan application data does not allow us to fully separate demand from supply effects, i.e., we cannot clearly distinguish the effect coming from the possible higher number of loan applications from risky borrowers in periods of low interest rates from the effect of an increased probability of granting a loan to a risky borrower, for the same pool of loan applications. Nonetheless, the effect is favorable to risk-taking, since a higher proportion of new loans is granted to risky firms.

Table 1.4: Risk-taking at the extensive margin: probability of granting a loan to a risky firm and interest rates

	I	II	III	IV	V	VI	VII	VIII	Small firms IX	Large firms X	Small banks XI	Large banks XII	LPM XIII
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
	S.e.	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*
i ECB eoq t-1	-0.043**	-0.043**	-0.048***	-0.048**	-0.029	0.028	-0.152***	-0.157	-0.025	-0.094***	-0.062***	-0.091	-0.008***
	(0.021)	*(0.019)*	*(0.017)*	*0.017*	*(0.022)*	*(0.050)*	*(0.044)*	*(0.236)*	*(0.022)*	*(0.016)*	*(0.024)*	*(.)*	*(0.001)*
i * liq_ratio t-1						-0.004*							
						(0.002)							
i * capital_ratio t-1							0.024***						
							(0.009)						
i * ln(assets) t-1								0.005					
								(0.010)					
liq_ratio t-1	-0.007***	-0.007**	-0.007**	-0.007**	-0.007***	0.004	-0.007**	-0.007**	-0.012***	-0.003	-0.011***	0.001	0.001*
	(0.001)	*(0.003)*	*(0.003)*	*0.003*	*(0.001)*	*(0.009)*	*(0.003)*	*(0.003)*	*(0.005)*	*(0.003)*	*(0.004)*	*(0.003)*	*(0.000)*
capital_ratio t-1	0.021***	0.021	0.021	0.021	0.023***	0.021	-0.052	0.022	0.026*	0.016	0.023*	0.010	-0.004**
	(0.004)	*(0.014)*	*(0.016)*	*0.016*	*(0.003)*	*(0.015)*	*(0.037)*	*(0.016)*	*(0.014)*	*(0.019)*	*(0.014)*	*(0.022)*	*(0.002)*
ln(assets) t-1	-0.042***	-0.042	-0.040	-0.040	-0.042***	-0.040	-0.039	-0.055	-0.053	-0.017	-0.023	0.178*	0.026*
	(0.007)	*(0.026)*	*(0.033)*	*0.033*	*(0.006)*	*(0.032)*	*(0.032)*	*(0.056)*	*(0.042)*	*(0.029)*	*(0.060)*	*(0.091)*	*(0.013)*
bank variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
borrower variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
unused credit lines	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
sectoral dummies	no	no	no	no	yes	no	no	no	no	no	no	no	no
macro variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
fixed effects	no	no	no	no	no	no	no	no	no	no	no	no	relationship
Clustered s.e.	quarter	quarter & bank	quarter & bank	quarter & bank & firm	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	
N obs.	2,655,604	2,655,604	2,479,691	2,655,604	2,086,479	2,479,691	2,479,691	2,479,691	835,022	387,385	845,868	1,633,823	2,346,526

Note: All variables defined in Table 1.1. Results of probit regressions (except column XIII, which is a linear probability model) on the dependent variable bad_hist conditional on a new loan (or a new loan including unused credit lines) being granted. Bank variables included and not reported: rel npl/assets, savings, CCAM, ICUE, M&A and IAS. Borrower variables included and not reported: ln(1+#rel), ln(credit), ln(2+age), ln(1+loan) and Cred_LT_prop. Macro variables included and not reported: GDP PT and π PT. A constant and a quadratic trend are also included but their coefficients are not reported. Columns IX to XII report the results of the regression for sub-samples according to criteria defined in the top of the column. Small (large) firms proxied by the size of the total credit by the firm: Small firms are below the median, large firms are in the top-10 percentile. Large banks are the 5 largest banks in Portugal, representing around half of the total corporate loan market; small banks are the remaining ones. Multi-way clustering computed following Cameron, Gelbach and Miller (2011) and Cameron and Miller (2015). For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

This result holds in most specifications. The results are similar regardless of whether standard errors are clustered at the quarter level or multi-clustered at the quarter and bank or at the quarter, bank and firm level (columns I to IV). Moreover, adapting the dependent variable to include unused credit lines yields similar results (column III). However, the coefficient on the policy rate lacks statistical significance when we control for sectoral effects (column V).

As in the previous sub-section, we try to determine whether bank characteristics play a role in the way the risk-taking channel operates. Again, there are interesting differences between the intensive and extensive margin. While at the intensive margin bank characteristics did not seem to play a role, at the extensive margin we find that risk-taking behaviors are more relevant for banks with more liquidity and, especially, less capital (columns VI to VIII).

On one hand, banks with more liquidity will possibly be more interested in doing some risk-shifting when interest rates are lower. Given that liquid assets usually offer null or very small remunerations, in a low interest rate environment banks with more liquid assets may divert some of these resources to grant riskier loans, in a search for yield strategy. Furthermore, banks with more liquidity may show a riskier behavior because managers' incentives to monitor risks decrease (Acharya & Naqvi (2012), Altunbas *et al.* (2010)).

On the other hand, banks with less capital are usually more prone to risk-taking behaviors. There is evidence that banks closer to minimum regulatory ratios take more risk, as they do not fully internalize the potential consequences of the risks taken (Jiménez *et al.* (2014), Diamond & Rajan (2012)). Our results do not support the hypothesis that banks with higher capital buffers take more risk (DellAriccia *et al.* 2011).

Following again the same steps taken in the analysis of the intensive margin, we look separately at small and large firms (columns IX and X) and at small and large banks (columns XI and XII). We find evidence of risk-taking at the extensive margin only for large firms, which are arguably less risky than smaller firms. In terms of

bank size, risk-taking exists both for small and large banks.[8]

Finally, in column XIII we show the results of our estimations with a linear probability model. We do this because in the probit specifications we are not able to use relationship fixed effects. When we add these fixed effects, we still find evidence that there is risk-taking on the extensive margin[9].

In Table 1.5 we replicate all the estimations reported in Table 1.4. The only difference is the dependent variable: while in Table 1.4 the dependent variable was *bad_hist*, taking the value one if the firm was in default in this quarter and in the previous one, in this new table the dependent variable takes the value one if the firm is a first time borrower (*new_bor*). We consider that this is also a form of risk-taking, as information asymmetries are more acute when giving a loan to a firm without credit history (Diamond (1991), Thakor (2012)). Note that at the intensive margin we are only able to explore risk-taking within ongoing relationships. Adding this dimension of analysis at the extensive margin provides new insights on the workings of the risk-taking channel through different angles.

[8]In column XII, it is not possible to calculate the standard error for the interest rate coefficient, likely due to the high demanding multi-clustering structure imposed. Indeed, when we cluster standard errors by quarter only (not reported, available at request) we get a strongly negative significant coefficient.

[9]To be sure that the results are not being driven by the change in estimation methodology, we also estimate a linear probability model without relationship fixed effects. The results for the coefficient associated with risk-taking are entirely consistent.

Table 1.5: Risk-taking at the extensive margin: probability of granting a loan to a first time borrower and interest rates

	I	II	III	IV	V	VI	VII	VIII	Small firms IX	Large firms X	Small banks XI	Large banks XII	LPM XIII
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
	S.e.	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*
i ECB eoq t-1	-0.045**	-0.045**	-0.047***	-0.047**	-0.038	-0.010	-0.062*	-0.088	-0.062***	0.054	-0.034**	-0.086***	-0.008**
	(0.022)	*(0.019)*	*(0.018)*	*0.018*	*(0.034)*	*(0.036)*	*(0.034)*	*(0.106)*	*(0.022)*	*(0.051)*	*(0.014)*	*(0.019)*	*(0.004)*
i * liq_ratio t-1						-0.002							
						(0.001)							
i * capital_ratio t-1							0.003						
							(0.006)						
i * ln(assets) t-1								0.002					
								(0.005)					
liq_ratio t-1	-0.007***	-0.007***	-0.008***	-0.008***	-0.004***	-0.002	-0.008***	-0.008***	-0.007***	-0.001	-0.005*	-0.008***	-0.001***
	(0.001)	*(0.002)*	*(0.002)*	*0.002*	*(0.001)*	*(0.006)*	*(0.002)*	*(0.002)*	*(0.002)*	*(0.002)*	*(0.003)*	*(0.002)*	*(0.000)*
capital_ratio t-1	0.014***	0.014	0.015	0.015	0.010***	0.014	0.004	0.015	0.006	-0.002	0.020***	-0.027	0.002
	(0.002)	*(0.011)*	*(0.010)*	*0.010*	*(0.003)*	*(0.010)*	*(0.026)*	*(0.010)*	*(0.008)*	*(0.014)*	*(0.007)*	*(0.020)*	*(0.001)*
ln(assets) t-1	-0.003	-0.003	0.003	0.003	-0.030***	0.002	0.003	-0.003	-0.040*	0.074*	-0.044	0.079**	0.009
	(0.008)	*(0.018)*	*(0.021)*	*0.021*	*(0.010)*	*(0.020)*	*(0.020)*	*(0.030)*	*(0.022)*	*(0.041)*	*(0.035)*	*(0.039)*	*(0.007)*
bank variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
borrower variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
unused credit lines	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
sectoral dummies	no	no	no	no	yes	no	no	no	no	no	no	no	no
macro variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
fixed effects	no	no	no	no	no	no	no	no	no	no	no	no	relationship
Clustered s.e.	quarter	quarter & bank	quarter & bank	quarter & bank & firm	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	quarter & bank	
N obs.	3,432,579	3,432,579	3,287,338	3,432,579	2,743,953	3,287,338	3,287,338	3,287,338	1,388,318	421,775	1,166,743	2,120,595	2,990,903

Note: All variables defined in Table 1.1. Results of probit regressions (except column XIII, which is a linear probability model) on the dependent variable new_borrower conditional on a new loan (or a new loan including unused credit lines) being granted. Bank variables included and not reported: rel npl/assets, savings, CCAM, ICUE, M&A and IAS. Macro variables included and not reported: GDP PT and PT. A constant and a quadratic trend are also included but their coefficients are not reported. Columns IX to XII report the results of the regression for sub-samples according to criteria defined in the top of the column. Small (large) firms proxied by the size of the total credit by the firm: Small firms are below the median, large firms are in the top-10 percentile. Large banks are the 5 largest banks in Portugal, representing around half of the total corporate loan market; small banks are the remaining ones. Multi-way clustering computed following Cameron, Gelbach and Miller (2011) and Cameron and Miller (2015). For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

The results regarding the effect of monetary policy interest rates on risk-taking are entirely consistent: when interest rates are lower, banks become more likely to grant loans to new borrowers than to existing ones.

When we interact interest rates with bank characteristics, we do not find any statistically significant results in this case (columns VI to VIII). When we run sample splits by firm size we get an interesting difference: risk-taking through new borrowers occurs mainly through small firms (which are more likely to be first time borrowers), while we had found that for bad quality borrowers the effect was coming mainly from large firms. The results of splitting the sample by bank size are consistent with what we found for borrowers in default, given that risk-taking through new borrowers exists for both small and large banks.

As in the previous section, we also conduct the same analysis but using the Taylor residuals as the main explanatory variable, instead of the monetary policy rate (Table 1.6). In this case, we find an increase in ex-ante banks' risk-taking at the extensive margin for new borrowers (columns III and IV) but not for existing borrowers (columns I and II). This may signal that banks' risk-taking behaviors are associated mainly with environments of low monetary policy interest rates, rather than by periods in which monetary policy is too accommodative.

Summing up, our results consistently show that there is a risk-taking channel working at the extensive margin. Riskier borrowers are more likely to get new loans when interest rates are lower. These effects are stronger for banks with less capital.

1.6 The risk-taking channel assessed ex-post

In the previous section we found evidence supporting the risk-taking channel at the extensive margin, based on banks' assessment when granting a loan. But what happens to the loans granted when interest rates are low? Even if bad quality borrowers get more loans, does that imply an overall deterioration on loan portfolio quality ex-post? To answer these questions, in this section we turn our attention to the assessment of the effect of policy rates on credit portfolio quality. We do

Table 1.6: Risk-taking at the extensive margin: probability of granting a loan to a risky firm and interest rates

	Bad history		New borrower	
	I	II	III	IV
	Coef.	Coef.	Coef.	Coef.
	S.e.	*S.e.*	*S.e.*	*S.e.*
Taylor residual t-1	-0.024	-0.030	-0.051*	-0.043*
	(0.026)	*(0.021)*	*(0.029)*	*(0.025)*
liq_ratio t-1	-0.007**	-0.007**	-0.007***	-0.008***
	(0.003)	*(0.003)*	*(0.002)*	*(0.002)*
capital_ratio t-1	0.022	0.022	0.014	0.015
	(0.014)	*(0.016)*	*(0.011)*	*(0.010)*
ln(assets) t-1	-0.043*	-0.041	-0.003	0.002
	(0.026)	*(0.033)*	*(0.018)*	*(0.020)*
bank variables	yes	yes	yes	yes
borrower variables	yes	yes	yes	yes
unused credit lines	no	yes	no	yes
sectoral dummies	no	no	no	no
macro variables	yes	yes	yes	yes
fixed effects	no	no	no	no
Clustered s.e.	quarter & bank	quarter & bank	quarter & bank	quarter & bank
N obs.	2,597,851	2,424,200	3,355,783	3,212,352

Note: All variables defined in Table 1.1. Results of probit regressions on the dependent variable bad_hist (columns I and II) or on the dependent variable new_borrower (columns III and IV), conditional on a new loan (or a new loan including unused credit lines) being granted. Bank variables included and not reported: rel npl/assets, savings, CCAM, ICUE, M&A and IAS. Borrower variables included and not reported: ln(1+#rel), ln(credit), ln(2+age), ln(1+loan) and Cred_LT_prop. Macro variables included and not reported: GDP PT and π PT. A constant and a quadratic trend are also included but their coefficients are not reported. Multi-way clustering computed following Cameron, Gelbach and Miller (2011) and Cameron and Miller (2015). For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

that in two parts. First, we examine the ex-post performance of loans granted to firms, taking into account the level of policy rates when loans are granted, using a duration analysis framework. Our goal is to test to what extent the level of policy rates when a new loan is granted influences the ex-post probability of default of the loan. Second, we distinguish the loans granted when policy rates were low from all the others and analyze what happens to these loans when interest rates increase. We do this by relying on a differences-in-differences approach. Our goal is to understand if loans granted when rates are low and stable are riskier in the sense of showing heightened sensitivity to interest rate increases.

1.6.1 Does the level of the policy rate when loans are granted influence the (ex-post) probability of default?

Table 1.7 presents the results of the survival estimation (equation 1.3). A brief inspection of the first line of the table shows that there is no evidence of an ex-post risk-taking channel. The level of monetary policy interest rates in the moment loans are granted does not affect the ex-post default performance of the loans. The only exception is reported in column X, where we show our baseline results estimated with time-varying covariates. In this case, we find evidence supporting the risk-taking channel ex-post. However, in this specification, we are explicitly considering the role of changing firm, bank and macro characteristics over the life of the loan, while considering only the interest rate at the moment of concession. As these changes could not be fully anticipated by the bank when deciding to grant a loan, it is not reasonable to argue that banks were taking more risk based solely on this specification. As such, this latter result should be interpreted with caution. In sum, we cannot find consistent evidence to support the hypothesis that the level of interest rates when loans are granted matters for their ex-post default probability.

Table 1.7: Ex-post assessment of risk-taking: Survival analysis of default and interest rates

Dependent variable: hazard rate (loan level)															
											Small firms	Large firms	Small banks	Large banks	Taylor residuals
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
	S.e.	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*
i ECB eoq t-1	0.019	0.021	0.023	0.030	0.016	0.523	0.032	0.012	0.520	-0.041**	0.012	0.070	0.106*	-0.115***	0.017
	(0.022)	*(0.039)*	*(0.038)*	*(0.040)*	*(0.040)*	*(0.374)*	*(0.039)*	*(0.039)*	*(0.375)*	*(0.020)*	*(0.051)*	*(0.058)*	*(0.061)*	*(0.034)*	*(0.027)*
bad_hist t-1	2.350***	1.770***	2.013***	1.806***	1.801***	1.822***	1.858***	1.682***	1.907***	2.192***	1.835***	1.869***	1.820***	1.834***	2.487***
	(0.059)	*(0.096)*	*(0.339)*	*(0.098)*	*(0.100)*	*(0.093)*	*(0.084)*	*(0.142)*	*(0.326)*	*(0.022)*	*(0.098)*	*(0.126)*	*(0.122)*	*(0.100)*	*(0.071)*
i*bad_hist t-1			-0.061												
			(0.102)												
i*liq_ratio t-1				0.001			0.001								
				(0.001)			*(0.001)*								
i*capital_ratio t-1					0.014**			0.014**							
					(0.006)			*(0.006)*							
i*ln(assets) t-1						-0.022			-0.021						
						(0.016)			*(0.016)*						
i*bad_hist t-1							-0.001								
* liq_ratio t-1							*(0.001)*								
i*bad_hist t-1								0.010							
* capital_ratio t-1								*(0.007)*							
i*bad_hist t-1									-0.001						
*ln(assets) t-1									*(0.004)*						
liq_ratio t-1	-0.004***	-0.008***	-0.007***	-0.008***	-0.005***	-0.007***	-0.008***	-0.005***	-0.007***	-0.012***	-0.005*	-0.013***	-0.004	0.005	-0.004**
	(0.001)	*(0.002)*	*(0.002)*	*(0.003)*	*(0.002)*	*(0.002)*	*(0.003)*	*(0.002)*	*(0.002)*	*(0.002)*	*(0.003)*	*(0.002)*	*(0.004)*	*(0.005)*	*(0.002)*
capital_ratio t-1	0.106***	0.064***	0.067***	0.067***	0.044**	0.067***	0.067***	0.042**	0.067***	0.038***	0.089***	0.079***	0.056***	0.094**	0.138***
	(0.009)	*(0.016)*	*(0.016)*	*(0.015)*	*(0.020)*	*(0.016)*	*(0.015)*	*(0.020)*	*(0.016)*	*(0.006)*	*(0.020)*	*(0.020)*	*(0.014)*	*(0.037)*	*(0.011)*
ln(assets) t-1	0.080***	0.020	0.024	0.008	0.006	0.093*	0.008	0.007	0.092*	-0.040***	-0.024	0.050	0.017	0.399***	0.102***
	(0.016)	*(0.027)*	*(0.024)*	*(0.022)*	*(0.023)*	*(0.054)*	*(0.022)*	*(0.023)*	*(0.054)*	*(0.015)*	*(0.027)*	*(0.037)*	*(0.039)*	*(0.101)*	*(0.019)*
bank variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
borrower variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
credit lines	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
sectoral dummies	no	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
macro variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
time-variant	no	no	no	no	no	no	no	no	no	yes	no	no	no	no	no
shared frailty	firm	no	no	no	no	no	no	no	no	no	no	no	no	no	firm
Clustered s.e.		quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter	
N obs.	1,384,696	1,053,493	1,384,696	1,339,370	1,339,340	1,384,696	1,339,370	1,339,340	1,384,696	5,833,210	489,228	206,849	397,071	987,625	906,317
Log pseudolikel.	-44 823	-34 399	-46 712	-44 893	-44 864	-46 711	-44 892	-44 862	-46 710	-231 877	-16 086	-6 069	-16 579	-29 986	-30 036
Prob ¿ chi2	0.0000	.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: All variables defined in Table 1.1. Results of the estimation of a Weibull hazard function at the loan level, i.e., of the probability of default of the firm relative to the bank at each moment, given that there was no default observed since a new loan was granted. t refers to the moment when the loan is granted. i ECB eoq is fixed to the moment prior to the loan concession. Bank variables included and not reported: rel npl/assets, savings, CCAM, ICUE, M&A and IAS. Borrower variables included and not reported: ln(1+#rel), ln(credit), ln(2+age), ln(1+loan) and Cred_LT_prop. Macro variables included and not reported: GDP PT (GDP growth fixed at the moment the loan is granted), GDP PT_tv (time-varying GDP growth) and π PT. A constant and a quadratic trend are also included but their coefficients are not reported. Columns XI to XIV report the results of the regression for sub-samples according to criteria defined in the top of the column. Small (large) firms proxied by the size of the total credit by the firm: Small firms are below the median, large firms are in the top-10 percentile. Large banks are the 5 largest banks in Portugal, representing around half of the total corporate loan market; small banks are the remaining ones. Column XV reports the results using Taylor residuals instead of interest rates. For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

It is important to note that these results are not in contradiction with the previous analysis. In the first part of our analysis, we wanted to assess how monetary conditions influence lending to ex-ante riskier borrowers (i.e., their riskiness was to some extent verifiable). In this section, we are evaluating how monetary policy rates when loans are granted affect borrowers' ex-post probability of default, increasing the credit risk implicit in banks' balance sheet. As banks do not have perfect foresight on borrower quality, the risk-taking behavior on these two situations is quite different: whereas in the former banks were granting loans to borrowers which had verifiably poor quality, in the latter case the results reflect more than just the decision of the bank. A possible interpretation is that even though when monetary policy rates are lower banks grant credit to riskier borrowers, which are more likely to default in the future, the overall risk of banks' loan portfolio does not increase significantly. Thus, these arguments are in favor of the existence of a risk-taking channel in Portugal, but with limited impact in terms of financial stability. Moreover, we are assessing the entire interest rate cycle, while this channel may operate only in low interest rate periods, possibly undermining the results. To better capture this, in the next section we will focus specifically on these periods.

Besides the main results reported in the first line of Table 1.7, there are other results worth highlighting. We find that borrowers with recent defaults take less time to default again than other borrowers. This recidivist behavior is consistent with previous results found for Portuguese firms by Bonfim *et al.* (2012). However, when we interact this variable with the interest rate in the moment loans were granted (column III), we do not find any statistically significant effect. Recidivism is independent of the level of interest rates when loans are granted.

Looking across the board at the role of bank characteristics shown at the bottom of the table, we find that ex-post default probabilities are higher for loans granted by larger banks, as well as for banks with more capital and less liquidity. When we interact these bank characteristics with the level of interest rates at loan origination (columns IV to VI), the only significant results refer to capital ratios. This means that the previous result stating that banks with more capital grant loans

with a higher default probability is mitigated when interest rates are lower. Bank size and liquidity do not play a role. When we further interact these variables with the dummy proxing for loan quality, in order to get closer to the specifications implemented for the ex-ante analysis, we do not obtain any additional result (columns VII to IX).

To be consistent with the analysis of ex-ante risk-taking, we run sample splits by firm and bank size. Regarding firm size, the ex-post risk-taking channel does not work independently of the size of the firm (columns XI and XII). In turn, regarding bank size we find some interesting differences (columns XIII and XIV). There is evidence supporting the existence of ex-post effects of risk-taking when interest rates are low especially for large banks. Finally, the lack of evidence of a risk-taking channel working ex-post across all firms and banks does not depend on the way we measure monetary policy stance, given that the results are similar when we consider Taylor residuals instead of monetary policy rates (column XV).

We conclude that the results from the survival analysis show that the risk-taking channel does not have relevant ex-post consequences in terms of financial stability. In the next subsection we look at another possible way to identify the impact of the risk-taking channel on ex-post loan performance.

1.6.2 Are loans granted when policy rates are lower more likely to default when interest rates increase?

The results of the previous sub-section suggest that loans granted during periods of lower interest rates do not contribute to a significant deterioration in the overall loan portfolio quality. In this section, we explore a related issue. Instead of analyzing how default probabilities evolve in general, taking the level of interest rates at loan approval as given, we focus our attention specifically on what happens to loans granted during low interest rates periods when rates increase. It should be expected that riskier borrowers are more sensitive to interest rate hikes, which may stretch their debt servicing capacity.

Instead of looking at the whole interest rate cycle, we zoom in a particularly interesting period for analysis. Monetary policy interest rates in the euro area began to increase in December 2005, after a prolonged period of low and stable interest rates. The ECB maintained the main policy interest rate fixed at the historical minimum of 2 per cent during a period of more than two years (between June 2003 and December 2005). Around October 2005 the ECB communication changed, signaling a possible increase in interest rates. This lead to a substantial revision of interest rate expectations, as illustrated in Figure 2. This revision was fast and sizeable. We believe that focusing on this period provides a great framework to address the interaction between risk-taking behaviors in low interest rate periods and the ex-post performance of the loans.

We implement a differences-in-differences approach (DID). To grasp the effect of an increase in interest rates after a relatively long period of accommodative monetary policy, we compare two groups of loans: the treatment group includes the loans granted immediately before interest rates began to increase in December 2005, when interest rate expectations were still anchored at low levels (January to September 2005). The loans in the control group are those granted in the period when interest rates were still low, but interest rate expectations had increased markedly (October 2005 to March 2006). The main difference between the loans granted in the treatment and control groups is related to the level of interest rate *expectations*, as the level of interest rates in itself remained low in both periods. Furthermore, the effective interest rates charged by banks on loans granted to firms between January 2005 and March 2006 was very similar, as illustrated in Figure 2.

The performance of these two groups of loans is then compared in two different moments: we consider the probability of default before and after the monetary policy interest rate starts to increase ($after = 0$ and $after = 1$, respectively). This setting provides a unique opportunity to identify risk-taking behaviors. We are able to compare loans granted with similar levels of effective interest rates, but with underlying different expectations regarding the future path of monetary policy. We are thus able to test whether banks take more risk when they believe that interest

rates will remain low for a long period. In this setting, risk is measured by borrowers' sensitivity to interest rate hikes.

Our analysis would support the existence of a risk-taking channel if loans granted during the period of low and stable interest rate expectations show a higher default probability when interest rates increase.

Table 1.8 presents the results of the DID estimation, where we estimate a probit model for the probability of default of the firm (equation 1.4).[10] We obtain a negative coefficient on the *treatment* variable. This means that loans granted when interest rate expectations are low are generally less likely to default. The coefficient on the *after* variable is also negative in most specifications, suggesting that when interest rates increase, default probabilities are actually lower. However, this result is slightly less consistent than the previous one.

[10]For consistency reasons with previous sections, we considered default episodes in two consecutive quarters. The results are robust to the consideration of default in only one quarter.

Table 1.8: Ex-post assessment of risk-taking: Differences-in-differences approach in a short sub-period (2005-2007)

	I	II	III	IV	V	VI	VII	Small firms VIII	Large firms IX	Small banks X	Large banks XI
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
	S.e.	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*	*S.e.*
treatment t	-0.273***	-0.273***	-0.273	-0.261***	-0.273***	-0.273***	-0.273***	-0.413***	-0.107**	-0.294***	-0.282***
	(0.051)	*(0.040)*	*0.040*	*(0.050)*	*(0.051)*	*(0.051)*	*(0.051)*	*(0.060)*	*(0.054)*	*(0.050)*	*(0.040)*
after t	-0.164***	-0.164	-0.164	-0.189***	-0.164***	-0.164***	-0.165***	-0.251***	-0.072***	-0.193***	-0.205***
	(0.022)	*(.)*	*0.000*	*(0.023)*	*(0.022)*	*(0.022)*	*(0.022)*	*(0.020)*	*(0.021)*	*(0.039)*	*(0.034)*
treatment * after t	0.242***	0.242***	0.242	0.225***	0.199***	0.253***	-0.062	0.337***	0.101*	0.256***	0.267***
	(0.058)	*(0.041)*	*0.041*	*(0.056)*	*(0.053)*	*(0.068)*	*(0.133)*	*(0.066)*	*(0.061)*	*(0.058)*	*(0.046)*
treatment * after t * liq_ratio t-1					0.003***						
					(0.001)						
treatment * after t * capital_ratio t-1						-0.002					
						(0.002)					
treatment * after t * ln(assets) t-1							0.013*				
							(0.007)				
liq_ratio t-1	0.003***	0.003	0.003	0.003***	0.003***	0.003***	0.003***	0.002	0.003***	0.002**	-0.001
	(0.001)	*(0.002)*	*0.002*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.001)*	*(0.002)*
capital_ratio t-1	-0.002	-0.002	-0.002	-0.003**	-0.002	-0.002	-0.002	0.001	0.000	0.002	0.043***
	(0.002)	*(0.008)*	*0.008*	*(0.002)*	*(0.002)*	*(0.002)*	*(0.001)*	*(0.002)*	*(0.004)*	*(0.002)*	*(0.010)*
ln(assets) t-1	-0.027***	-0.027	-0.027	-0.021**	-0.027***	-0.027***	-0.029***	-0.028**	-0.030***	0.062***	-0.044
	(0.009)	*(0.022)*	*0.023*	*(0.009)*	*(0.009)*	*(0.009)*	*(0.009)*	*(0.011)*	*(0.004)*	*(0.023)*	*(0.041)*
bank variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
borrower variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
sectoral dummies	no	no	no	yes	no	no	no	no	no	no	no
macro variables	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
fixed effects	no	no	no	no	no	no	no	no	no	no	no
Clustered s.e.	quarter	quarter & bank	quarter & bank&firm	quarter	quarter	quarter	quarter	quarter	quarter	quarter	quarter
N obs.	1,640,137	1,640,137	1,640,137	1,509,658	1,640,137	1,640,137	1,640,137	692,727	189,480	605,002	1,035,135

Note: All variables defined in Table 1.8. Results of a probit estimation on the dependent variable bad_hist. Treatment equals 1 for firm-bank relationships with a new loan was granted between Jan-05 to Sep-05 and equals 0 for firm-bank relationships with a new loan granted between Oct-05 and Mar-06. After equals 1 for the period when interest rates began to rise (from Jan-06 onwards). Bank variables included and not reported: rel npl/assets, savings, CCAM, ICUE, M&A and IAS. Borrower variables included and not reported: ln(1+#rel), ln(credit), ln(2+age), ln(1+loan) and Cred_LT_prop. Macro variables included and not reported: GDP PT and π PT. A constant and a quadratic trend are also included but their coefficients are not reported. Columns VIII to XI report the results of the regression for sub-samples according to criteria defined in the top of the column. Small (large) firms proxied by the size of the total credit by the firm: Small firms are below the median, large firms are in the top-10 percentile. Large banks are the 5 largest banks in Portugal, representing around half of the total corporate loan market; small banks are the remaining ones. Multi-way clustering computed following Cameron, Gelbach and Miller (2011) and Cameron and Miller (2015). For each variable, we report the coefficient, the standard deviation (below in italics) and the significance level (* significance at 10 per cent, ** significance at 5 per cent, *** significance at 1 per cent).

The coefficient on the interaction term provides the main test to our hypothesis. The coefficient is positive and significant in most of the specifications considered, meaning that loans granted in the period of low and stable interest rates are more likely to default when interest rates increase relative to the loans granted when policy interest rate rises were already expected. This result provides new evidence on an important dimension of the risk-taking channel. Banks take more credit risk when policy rates are expected to remain low for a considerable horizon, though this risk only materializes when interest rates increase.

As already mentioned, this result holds across many specifications. We should thus briefly summarize the reasoning behind each specification presented in Table 1.8. In the first column we show the results for the main variables of interest (*treatment, after* and the interaction term), controlling for bank, borrower and macroeconomic variables. In columns II and III we present the results using standard errors multi-clustered at the quarter and bank and at the quarter, bank and firm level respectively, instead of only at the quarter level. In column IV we go back to clustering at the quarter level and add sectoral controls. The interaction term that captures risk-taking remains almost unchanged across these specifications.

In columns V to VII we analyze the role of bank characteristics in the transmission of the risk-taking channel, as we did in the previous tables.[11] Again, we find evidence in favor of greater risk-taking by larger banks and especially by banks with higher liquidity ratios. This provides further support of the hypothesis of risk-shifting for banks with poor managerial incentives. In columns VIII and XI we run again sample splits according to firm and bank size. We find that there is risk-taking across all firm size categories, though slightly stronger for smaller firms, and across all bank size categories.

All in all, the results presented in this section provide support to the existence of a risk-taking channel in prolonged periods of low interest rates, which materializes once interest rates start to increase.

[11] Unlike what we did in previous tables, from these columns onwards the results use only quarterly clustering, as the multi-clustering procedure is excessively demanding for the narrow estimation window behind this identification strategy.

1.7 Concluding remarks

Banks play a key role in the transmission of monetary policy. Banks' lending decisions are shaped by the stance of monetary policy. While most of the classic literature on the transmission of monetary policy focused on volumes, more recently the quality of credit granted has also deserved a lot of attention. The more recent literature on the risk-taking channel thus asks whether loans granted when monetary policy is more accommodative are generally riskier.

Many recent papers offer evidence supporting the existence of this channel. However, the fast expansion of this literature led to scattered evidence, obtained under inconsistent analytical frameworks and methodologies. In this paper we analyze the risk-taking channel through different angles, using detailed bank and borrower information over time. We looked at the risk-taking channel from an ex-ante and an ex-post perspective and considered both intensive and extensive margins. We tracked loan performance over time and we analyzed what happens to loans granted when interest rates were low for a long time once rates increase.

We obtain evidence supporting the existence of the risk-taking channel along different dimensions. When we consider the information that banks have when granting a loan, we find that banks take more risk when interest rates are lower, but only at the extensive margin. When we track loan performance over time, we find that the level of policy interest rates does not have a significant impact on the overall loan portfolio quality, when looking at a full interest rate cycle. However, when we zoom in into the period of low policy rates, we find a higher sensitivity to interest rate hikes from loans granted in a period of low and stable interest rates. These loans are being compared with loans with very similar conditions, with the only relevant difference being the prevailing expectations about the future path of interest rates. Banks take more credit risk when policy rates are expected to remain low for a considerable horizon, though this risk only materializes when interest rates increase.

We also explore the role of firms' and banks' heterogeneity in the risk-taking

channel. The results regarding firm size are mixed, depending on the way we look at the risk-taking channel. At the extensive margin, risk-taking is stronger for large firms when we consider being in default as the measure of riskiness. In contrast, when we proxy riskiness by lending to first time borrowers, we find that risk-taking is more concentrated in loans to the smallest firms. We also find that smaller firms are more sensitive to interest rate hikes.

Regarding bank size, our results suggest that risk-taking behaviors are common across all bank-size categories, despite some differences in intensity. The results seem to point to higher intensity of risk-taking by large banks.

These heterogeneous results on firm and bank size highlight the relevance of looking at the risk-taking channel through different angles. To further explore this heterogeneity, we also consider the role of banks' capital and liquidity. We find that risk-taking is stronger for less capitalized banks. This is consistent with previous empirical and theoretical evidence (Jiménez *et al.* (2014), Diamond & Rajan (2012)). Banks closer to minimum capital requirements are less likely to fully internalize the potential consequences of the risks taken. Moreover, there is also some evidence that banks with more liquidity may also take more risk, in line with the literature of risk-shifting strategies for banks with poor managerial incentives (Acharya & Naqvi 2012).

These results have important policy implications. Interactions between monetary policy and financial stability should be especially taken into account during prolonged periods of accommodative monetary policy. While for monetary policy purposes, an expansion of credit would be desirable in times of high macroeconomic risk, this could have undesired effects on banks' soundness. Thus, this may call for an active role of macroprudential policy in taming possible undesirable effects of monetary policy.

This may be especially important after a decade during which central banks in advanced economies promoted a huge expansion of liquidity to fight the lasting consequences of the global financial crisis. This prolonged environment of very low interest rates and ample liquidity may have offered incentives for some banks to

engage in risk-taking strategies, lending to riskier borrowers as a way to boost short term profitability. Our results show that this behavior was possibly more prevalent among banks with weaker capital ratios. Crucially, our analysis also suggests that the effects of these risky strategies will become apparent only when interest rates increase again.

Chapter 2

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

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 analyzing 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.

Keywords: lender of last resort, monetary policy, credit channel, financial crisis.

[0]This is joint work with Nuno Alves and Diana Bonfim.

[0]The views expressed in this paper are those of the authors and do not reflect the views of the Banco de Portugal or the Eurosystem.

2.1 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 at risk (Freixas *et al.* 2000, 2004, Repullo 2005, Rochet & 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. In May 2010 Portuguese banks suddenly lost access to international medium and long-term wholesale debt markets, which was an important source of their funding. This sudden stop scenario was mainly linked to investors' concerns about contagion from the sovereign crisis that was then emerging in Greece. Portuguese banks then escalated their recourse to Eurosystem monetary operations, which increased by 20% 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 ECB in counterbalancing the adverse and unexpected liquidity shock that hit the Portuguese banking system.

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 to non-financial corporations. 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 collect bank-level data on the recourse to monetary policy operations and standing facilities, and the collateral pool.

Ensuring a proper identification of the role of the enhanced liquidity provision by the Eurosystem raises considerable challenges. In this respect, several features

of the data help in the identification. First, the liquidity shock was arguably exogenous and unanticipated. When Portuguese banks lost access to markets, there were no explicit concerns about financial stability in Portugal. The shock was due to changes in the perception of market players regarding long standing structural vulnerabilities of the Portuguese economy, amidst heightened uncertainty due to the Greek crisis. 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 across banks at the 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 & Mian 2008). Further, bank variables are included at their levels prior to the liquidity shock, in order to mitigate endogenous effects. 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.

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.

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 larger banks and banks with higher capital granted less credit than other banks, for similar increases in central bank funding.

To clearly establish the role of the lender of last resort on banks' balance sheets 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 had been no alternative source of funding when access to wholesale markets suddenly disappeared in May 2010. This allows us to more precisely quantify the magnitude of the shock. 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.

Though many things remained surprisingly unchanged after this unprecedented shock, banks' balance sheets did not go unscathed. The increase in ECB funding during this period largely surpassed the liabilities that needed to be refinanced. This led to a (temporary) expansion of banks' balance sheets. We show that at least part of this excess liquidity was channeled to an increase in holdings of domestic sovereign bonds. This is consistent with the idea that there was financial repression in this period, with sovereigns in distress encouraging banks to buy their debt (Becker & Ivashina 2014, Ongena *et al.* 2016).

Our paper contributes to the empirical literature on the role of the lender of last resort, which is almost nonexistent. One notable recent exception is Drechler *et al.* (2016). 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 lending 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 & Huang 2004, Ratnovski 2009, Rochet & Tirole 1996, Rochet & 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 loan-level data (Acharya & Mora 2015, Acharya *et al.* 2016, Andrade *et al.* 2015, Cantero-Saiz *et al.* 2014, Carpinelli & Crosignani 2015, Chakraborty *et al.* 2016, Chodorow-Reich 2014, Crosignani *et al.* 2016, Daetz *et al.* 2016, Darracq-Paries & De Santis 2015, Ferrando *et al.* 2015, Garcia-Posada & Marchetti 2015, Morais *et al.* 2015, Ramcharan & Yu 2014).

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 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 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 7 we explore whether banks used ECB funding to buy sovereign debt, amidst an environment of financial repression. In Section 8 we summarize our main findings.

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

Bagehot (1873) was among 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.

Since then, several models have been designed to better understand the role of the lender of last resort, focusing in particular in the moral hazard problem created by this mechanism (Freixas *et al.* 2000, 2004, Gorton & Huang 2004, Ratnovski 2009, Rochet & Tirole 1996, Rochet & Vives 2004, Wagner 2007). However, despite these extensive theoretical underpinnings, to the best of our knowledge, there are only a few papers empirically looking at the role of central banks as lender of last resort during the global financial crisis. The paper that is closest to ours is Drechler *et al.* (2016). Using weekly data on bank-level borrowing from the ECB between August 2007 and December 2011, 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.

Garcia-de-Andoain *et al.* (2015) examine the role of the ECB as a lender of last resort during the global financial crisis. Using data from interbank payments, these authors show that the ECB was able to satisfy the demand for liquidity in the interbank market in the aftermath of the failure of Lehman Brothers. Further, the ECB increased the supply of liquidity in stressed countries during the euro sovereign debt crisis.

Acharya *et al.* (2016) contrast the role of the ECB as a lender of last resort to that of a buyer of last resort. This amounts to comparing the effect of central bank lending through Long Term Refinancing Operations (LTRO) to the effect of buying assets through Outright Monetary Transactions (OMT). The effects of the announcement of these operations are assessed on sovereign bond yields, sovereign credit default swap spreads, banks holdings of sovereign bonds, banks equity prices, banks credit default swap spreads, and US money market funds investments in European banks. The authors find that buying assets proved more effective than lending to banks by containing pervasive bank-sovereign feedback loops.

Though de Haan *et al.* (2015) do not look explicitly at the role of the lender of last resort, these authors do find that borrowing from central banks allowed euro area banks to mitigate the impact of wholesale funding shocks on lending to the real economy.

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 fulfill 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 procedure 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. During this period the ECB also implemented longer-term refinancing operations (with maturities up to one year), foreign exchange operations, and the Covered Bond Purchase Program. Later on, the ECB implemented the Securities Market Program to purchase sovereign bonds.

These measures implied a considerable expansion of the ECB balance sheet. However, Portuguese banks recorded only a mild increase in their access to ECB funding in this early period of the crisis (2007-08). 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. 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.[1] In turn, loan flows were unaffected during this period, with credit growth rates remaining far above those of the euro area, despite the declining trend. In December 2008 the annual growth rate of loans to non-financial corporations stood at 10.5%.

This relatively benign scenario in Portugal suffered a blow in May 2010. Suddenly, Portuguese banks entirely lost access to funding in international wholesale debt markets (Figure 2.1).[2] 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 sovereign euro area crisis, when investors were wary of potential contagion from Greece. This sudden loss of access to markets was sizable enough to threaten the survival of many Portuguese banks, which operated with relatively high loan-to-deposit ratios (around 160% in early-2010). However, despite the high dependence on access to wholesale markets, when

[1] Interbank markets remained severely impaired for a long period (Acharya & Merrouche 2013, Afonso *et al.* 2011, Brunnermeier 2009). Iyer *et al.* (2014) examine the 2007 shock on interbank markets using Portuguese data.

[2] "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.

we look at credit growth during this period it seems that nothing happened (Figure 2.2). The annual growth rate of loans to non-financial corporations was stable at around 1% during 2010, thus implying that banks were refinancing most loans and even extending some new credit.[3]

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. In just a few months, the recourse of Portuguese banks to the Eurosystem increased by 20% of GDP. The evolution of this variable clearly illustrates the unanticipated nature of this shock (Figure 2.1). If banks were anticipating that they would get 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. Note that in this period the Eurosystem did not implement new monetary policy measures and the Eurosystem aggregate excess liquidity remained broadly stable.

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 this perfect storm without jeopardizing financing to the real economy.

2.3 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), 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 report to the CRC on a monthly basis all loans above 50 euro). We consider only loans granted to non-financial corporations.[4]

[3]Loan growth rates became negative later, in 2011, when the country was under an international financial assistance program.

[4]de Haan *et al.* (2015) shows that lending to non-financial firms is more sensitive to wholesale funding shocks than lending to households.

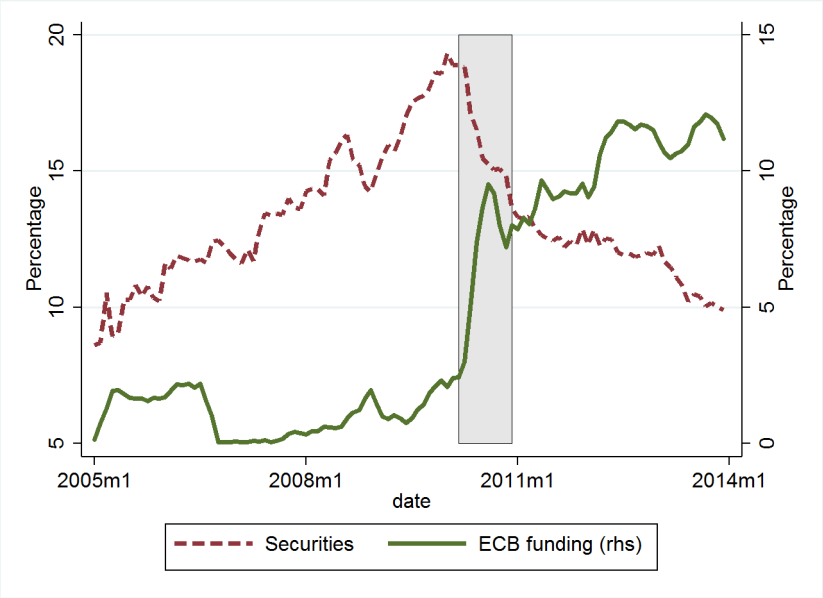


Figure 2.1: Portuguese banks' funding through securities (lhs) and through the Eurosystem (rhs) as a percentage of total assets

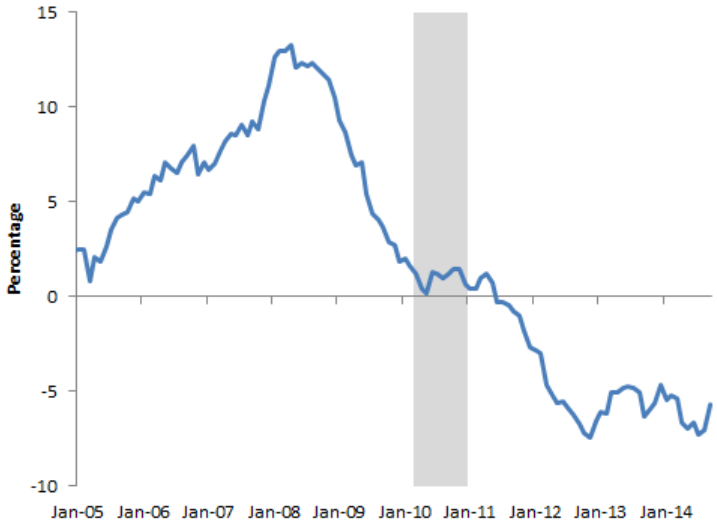


Figure 2.2: Annual growth rate of loans to non-financial corporations in Portugal. The growth rate is adjusted for securitization operations, reclassifications, write-offs/write-downs, credit portfolio changes, exchange rate changes, and price revaluations.

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 are merged with data on banks' characteristics coming from supervisory reports. There are 29 credit institutions eligible to participate in Eurosystem operations that were active in the corporate loan market between March and December 2010.[5] 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. These branches do not report regulatory capital ratios. We run a regression of regulatory capital ratios on banks' leverage ratios (defined as equity as a percentage of total assets), which is available for all the credit institutions in the sample. We then use the predicted values of these regressions as proxies for the regulatory capital ratio of the five branches of credit institutions with head office in the EU in our database.

We collect monthly data on banks' supervisory liquidity reports. These reports include detailed information for banks' assets and liabilities in several maturity brackets, thereby allowing us to compute liquidity gaps between assets and liabilities in different time horizons. The information included in these reports also allows us to identify the value of eligible assets for Eurosystem operations on banks' balance sheets (including those that are not currently part of the collateral pool).

We collect data at the bank level on the recourse to Eurosystem liquidity by type of operation (both liquidity provision and absorption), and on the pool of eligible assets to refinancing operations. 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.

Finally, in order to control for firms' characteristics, we also used data on firms' balance sheet and income statements reported through *Informação Empresarial*

[5]In March 2010 there were 42 credit institutions that were eligible to participate in Eurosystem operations. However, 13 were investment banks or credit institutions specialized in consumer credit, thus not granting loans to non-financial corporations.

Simplificada (*IES*). This database covers the entire universe of Portuguese non-financial corporations, given its mandatory nature. The frequency of the data is annual.

Table 2.1 summarizes the variables used in the analysis of the period in which Portuguese banks lost access to wholesale markets, using loan level data.[6]

Table 2.1: Descriptive statistics of the variables used in the analysis

Variable	T	Unit	Obs	Mean	Std.Dev.	P25	Median	P75
Ln(assets)$_j$	Mar/2010	ln(euro)	218,283	24.27	1.10	23.35	24.72	25.23
Loan-to-dep$_j$	Mar/2010	ratio	218,283	164.76	30.27	144.36	161.01	180.54
Liq ratio$_j$	Mar/2010	ratio	218,283	16.60	7.81	10.26	15.46	22.00
Solv ratio$_j$	Mar/2010	ratio	218,283	9.43	11.95	11.47	12.10	13.90
ECB funding$_j$	Mar/2010	ratio	217,291	0.03	0.02	0.01	0.02	0.05
collateral$_j$	Mar/2010	ratio	218,283	10.82	6.03	7.45	9.20	12.87
Liq gap 1M-3M$_j$	Mar/2010	ratio	218,283	-3.27	6.36	-4.55	-3.53	-0.72
ΔECB funding$_j$	Mar-Aug/10	b.p. change	220,688	6.19	5.53	0.00	7.00	10.90
ΔSecurities$_j$	Mar-Aug/10	b.p. change	201,828	-2.19	5.11	-3.36	-3.05	0.00
loan growth$_{ij}$	Mar-Dec/10	log change	188,796	-10.94	67.18	-24.70	-2.54	1.09
(loan+lines) growth$_{ij}$	Mar-Dec/10	log change	168,469	-11.12	75.40	-29.59	-5.77	5.18
ΔLn(assets)$_j$	Mar-Dec/10	log change	191,729	1.68	11.76	-4.37	5.49	8.65
ΔLoan-to-dep$_j$	Mar-Dec/10	p.p. change	191,729	-4.97	17.15	-13.89	-4.59	0.20

Notes: The index j stands for bank and the index i 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. *Loan-to-dep* is the ratio between total credit granted by the bank and resources from customers. *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. For branches of credit institutions with head office in the EU, which do not report prudential capital ratios, we use the predicted values of a regression of capital ratios on leverage ratios. *ECB funding* is the total amount of liquidity provided by the Eurosystem net of liquidity deposited at the Eurosystem, over total assets of the bank. *Liq gap 1M-3M* is the difference between liquid assets and liabilities with residual maturity between 1 and 3 months as a percentage of stable funding. A higher gap thus represents more liquidity. *Collateral* is the amount of reported assets in the bank's balance sheet eligible for Eurosystem operations over total assets of the bank. *loan growth* is the log change of the total amount of effective loans granted by the bank to the borrower. *(loans + lines) growth* is the log change of the loans including unused credit lines. *Securities* is the outstanding amount (book-value) of securities issued by each bank. Loan growth rates were winsorized at the 1st and 99th percentiles, while the liquidity variables were winsorized at the 5th and 95th percentiles.

[6]Table 2.16 in the Appendix shows the descriptive statistics for bank level data.

2.4 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 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 2.1 shows that the large fall in funding by securities was offset by the sharp increase in access to Eurosystem funding in the Spring and Summer of 2010. While after the collapse of Lehman Brothers in September 2008 there was only a mild and temporary increase in access to these operations, in 2010 the situation was entirely different. Between March and August, the increase in these operations was around 20% of GDP.

Figure 2.2 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 stable during this period. Only more than one year later, after the request for financial assistance by the Portuguese government, did loan growth rates start to move into negative territory.

These two figures depict the aggregate picture, but it is also worth noting the substantial heterogeneity between banks. Figures 2.3 to 2.8 inform us about this heterogeneity, focusing only on potentially exposed banks, i.e., those that issued securities at least once prior to 2010.[7] These figures depict the empirical distributions of several bank characteristics using estimated kernel densities weighted by banks' total assets.

Figure 2.3 shows that even though the average loan-to-deposit ratio was high by international standards, pointing to a strong reliance on access to wholesale debt markets, there is a great deal of dispersion in this measure. Figure 2.4 complements this idea of dependence from wholesale markets, showing the funding by securities as a percentage of total assets. Moreover, it shows how important the shock was, as the estimated density shifted considerably to the left and became much more

[7] These 24 banks represented 60% of the sample of banks and 94% of the total assets of the sample in March 2010.

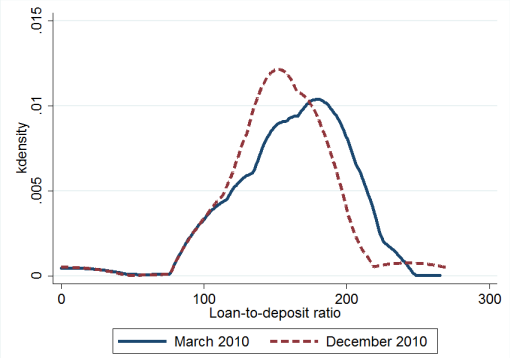


Figure 2.3: Estimated kernel density of the loan-to-deposit ratio weighted by banks' assets

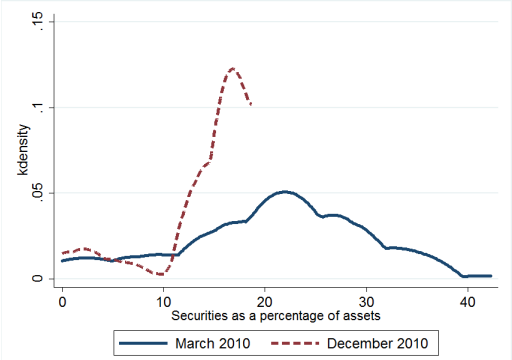


Figure 2.4: Estimated kernel density of the funding by securities as a share of total assets, weighted by banks' assets

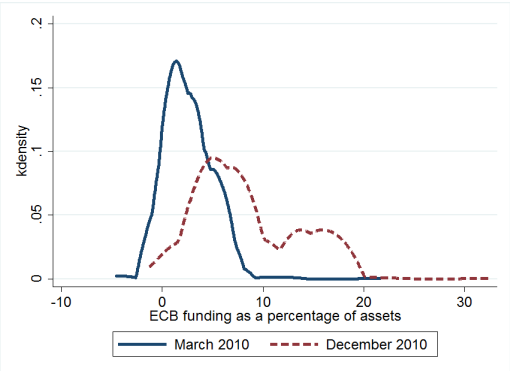


Figure 2.5: Estimated kernel density of the ECB funding as a share of total assets, weighted by banks' assets

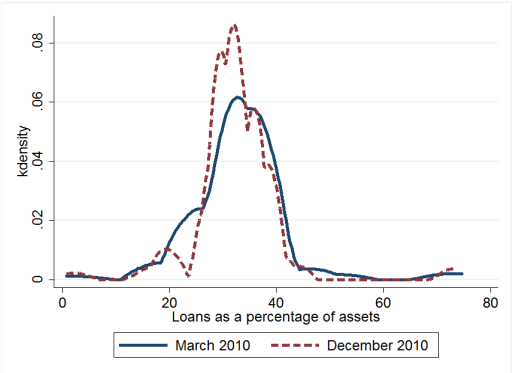


Figure 2.6: Estimated kernel density of loans to non-financial firms including credit lines as a share of total assets, weighted by banks' assets

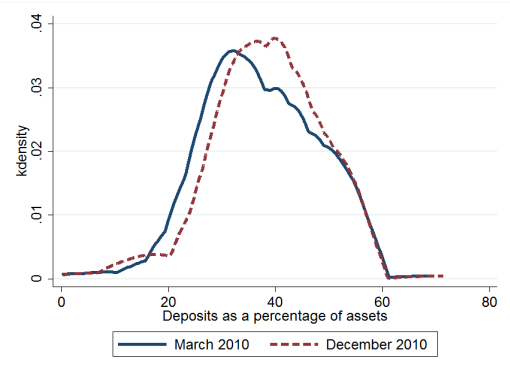


Figure 2.7: Estimated kernel density of deposits as a share of total assets, weighted by banks' assets

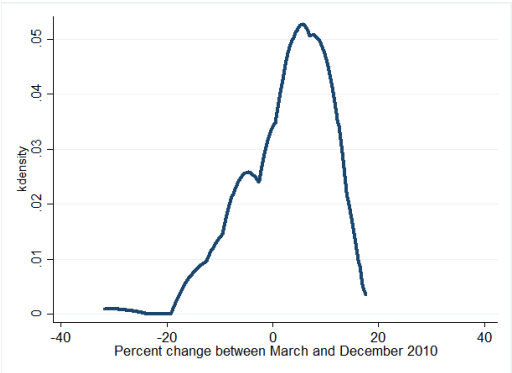


Figure 2.8: Estimated kernel density of the percent changes in assets between March and December 2010, weighted by banks' assets

concentrated between March and December 2010. Simultaneously, the density of the ECB funding shifted to the right, illustrating the funding substitution (Figure 2.5).

However, despite the remarkable heterogeneity in the way the shock was felt and in the banks' reaction, the share of loans (including credit lines) on banks' balance sheets barely changed (Figure 2.6). Moreover, between March and December 2010 the remaining balance sheet items of the banks also remained relatively stable across the entire sample. Figure 2.7 shows that deposits as a percentage of banks' total assets almost did not change during this period. Further, Figure 2.8 reveals that the change in banks' total assets was concentrated slightly above zero. This shows, on the one hand, that despite the large and heterogeneous magnitude of the shock to wholesale funding, its impact on banks total assets and loan portfolios was very homogeneous and hardly visible, and, on the other hand, banks' deposits, which are their main funding source, did not react to or co-move with the shock.[8]

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

2.5.1 Identification strategy

In a crisis environment, in which many things may be happening simultaneously, it is quite challenging to design a proper identification strategy to establish a causal relationship between variables. We do this by exploring the richness of the dataset available in the quasi-natural experimental setting that we are examining.

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 about the Greek sovereign debt crisis spreading to

[8]The interbank market remained impaired at the time. Changes in interbank assets and liabilities in this period reflect intra-group funding for the largest banking groups.

other vulnerable euro area countries. Given the fragilities of the fiscal and economic situation of the Portuguese economy in that period, investors perceived Portugal to be the next "victim". These concerns actually materialized, but only one year later, with the government asking for international financial assistance. Another important aspect to consider is that the ECB did not adopt any specific measure as a reaction to these events. Portuguese banks were able to benefit from a safety net that had been created during the previous years, including the fixed rate full allotment procedure and the extended list of eligible collateral. These two measures allowed banks to access all the liquidity they wished from the ECB at a fixed rate, using an expanded list of assets that could be used as collateral. Indeed, the collateral constraint was not binding at the time, thus allowing banks to use ECB's monetary policy operations without major limitations.

For identification purposes, it is also worth highlighting the heterogeneity within Portuguese banks. Their situation diverged substantially in terms of their recourse to the Eurosystem, both before and after the liquidity shock. Moreover, banks' dependence on wholesale markets was also heterogeneous, 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 only bank-level data would allow us to establish some relationships between access to ECB funding and credit dynamics, it is important to note that at this level it would not be 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.[9] This selection, together with firm fixed-effects estimation, allows us to control for firm-specific loan demand effects (Khwaja & Mian 2008), thereby allowing us to explicitly identify credit supply effects at the bank-firm level.

[9]More than 70% of the observations in the CRC in 2010 refer to firms with multiple bank relationships. If we exclude micro firms, the percentage goes up to 93%. If we consider the number of firms instead of the number of relationships, 53% of the firms borrow from more than one bank (81% if we exclude micro firms).

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

Our baseline specification is:

$$loan\_growth_{ijT} = c + \alpha_i + \beta \Delta ECB\_funding_{jT-4} + \delta X_{jT-9} + \varepsilon_{ijT} \tag{2.1}$$

where T refers to December 2010, α_i are firm fixed effects and $loan\_growth_{ijT}$ refers to the log change of loans between March 2010 and December 2010 granted by bank j to firm i. $\Delta ECB\_funding_{jT-4}$ is the change in ECB funding as a percentage of banks' assets between March 2010 and August 2010. The difference in the time horizons considered intends to capture lags in the process of loan approval. Moreover, the period between March and August captures the peak in access to ECB funding. Finally, X_{jT-9} are a set of bank controls measured before the shock, in March 2010, to mitigate endogeneity concerns.

2.5.2 Testing in the perfect lab

Table 2.2 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 us to capture all dimensions related to firm demand. In the third column we control for a number of bank characteristics, namely total assets, the loan-to-deposit ratio, the liquidity ratio, and the solvency ratio. This will be our baseline specification. In the fourth column we consider the same specification, but using loan growth excluding unused credit lines as the dependent variable (instead of the total loan exposure). While including unused credit lines allows us to control for the full exposure of a bank to a firm, excluding them allows us to look at the effective outstanding debt of the firm. This latter measure is affected by demand, as firms actively choose to draw down credit lines, most notably in stress scenarios (Carpinelli & Crosignani 2015, Ippolito *et al.* 2016).

In the fifth column we consider all firm-bank relationships, without imposing that firms have multiple relationships and without firm fixed effects. This is a departure from our identification strategy based on Khwaja & Mian (2008). Our goal is to be sure that the results are not affected by using a sample that includes only firms with multiple bank relationships. However, this specification does not allow to control for demand effects.

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 supply 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.

Our results are consistent with those of Abbassi *et al.* (2016), who find that German banks who borrowed more from the ECB did not grant significantly more nor less credit to firms than other banks. Note that this result holds in a situation that is quite different from that analyzed in our paper, in which the increase in ECB funding was due to a sudden stop scenario for Portuguese banks in wholesale debt markets.

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

One important assumption underlying our previous estimations is that the magnitude of the shock is captured by the change in access to ECB funding, given that there were no binding collateral constraints at the time. However, the amount borrowed from the ECB might be an endogeneous choice, most notably given the fixed rate full allotment procedure implemented by the ECB. As such, in Table 2.3 we explore more directly the effect of the shock that hit Portuguese banks in May 2010. In the first column we report the results exploring the effect of the shock in banks' funding on loan growth. We measure the shock as the change in the outstanding amount of securities issued by each bank between March and August 2010, as a percentage of total assets. In the second column we consider that effect together

with the change in ECB funding during the same period. In the third column we add a measure of banks' vulnerability to the shock, captured by the *Liq gap 1M-3M* in March 2010. Banks with less liquid assets and more short-term liabilities to be refinanced were more exposed to the shock. Regardless of the specification, we still do not find statistically significant effects, thus lending further support to the hypothesis that the ECB successfully avoided a collapse in credit markets in Portugal.

Table 2.2: Results for the regressions at the loan level

Dependent variable: $loan\_growth_{ij}$

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
ΔECB funding$_{jT-4}$	-0.0263	0.0457	-0.118	-0.169	-0.328
	(0.352)	(0.366)	(0.329)	(0.388)	(0.298)
Ln(assets)$_{jT-9}$			-1.091	-1.300	-0.263
			(1.550)	(1.788)	(1.316)
Loan-to-dep$_{jT-9}$			-0.0747*	-0.0905**	-0.0243
			(0.0370)	(0.0420)	(0.0317)
Liq ratio$_{jT-9}$			0.334*	0.343	0.205
			(0.186)	(0.220)	(0.165)
Solv ratio$_{jT-9}$			0.552***	0.578***	0.423***
			(0.0808)	(0.0946)	(0.0680)
Constant	-10.83***	-11.32***	17.71	25.03	-5.596
	(3.614)	(3.541)	(37.98)	(43.17)	(33.08)
Firm FE	N	**Y**	**Y**	**Y**	N
Unused credit lines	**Y**	**Y**	**Y**	N	**Y**
Relationships	Multiple	Multiple	Multiple	Multiple	All
Banks	29	29	29	29	29
Firms	72 772	72 772	68 378	66 266	180 974
N obs	182,685	182,685	178,291	159,417	316,279
Prob¿F	0.9409	0.9016	0.0000	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level between March and December 2010. In the first column we report the results without firm fixed effects and without controlling for bank characteristics. In the second column we introduce firm fixed effects. In the third column we introduce bank characteristics. This is our baseline regression. In the fourth column we consider a modified version of the dependent variable, excluding the unused amounts of credit lines from the definition of loan growth. In the fifth column we consider all firm-bank relationships, without imposing that firms have multiple relationships and without firm fixed effects. All variables defined in Table 1. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 2.3: Results for the regressions for different measures of the liquidity shock

Dependent variable: $loan\_growth_{ij}$			
	(1)	**(2)**	**(3)**
ΔSecurities$_{jT-4}$	0.0141	0.000219	-0.0646
	(0.281)	(0.295)	(0.326)
ΔECB funding$_{jT-4}$		-0.101	
		(0.341)	
Liq gap$_{jT-9}$			0.443
			(0.401)
Ln(assets)$_{jT-9}$	-1.871	-1.665	-0.644
	(1.738)	(1.805)	(1.742)
Loan-to-dep$_{jT-9}$	-0.0729	-0.0692	-0.0622
	(0.0465)	(0.0476)	(0.0463)
Liq ratio$_{jT-9}$	0.357*	0.351	0.379**
	(0.196)	(0.206)	(0.172)
Solv ratio$_{jT-9}$	0.567***	0.567***	0.358
	(0.132)	(0.129)	(0.252)
Constant	35.07	30.20	6.277
	(43.19)	(43.84)	(42.07)
Banks	18	18	18
Firms	68 260	68 260	68 260
N obs	172,333	172,333	172,333
Prob¿F	0.0000	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All regressions include firm fixed effects. In the first column we report the results exploring the effect of the shock in banks' funding on loan growth. We measure the shock as the change in the outstanding amount of securities issued by each bank between March and August 2010, as a percentage of total assets. In the second column we consider that effect together with the change in ECB funding during the same period. In the third column we add a measure of banks' vulnerability to the shock, captured by the *Liq gap 1M-3M* in March 2010. All other variables defined in Table 1. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Exploring firm heterogeneity

Even though we do not find any statistically significant impact of access to ECB funding on loan growth, it is possible that firms were affected in different ways. We explore this by running the regression presented in the third column of Table 2.2 for different groups of firms. We explore differences across firm size cohorts, loan maturities (short-term versus long-term) and the riskiness of firms (firms in default versus others).

In Table 2.4 we report the results for different firm size cohorts, i.e., micro, small, medium and large firms. The effect of access to ECB funding is not significant for any firm size category, suggesting that there was no credit crunch in any of these segments of corporate loans in this period.

Table 2.4: Results for the regressions for different samples according to firm size

Dependent variable: $loan\_growth_{ij}$				
	Micro	**Small**	**Medium**	**Large**
ΔECB funding$_{jT-4}$	-0.0343	-0.0934	0.261	-0.300
	(0.352)	(0.348)	(0.324)	(0.546)
Ln(assets)$_{jT-9}$	-2.078	-1.406	-0.179	-0.189
	(1.714)	(2.068)	(1.782)	(3.209)
Loan-to-dep$_{jT-9}$	-0.0815*	-0.0834	-0.0834**	-0.122*
	(0.0450)	(0.0514)	(0.0343)	(0.0625)
Liq ratio$_{jT-9}$	0.327	0.326	0.480***	0.236
	(0.232)	(0.193)	(0.123)	(0.248)
Solv ratio$_{jT-9}$	0.445***	0.497***	0.366***	0.245*
	(0.0832)	(0.115)	(0.0585)	(0.134)
Constant	43.05	30.43	-0.00385	13.75
	(42.78)	(51.78)	(43.10)	(75.10)
Banks	25	26	28	26
Firms	33,030	18,101	4,115	778
N obs	77,350	52,413	16,402	3,720
Prob¿F	0.0000	0.0000	0.0000	0.1934

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All regressions include firm fixed effects. Firm size categories are defined according to the EU Recommendation 2003/361. All other variables are defined in Table 1. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Even though it seems that banks successfully substituted market funding with ECB funding, we should not forget that this led to a sizeable shortening in the

Table 2.5: Results for the regressions for different samples according to loan maturity

Dependent variable:	$loan\_growth_{ij}$	
	Short-term	**Long-term**
ΔECB funding$_{jT-4}$	-0.225	-0.0749
	(0.870)	(0.282)
Ln(assets)$_{jT-9}$	0.561	-1.520
	(4.202)	(1.470)
Loan-to-dep$_{jT-9}$	0.0254	-0.0498
	(0.0915)	(0.0329)
Liq ratio$_{jT-9}$	-0.235	0.256**
	(0.402)	(0.119)
Solv ratio$_{jT-9}$	0.207	0.0657
	(0.166)	(0.0703)
Constant	-31.20	31.14
	(92.35)	(37.17)
Banks	25	26
Firms	32,736	47,739
N obs	47,415	77,477
Prob¿F	0.0400	0.1960

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. In the first column we consider only short-term loans in the dependent variable (i.e., with maturities less than one year). In the second columns we consider only long-term loans (i.e., with maturities above one year). Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

maturities of banks' liabilities. As such, it is possible that long-term loans were more affected by this shock than short-term loans granted by banks. In Table 2.5 we estimate our baseline regression separately for growth rates of loans in these two maturity segments. We find that there are no visible differences in the maturity of banks' portfolios, despite the shock in the maturity of their liabilities.

Another possibility is that banks used ECB funding to engage in risk-shifting strategies by providing loans to riskier borrowers. In Table 2.6 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 quarters. 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.

Table 2.6: Results for the regressions for different samples according to firm recent credit history

Dependent variable:	$loan\_growth_{ij}$	
	Bad	**Good**
ΔECB funding$_{jT-4}$	-0.397	-0.0368
	(0.518)	(0.335)
Ln(assets)$_{jT-9}$	0.284	-1.564
	(2.062)	(1.783)
Loan-to-dep$_{jT-9}$	-0.00709	-0.0930**
	(0.0406)	(0.0413)
Liq ratio$_{jT-9}$	0.298	0.339*
	(0.206)	(0.189)
Solv ratio$_{jT-9}$	1.307***	0.356***
	(0.0660)	(0.0859)
Constant	-43.09	36.80
	(48.86)	(44.41)
Banks	26	29
Firms	15,504	52,944
N obs	39,107	139,184
Prob¿F	0.0000	0.0001

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All regressions include firm fixed effects. Bad firms are those in default in the current and the past quarter. All the remaining firms are classified as good firms. All other variables are defined in Table 1. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Exploring bank heterogeneity

As shown above, there is substantial heterogeneity in the way banks were affected by the sudden loss of access to wholesale debt markets. Furthermore, Acharya *et al.* (2015) show that during crises, the transmission of central bank liquidity is impaired, affecting banks differently depending on their soundness. As such, it is quite likely that there are important differences between banks. Thus, in what follows we run additional regressions with subsamples defined according to bank characteristics (bank size, capital, liquidity and collateral availability).

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 2.7). For the largest banks we find a large and statistically significant negative effect of access to ECB on loan growth. This means that within these largest banks, those that used ECB funds more intensively, as a percentage of their assets, actually granted less credit to firms. One possibility, to be explored later, is that the larger 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 by banks was preceded by the loss of access by the sovereign (Becker & Ivashina 2014, Ongena *et al.* 2016). 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.

Table 2.7: Results for the regressions for different samples according to bank size

Dependent variable: $loan\_growth_{ij}$		
	Big 5	**Other banks**
ΔECB funding$_{jT-4}$	-2.244***	-0.203
	(0.151)	(0.165)
Ln(assets)$_{jT-9}$	35.45***	7.284***
	(2.949)	(1.616)
Loan-to-dep$_{jT-9}$	0.235***	-0.0444
	(0.0237)	(0.0332)
Liq ratio$_{jT-9}$	0.917***	0.0496
	(0.0861)	(0.0802)
Solv ratio$_{jT-9}$	-	0.588***
	-	(0.0239)
Constant	-934.8***	-173.2***
	(75.27)	(34.65)
Banks	5	24
Firms	37,863	14,248
N obs	89,672	34,018
Prob¿F	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All variables are defined in Table 1. All regressions include firm fixed effects. The solvency ratio is omitted from the large banks' regression due to collinearity. The number of observations is lower than in Tables 2.2 to 2.6 because we impose that firms have at least two bank relationships within each subsample of banks. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Another potential 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 the median of the empirical distribution of this variable (Table 2.8). We find a negative and statistically significant effect for the better capitalized banks (i.e., above the median), which, like the largest banks, granted less credit when they used the ECB's facilities more intensively. The magnitude of the effect is also quite large, meaning that an increase of 1 p.p. in the share of ECB funding over total assets implies a fall of 1.9 p.p. in the growth rate of loans to firms. This result is somewhat counterintuitive and might also be related with the financial repression hypothesis. We will return to this issue in Section 7.

Table 2.8: Results for the regressions for different samples according to banks' capital ratio

Dependent variable: $loan\_growth_{ij}$		
	Below median	**Above median**
ΔECB funding$_{jT-4}$	0.466	-1.876***
	(0.293)	(0.458)
Ln(assets)$_{jT-9}$	-0.876	3.329***
	(0.946)	(0.857)
Loan-to-dep$_{jT-9}$	-0.0291	-0.0178
	(0.0320)	(0.0625)
Liq ratio$_{jT-9}$	0.595***	0.00136
	(0.127)	(0.129)
Solv ratio$_{jT-9}$	0.442***	1.245
	(0.0254)	(0.823)
Constant	-3.589	-88.33**
	(19.10)	(34.11)
Banks	15	12
Firms	19,917	19,925
N obs	47,525	43,516
Prob¿F	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All regressions include firm fixed effects. The table reports sample splits based on the median of the empirical distribution of the prudential capital ratio. All variables are defined in Table 1. The number of observations is lower than in Tables 2.2 to 2.6 because we impose that firms have at least two bank relationships within each subsample of banks. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

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 start by running the regressions separately for subsamples of banks determined by their position in the empirical distribution of the loan-to-deposit ratio distribution (Table 2.9). In this case, we find a statistically significant negative effect for the role of ECB funding for the banks with a loan-to-deposit ratio below the median, i.e., those which were arguably less hit by the shock.

We perform a similar exercise for another measure of liquidity, the liquidity gap, which measures the difference between assets and liabilities in a horizon between 1 month and 3 months (Table 2.10). The banks with a lower liquidity gap, i.e. those with less liquid assets, show a negative coefficient on the recourse to the ECB. This is in line with expectations, as these banks were more vulnerable to the shock.

Finally, we test whether collateral availability leads to any differences (Table 2.11). Banks with less collateral available for ECB operations might have been more constrained in using this funding source. In line with what we could expect, we find a negative effect for banks with less collateral available and a positive effect for those with greater collateral availability.

Table 2.9: Results for the regressions for different samples according to banks' loan-to-deposit ratio

Dependent variable: $loan\_growth_{ij}$		
	Below median	**Above median**
ΔECB funding$_{jT-4}$	-0.736*	-0.381
	(0.382)	(0.346)
Ln(assets)$_{jT-9}$	3.356***	2.306
	(0.422)	(2.459)
Loan-to-dep$_{jT-9}$	0.145	0.0650
	(0.106)	(0.118)
Liq ratio$_{jT-9}$	0.0669	0.517**
	(0.261)	(0.210)
Solv ratio$_{jT-9}$	0.584***	0.395
	(0.0530)	(0.236)
Constant	-109.6***	-91.33
	(14.31)	(85.41)
Banks	12	15
Firms	16,262	24,310
N obs	37,837	55,528
Prob¿F	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All variables are defined in Table 1. All regressions include firm fixed effects. The table reports sample splits based on the median of the empirical distribution of the loan-to-deposit ratio. The number of observations is lower than in Tables 2.2 to 2.6 because we impose that firms have at least two bank relationships within each subsample of banks. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 2.10: Results for the regressions for different samples according to bank 1-month to 3-month liquidity gap

Dependent variable: $loan\_growth_{ij}$		
	Below median	**Above median**
ΔECB funding$_{jT-4}$	-2.203**	0.987
	(0.974)	(0.708)
Ln(assets)$_{jT-9}$	6.553*	0.794
	(3.537)	(2.749)
Loan-to-dep$_{jT-9}$	-0.252	0.0301
	(0.165)	(0.0715)
Liq ratio$_{jT-9}$	0.222	0.758
	(0.257)	(0.564)
Solv ratio$_{jT-9}$	0.837**	3.798
	(0.310)	(2.767)
Constant	-118.5	-89.32
	(71.02)	(85.73)
Banks	14	14
Firms	23,277	17,392
N obs	52,516	40,254
Prob¿F	0.0000	0.7521

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All variables are defined in Table 1. All regressions include firm fixed effects. The table reports sample splits based on the median of the empirical distribution of the 1-month to 3-month liquidity gap. The liquidity gap is defined as the difference between liquid assets and liabilities with residual maturity between 1 and 3 months as a percentage of stable funding. A higher gap thus represents more liquidity. The number of observations is lower than in Tables 2.2 to 2.6 because we impose that firms have at least two bank relationships within each subsample of banks. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

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:

$$loan\_growth_{ijT} = c + \alpha_i + \beta \Delta ECB\_funding_{jT-4} + \gamma \Delta ECB\_funding_{jT-4} * X_{jT-9} + \delta X_{jT-9} + \varepsilon_{ijT} \quad (2.2)$$

where γ captures differential effects of access to ECB funding depending on bank characteristics. The results for the interactions with the loan-to-deposit ratio, the

Table 2.11: Results for the regressions for different samples according to bank collateral availability to Eurosystem operations

Dependent variable: $loan\_growth_{ij}$		
	Below median	**Above median**
ΔECB funding$_{jT-4}$	-1.185***	1.365***
	(0.367)	(0.228)
Ln(assets)$_{jT-9}$	6.499*	-0.696
	(3.262)	(0.647)
Loan-to-dep$_{jT-9}$	0.00142	-0.0859***
	(0.0325)	(0.0203)
Liq ratio$_{jT-9}$	0.239*	-0.717***
	(0.132)	(0.133)
Solv ratio$_{jT-9}$	0.406***	3.704***
	(0.122)	(1.096)
Constant	-168.8*	-22.09
	(82.74)	(18.15)
Banks	15	12
Firms	13,585	20,972
N obs	30,700	48,287
Prob¿F	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All variables are defined in Table 1. All regressions include firm fixed effects. The table reports sample splits based on the median of the empirical distribution of collateral available for Eurosystem operations. The number of observations is lower than in Tables 2.2 to 2.6 because we impose that firms have at least two bank relationships within each subsample of banks. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

liquidity gap, the eligible collateral, the capital ratio and total assets are shown in Table 2.12. The goal is to explore some of the effects reported in Tables 2.7 to 2.11, but instead of relying on sample splits, using the interactions between changes in ECB funding and each bank's characteristics. The only statistically significant effect comes from the regressions where access to the ECB is interacted with the loan-to-deposit ratio. In this case we find that banks generally granted more credit when they received more funding from the ECB, though this effect is offset for banks with a higher loan-to-deposit ratio. This means that for the banks more affected by the shock, the access to the ECB was possibly not enough to avoid some contraction in lending.

Summing up, we find that the ECB successfully played its role as lender of last resort. Despite the massive shock in access to funding, this had no material impact on banks' ability to grant credit to firms, as they were able to use ECB funding to continue financing the economy. Credit continued to flow to firms, regardless of their size, loan maturity or credit quality. However, for some banks, we find that the larger the amounts they obtained from the ECB, the less they lent to firms. This was the case of the largest banks and the most capitalized. Taken together, this suggests that banks with stronger positions channeled ECB funding elsewhere. In the next section we investigate this issue further.

Further tests

In addition to the results reported in the previous tables, we extend our analysis in several dimensions.

First, we test whether foreign and domestic banks behaved differently during this period. We could argue that domestic banks were more severely affected by the shock, given the stronger bank-sovereign links. Further, foreign banks could more easily obtain funding through their parent banks. At the same time, it is also possible that foreign banks became more reluctant to grant credit during a period of heightened tensions (Haas & Horen 2013, Ongena *et al.* 2015). When we run our baseline regression separately for domestic and foreign banks, we do not find

any differences. For both groups, access to ECB funding enabled banks to continue lending to firms.

Second, we consider the possibility that firms with weaker relationships with their banks could have been more affected by this shock. We define firms with strong relationships with a bank as those that concentrate more than 50% of their borrowing in that bank. Our main results hold both for firms with and without these closer ties with banks.

Finally, all our previous results focus on the intensive margin. This implies that we are only considering firms that were borrowing from a bank before and after the shock. However, the extensive margin may also be important to analyze the role of the ECB during this period, most notably for firms that stopped borrowing from some banks. To explore the extensive margin, we consider firm-bank relationships that existed in December 2010, but not in March 2010 (new relationships) and firm-bank relationships that existed in March 2010, but not in December 2010 (terminated relationships). We find no significant effect from ECB funding on the likelihood of establishing a new relationship. However, we find some tentative evidence that the banks more hardly by the shock and that used more ECB funding were more likely to terminate relationships. However, this result only holds for specifications without firm fixed effects, implying that it might be capturing demand side factors. For instance, it is possible that firms may be more likely to terminate relationships with banks that were more dependent on access to wholesale debt markets.

Table 2.12: Results for the regressions interacting the recourse to Eurosystem funding with bank characteristics

Dependent variable: $loan\_growth_{ij}$

	Interaction term x_{jT-9}:				
	LTD	**LiqGap 1M-3M**	**Collateral**	**Solv ratio**	**Assets**
ΔECB fund$_{jT-4} * x_{jT-9}$	-0.0218**	0.108	0.00907	-0.0779	-0.284
	(0.00929)	(0.0671)	(0.0149)	(0.0459)	(0.184)
ΔECB funding$_{jT-4}$	3.709**	0.336	-0.210	0.837	6.795
	(1.678)	(0.435)	(0.335)	(0.512)	(4.325)
Ln(assets)$_{jT-9}$	-1.152	-0.0986	-0.969	-0.475	0.666
	(1.223)	(1.485)	(1.539)	(1.775)	(2.413)
Loan-to-dep$_{jT-9}$	0.0385	-0.0652**	-0.0805*	-0.0775**	-0.0764**
	(0.0596)	(0.0313)	(0.0414)	(0.0349)	(0.0306)
Liq ratio$_{jT-9}$	0.222	0.397**	0.340*	0.327	0.360*
	(0.164)	(0.158)	(0.191)	(0.195)	(0.184)
Solv ratio$_{jT-9}$	0.451***	0.510***	0.553***	0.548***	0.519***
	(0.0761)	(0.0800)	(0.0805)	(0.0768)	(0.0787)
Constant	2.912	-8.757	15.56	3.623	-24.17
	(29.10)	(37.16)	(37.70)	(42.52)	(57.47)
Banks	29	29	29	29	29
Firms	68,378	68,378	68,378	68,378	68,378
N obs	178,291	178,291	178,291	178,291	178,291
Prob¿F	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: Dependent variable: Log change in loans at the firm-bank level, including unused credit lines, between March and December 2010. All variables are defined in Table 1. All regressions include firm fixed effects. In each column we report the results for the estimation of equation 2.2 with different interactions between ΔECB funding and bank characteristics x_{jt-9}. The bank characteristics interacted in each column are reported in the heading of the table. Second line values in parentheses are the robust standard errors clustered at the bank level. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

2.6 What if? A counterfactual approach

To grasp the consequences of what could have been the situation if there had not been a lender of last resort available to provide support to an entire banking system hit by a large and unexpected shock, we design a simple counterfactual scenario. The main idea is to understand what could have happened if there had not been 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 level data[10]:

$$Y_{jt} = c + \alpha_j + \beta_1 securities_{jt-3} + \beta_2 X_{jt} + \beta_3 trend_t + \varepsilon_{jt} \tag{2.3}$$

where Y_{jt} refers to total loans or total assets of bank j in period t and α_j are bank fixed effects. The coefficient β_1 represents the impact on these bank variables from funding via wholesale markets ($securities_{jt-3}$ refers to the amount outstanding of debt issued by banks in the previous 3 months). X_{jt} is a vector of bank characteristics (including liquidity and capital ratios). The goal of this regression is to explore the structural relationship between funding through wholesale markets and lending to gauge the magnitude of the shock and, in a second step, to understand to what extent ECB funding was successful in substituting market funding. To do that, we first estimate this regression in the pre-shock period (2005-2009). The coefficient β_1 gives us the elasticity of lending or total assets to funding in wholesale markets. Second, we estimate a modified version where we consider the sum of funding through securities and through the ECB, in order to confirm whether central bank funding was relevant in the pre-shock period (given that this value was negligible in this period, we expect the results to be very similar):

$$Y_{jt} = c + \alpha_j + \beta_1 (securities_{jt-3} + ECB_{jt-3}) + \beta_2 X_{jt} + \beta_3 trend_t + \varepsilon_{jt} \tag{2.4}$$

[10] In the appendix we report summary statistics for the variables used in these regressions.

The next step is to estimate these two equations in the post-shock period (2010-2011). Given the sudden loss of access to markets, we expect that the pre-shock relationship between funding in wholesale markets and lending or total assets breaks down (reflected in a significant change in β_1 in equation 2.3). Adding ECB funding to market funding (by estimating equation 2.4 for the post shock period) will finally allow us to confirm if the lender of last resort role of the ECB played a part in avoiding a collapse in banks assets.

As we run the regression in levels, we first confirm that there is a cointegration relationship between the variables with a time trend. This trend can be related to common factors for Portuguese banks explaining their evolution prior to the crisis. In these regressions we consider only the 24 banks that issued securities at least once prior to 2010 and that were eligible to participate in Eurosystem operations.

Tables 2.13 and 2.14 present our results. Table 2.13 reports the impact on loans to firms (including credit lines) and Table 2.14 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 positive and statistically significant relationship between market funding and banks' loans and assets (column 1). Portuguese banks strongly relied on access to international debt markets to finance their activity. For the average bank, half of the amount financed in the wholesale market would be directed to loans to firms. Moreover, it contributed to leverage banks' balance sheets, as the relationship between securities and total assets is larger than one. 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 (equation 2.4). 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[11]. If our hypothesis is correct, we would expect the positive relationship between loans or assets and securities to break. However,

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

Table 2.13: Results for the panel regression at the bank level for the evolution of loans (including credit lines) to non-financial firms

Dependent variable: Total loans (including credit lines)$_j$				
	2005-2009		**2010-2011**	
	(1)	**(2)**	**(3)**	**(4)**
securities$_{jt-3}$	0.555***		-0.112**	
	(0.0422)		(0.0413)	
(securities + ECB)$_{jt-3}$		0.480***		-0.110*
		(0.0954)		(0.0620)
Liq ratio$_{jt-12}$	-8.811***	-8.250*	4.204	8.631
	(3.046)	(4.089)	(6.120)	(8.436)
Solv ratio$_{jt-12}$	8.179	13.84	48.39	66.11*
	(15.42)	(21.55)	(35.18)	(33.98)
trend	19.73**	26.80**	-18.46	-7.218
	(7.621)	(12.12)	(15.47)	(16.33)
Constant	4,214***	4,795***	9,344***	8,599***
	(349)	(511)	(1,319)	(1,315)
Banks	24	18	19	18
N obs	1,032	864	436	427
Prob¿F	0.0000	0.0000	0.0315	0.1186

Notes: All variables are defined in Table 1. The dependent variable is total loans granted by banks, including unused credit lines. In columns 1 and 3 we report the results for the estimation of equation (2.3) in the periods before (2005-2009) and after (2010-2011) the shock, respectively. In columns 2 and 4 we report the results for the estimation of equation (2.4) for the same two periods. All regressions include bank fixed effects. Second line values in parentheses are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

Table 2.14: Results for the panel regression at the bank level for the evolution of total assets

Dependent variable: Total assets$_j$

	2005-2009		**2010-2011**	
	(1)	**(2)**	**(3)**	**(4)**
securities$_{jt-3}$	1.597***		0.0539	
	(0.143)		(0.132)	
(securities + ECB)$_{jt-3}$		1.444***		0.352***
		(0.227)		(0.0792)
Liq ratio$_{jt-12}$	-27.54**	-27.26	17.67	43.76
	(12.94)	(18.62)	(21.40)	(38.06)
Solv ratio$_{jt-12}$	68.38	85.43	115.1	80.41
	(52.21)	(70.41)	(68.11)	(61.62)
trend	88.16**	108.9**	23.61	13.27
	(32.83)	(44.25)	(48.83)	(42.54)
Constant	9,992***	11,052***	21,615***	20,829***
	(1,148)	(1,503)	(4,443)	(3,903)
Banks	23	18	19	18
N obs	1,031	864	436	427
Prob¿F	0.0000	0.0000	0.2278	0.0017

Notes: All variables are defined in Table 1. The dependent variable is banks' total assets. In columns 1 and 3 we report the results for the estimation of equation (2.3) in the periods before (2005-2009) and after (2010-2011) the shock, respectively. In columns 2 and 4 we report the results for the estimation of equation (2.4) for the same two periods. All regressions include bank fixed effects. Second line values in parentheses are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

this relationship should hold when we include ECB funding if this is a quasi-perfect substitute for the lost wholesale market funding. The results are indeed strikingly different from those of the first period, confirming our hypothesis: the positive correlation between outstanding debt securities and banks' assets entirely disappears. The coefficient is not statistically significant for total assets (Table 2.14) and is actually negative for loans (Table 2.13). The more market debt outstanding banks had, the lower their stock of loans to firms during this period. This result is consistent with Dagher & Kazimov (2015), who find that there is a negative relation between wholesale funding and the supply of credit, but only during the global financial crisis.

In the last column we consider the joint effect of securities issued and access to ECB funding in the crisis period, in order to test if access to the central bank allowed to restore the previous relationship between securities and loans to firms. For loans we still obtain a negative coefficient. Given that in these regressions we are not controlling for demand effects, unlike what we did when using loan level data, it is possible that this result is being affected by a contraction of loan demand in a period of strong adjustment of expectations.

In contrast, 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 granting loans to firms.

2.7 Where did the money go?

This last result, together with other results obtained earlier with the loan-level regressions, hints at the hypothesis that banks used ECB funding to invest in assets other than loans to firms. These results are consistent with the hypothesis of fi-

nancial repression presented by Becker & Ivashina (2014) and Ongena *et al.* (2016). These authors argue that during this period sovereigns in distress encouraged banks to buy their debt. To test this hypothesis in our setting, we estimate the following equation:

$$Sov_{jt} = c + \alpha_j + \beta_1(ECB_{jt-3}) + \beta_2 X_{jt} + \beta_3 trend_t + \varepsilon_{jt} \tag{2.5}$$

where Sov_{jt} are the holdings of Portuguese sovereign bonds by banks. The results are shown in Table 2.15.

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 support to the financial repression hypothesis. These results are consistent with those of Drechler *et al.* (2016). 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.

Table 2.15: Results for the panel regression at the bank level for the evolution of Portuguese sovereign bond holdings

Dependent variable: Holdings of domestic sovereign bonds$_j$		
	2005-2009	**2010-2011**
ECB funding$_{jt-3}$	0.0271	0.204***
	(0.0372)	(0.0480)
Liq ratio$_{jt-12}$	-3.403	-6.956
	(2.571)	(17.09)
Solv ratio$_{jt-12}$	14.49	-5.547
	(15.52)	(16.90)
trend	5.651*	0.328
	(2.724)	(10.44)
Constant	-97.42	651.8
	(290.2)	(887.4)
Banks	16	15
N obs	705	331
Prob¿F	0.1522	0.0002

Notes: All variables are defined in Table 1. The dependent variable is total Portuguese government bond holdings. The table reports the results for the estimation of equation (2.3) in the periods before (2005-2009) and after (2010-2011) the shock, in columns 1 and 2, respectively. All regressions include bank fixed effects. Second line values in parentheses are the robust standard errors. * significance at 10 per cent; ** significance at 5 per cent; *** significance at 1 per cent.

We should recall that the Portuguese government also lost access to markets in the Spring of 2010. As such, we argue that the increase in sovereign holding by Portuguese banks during this period was likely more related with financial repression and moral suasion effects, as discussed by Becker & Ivashina (2014) and Ongena *et al.* (2016), instead of pure risk-shifting incentives, as discussed in Acharya *et al.* (2014) and Drechler *et al.* (2016). Actually, it is possible to argue that in that moment lending to the sovereign was actually less risky for banks, given the uncertainty regarding the prospects for an overly indebted corporate sector. The difference in risk weights on these two exposures also provided incentives for banks to prefer this type of allocation of resources. Further, the loan level results presented in Table 4 also do not support the risk-shifting hypothesis.

In sum, we find that the positive relationship between securities issued and banks' loans and total assets observed before 2010 broke after banks lost access to markets. Unlimited access to the ECB successfully helped banks to substitute market funding, leaving banks' assets virtually unchanged. However, this new funding is not directed

only to loans to non-financial firms. Banks also used these funds to buy sovereign bonds, in a period in which the sovereign also faced difficulties in access to markets. Our results thus 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.

2.8 Concluding remarks

What happens when an entire banking system suddenly loses access to debt markets? At the very least, a credit crunch might 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 market funding, as their loan-to-deposit ratios were around 160%.

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.

2.9 Appendix

Table 2.16: Descriptive statistics of the variables used in the analysis at the bank level

Variable	Unit	Obs	Mean	Std. Dev.	P25	Median	P75
Loans + lines	Million euro	3,629	4,211	8 136	113	723	3,653
Loans	Million euro	3,629	3,269	6,128	93	557	3,186
Assets	Million euro	3,591	12,505	23,509	758	2,347	7,706
Securities	Million euro	3,629	1,685	4,191	0	0	495
ECB funding	Million euro	2,891	821	2,278	0	0	310
PT bonds	Million euro	2,085	609	1,228	6	82	543
Liq ratio	ratio	3,615	25.6	23.8	9	17	37
Solv ratio	ratio	3,622	12.1	13.6	9	11	14

Chapter 3

The impact of ECB unconventional monetary policy in the money market

Abstract

The money market functioning got severely impaired during the financial crisis, leading central banks to unprecedented interventions. I assess ECB policy measures directed at the money market using micro data on Portuguese interbank market transactions. The fixed rate full allotment policy and the large excess liquidity in the banking system were effective in reducing interest rates in the market. Conversely, the increased intermediation by the central bank contributed to the reduction in the transactions loan amounts. Banks balance sheet items did not used to be a relevant determinant of the interest rates priced in the market prior to the crisis. But there is some light evidence that this may have change with the crisis, with banks with worse liquidity ratios being penalized.

JEL Codes: E58, G21.

Keywords: money market, financial crisis, monetary policy

[0]The views expressed in this paper are those of the authors and do not reflect the views of the Banco de Portugal or the Eurosystem.

3.1 Introduction

Interbank money markets are an essentially feature of a financial system. They are critical for the stability of the financial system and are central for monetary policy implementation. A well-functioning money market ensures that liquidity is disseminated through the banks of the system and idiosyncratic shocks are smoothed without any impact in the system. However, the money market was one of the financial markets most hit during the financial crisis that started in August 2007. This has led central banks to intervene in order to restore market functioning and the adequate transmission of monetary policy. The aim of this paper is to better understand the impact of monetary policy measures on the money market, assessing their impact using micro data on the Portuguese money market.

In August 2007, the suspension of investment funds of the BNP Paribas due to the exposure to the US subprime credit market brought volatility and uncertainty to a once very stable money market. The huge demand for funds led the ECB to inject liquidity. Since then, the ECB has provided more liquidity than strictly necessary and for longer maturities. In September 2008, the situation worsened with the failure of Lehman Brothers. The ECB has responded with increased liquidity, more refinancing operations for new maturities, an expansion of the eligible collateral to monetary policy operations and, most importantly with the a fixed rate full allotment (FRFA) policy at the main refinancing operations that extended later to all refinancing operations. The FRFA policy means that the Eurosystem would satisfy completely banks demand for funds at the regular operations at a fixed rate equal to the main refinancing rate. As a consequence, liquidity supply in the Eurosystem was then demand driven, inducing an aggregate excess liquidity.

Following the Lehman Brothers failure, the ECB has also tightened the interest rate corridor formed by the lending facilities. This corridor was usually 200 b.p. and was then reduced to 100 b.p. On January 21, 2009, with the improvement in the market conditions, the corridor was again widened to 200 b.p. However, on May 13, given the already low level of the deposit facility rate (0.25%), the corridor was again tightened to 150 b.p. In July 11, 2012 the deposit facility reached 0%

and in May 8, 2013, in order to cut official interest rates further without bringing the deposit facility rate to negative levels, the amplitude of the corridor was again reduced to 100 b.p. On November 13, the corridor was again tightened to 75 b.p. and it was for the first time asymmetric relative to the main refinancing rate.

In late 2009, the financial crisis deteriorated again and the phase of the sovereign debt crisis began with the uncertainty surrounding Greece's government accounts. In May 2010, Greece receives the first financial support package and in November it was the turn of Ireland. During the summer, the release of the result on banks stress test did not ease the fears about the negative feedback loop between sovereigns and the banking system. In April 2011, the Portuguese government also requested financial assistance, which was approved on May 17. However, market conditions continued to deteriorate and in December 2011 the ECB announced a series of measures addressed at supporting bank lending and money market activity. These included two 3-year LTROs (VLTRO), the reduction in the reserve ratio from 2% to 1% and the increase in the collateral availability.

Besides these measures more aimed at the money market, the ECB also implemented other non-standard monetary policy measures. It implemented two Covered Bond Purchase Programs (CBPP and CBPP2), aimed at provide support to this specific market considered relevant for the funding of banks. In May 2010, the Securities Market Programme (SMP), consisting in the purchase of government debt securities, was launched. The purpose of the programme was to tackle the severe malfunctioning in the price formation process in the bond markets of euro area countries and, consequently, the malfunctioning of the transmission mechanism. The liquidity injected through the purchases was sterilized in weekly operations. Finally, given the spread of the sovereign debt crisis to large countries such as Spain and Italy, in the summer of 2012, the ECB President mentioned that "within our mandate, the ECB is ready to do whatever it takes to preserve the euro". In the follow up of this compromise, the ECB announced in September the Outright Monetary Transactions (OMT) with the purpose of addressing severe distortions in government bond markets which originate from, in particular, unfounded fears on the part of investors of

the reversibility of the euro. The OMT consists in an unlimited purchase of government bond securities with maturities between one and three years, conditional on the member state being in an EFSF macroeconomic adjustment programme or a precautionary programme. The OMT have never been used so far.

With efficient interbank markets, monetary policy implementation would consist on the central bank providing liquidity via open market operations, not to individual institutions, and the interbank market would reallocate liquidity (Goodfriend & King 1988). However, there are several cases considered in the literature that justify central bank intervention. The lender of last resort function has been widely confirmed. It has been showed that in banking crisis the central bank can use open market operations to provide liquidity in order to smooth interest rates (Goodfriend & King (1988), Allen *et al.* (2009)). Acharya *et al.* (2012) defend that when there are market power issues, open market operations may not succeed unless the central bank pumps enough liquidity to break the market power of some banks. The central bank should be ready to accept some losses and to accept less liquid collateral in order to have impact. Moreover, the central bank is only capable of improving the outcome if it is better at monitoring than outside investors, which provides grounds for having monetary policy and supervising responsibilities both at the central bank. Freixas *et al.* (2011) study the optimal central bank response when the interbank market is subject to both idiosyncratic and aggregate shocks and find that the central bank should use different tools according to the types of shocks. When facing idiosyncratic shocks, the central banks should respond using the interest rate, and should respond to aggregate shocks by injecting liquid assets into the banking system.

So, one can find many justifications in the literature for central bank intervention in the interbank market, providing theoretical grounds for some of the Eurosystem's decisions. Nonetheless, one should evaluate the measures taken and their effectiveness. This is the main motivation behind this paper. I use data on overnight interbank transactions, identified from TARGET payment systems data using an algorithm similar to Furfine (1999). Overnight transactions represent the large share

of the turnover in the unsecured money market of the euro area (ECB 2012) and is the most relevant segment for monetary policy analysis. Crossing this data with banks' balance sheet variables and relationship variables, I show the impact of policy measures on market pricing and activity, namely the FRFA policy and the excess liquidity created in the market. The major contribution of this paper is then the use of micro data on the evaluation of policy effects on the money market. I find that the measures were effective in reducing interest rates in the market, but the impact on market activity was negative. Indeed, following the increased intermediation by the central bank, market activity was reduced, both in terms of access to the market and volume traded. I also find that the overnight market seems to already respond to risk considerations, by imposing higher interest rates to banks with lower solvability or liquidity ratios. The results also seem to confirm the idea of a significant market segmentation across euro area jurisdictions following the sovereign debt crisis, with Portuguese banks being penalized and seeing the impact of policy measures substantially reduced.

Thus, this paper also goes along the lines of the empirical literature on the effects of monetary policy measures during the financial crisis. Several papers have looked into the impact on money market benchmark rates such as the EONIA or the EURIBOR (Soares & Rodrigues (2013), Carpenter *et al.* (2013), Szczerbowicz (2015),Frank & Hesse (2009)), finding a positive effect in the reduction of interbank spreads and/or volatility, although with a significant degree of dispersion among studies. Few studies use micro data. Brunetti *et al.* (2011) use data on transactions on e-MID, an interbank market electronic platform, with results not very favorable on the impact of ECB policy measures on the interbank market. They find that central bank intervention consistently adds up uncertainty to the interbank market and that interventions that do not specifically target interbank asymmetric information fail to improve market liquidity. Arciero *et al.* (2014) make a brief description of the euro area interbank market during the crisis. Bräuning & Fecht (2017) look into the German interbank market in the early stages of the crisis, but their data end in 2008, which does not allows to assess the impact of the most important policy measures. Abbassi *et al.* (2015) also use micro data on interbank transactions for

the whole euro area, focusing on two episodes: the Lehman bankrupcy and the start of the sovereign debt crisis. They find that price dispersion, which increases with crisis indicators, falls substantially with the FRFA and the VLTRO. In the current study, the evidence is strongly in favour of a liquidity effect and of a reduction in market activity due to the increased central bank intermediation.

The paper is organized as follows. Section 2 presents the databases used and explains the methodology used to identify overnight operations. Section 3 presents some descriptive statistics. Section 4 presents the results of the econometric analysis on interest rates and loan volumes. Finally, some concluding remarks are presented on section 5.

3.2 Data and methodology

The majority of money market transactions are settled via the euro area large value payment system TARGET/TARGET2 (Trans-European Automated Real-time Gross settlement Express Transfer).[1] Thus, the principal database I use includes transactions settled on the Portuguese real-time gross settlement system (RTGS), part of TARGET/TARGET2, managed by the Banco de Portugal. Up to 2008, transactions were settled in TARGET, which joined together each country's RTGS. Since 2008, Banco de Portugal joined TARGET2, a single centralized system. Both systems settle payments related to monetary policy operations, as well as transactions related to other payment and securities settlement systems. TARGET2 is accessible by a large number of participants and it is the major large value payment system of the euro area.[2]

It is not possible to directly identify money market transactions from the payments system data. This includes data on each payment, on the sender and receiver of the payment, amount sent and date and time of the payment. One can identify

[1] There are other settlement systems of money market operations, of which the most important is the Italian e-MID, representing around a fifth of the euro area market. See Arciero *et al.* (2014) for a comparison between e-MID transactions and the ones drawn from TARGET data.

[2] In 2011, it had a market share of 59% in quantities and 91% in value(BdP 2012).

interbank money market transactions by applying the Furfine (1999) algorithm. The algorithm consists in identifying candidates to an overnight money market transaction by selecting large and round amounts. The second step consists in selecting the payments in the next business day that may correspond to the maturing overnight operation, i.e., that include interest payment at a plausible interest rate. I consider plausible interest rates the ones inside an interval, where the lower bound is the minimum between the EONIA minus 100 b.p. and the deposit facility rate and the upper bound is the maximum between the EONIA plus 100b.p. and the marginal lending facility rate. This wider interval has proven to capture more overnight operations, namely some intra-group transactions (Fernandes 2011). The algorithm has been largely used, for the euro area (Arciero *et al.* (2014), Bräuning & Fecht (2017), Heijmans *et al.* (2011),Farinha & Gaspar (2008)) as well as for other countries (Furfine (1999), Demiralp *et al.* (2006), Armantier & Copeland (2012)). The algorithm does not provide perfect data on interbank transactions and is subject to some errors. It can wrongly identify an overnight transaction, more common for a larger plausibility interest rate corridor. It can also fail to identify transactions, for several reasons: the transaction was not settled in TARGET, the interest rate lies outside the plausibility corridor or the amount does not correspond to the specified round amounts. Finally, we can have multiple matches. The most relevant criteria I've chosen to overcome multiple matches was to choose the match with the interest rate closest to the EONIA rate. Despite these problems, the evidence is in favor of the results of the algorithm, at least for the euro area. Arciero *et al.* (2014) show there is a very little share of errors in the identification of the operations.[3] Of course, the problems of identification are enlarged with a financial crisis and when interest rate are close to the zero lower bound. Regarding this, I assume a strictly positive interest rate in identifying overnight operations. In the next section, some statistics are presented on the Portuguese overnight market as identified through the Furfine algorithm.

The TARGET payments database is complemented with monthly data on Por-

[3]On the other hand, Armantier & Copeland (2012) find a large share of type I and type II errors for the fed funds market.

tuguese banks' balance sheet, coming from supervisory authorities (responsibility of the Banco de Portugal). There is also data on Portuguese monetary policy counterparties use of policy instruments, namely reserve requirements, monetary policy operations, standing facilities and collateral use. Finally, monetary policy instruments data at the Eurosystem level was taken from the ECB website.

The data has daily frequency and covers the period from January 1st, 2005 up to December 31st, 2013. So we have a wide period of data, covering the financial crisis but also more than two years of pre-crisis period.

3.3 Statistics

3.3.1 Recourse to monetary policy instruments

Eurosystem liquidity provision became more volatile with the start of the financial crisis and expanded namely since the onset of the FRFA policy. Since then, the Eurosystem banking system showed a clear preference for working with an aggregate excess liquidity[4], reaching a maximum of more than 800 billion euro following the 3-year VLTRO conducted at the end of 2011 and the beginning of 2012 (Figure 3.1). However, this huge amount of liquidity was unevenly spread through the euro area, specially since the sovereign debt crisis which implied a geographically broken transmission mechanism.

Portuguese banks recourse to Eurosystem funding was historically insignificant and remained quite limited in the early stages of the crisis. However, Portugal suffered the contagion from the Greek debt crisis and in the Spring 2010, Portuguese banks got excluded from international funding markets. Their funding through the Eurosystem increased by 20 p.p. of GDP during that time. However, the equivalent "excess liquidity" to the Portuguese banking system remained very close to zero throughout the period, probably meaning that Portuguese banks had no opportunity

[4]Excess liquidity is defined as the sum of excess reserves and the net recourse to the deposit facility. It is "excess" in the accounting (central bank balance sheet) meaning of the word, not refleting the agents' preferences.

Figure 3.1

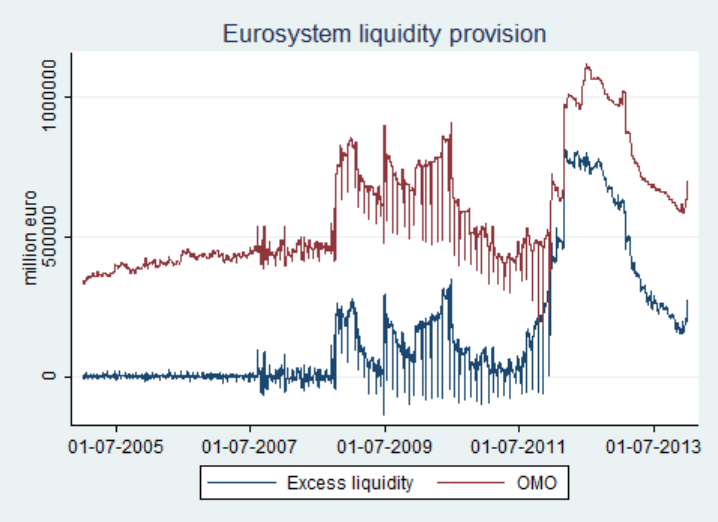
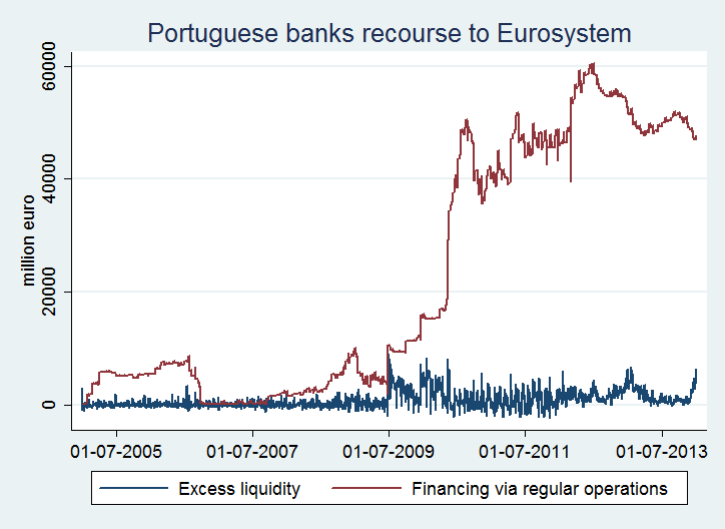


Figure 3.2

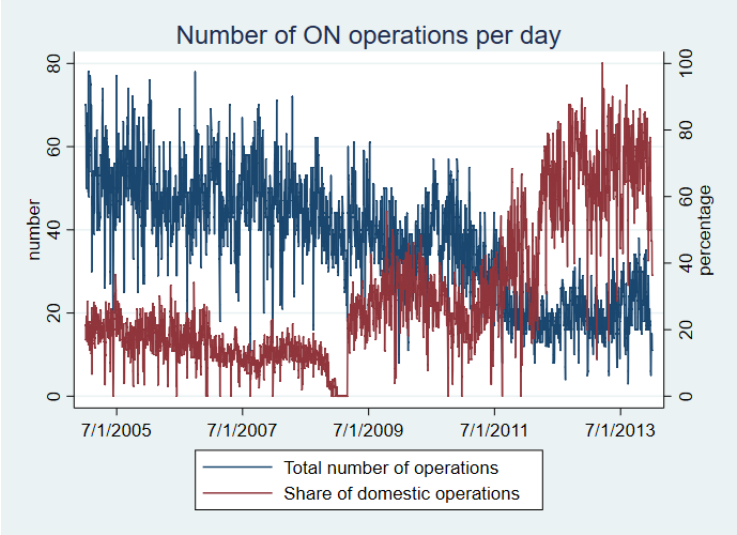


to create a liquidity buffer or that this was too expensive (Figure 3.2). Thus, there was virtually no contribution from Portuguese banks to the Eurosystem aggregate liquidity. Moreover, ECB's policy decisions were taken in response to euro area developments, not to specific Portuguese developments and the liquidity provision to Portuguese banks follows a distinct evolution from the Eurosystem provision. In this way, one can claim that the policy response measured by the Eurosystem excess liquidity is exogenous to the Portuguese market.

3.3.2 Market activity

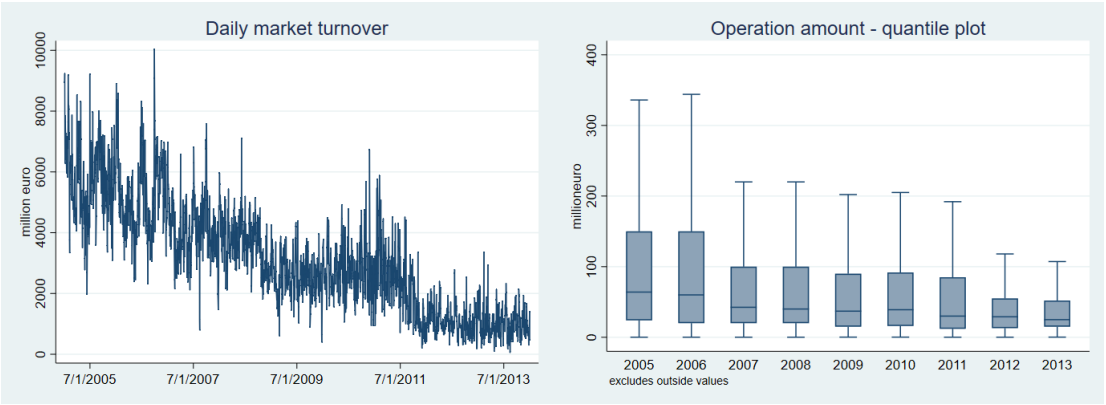
On average, there were 42 overnight operations made per day in the Portuguese money market between 2005 and 2013. Of these, about a quarter corresponded to domestic operations, i.e., to operations conducted between two banks registered in Portugal. However, these numbers changed significantly since the financial crisis and especially with the sovereign debt crisis, as can be observed in Figure 3.3. Up to the beginning of the crisis, the average number of operations per day was 51, of which 17% were domestic. Between 2007 and 2009, when the sovereign debt crisis began, the number fell to 45 operations, and further to 39 between 2009 and the start of the financial assistance program in 2011. The decrease was even larger afterwards, to an average of 22 operations since then. The share of domestic operations increased up to an average of 50% between 2011 and 2013, both because of the fall in the total number of transactions and because of the increase in the number of domestic operations. Thus, at a first glance we indeed find evidence of a market segmentation in the euro area, favoring the idea that Portuguese banks saw their access to the cross-border market reduced.

Figure 3.3



Besides the increase in the domestic market activity, one can also notice a change in the side of the cross-border operation of the domestic bank. Indeed, the share of Portuguese banks lending in cross-border operations decreased during the financial

Figure 3.4



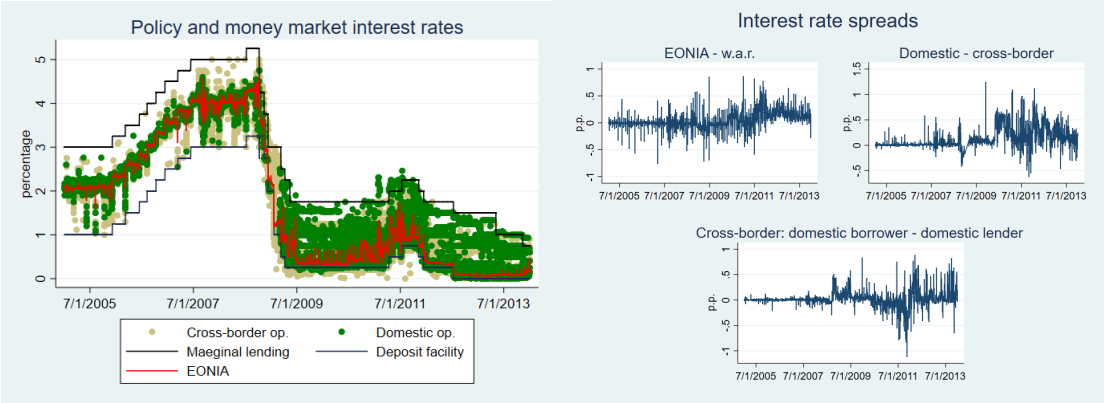
crisis, due both to the fall in the number of cross-border operations and in the number of operations with a Portuguese lender. This share was below 20% up to the beginning of the financial crisis in 2007 and doubled in the period after 2009.

3.3.3 Market turnover

The evolution of market turnover is quite similar to the evolution in the number of transactions (see Figure 3.4). Turnover has steadily decreased during the period under analysis, corresponding to a fall in the number of operations and in the average operation amount. The average operation amount fell from 110 million euro in 2005 to 50 million euro in 2013. As one would expect, cross-border operations are usually for a larger amount than domestic operations. The average amount in a cross-border operation was 121 million euro in 2005 and fell to 75 million euro in 2013. The amounts involved in domestic operations were more volatile and showed a peak in 2008 of 180 million euro on average per operation, falling afterwards to 38 million euro in 2012 and 2013.

Figure 3.4 also shows the operation amount distribution per year, showing the high dispersion in the amounts traded. The high degree of dispersion is common to domestic and cross-border operations.

Figure 3.5



3.3.4 Interest rates

Interest rates of the identified operations followed closely the EONIA rate. This is a consequence of the algorithm described previously, which identifies operations according to their interest rate proximity to the EONIA. Nonetheless, rates showed an increased dispersion in the financial crisis, especially during the period of large excess liquidity and when the deposit facility rate was close to the zero lower bound, i.e. since the fourth quarter of 2008 (see Figure 3.5). Up to 2010, the weighted average rate of all operations followed very closely the EONIA. Since then, it has been slightly below the EONIA, i.e., on average, banks in the Portuguese ON market tended to trade below the EONIA. This may be related to the increased importance of the domestic market, since operations in the domestic market tended to be priced at a higher rate (see Figure 3.5). Relative to the interest rates priced in cross-border operations, Portuguese borrowing banks usually pay higher interest rates than the Portuguese lenders in the crisis. The exception was during 2011, when Portuguese lenders were able to trade at higher rates than the ones that were borrowing cross-border.

3.4 Estimation results

In this section, I plan to better understand the effects of monetary policy measures on the Portuguese money market by means of an econometric analysis. I run

a panel data model and autoregressive disturbance of order 1 (given that I have financial data with daily frequency). Both random effects model and fixed effects models, i.e. with borrower-lender pair fixed effects and with borrower and lender fixed effects, are estimated.[5]

In this way, the following model is estimated, where i refers to the borrower and j to the lender:

$$\begin{aligned} x_{ijt} &= c + \alpha EL_t + D_i^{b,dom} x_{it}^{b\prime} \beta^{b,dom} + \beta^{b,for} D_i^{b,for} + D_j^{l,dom} x_{jt}^{l\prime} \beta^{l,dom} + \beta^{l,for} D_j^{l,for} \\ &\quad + crisis_t' \lambda + \gamma^b BPI_{ijt} + \gamma^l LPI_{ijt} + \gamma^g IG_{ijt} + controls_t' \delta + fe_i + fe_j + \varepsilon_{ijt} \\ \varepsilon_{ijt} &= \rho \varepsilon_{ijt-1} + \nu_{ijt} \end{aligned}$$

The dependent variable x_{ijt} can be the spread between the transaction interest rate and the ECB main refinancing rate (section 3.4.1) or the logarithm of the amount traded (section 3.4.2). I also look at the probability of making a transaction using a probit model with a similar specification. The main explanatory variable is the Eurosystem Excess Liquidity at the beginning of the day (EL_{t-1}), calculated as the sum of excess reserves and the net use of the deposit facility. This is the main policy variable that I'm interested in evaluating. The Portuguese banking system is relatively small relative to the euro area. Moreover, as seen before, the huge increase in the recourse to the Eurosystem by Portuguese banks did not coincide with the increases at Eurosystem level and occurred at a period when Eurosystem funding was relatively stable. So, Eurosystem excess liquidity is an exogenous measure of the ECB policy expansion by unconventional measures. Moreover, it was driven mainly by the fixed rate full allotment procedure and by the increase in the number and type of operations conducted, which aimed mostly at improving money market conditions. All in all, it is the most adequate measure to evaluate the policy effect on money markets.

Portuguese banks faced two types of crisis: first, a financial crisis that hit money markets in a generalized way, and then a sovereign debt crisis that induced a market

[5]The Hausman test rejects the null hypothesis of validity of the random-effects model. Nonetheless, conclusions are broadly the same across random effects and fixed effects models.

fragmentation in the euro area. In this way, I include two crisis indicators ($crisis_t$): the spread between the 1-month Euribor and the 1-month OIS, and the Portuguese sovereign CDS (Abbassi *et al.* 2015).

I then control for bank characteristics for the Portuguese banks, both for the borrower and for the lender, (x^b_{it}, x^l_{jt}), namely the solvability ratio, total assets (in logarithms), liquidity ratio and the excess reserves cumulated over the reserve maintenance period as a share of total assets (included with a lag). I control for foreign banks using a dummy ($D^{b,for}_{it}$, $D^{l,for}_{jt}$). It has been shown in previous studies the importance of relationship lending in this market. Thus, I include two measures of bank relationships and a dummy equaling one when the operation involves two banks from the same group (IG_{it}).[6] The bank relationship measures used are the borrower and lender preference indexes calculated as (Cocco *et al.* 2009):

$$BPI_{l,b,t} = \frac{\sum_{t\in T} M_{l,b,t}}{\sum_{b\in B}\sum_{t\in T} M_{l,b,t}}$$
$$LPI_{l,b,t} = \frac{\sum_{t\in T} M_{l,b,t}}{\sum_{l\in L}\sum_{t\in T} M_{l,b,t}}$$

Where $M_{l,b,t}$ is the amount lend to bank b by bank l in day t and B is the entire set of borrowers and T is an interval of 30 days. These indexes translate the importance of a specific lender or borrower to that bank.

Finally, in the controls group there are some dummies, namely for the periods when the standing facilities corridor was tightened and for the days when any open market operation was conducted.

3.4.1 On interest rates priced

Tables 1 and 2 show the results. The effect of the excess liquidity on money market interest reveals a liquidity effect that is clearly significant. For each 100

[6] I define a transaction as intra-group if lender and borrower share the same first four letters of the BIC code, which refer to the bank code. This is a strict criteria with the major disadvantage of excluding banks with different codes but belonging to the same group. I also used for robustness the definition of banking groups coming from supervisory data, which includes all the domestic institutions belonging to the group. The handicap is that it only includes domestic institutions and so it can also be ony considered as a lower bound. The results using the two criteria are similar.

Table 3.1: Descriptive statistics of the variables used

Variables	**Description**	**N. Obs**	**Mean**	**St. dev.**	**Min**	**Max**
Dependent variables						
spread	Transaction interest rate minus main refinancing rate	78,008	-0.153	0.338	-1.784	1.300
ln(amount)	Log of the transaction amount	78,008	3.728	1.368	-2.303	8.220
Policy variable						
exc_liq	Eurosystem excess liquidity given by net deposit facility plus excess reserves	78,008	89.500	172.133	-134.833	811.857
Crisis indicators						
1M Euribor-OIS	Spread between the 1-month Euribor and OIS	53,782	21.494	24.633	-4.8	156.75
PT sov CDS	CDS spread on Portuguese sovereign debt	53,782	261.163	333.318	3.4	1600.98
Period dummies						
d_corridor150	Dummy=1 when the facilities interest rate corridor was 150; 0 otherwise	78,008	0.326	0.469	0	1
d_corridor100	Dummy=1 when the facilities interest rate corridor was 100; 0 otherwise	78,008	0.063	0.243	0	1
d_corridor75	Dummy=1 when the facilities interest rate corridor was 75; 0 otherwise	78,008	0.007	0.082	0	1
d_crisis	Dummy=1 for the crisis period starting on 8 August 2007	78,008	0.600	0.490	0	1
d_frfa	Dummy=1 for the fixed rate full allotment period starting on 14 October 2008	78,008	0.430	0.495	0	1
Banks variables						
lend_ln_assets	Log of bank's total assets (portuguese lenders	60,071	23.531	1.703	17.940	25.443
lend_liq_ratio	Ratio between the bank's liquid assets and total assets (portuguese lenders)	60,071	25.095	20.514	0.000	94.491
lend_solv_ratio	Bank solvability ratio (portuguese lenders)	60,070	0.123	0.099	-0.602	1.840
lend_er_assets	Bank's cumulated excess reserves over the maintenance period over total assets (portuguese lenders)	60,066	0.011	0.048	-0.209	1.920
d_lend_foreign	Dummy = 1 if the lender is foreign	78,008	0.216	0.412	0.000	1.000
borr_ln_assets	Log of bank's total assets (portuguese borrowers)	34,564	23.383	1.628	17.940	25.443
borr_liq_ratio	Ratio between the bank's liquid assets and total assets (portuguese borrowers)	34,564	22.235	14.146	0.034	87.331
borr_solv_ratio	Bank solvability ratio (portuguese borrowers)	34,561	0.107	0.074	-0.597	0.695
borr_er_assets	Bank's cumulated excess reserves over the maintenance period over total assets (portuguese borrowers)	34,561	0.008	0.047	-0.268	1.134
d_borr_foreign	Dummy = 1 if the borrower is foreign	78,008	0.555	0.497	0.000	1.000
intragroup	Dummy = 1 if the operation is between banks of the same group, according to the first four digits of the BIC	78,008	0.044	0.206	0.000	1.000
lpi	Lender preference index	78,008	0.518	0.402	0.000	1.000
bpi	Borrower preference index	78,008	0.717	0.363	0.000	1.000

billion euro of excess liquidity, interest rates lower by 8 to 9 b.p. The results are in line with the predictions of Acharya *et al.* (2012), where central bank intervention granting liquidity to constrained banks manages to reduce the market price and avoids inefficient asset sales.

The coefficients of the crisis variables show portuguese banks were more negativelly affected by the sovereign debt crisis period. Indeed, interest rates observed in the portuguese market are positivelly correlated with the portuguese government CDS spread, while they have even decreased as the tensions in money markets increased. This goes in line with the hypothesis of market fragmentation and that portuguese banks were significantly penalized by the sovereign crisis.

It is also relevant to analyse the effect of banks' characteristics. Domestic banks trading abroad have lower interest rates. This is contrary to Freixas & Holthausen (2005), who anticipate more expensive cross-border transactions due to the reduced access to information on domestic banks by the foreign banks. Our result may be related to the fact that banks borrowing abroad tend to be larger banks, on which there is more information available, and that can easily get access to foreign funds at a better price than domestically, contrary to smaller banks (in line with Cocco *et al.* (2009) result). Indeed, when an interaction variable of the foreign lender dummy with the size of the borrower is included, the coefficient is negative, meaning that larger borrowers manage to get even lower rates when borrowing abroad. Nonetheless, the overall effect for all borrowers remains negative and significant. Similarly, domestic banks lending abroad also tend to charge a lower interest rate, but this result is not robust across specifications.

Larger banks tend to pay less for overnight transactions, which is in line with expectations and with other authors find (Cocco *et al.* 2009). Banks with a higher solvability ratio also tend to pay less in overnight transactions. However, when looking at sub-sample periods, we see that this relationship changed throughout the crisis, since it was not a significant determinant prior to August 2007 and became very significant aftewards. This thus suggests that more riskier banks started to be discriminated as the crisis unfolded.

Banks that usually have larger excess reserves at the central bank also pay less for overnight funds, which is also widely expected. However, this effect seems to occur only during the financial crisis period, which may be related to the high preference for liquidity during this period.

As regards the lending side of the market, larger lenders and those with higher solvability ratios trade in the overnight market at a lower interest rate. However, this effect is not clear throughout the whole period. Prior to the financial crisis, large banks used to charge more, but this changed since August 2007. Similarly to the borrowing side, the capital ratio was not relevant before the crisis, while during the crisis banks with better ratios charged less in overnight loans. There is also evidence that banks with larger excess reserves lend in the overnight market at lower rates, but again, this only started to be important with the crisis.

Finally, we measure the importance of bank relationships. Contrary to what theory would predict, i.e., that proximity reduces the premium associated with asymmetric information (Freixas & Holthausen 2005), we find that banks tend to pay more to lenders with whom they have more frequent relationships. In contrast, Cocco *et al.* (2009) found that frequent lending relationships lead to lower funding costs to borrowers when controlling for borrower and lender characteristics. There is also evidence in favor of more favorable terms in intra-group operations.

3.4.2 On market activity

Tables 3 and 4 show the results for the estimation on transactions log amount. The policy expansion given by the excess liquidity contributed to reduce the amounts traded in the overnight market. However, it is hard to really understand what the effect of policy measures on the money market really was. Since the central bank increased intermediation, then it is expectable to have reduced market activity. But we do not have the counterfactual. What would be the consequences had not the central bank intervened? Probably some institutions would have failed and the money market would have likely frozen.

Table 3.2: Results of the estimation for the interest rate spread with random effects.

	(1)		(2)		(3)		(4)		(5)	
EL	-0.0003	***	-0.0003	***	-0.0001	***	-0.0002	***	-0.0001	***
	0.0000		*0.0000*		*0.0000*		*0.0000*		*0.0000*	
1M Euribor-OIS							-0.0004	***	-0.0013	***
							0.0001		*0.0001*	
PT sov CDS							-0.0001	***	0.0001	***
							0.0000		*0.0000*	
borr_solv_ratio			-1.4024	***	-0.5286	***	-1.3540	***	-0.6680	***
			0.1194		*0.1028*		*0.1500*		*0.1331*	
borr_ln_assets			-0.0699	***	-0.0381	***	-0.0452	***	-0.0365	***
			0.0052		*0.0041*		*0.0064*		*0.0055*	
borr_liq_ratio			0.0002		-0.0010	***	0.0007		0.0004	
			0.0004		*0.0004*		*0.0006*		*0.0005*	
borr_er_assets			-0.1265	***	-0.0686	*	-0.0957	**	-0.0638	
			0.0364		*0.0354*		*0.0418*		*0.0411*	
d_borr_foreign	0.0544	***	-1.6830	***	-0.9759	***	-1.1383	***	-0.9230	***
	0.0135		*0.1231*		*0.0984*		*0.1540*		*0.1325*	
lend_solv_ratio			-0.3024	***	-0.0950	**	-0.3174	***	-0.1257	***
			0.0420		*0.0380*		*0.0528*		*0.0480*	
lend_ln_assets			-0.0499	***	-0.0116	***	-0.0208	***	-0.0027	
			0.0038		*0.0030*		*0.0051*		*0.0043*	
lend_liq_ratio			-0.0002		-0.0010	***	0.0004		0.0002	
			0.0002		*0.0002*		*0.0004*		*0.0003*	
lend_er_assets			-0.1266	***	-0.0839	***	-0.0869	***	-0.0782	***
			0.0228		*0.0222*		*0.0263*		*0.0259*	
d_lend_foreign	-0.0059		-1.1411	***	-0.3275	***	-0.4809	***	-0.0808	
	0.0147		*0.0908*		*0.0712*		*0.1241*		*0.1050*	
BPI			-0.0012		0.0006		0.0001		0.0008	
			0.0020		*0.0020*		*0.0029*		*0.0029*	
LPI			0.0060	**	0.0093	***	0.0114	***	0.0114	***
			0.0029		*0.0028*		*0.0037*		*0.0035*	
IG			-0.0265	***	-0.0234	***	-0.0205	***	-0.0263	***
			0.0068		*0.0065*		*0.0077*		*0.0076*	
constant	-0.1564	***	2.8093	***	1.2489	***	1.4908	***	0.9156	***
	0.0124		*0.1504*		*0.1203*		*0.1965*		*0.1683*	
dummies	no		no		yes		no		yes	
IG	yes		yes		yes		yes		yes	
lend-borr FE	no		no		no		no		no	
ρ	0.9403		0.9376		0.9328		0.9354		0.9273	
R2 overall	0.1233		0.0786		0.3552		0.0550		0.2726	
N° obs.	77981		76768		76768		52601		52601	

Table 3.3: Results of the estimation for the interest rate spread with lender and borrower fixed effects .

	(1)		(2)		(3)	
EL	-0.0003	***	-0.0002	***	-0.0001	***
	0.0000		*0.0000*		*0.0000*	
1M Euribor-OIS			-0.0010	***	-0.0012	***
			0.0001		*0.0001*	
PT sov CDS			0.0001	***	0.0002	***
			0.0000		*0.0000*	
borr_solv_ratio					-0.7293	***
					0.1266	
borr_ln_assets					-0.0712	***
					0.0151	
borr_liq_ratio					0.0020	***
					0.0007	
borr_er_assets					-0.0739	*
					0.0415	
d_borr_foreign					-1.7214	***
					0.3801	
lend_solv_ratio					-0.0609	
					0.0507	
lend_ln_assets					-0.1122	***
					0.0157	
lend_liq_ratio					0.0019	***
					0.0005	
lend_er_assets					-0.0732	***
					0.0260	
d_lend_foreign					-2.1014	***
					0.3911	
BPI					-0.0009	
					0.0029	
LPI					0.0082	**
					0.0037	
IG					-0.0243	
					0.0280	
dummies	no		yes		yes	
IG	yes		no		yes	
lend-borr FE	yes		yes		yes	
ρ	0.9403		0.9285		0.9273	
R2 overall	0.3711		0.5353		0.4943	
N^o obs.	77981		46605		52601	

The crisis indicators confirm the previous idea that portuguese banks were specially hit by the sovereign debt crisis. Indeed, An increase in the euro money market spreads had no relevant impact in the amounts traded, while the rise in the sovereign CDS spread contributed to a fall in the traded amounts.

As one could easily expect, large banks lend and borrow larger amounts. Foreign banks lend and borrow significantly larger amounts per transaction, which may also be related with their size. Borrowers with lower solvability ratios get larger loans, and this already occured prior to the crisis. On the liquidity ratio, the impact is different depending on which side of the market the bank is. Borrowers with a lower liquidity ratio have larger loans, which could be related to the effect found for the solvability ratio. I.e., banks that seem to be riskier also have higher daily borrowing needs. When lending, banks with a higher liquidity ratio lend for larger amounts. This can be related to their higher availability of funds. Looking at daily availability of funds based on the excess reserves the bank has at the begginning of the day, one confirms a small positive effect for lenders.

Finally, more frequent relationships in the overnight market translate into larger amounts traded, while intragroup loans are smaller.

3.4.3 On market access

During the crisis, anedoctal evidence pointed to the more difficulty in trading and, as the sovereign debt crisis unfolded, an exclusion of the market participants from stressed jurisdictions. In this section, I intend to evaluate the effect of the ECB policy on the likelihood of finding a counterparty to trade with.

In order to do so, I consider all pairwise combinations of lender and borrower that have traded at least once. Since this implies a huge boost in the amount of data, I restrict to the period 2008-2010 and I exclude intragroup operations. Then I consider the dummy variable access that assumes value 1 if a transaction was made between those two banks in that day and 0 otherwise. A probit model is estimated against the same set of covariates and including lender and borrower fixed effects

Table 3.4: Results of the estimation for the log amount with random effects.

	(1)		(2)		(3)		(4)		(5)	
EL	-0.0003	***	-0.0004	***	-0.0002	***	-0.0002	***	-0.0002	***
	0.0000		*0.0000*		*0.0000*		*0.0000*		*0.0000*	
1M Euribor-OIS							0.0008	***	0.0001	
							0.0003		*0.0003*	
PT sov CDS							-0.0003	***	-0.0002	***
							0.0000		*0.0000*	
borr_solv_ratio			-2.6219	***	-1.9702	***	-2.6134	***	-2.1848	***
			0.4065		*0.4089*		*0.4743*		*0.4802*	
borr_ln_assets			0.3304	***	0.3674	***	0.3058	***	0.3155	***
			0.0214		*0.0214*		*0.0249*		*0.0249*	
borr_liq_ratio			-0.0027	**	-0.0034	***	-0.0071	***	-0.0066	***
			0.0013		*0.0013*		*0.0018*		*0.0018*	
borr_er_assets			0.0408		0.0900		0.0598		0.0896	
			0.1495		*0.1491*		*0.1575*		*0.1574*	
d_borr_foreign	0.5054	***	7.5427	***	8.3860	***	6.8194	***	7.0791	***
	0.0678		*0.5055*		*0.5065*		*0.5951*		*0.5950*	
lend_solv_ratio			-0.0330		0.1053		-0.0568		0.0191	
			0.1170		*0.1170*		*0.1371*		*0.1379*	
lend_ln_assets			0.3180	***	0.3596	***	0.3851	***	0.3981	***
			0.0007		*0.0158*		*0.0191*		*0.0192*	
lend_liq_ratio			0.0037	***	0.0030	***	0.0082	***	0.0083	***
			0.0007		*0.0007*		*0.0012*		*0.0012*	
lend_er_assets			0.1119		0.1688	*	0.1758	*	0.1856	
			0.0977		*0.0976*		*0.1040*		*0.1040*	
d_lend_foreign	-0.3667	***	6.6755	***	7.5745	***	8.4252	***	8.7171	***
	0.0726		*0.3675*		*0.3708*		*0.4596*		*0.4603*	
BPI			0.0397	***	0.0434	***	0.0409	***	0.0423	***
			0.0093		*0.0092*		*0.0123*		*0.0122*	
LPI			0.1072	***	0.1114	***	0.0851	***	0.0850	***
			0.0128		*0.0127*		*0.0152*		*0.0152*	
IG			-0.3311	***	-0.3274	***	-0.3172	***	-0.3198	***
			0.0320		*0.0319*		*0.0333*		*0.0333*	
constant	3.3916	***	-11.3279	***	-13.1154	***	-12.3156	***	-12.8487	***
	0.0630		*0.6086*		*0.6183*		*0.7486*		*0.7505*	
dummies	no		no		yes		no		yes	
IG	yes		yes		yes		yes		yes	
lend-borr FE	no		no		no		no		no	
ρ	0.8626		0.8599		0.8593		0.8550		0.8547	
R2 overall	0.1115		0.2193		0.2239		0.1794		0.1787	
N° obs.	77981		76768		76768		52601		52601	

Table 3.5: Results of the estimation for the log amount with lender and borrower fixed effects.

	(6)		(7)		(8)	
EL	-0.0003	***	-0.0001	**	-0.0002	***
	0.0000		*0.0000*		*0.0000*	
1M Euribor-OIS			0.0002		0.0001	
			0.0003		*0.0003*	
PT sov CDS			-0.0001	**	-0.0001	***
			0.0000		*0.0000*	
borr_solv_ratio					-2.0519	***
					0.4550	
borr_ln_assets					0.0724	
					0.0518	
borr_liq_ratio					-0.0042	*
					0.0022	
borr_er_assets					0.0494	
					0.1582	
d_borr_foreign					0.5961	
					1.3290	
lend_solv_ratio					-0.1190	
					0.1427	
lend_ln_assets					-0.0505	
					0.0495	
lend_liq_ratio					0.0127	***
					0.0014	
lend_er_assets					0.2128	**
					0.1042	
d_lend_foreign					-2.2573	*
					1.2608	
BPI					0.0514	***
					0.0123	
LPI					0.0900	***
					0.0153	
IG					0.3018	*
					0.1541	
dummies	no		yes		yes	
IG	yes		no		yes	
lend-borr FE	yes		yes		yes	
ρ	0.8626		0.8662		0.8552	
R2 overall	0.6199		0.5754		0.5713	
N° obs.	77981		46605		52601	

(I do not include banks' variables, given the high reduction in the sample, which biases the results). Results are presented in table 5.

Results confirm previous evidence in favor of a significant market fragmentation in consequence of the sovereign debt crisis and of an increased intermediation role by the ECB. Again, portuguese banks were negativelly affected by the sovereign credit risk and indeed were less likely to trade in the market during that period. Moreover, the coefficient on Eurosystem excess liquidity is negative, thus meaning that the increase in central bank liquidity and the FRFA implied that banks recourse to the money market reduced.

Table 3.6: Results on the probit estimation on the probability of making a transaction including lender and borrower fixed effects.

	(1)		(2)		(3)		(4)	
EL	-0.0006	***	-0.0004	***	-0.0006	***	-0.0004	***
	0.0000		*0.0000*		*0.0000*		*0.0000*	
1M Euribor-OIS					0.0009	***	0.0000	
					0.0001		*0.0002*	
PT sov CDS					-0.0001	***	0.0000	*
					0.0000		*0.0000*	
dummies	no		yes		no		yes	
IG	no		no		no		no	
lend-borr FE	yes		yes		yes		yes	
Prob > chi2	0.0000		0.0000		0.0000		0.0000	
N^o obs.	917070		917070		917070		917070	

3.5 Concluding remarks

This paper presents one of the first evaluations of the impact of monetary policy measures on the money market using micro data. Using data on overnight interbank transactions, identified from TARGET payment systems data using an algorithm similar to Furfine (1999), and crossing it with banks' balance sheet data, I assess the impact of the excess liquidity in interbank markets on interest rates and loan amounts in the Portuguese interbank market. These measures were effective in reducing interest rates in the market. On the other hand, the increased intermediation by the central bank contributed to the reduction in the transactions loan amounts and in the likelihood to find a trading partner.

Market interest rates seem to be mainly driven by the geographic location of the banks, i.e., domestic vs. foreign, and by the size of the bank. However, during the crisis it seems that some risk considerations started to be taken into account in the overnight market segment. Indeed, banks with lower solvability ratios trade at higher interest rates.

The policy followed by the ECB was then capable of influencing prices, while activity was reduced. This can be considered as a consequence of opting for the FRFA policy, where the market became more centralized. Questions related to the comparison between centralized and decentralized markets naturally follow, especially as market conditions further normalize.

Chapter 4

Welfare effects of common shocks in a financially integrated small open economy

Abstract

It is well known that countries would benefit from financial integration when hit by idiosyncratic shocks. However, when evaluating the gains to a country like Portugal of belonging to the Monetary Union, and participating in the more integrated assets markets that the common currency and monetary policy back, the evidence supports the hypothesis that a large share of output volatility is not due to individual shocks but instead to common shocks. This paper explores one mechanism that can support the advantage of staying inside the union even in this case for a SOE. We introduce heterogeneity at the country level and show that, despite aggregate and distributional effects from common shocks when countries are perfectly integrated, quantitatively the aggregate effect is not significant. Nonetheless, the distributional effect is quantitatively significant for the SOE, meaning that for these economies there is a clear advantage due to a risk sharing mechanism. The

[0]This is joint work with Bernardino Adão.

[0]The views expressed in this paper are those of the authors and do not reflect the views of the Banco de Portugal or the Eurosystem.

source for these effect is the difference in the parameters that govern the risk aversion/intertemporal substitution across economies. Using evidence that corroborates the usual perception, a very simple general equilibrium model is calibrated and simulated to evaluate the question above.

JEL Codes: E44, E5, G21.

Keywords: elasticity of intertemporal substitution, risk aversion, heterogeneous agents, business cycles, monetary union.

4.1 Introduction

It is well known that when there are idiosyncratic shocks there is room for risk sharing among heterogeneous households. But what if the shocks are aggregate shocks? This is a less studied case. Here too, there is room for risk sharing if households have different elasticities of intertemporal substitution. Households with smaller elasticities would value more a smoother consumption path than the households that have higher elasticities. In the presence of aggregate shocks households face fluctuations in their consumption which can be mitigated by investing in physical capital. However, there can be additional gains if households can have access to financial markets. We verify that with complete financial markets, after a positive shock the households with smaller elasticities of intertemporal substitution achieve a smoother consumption path by buying debt from the households with higher elasticities. Thus, after a positive shock the households with higher elasticities have more debt and the households with lower elasticities have less debt.

In this paper we use this insight to show that a small economy has a lot more to gain by joining a monetary union than the remaining countries of the union. For that to happen the only condition that must be fulfilled is that the representative household of the small country is not equal to the representative household of the union. The more different the representative households are the bigger the gain for the small economy.

Additionally, we use this insight to explain the evolution of the Portuguese foreign debt during the last 3 decades. Since the 90's until the sovereign debt crisis, the Portuguese foreign debt increased, and after the Portuguese foreign debt has decreased. This follows for two reasons: (i) the representative Portuguese household has a higher elasticity of intertemporal substitution than the representative household of the euro area, and (ii) in the first period the majority of the aggregate shocks in the euro are were positive, while in the second the majority of them were negative.

We use a model were the main ingredients are: (i) aggregate shocks, (ii) ac-

cess to the international financial market, and (iii) heterogeneous households. The empirical literature has shown they are relevant. For instance Giannone & Reichlin (2006) established that the variance of a country output in the euro area, is mainly explained by common shocks with similar propagation mechanisms, while idiosyncratic shocks, although persistent, have a limited role in explaining output fluctuations. Additionally, Giannone & Reichlin (2006) found a higher degree of consumption cross-country correlations conditionally on output and a decrease in the risk not insured since the early 90's for euro area countries. This means that the ability of sharing risk among European countries increased since the early 90's when capital and good market integration accelerated in Europe. Financial market integration made it easier for consumers to insure against risk through borrowing and lending and cross country ownership of assets. Finally, the empirical literature documents that smaller countries have a higher variance of consumption than the larger countries. For instance, Giannone & Reichlin (2006) compute for the period 1993-2003 that the variance consumption in Ireland was 10 times larger than the one of Germany, and that the variance consumption in Portugal was 6 times larger than the one of Germany. In the context of a CRRA utility function this justifies that the smaller country having a higher intertemporal elasticity of substitution than the larger country.

4.2 A model with risk aversion heterogeneity

We consider a simple extension of the standard stochastic growth model. In this economy there are contingent assets and no frictions. Firms produce using capital as the only input of production. The good produced can be used in investment or consumption. There are two types of aggregate shocks: productivity and capital shocks. There are two types of households, which are heterogeneous with respect to preferences and wealth. They have different levels of wealth and their preferences have different degrees of elasticity of intertemporal substitution (EIS). This will lead them to hold different assets and respond differently to shocks. The household with the higher intertemporal elasticity represents the small open country that shows

a higher consumption volatility, while the household with a lower intertemporal elasticity represents the large country that shows a lower consumption volatility. The wealth distribution in the union could be a consequence of this heterogeneity and of the sequence of past shocks.

4.2.1 Households

Households preferences depend only on consumption, $c_{i,t}$, according to the CRRA utility function:

$$u\left(c_{i,t}\right) = \frac{c_{i,t}^{1-\gamma_i}}{1-\gamma_i} \qquad i = a, b,$$

where γ_i is the inverse of intertemporal elasticity of substitution (and simultaneously the coefficient of risk aversion). In period t the household of type i has a share $\varphi_{i,t}$ of the firm. The firm pays dividends d_t and has a price of V_t. The household also holds one-period contingent bonds $B_{i,t}$. Thus, at date t an household of type i has wealth equal to $B_{i,t} + \varphi_{i,t}\left(V_t + d_t\right)$. The household uses this wealth to consume, $c_{i,t}$, to buy bonds, $E_t q_{t+1} B_{i,t+1}$, and invest in the firm $\varphi_{i,t+1} V_t$. The q_{t+1} is the price at date t (normalized by the probability of the state at date $t+1$) of a bond that pays one unit of date $t+1$ good at a particular state. Thus the budget constraint of the household can be written as:

$$c_{i,t} + E_t q_{t+1} B_{i,t+1} + \varphi_{i,t+1} V_t = B_{i,t} + \varphi_{i,t}\left(V_t + d_t\right) \qquad i = a, b. \tag{4.1}$$

The household i's optimization problem is to choose a sequence of consumptions and asset positions, $\{c_{i,t}, B_{i,t+1}, \varphi_{i,t+1}\}_{t=0}^{\infty}$, given dividends and prices, $\{d_t, V_t, q_{t+1}\}_{t=0}^{\infty}$, and the initial assets $B_{i,0}$ and $\varphi_{i,0} V_0$, that maximizes

$$\sum_{t=0}^{\infty} \beta^t \frac{c_{i,t}^{1-\gamma_i}}{1-\gamma_i},\ 0 < \beta < 1,$$

subject to the infinite sequence of state contingent constraints (4.1).

The optimization problem for household i across time and states implies the standard intertemporal condition:

$$q_{t+1} = \beta \left(\frac{c_{i,t+1}}{c_{i,t}} \right)^{-\gamma_i} \qquad i = a, b. \tag{4.2}$$

4.2.2 Firms

Firms operate under perfect competition. They produce one final good, decide investment in capital and pay dividends to the households. To produce the good firms use only capital according to the function:

$$Y_t = A_t K_{t-1}^{\alpha}, \tag{4.3}$$

where A_t is the aggregate productivity shock. The A_t follows an AR(1) process:

$$\log A_t = \rho^a \log A_{t-1} + \varepsilon_t^a, \tag{4.4}$$

with $0 < \rho^a < 1$, and where ε_t^a denotes an independently and identically distributed white noise process with mean zero and variance σ_a^2.

Following Gertler *et al.* (2017) we introduce a capital quality shock that aims at capturing some form of economic obsolescence, as opposed to physical depreciation. Let $\tilde{K}_t$ be the aggregate capital stock "in process" for period $t+1$. Capital in process at t for $t+1$ is the sum of current investment I_t and the stock of undepreciated capital, $(1-\delta)K_{t-1}$:

$$\tilde{K}_t = (1-\delta)K_{t-1} + I_t.$$

Capital in process for period $t+1$ is transformed into capital for production after the realization of a multiplicative shock to capital quality, μ_t:

$$K_t = \mu_t \tilde{K}_t.$$

The shock μ_t follows an AR(1) process:

$$\log \mu_t = \rho^{\mu} \log \mu_{t-1} + \varepsilon_t^{\mu} \tag{4.5}$$

where ε_t^{μ} is an iid shock with mean zero and variance σ_{μ}^2.

The firm chooses the sequence $\{K_t, I_t\}_{t=0}^{\infty}$ that maximizes the present value of all dividends, $\sum_{t=0}^{\infty} E_t q_t d_t$, where

$$d_t = A_t K_{t-1}^{\alpha} - I_t, \tag{4.6}$$

taking as given the prices $\{q_t\}_{t=0}^{\infty}$, with $q_0 = 1$, and the initial level of capital K_{-1}. Formally the problem can be written as:

$$\begin{aligned} \max_{\{K_t, I_t\}} V_t &\equiv \sum_{t=0}^{\infty} E_t q_t (A_t K_{t-1}^{\alpha} - I_t) \\ \text{s.t.} \qquad K_t &= \mu_t[(1-\delta)K_{t-1} + I_t] \end{aligned} \tag{4.7}$$

The first order condition of the firms' problem is:

$$1 = E_t q_{t+1} \mu_t [\alpha A_{t+1} K_t^{\alpha - 1} + 1 - \delta] \tag{4.8}$$

This equation says that the marginal cost of capital, 1, must be equal to the marginal benefit of investment, which is marginal product of future capital plus the quantity of capital that will be left in the future after depreciation, all discounted back to the present.

4.2.3 Market clearing

There are three markets: the state contingent bond market, stock market and the market for the good. In equilibrium all markets clear at all dates and states:

$$
\begin{aligned}
B_{a,t} + B_{b,t} &= 0, \\
\varphi_{a,t} + \varphi_{b,t} &= 1, \\
c_{a,t} + c_{b,t} + I_t &= Y_t.
\end{aligned}
\tag{4.9}
$$

4.2.4 Equilibrium conditions

The equilibrium conditions of this economy are: the intertemporal conditions for the households (4.2), the firms' optimal investment rule (4.8), the market clearing equations (4.9), the equation for dividends (4.6), the production function (4.3), the budget constraints (4.1) and the stochastic processes for the shocks (4.4) and (4.5).

An equilibrium for this economy is a sequence $\{c_{a,t}, c_{b,t}, B_{a,t+1}, B_{b,t+1}, \varphi_{a,t+1}, \varphi_{b,t+1}, d_t, I_t, K_t, Y_t, q_{t+1}\}_{t=0}^{\infty}$ that satisfies the equilibrium conditions and the initial $\{B_{a,0}, B_{b,0}, \varphi_{a,0}, \varphi_{b,0}, K_{-1}\}$. As markets are complete the equilibrium portfolio $\{B_{a,t+1}, B_{b,t+1}, \varphi_{a,t+1}, \varphi_{b,t+1}\}$ is not uniquely determined, i.e. there are many combinations of the stock and contingent bonds that guarantee the same payment in each state of nature. Thus, without loss of generality we assume that households hold a constant share of the firm: $\varphi_{a,t} = \varphi_a$, and $\varphi_{b,t} = \varphi_b$. The budget constraints (4.1) simplify substantially as the variable, V_t, the value of the firm drops from these constraints. The equations become:

$$
c_{i,t} + E_t q_{t+1} B_{i,t+1} = B_{i,t} + \varphi_i d_t \qquad i = a, b.
$$

4.2.5 Aggregate and individual risk aversion

Households preferences do not allow for the existence of a representative consumer, as shown in the following lemma.

Lemma 1. Aggregate consumption of an economy composed of consumers with different degrees of risk aversion can not be represented by a consumer with a constant

risk aversion parameter.

From the Euler equation 4.2, each consumer's marginal rate of intertemporal substitution should be equal, as well as the representative agent if it were to exist:

$$
\begin{aligned}
c_{a,t}^{-\gamma_a} &= \frac{\beta}{q_{t+1}} c_{a,t+1}^{-\gamma_a} \\
c_{b,t}^{-\gamma_b} &= \frac{\beta}{q_{t+1}} c_{b,t+1}^{-\gamma_b} \\
C_t^{-\gamma} &= \frac{\beta}{q_{t+1}} C_{t+1}^{-\gamma} \\
\text{where} \quad C_t &= c_{a,t} + c_{b,t}
\end{aligned}
$$

The last expression would hold if we could consider the aggregate risk aversion γ a constant parameter. What would be necessary for that to be true and how could γ be defined in that case? In order to derive it, consider the change in aggregate consumption given by:

$$
\frac{dC_t}{C_t} = \frac{C_{a,t}}{C_t} \frac{dC_{a,t}}{C_{a,t}} + \frac{C_{b,t}}{C_t} \frac{dC_{b,t}}{C_{b,t}} \tag{4.10}
$$

By deriving the Euler equation of the representative agent we should get:

$$
\frac{dC_t}{C_t} = \frac{dC_{t+1}}{C_{t+1}} + \frac{1}{\gamma} \frac{dq_{t+1}}{q_{t+1}} \tag{4.11}
$$

Two similar expressions to 4.11 hold for consumers A and B, that can be replaced in equation 4.10, yielding:

$$
\frac{dC_t}{C_t} = \frac{C_{a,t}}{C_t} \frac{dC_{a,t+1}}{C_{a,t+1}} + \frac{C_{b,t}}{C_t} \frac{dC_{b,t+1}}{C_{b,t+1}} + \frac{dq_{t+1}}{q_{t+1}} \left[\frac{1}{\gamma_a} \frac{C_{a,t}}{C_t} + \frac{1}{\gamma_b} \frac{C_{b,t}}{C_t} \right] \tag{4.12}
$$

Comparing equations 4.11 and 4.12, we would have the aggregate risk aversion γ given by:

$$\frac{1}{\gamma} = \frac{1}{\gamma_a}\frac{C_{a,t}}{C_t} + \frac{1}{\gamma_b}\frac{C_{b,t}}{C_t} \tag{4.13}$$

if the consumption shares would not change over time and state, meaning that γ would be a parameter. In discrete time this is just an approximation while it is exact in continuous time (Cochrane 2017).[1] Thus, aggregate risk aversion will vary over time and state in order to respect the aggregate Euler equation:

$$q_{t+1}C_t^{-\gamma_t} = \beta C_{t+1}^{-\gamma_{t+1}} \tag{4.14}$$

Thus, aggregate risk aversion in this setup is an endogenous variable that can be defined in terms of the distribution of individual risk aversions and of the wealth distribution. These two distributions interact between them resulting in different degrees of aggregate risk aversion across time and states. Nonetheless, the distribution of wealth impacts only through the budget constraint, and thus would still allow for aggregation if there would be no heterogeneity in the degree of risk aversion.

4.2.6 The steady-state

In the deterministic steady-state there are many possible distributions of consumption between capitalists and, accordingly, many possible holdings of financial assets that respect the conditions:

$$\begin{aligned} c_a &= B_a(1-q) + \varphi d \\ c_b &= B_b(1-q) + (1-\varphi)d \\ B_a + B_b &= 0 \\ C &= d \end{aligned} \tag{4.15}$$

[1] In a continuous time setup with recursive preferences, Gârleanu & Panageas (2015) show that aggregate risk aversion can not be withdrawn from a representative agent expected utility-maximizing agent.

It is possible to impose the initial steady-state distribution of consumption between capitalists and we get the amount of financial assets that each will have. Thus, define the share of consumer A consumption $\frac{c_a}{c_a+c_b} = \psi$, and the steady-state financial assets of this consumer will be

$$B_a = \frac{\psi - \varphi}{1-q} d$$

This implies that consumer A will hold financial assets in the steady-state to compensate the difference between the consumption share and the firm holding share. In case the household A consumes more than its share of the firm, i.e., $\psi > \varphi$, it will hold positive financial assets. If we define the households wealth as the sum of equity and financial assets, in the steady-state each household will consume its wealth and the consumption share ψ is the same as the wealth share in steady-state. In order to better understand the effects of heterogeneity (both of risk aversion and initial wealth distribution) between households, we consider that in the initial steady-state there are no asset holdings ($\psi = \varphi$), i.e., the wealth and the income distributions are the same, in order to better understand the effects on the equilibrium through financial markets.

The risk aversion parameter does not affect directly the steady-state. However, heterogeneity in risk aversion influences the economic dynamics and implies differentiated effects on households and thus has permanent impact in the wealth distribution. In this way, different risk aversion coefficients in heterogeneous agents will imply that, following a shock, the wealth distribution will change, and thus so will the aggregate risk aversion in the economy, influencing indirectly the steady-state.

4.3 The model applied to the euro area

The model will be used to replicate the euro area since its inception in order to understand the benefits from financial integration when the economies face common shocks. Giannone & Reichlin (2006) argue that the output dynamics in euro area

countries is mainly driven by common shocks. However, there are persistent gaps in levels of income per capita. This feature can be related with the fundamental heterogeneity in our model. In this framework, we want to understand the potential benefits from integrating these different economies. More specifically, are there benefits from risk sharing in integrated complete markets compared to complete markets in two separate economies when both economies are subject to the same aggregate shocks? We will look into two subperiods of the monetary union. The first corresponds to the pre-crises periods, with integrated markets and sequence of positive shocks. The second corresponds to the financial and sovereign debt crises period, when the euro area is hit by a large negative aggregate shock. We consider two extreme cases for comparison: (i) the euro area continues perfectly integrated and countries trade with no frictions in the asset market, as before, and (ii) financial market transactions between the two countries shutdown completely.

4.3.1 Model calibration

The model is fairly simple and calibration is according to the usual values found in the literature. The share of capital in production α is 30%, the discount factor β is 0.97, implying a steady-state risk-free rate close to 3%. Capital depreciates at an annual rate δ of 10% and shocks have a large persistence ($\rho^a = \rho^\mu = 0.8$). The distribution of shocks is also calibrated in line with the literature, with a standard deviation of the productivity shock of 0.01 (Rudebusch & Swanson 2012) and of the capital shock of 0.0075 (Gertler *et al.* 2017).

We still need to define the parameters of each economy. For simplicity, the union is made up of only Portugal and Germany, where Portugal represents 10% of the total population of the union. Wealth and income distribution are the same and given by the GDP per capita in the two countries. Given that Germany's GDP per capita has been roughly the double of Portugal's GDP per capita, we set the share of Portugal's wealth in aggregate wealth to $\psi = \frac{1}{3}$. The EIS parameters are set accordingly to the consumption volatility. We use the real individual consumption growth variance during the period of financial integration presented in Giannone

& Reichlin (2006) for Portugal and Germany, given that during this period they shared the same interest rate, by the Euler equation (4.2).[2] Given that consumption volatility is higher in Portugal than in Germany, we have $\gamma_{PT} > \gamma_{DE}$.

We work with third-order approximation following Swanson *et al.* (2006) in order to grasp the effects of risk aversion, which disappear in linear models. Non-linear model approximations also allow to monitor the dynamics of financial variables such as the equity risk premium, although in simple RBC models with no frictions this premium turns out to be of little relevance (Swanson 2018). Moreover, higher-order solutions are more relevant for larger shocks and take into account the assymetric effects of negative shocks. Nonetheless, for small deviations the log-linear approximation is a fairly good model approximation.

4.3.2 The pre-crises period

The first decade of the EMU prior to the crisis was a period of positive growth, on average. We will represent this period in the model by the impulse response functions following positive shocks. The shocks size will equal one standard-deviation, i.e. a 1% productivity shock and a 0.75% capital shock. Figures 4.1 and 4.2 show the impulse response functions to the productivity and the capital shocks, respectivelly, under two alternative scenarios: (i) countries are integrated in the EMU, and (ii) countries are not integrated, and the aggregate variables are calculated with the respective population weight. In this way, we can both compare what happens with integration and what happens in homogenous economies with different EIS.

Overall, the responses of the two shocks are quite similar, with some differences on timing and amplitude of the shocks. Following a positive productivity shock (figure 4.1), the production technology needs less inputs (capital) to produce the same amount of goods, leading to a rise in ouput. The rate of return to capital increases, increasing the incentive of households to save. However, households want

[2]From the Euler equation, it must hold that $\gamma_{PT}\Delta c_{PT} = \gamma_{DE}\Delta c_{DE}$, thus we define the relationship between the two EIS parameters as $\frac{\gamma_{PT}}{\gamma_{DE}} = \sqrt{\frac{var(\Delta c_{DE})}{var(\Delta c_{PT})}}$, with $var\left(\Delta c_{DE}\right) = 0.97$ and $var\left(\Delta c_{PT}\right) = 2.98$. We fix $\gamma_{DE} = 5$, which gives $\gamma_{PT} = 2.85$ and $\gamma_{EMU} = 4$.

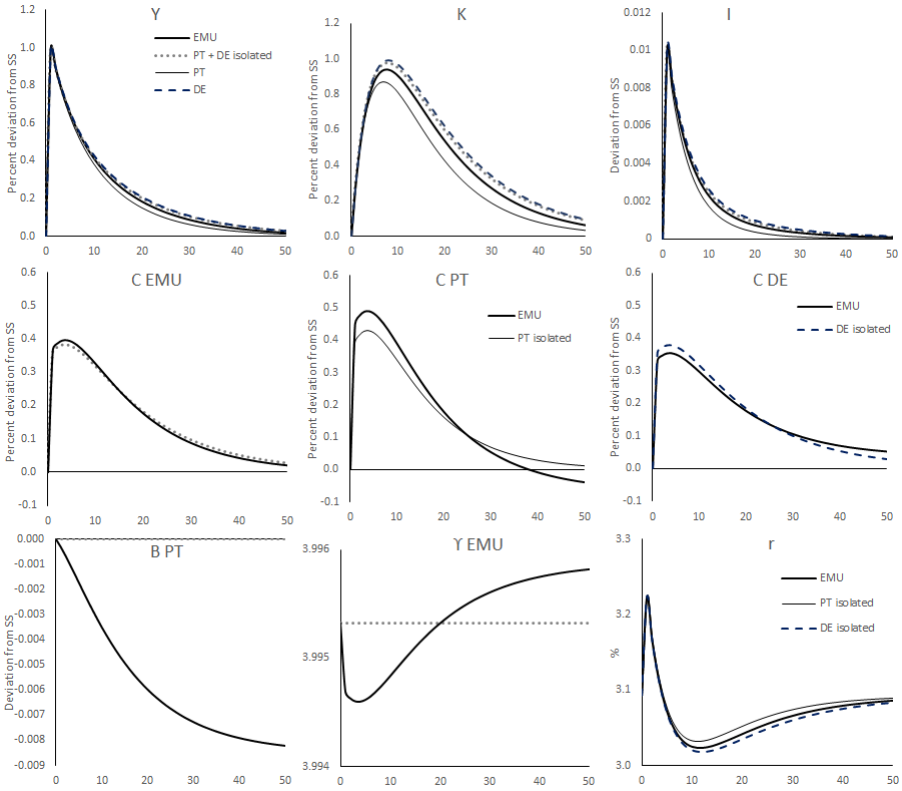


Figure 4.1: Impulse response functions following a positive productivity shock. Two cases shown: 'EMU' corresponds to the Portugal and Germany with integrated financial markets; 'isolated' to the responses where countries do not have integrated markets and the aggregate is calculated with the respective population weight.

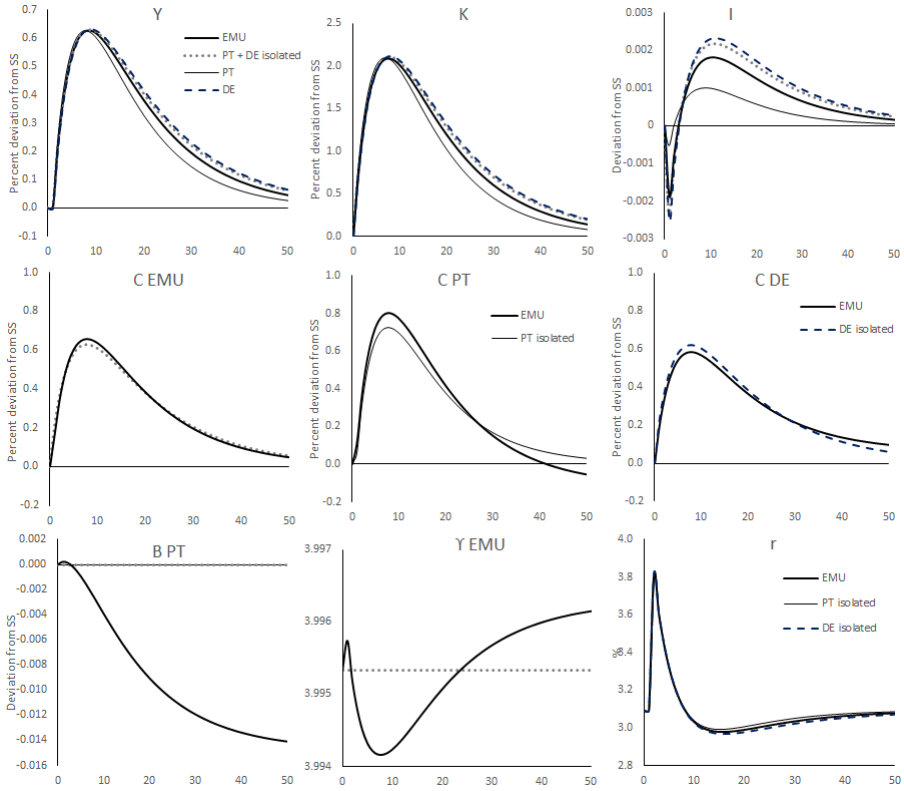


Figure 4.2: Impulse response functions following a positive capital shock. Two cases shown: 'EMU' corresponds to the Portugal and Germany with integrated financial markets; 'isolated' to the responses where countries do not have integrated markets and the aggregate is calculated with the respective population weight.

to smooth their consumption through time, leading also to a rise in consumption.

Recall that the capital shock has a different timing than the productivity shock. The shock hits capital that will be used in production only in the subsequent period, thus there is no immediate impact on output and on the return of capital (figure 4.2). So, these variables will only deviate in period 2, while the shock is observed in period 1. Given that EIS is lower than 1 for both economies, the income effect is larger than the substitution effect and households prefer to save less in period 1, when the rate of return remained constant at the steady-state level. As the rate of return increases in period 2, so do savings, especially for the consumers with lower EIS.

Heterogeneity does not influence directly the response of aggregate variables, which only depend on the aggregate γ. The aggregate EIS however is an endogenous variable, as we have shown before, and thus will vary through time with the individual γ and the wealth distribution, influencing thus indirectly the aggregate responses.[3]

The lower the consumers EIS are (the higher the γ), the less they want to change their consumption through time, the higher the income effect will be relative to the substitution effect. This is the reason why consumption in Germany increases by less than consumption in Portugal, both with and without integrated markets and in response to both shocks. Savings are higher in Germany, implying a higher and longer deviation of capital and output from their steady-state level. When countries are integrated, their consumption responses stress their intertemporal preferences. Portuguese consumers want to vary even more their consumption over time, so they increase their consumption in the initial periods following the shock by building up debt against German consumers. The γ is countercyclical, as the Portuguese consumers increase temporarily their consumption share via debt, and decrease it in the long run. Thus, in the long-run, a sequence of positive shocks will lead to a new steady-state where Portuguese consumers have a lower share of wealth and a lower consumption and where the aggregate EIS is lower. The effects are stronger

[3]See the appendix for a more detailed discussion on the effects of aggregate EIS and heterogeneity on the transition dynamics of the model.

for Portugal, as the aggregate dynamics is dominated by the large country. These results are in line with what we observed in the first decade of the EMU, where Portugal build up a current account deficit. In this context, financial integration in the euro area was equivalent to opening one market to explore heterogeneity in intertemporal preferences, allowing for risk sharing of aggregate shocks, which was not possible with the economies isolated (Allen & Gale 2004). This result is in line with Giannone & Reichlin (2006), that support the argument that European integration contributed to increase risk sharing in the euro area.

4.3.3 The crises period

There is no consensus on what kind of shock was behind the financial crisis. Jermann & Quadrini (2012) argue that financial shocks, in a particular a tightening of firms' financing conditions, were the shock that led to the Great Recession. Gertler *et al.* (2017) modeled the recession as a consequence of a capital shock in the lines of the one we also incorporate here. Moreover, in the euro area the sovereign debt crisis created a market fragmentation in previously well integrated financial markets. We do not take a position in what the true shock caused the Great Recession. The capital shock in our model could be more directly linked to the advanced factors behind the crisis, but there could a different type of shock that in our model is closely linked to the productivity shock. In this way, we look at the impulse response functions of both shocks, calibrated at 5 times the respective standard deviation. This leads to a fall of GDP in yearly terms at the through of 5% for the productivity shock and of 3.1% for the capital shock. This compares with a cumulated fall in GDP in the euro area from the financial and sovereign debt crises of around 5%.

Given the above assessment about the crisis, we consider that two extreme cases should be discussed: (i) the EMU continued working as before, (ii) the large shock led to a sudden stop in financial markets and this channel is completely shut down. These are two extreme scenarios. In reality, financial markets were indeed impaired and Portuguese banks access to money and debt markets was quite restrictive. On the other hand, monetary policy measures were able to counteract this sudden stop

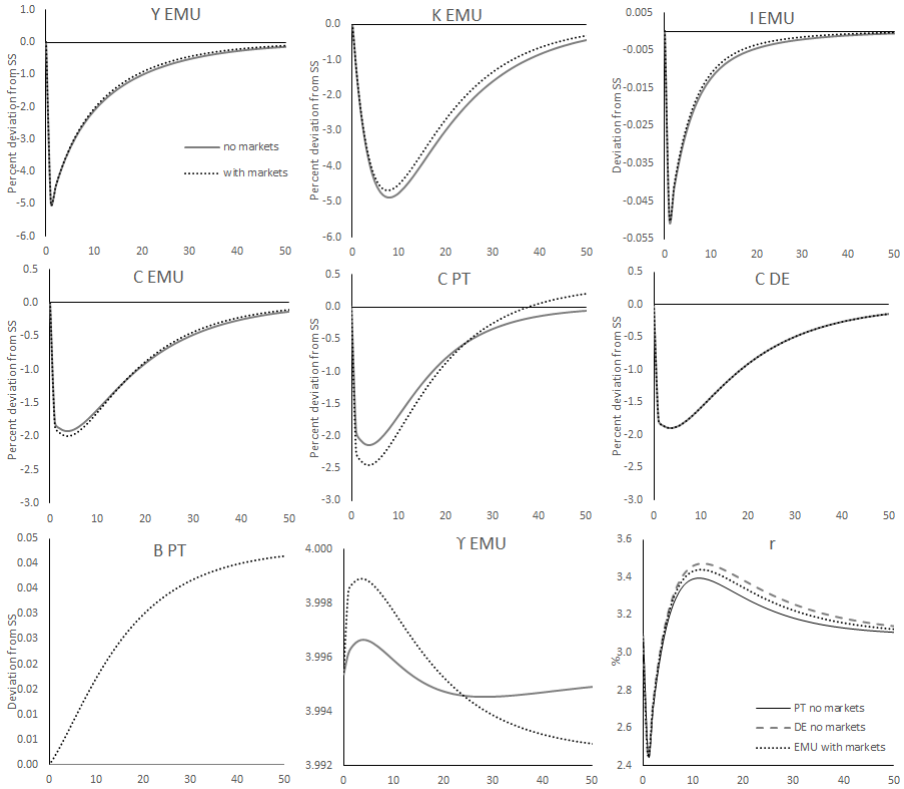


Figure 4.3: Impulse response functions following the same aggregate negative productivity shock of 5 standard-deviations. Two cases shown: 'EMU with markets' corresponds to Portugal and Germany in the monetary union with complete asset markets, 'no markets' corresponds to the EMU where markets are shutdown.

and, at least partially replace the lost market access (see chapters 2 and 3).

Figures 4.3 and 4.4 show the impulse response functions to the productivity and capital shocks, respectively. As in the period pre-crises, the impact of the two shocks is qualitatively very similar. As seen before, the capital shock implies a larger impact on the capital stock and a smaller impact on output and consumption than the productivity shock. The response to the shocks for the aggregate is mostly driven by the response of Germany, given its larger weight. The dynamics is mostly symmetric to the positive shocks case.

Keeping financial market integration between the countries would have allowed households in both countries to access one further market for insuring against future shocks, benefiting especially the poorer country. Households in Portugal have a higher elasticity, are more willing to vary more consumption over time relative to German households. Therefore, they would now prefer to lend to German con-

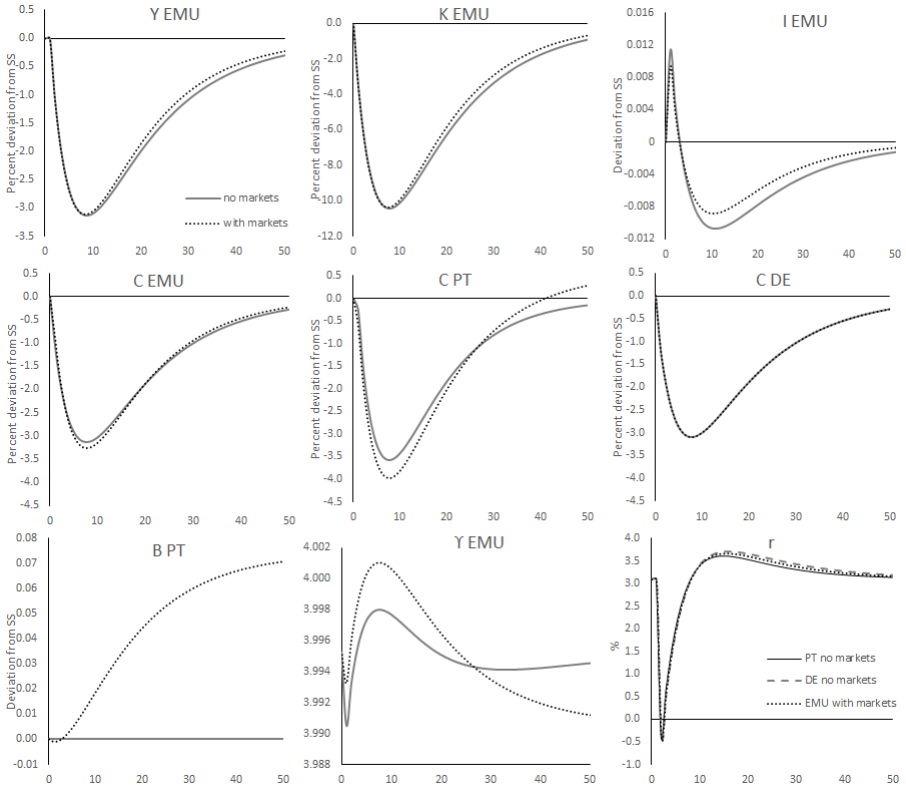


Figure 4.4: Impulse response functions following the same aggregate negative capital shock of 5 standard-deviations. Two cases shown: 'EMU with markets' corresponds to Portugal and Germany in the monetary union with complete asset markets, 'no markets' corresponds to the EMU where markets are shutdown.

sumers, counteracting the negative balance observed before the crisis. The effect for German consumers would bot be significant, given their large size. Both countries would be better with integrated markets than otherwise. In this way, keeping integrated market would allow for a balancing mechanism of the countries current account over time, at the same time allowing households to better fulfill their intertemporal consumption preferences.

As before, aggregate γ is countercyclical. The countries will converge to a new steady-state where the poorer country gains in terms of the wealth distribution relative to the initial steady-state and the aggregate economy will be overall more intertemporally elastic, besides the already mentioned gains during the transition. This dynamics occurs either with or without integrated markets, but it is stronger with integrated markets, given that markets allow each household to accentuate their preferences.

4.4 Possible extensions

4.4.1 Recursive preferences

The current setup does not allow to disentagle the effects from the elasticity of intertemporal substitution from risk aversion. There is a large number of studies, mostly in macro-finance, that take into account this distinction by using recursive preferences (Gârleanu & Panageas (2015), Schneider (2017), Silva (2015), Rudebusch & Swanson (2012), among many others). By separating risk aversion from intertemporal elasticity of substitution, these models are able to improve significantly on quantitative predictions, especially of financial variables (Gârleanu & Panageas (2015), Schneider (2017)).

Recursive or Epstein-Zin preferences can be expressed in the following form:

$$V_{i,t} = u(c_{i,t}) + \beta[E_t V_{i,t+1}^{1-\theta_i}]^{\frac{1}{1-\theta_i}} \qquad i = a, b$$

where, as before:

$$u(c_{i,t}) = \frac{c_{i,t}^{1-\gamma_i}}{1-\gamma_i} \qquad i = a, b$$

Current utility depends non-linearly on today's utility and future utility. For $\theta_i = 0$ we get the usual case of expected utility. Otherwise, θ_i works as a 'twisting' parameter, amplyfing (for positive values of utility) the risk aversion of the household, while keeping the elasticity of intertemporal substitution in $\frac{1}{\gamma_i}$. Swanson (2018) shows that the non-stochastic steady-state coefficient of relative risk aversion is, in this case, equal to $\gamma + \theta(1-\gamma)$.

The stochastic discount factor with these preferences turns out to be slightly different:

$$q_{t+1} = \beta \frac{V_{i,t+1}}{[E_t V_{i,t+1}^{1-\theta_i}]^{\frac{1}{1-\theta_i}}} \frac{u\prime(c_{i,t+1})}{u\prime(c_{i,t})} \qquad i = a, b \tag{4.16}$$

Again, we see that fixing $\theta_i = 0$ leads to the same discount factor as before (equation 4.2).

We have conducted simulations for different combination of parameters, namely for $\gamma = \{2; 5\}$ and for θ in an interval between 0 and 90. We have kept the γ always identical for both consumers and considered introducing heterogeneity only in the θ. Depending on the combination of parameters, the range of values for the steady-state coefficient of relative risk aversion goes from 2 to 357, while the elasticity of intertemporal substitution is always 0.5 or 0.2 (for $\gamma = 2$ or $\gamma = 5$). For the higher elasticity value, the model solution is broadly the same as in the case of expected utility. When allowing for heterogeneity, the dynamics changes very slightly but the consumption share of each consumers varies in a tight interval (with amplitude of 1 b.p. for the considered values of θ_i). However, when the elasticity of intertemporal substitution is set at 0.2, there are significant effects from

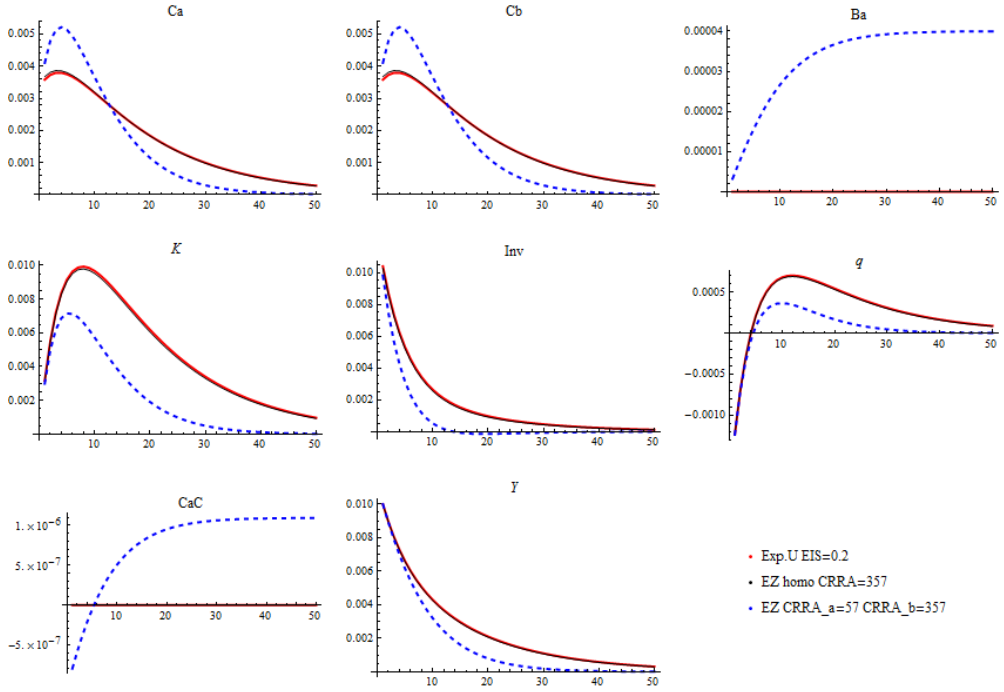


Figure 4.5: Impulse response functions following a positive productivity shock. Axis scales: Deviations from the steady-state, in logs for consumption, capital and output, in levels for investment, the rate of return, financial assets and consumption share of household A.

heterogeneity in risk aversion as measured by the Epstein-Zin parameter. Figure 4.5 shows the impulse responses to the 1 standard deviation productivity shock for different calibrations. Whenever households are completely identical, the responses are broadly the same, even when both agents risk aversion increases to 357. When heterogeneity in θ_i is introduced, the responses vary significantly. This may be related with the response of the stochastic discount factor (equation 4.16). In the homogeneous case, all terms on the right hand side are identical to both consumers. For the heterogeneous case, the fraction related to the expected utility in the future will be different for the two consumers. The more risk averse consumer is only willing to accept a lower price on financial assets. To keep the equality between the two consumers stochastic discount factor, the effect coming from the more risk averse consumer must be compensated with a higher marginal rate of substitution, thus implying more volatile consumption. The lower price of assets also implies a lower return on capital, does investment is lower and output also falls faster back to the steady-state.

It may matter whether labour is fixed or not. Swanson (2018) shows that risk aversion (both relative and absolute) is always lower when labour is not fixed. By having labour, the household could adjust to shock by varying its labour supply, instead of only through consumption.

4.4.2 Non linearities

In the setup developed so far non-linearities are of little relevance under feasible calibration. For the values considered throughout the paper, the third order approximation is broadly the same as the log-linear approximation. By increasing the variance of the shocks, some effects could be achieved, but this could be considered unrealistic. Another possibility, more feasible, would be to increase the shock persistence. From the literature, it seems that it would be necessary do add frictions or constraints to increase non-linear effects. On the other hand, Schneider (2017) is able to achieve relevant non linearities with recursive preferences and a macro-volatility shock without any friction.

4.4.3 Endogenous labour

In the current setup, households can only adjust to the shock via consumption. By adding labor, we could add a further channel of adjustment that interacts with households elasticity of intertemporal substitution. For example, following the negative capital shock above, a log-utility consumer that increases its consumption just immediately after the shock, could increase further consumption by decreasing labor, and could deepen the impact of the just in the following period. Swanson (2012) shows that using taking adequately into account the household labor margin can give better and more feasible values for the household's risk aversion. Thus, this is a issue that should also be taken into account when introducing labor in the model.

4.4.4 Policy intervention

From a central bank perspective, it is important to understand if there is any role for monetary policy and what effects it could have. In this simple frictionless model, there seems to be no role for welfare improvement by policy intervention. Nonetheless, policy makers could have a different criteria for their decisions, for instance to strive for an equitable wealth distribution or to reduce the amplitude of economic cycles, that could justify their intervention. This would necessarily lead to a second-best under the current framework.

We can think of central bank policy in two ways, interest rate policy or asset market intervention.

Interest rate policy

Usually, interest rate policy in new-keynesian models is thought as following a Taylor type rule to minimize deviations from inflation and output from a benchmark. This is justified by the existence of nominal rigidities, which are non-existent in the model presented.

Drechsler *et al.* (2018) follows a different line of reasoning to justify interest rate policy. Similarly to our paper, they have heterogeneous agents regarding risk preferences, but they add an imperfection in their model, in particular the possibility of runs. Risk-tolerant agents, i.e. banks, are levered, exposing them to funding risk. By lowering nominal rates, the central bank decreases the cost of leverage, leading to higher asset prices, volatility, investment, and growth. In this model, monetary policy works through a deposits channel, where banks and their cost of funding including the premium for risk are the main mechanism of the channel.

We could introduce a central bank that sets the area interest rate as a response to deviations in the aggregate. Given that there is heterogeneity in EIS, the responses would vary between countries, adding up a possibly interesting mechanism of distributional effects.

Asset market intervention

In our framework it would interesting to understand if and how the central bank could affect the aggregate EIS in the economy by changing the wealth distribution. This could be done along the lines developed in Silva (2015). Here, the central bank purchases risky assets (thus reducing net asset supply) when banks are weakly capitalized. As the net asset supply reduces, the market price of risk and volatility diminishes, and these effects are stronger the weaker the balance sheet of the banks. However, central bank intervention smooths the economic cycle at the cost of a lower average economic growth.

In our model, for the central bank asset purchases to matter, we would need to introduce some friction, such as a group of agents that have limited asset market participation. Otherwise, the effects of central bank intervention would be unwound by two households in their transactions in the perfectly state contingent bonds market. Consider that the central bank intervenes in the market following a rule, for instance to smooth the economic cycle as in Silva (2015). Asset market intervention is financed via tranfers to/from the agents with limited asset market participation. This would necessarily lead to different wealth and γ distributions. If we think of the euro area, this would imply that the central bank would be responding to the euro area economic developments by targeting specific markets and fostering risk-sharing in the euro area.

It may also be possible to consider a policy that aims at eliminating of reducing the friction, i.e., to intervene in the market in a such a way that the new wealth and γ distributions would replicate the first best in there was no limitation in the participation in the asset market.

4.5 Concluding remarks

The starting point of this paper was the apparent dichotomy between the benefits of financial integration and the evidence on the main shocks driving the economy. On the one hand, evidence suggests that a large share of the output volatility seems to

come from common shocks (Giannone & Reichlin 2006). On the other hand, welfare benefits from financial integration arise when the economy is hit by idiosyncratic shocks (Allen & Gale 2004). In this paper, we explored one possible mechanism that can support the benefits from financial integration for a small open economy even when common shocks are prepoderant.

To that end, we developed a standard stochastic growth model with no frictions and with heterogeneity in households intertemporal preferences. We show that, despite aggregate and distributional effects from common shocks when countries are perfectly integrated, quantitatively the aggregate effect is not significant. Nonetheless, the distributional effect is quantitatively significant for the SOE, meaning that for these economies there is a clear advantage due to a risk sharing mechanism. We showed this by simulating our model for Portugal and Germany. Prior to the crises, a sequence of past positive shocks could have justified the build up of debt in Portugal, given that Portuguese households are more willing to accept higher consumption volatility. A large negative shock with integrated financial markets leads to a symmetric response, with a reduction in the previously accumulated debt. Portugal, the small country, has quantitatively signifcant benefits from integration, while the larger country dominates the aggregate dynamics. In this environment, the protacted response to the crises is related to the size of the shock and the preferences of the households prior to the shock. Not having integrated markets or being outside the union would not have implied a quicker recovery from the crises.

The model developed is here is in line with the usual models used by central bankers for policy purposes. The fact that it aims at addressing the reaction to common shocks, it can also provide us information on the response of common monetary policy. Thus, it could provide a relevant contribution to the literature and policy advice. There are several ways on which the model can be improved upon, namely on introducing monetary policy, endogenous labour and other frictions usually found in new-keynesian models, in order to be useful for policy purposes.

.1 Appendix: Transition dynamics in a deterministic environment

In order to better understand how the dynamics of the variables in a deterministic setup depends on the γ coefficients, we solve the model in the absence of shocks for several values of these coefficients. Afterwards, we get the policy functions given the state variable K_{t-1}.

Figure 6 shows the result of this simulation for the case of homogeneous agents ($\gamma_a = \gamma_b$), that is, when there is a representative agent. The figure depicts capital and consumption in log deviations from the steady state relative to log deviations from the steady-state of the state variable K_{t-1}, that is, they represent the policy functions of K_t and C_t as a function of K_{t-1} for different values of γ. Different levels of aggregate EIS imply different dynamics of consumption. The higher the γ, the lower the EIS, the smoother the response of consumption and savings. Given that in this simple setup savings equals investment, there are differentiating effects on capital, but these are small, even for very large deviations in capital from the steady-state. We could extend the model and allow for endogenous labour supply, implying that households would be adjusting their labour supply when away from the steady state according to their preferences, and thus changing EIS could imply greater differences on output and capital. Changing the distribution of wealth does not imply different dynamics in this case, since it is a representative consumer case.

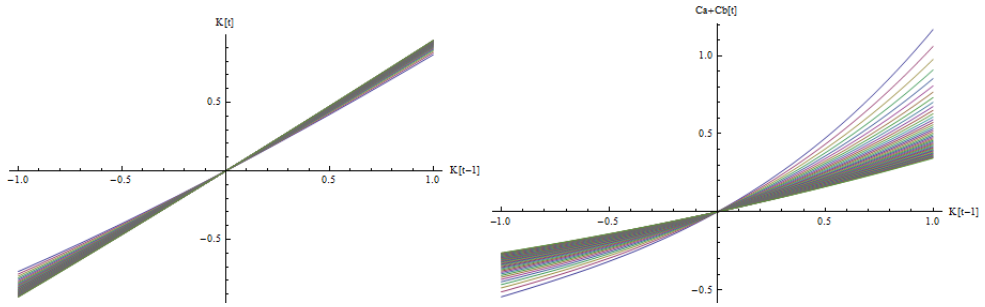


Figure 6: Policy function of K_t (left panel) and C_t (right panel) as a function of the state variable K_t around the steady-state for different levels of aggregate EIS (γ between 0.5 and 5, $\gamma_a = \gamma_b$) and in the absence of shocks ($A_t = \mu_t = 0$). Axis scales: Log percent deviations from the steady-state.

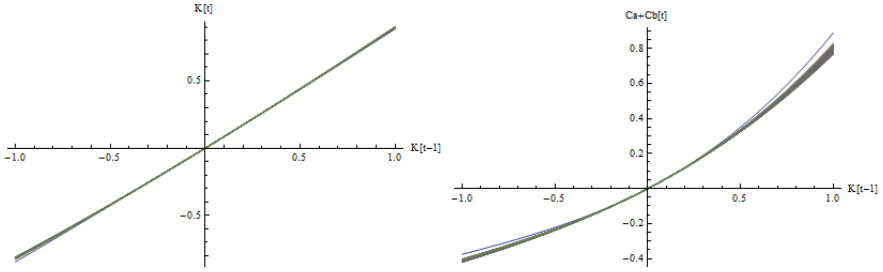


Figure 7: Transition dynamics from $t-1$ to t of K_t (left panel) and C_t (right panel) as a function of the state variable K_t around the steady-state and in the absence of shocks ($A_t = \mu_t = 0$). Different levels of individual EIS are considered, in particular combinations of γ_a and γ_b between 0.5 and 5 that ensure an ex-ante steady-state aggregate $\gamma = 1.1$. Axis scales: Log percent deviations from the steady-state.

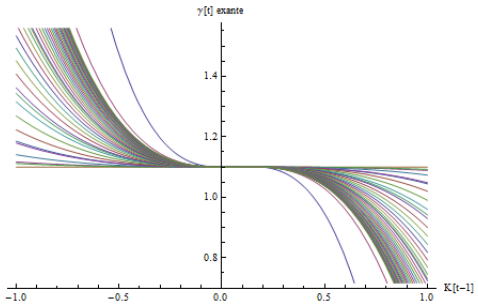


Figure 8: Transition dynamics from $t-1$ to t of γ_t as a function of the state variable K_t around the steady-state and in the absence of shocks ($A_t = \mu_t = 0$). Different levels of individual EIS are considered, in particular combinations of γ_a and γ_b between 0.5 and 5 that ensure an ex-ante steady-state aggregate $\gamma = 1.1$. Horizontal axis scale: Log percent deviations from the steady-state.

By introducing heterogeneity in the EIS, we loose the possibility of a representative agent as shown above. The aggregate γ varies through time, as shown in figures 7 and 8. Now the simulation carried out allows for heterogeneity in the EIS between households but imposes the same ex-ante aggregate steady-state γ of 1.1. Figure 7 shows that aggregate variables are hardly affected by the heterogeneity, as the steady-state aggregate γ is the same for all cases. However, for large deviations of capital from the deterministic steady-state (around below -20% and above 40%) the aggregate γ starts to significantly differ from its steady-state level (8).

The divergence in the aggregate EIS depends of the degree of heterogeneity. The more different the consumers are, the more different their consumption reaction will be and the more it will change the distribution of consumption and wealth in the economy. Indeed, figure 9 shows the reaction in the current period from capital

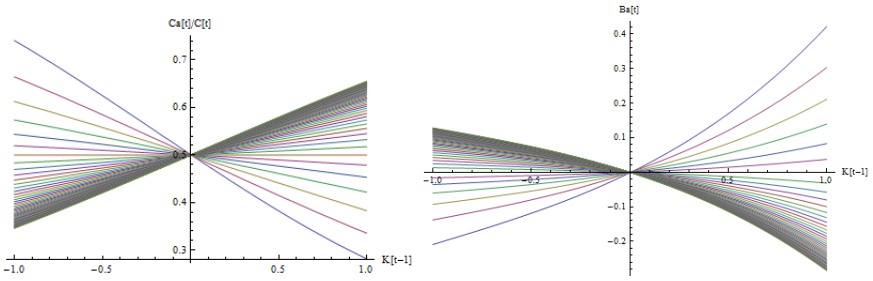


Figure 9: Transition dynamics from $t-1$ to t of $\frac{c_{a,t}}{C_t}$ (left panel) and $B_{a,t}$ (right panel) as a function of the state variable K_t around the steady-state and in the absence of shocks ($A_t = \mu_t = 0$). Different levels of individual EIS are considered, in particular combinations of γ_a and γ_b between 0.5 and 5 that ensure an ex-ante steady-state aggregate $\gamma = 1.1$, starting with an equitable wealth distribution ($\psi = 0.5$). Horizontal axis scale: Log percent deviations from the steady-state. Vertical axis scale: Percentage (left panel); deviation from the steady state (right panel).

deviations in the previous period in the consumption share of consumer A and in the financial assets holdings. The impact is the greater for the more heterogeneous cases and could imply a one-period change in the consumption distribution from 50/50 to 30/70 (for 100% capital deviations and when one of the consumers has a γ of 5 or more). Such a large change in one period of course impacts the aggregate EIS. Although this only occurs for large implausible deviations, there is the possibility a particular accumulation of shocks changing significantly the aggregate EIS and the distribution of wealth in the economy.[4]

[4]In case we consider different initial wealth distributions, for the different degrees of individual EIS considered in the charts but still imposing the same ex-ante steady-state aggregate EIS, we still do not have significant changes in the aggregate variables, especially for plausible values for capital deviations.

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