



Essays on Banking, Financial Markets, and Monetary
Economics

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supervised by:

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To my mother, for always being there.

To my grandmother, for always remembering me to enjoy life.

Biographical Note

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Abstract

This thesis contains three essays on how external factors influence banking activity. The first essay is a joint work with José Jorge, published in the *Economics Letters*. It is a theoretical work that reveals that low interest rates may turn off the deposits channel proposed by Drechsler, Savov and Schnabl. As the interest rates become too low, banks lose market power in the deposits activity. By compromising banks' main source of funding, low interest rates may lead to reductions on lending and on banks' profitability.

The second essay is an empirical work on the impact of law differences on mortgage origination. It shows that when law requires judicial foreclosures, mortgage interest rates are higher due to the increased debt recovery costs. It also shows that when law restricts recourse on mortgage credit, loan collateralization is higher to compensate for fewer recovery opportunities, in case of borrowers default.

The third essay is an empirical work on the influence of low interest rates on mortgage risk-taking. It demonstrates that, in the presence of low borrowing costs, households neglect future changes in the interest rates and do not behave rationally, when getting a mortgage. By acting myopically, households overspend and take more risks.

JEL Classification Codes: D10, D91, E40, E43, E52, E58, G12, G21, G28, K25, K35.

Keywords: Banking, deposits channel, monetary policy, low interest rates, mortgage, mortgage law, mortgage pricing, judicial foreclosure, non-recourse, mortgage risk-taking, myopic behavior.

Resumo

Esta tese inclui três ensaios sobre como fatores externos influenciam a atividade bancária. O primeiro ensaio, publicado na *Economics Letters*, é um trabalho conjunto com José Jorge. Trata-se de um estudo teórico que revela que baixas taxas de juro podem desativar o canal de depósitos proposto por Drechsler, Savov e Schnabl. À medida que as taxas de juro se tornam muito baixas, os bancos perdem poder de mercado na captação de depósitos. Por comprometerem a principal fonte de financiamento dos bancos, as baixas taxas de juro podem levar à redução do crédito e da rentabilidade dos bancos.

O segundo ensaio é um estudo empírico sobre o impacto das diferenças legais na originação de crédito habitação. O estudo revela que, na presença de exigência de execução judicial de hipotecas, a taxa de juro do crédito habitação é mais elevada devido ao acrescido custo de recuperação da dívida por incumprimento do devedor. O estudo revela também que, quando a lei não permite o crédito com recurso no crédito habitação, o nível de colateralização dos empréstimos é maior para compensar as poucas oportunidades de recuperação de dívida.

O terceiro ensaio é um estudo empírico sobre a influência de baixas taxas de juro na tomada de risco no crédito habitação. O estudo demonstra que, induzidas por custos de financiamento reduzidos, as famílias negligenciam potenciais alterações na taxa de juro e não agem racionalmente na obtenção de novo empréstimo habitação. Por agirem miopicamente, as famílias gastam mais e assumem mais risco.

Códigos de Classificação JEL: D10, D91, E40, E43, E52, E58, G12, G21, G28, K25, K35.

Palavras-chave: Bancos, canal de depósitos, política monetária, baixas taxas de juro, crédito habitação, lei do crédito habitação, preço do crédito habitação, execução judicial de hipotecas, crédito sem recurso, tomada de risco no crédito habitação, comportamento miópico.

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Chapter 1

Introduction

If I have to summarize my Ph.D. thesis in just one research question, I will say: How do external factors influence banks' activity? By external, I mean anything that is not in the power of a bank's CEO, like interest rate level, law, regulation, and households behavior. And, by banks' activity, I mean commercial banking business, such as deposits and lending. Along three essays, I approach some of the most recent concerns on lending and risk-taking, and I aim to contribute to the understanding of the interactions between monetary policy, financial markets, and banking.

The first essay in Chapter 2, is a joint work with José Jorge that is published in the *Economics Letters* (Sá and Jorge (2019)). Through a theoretical perspective, I study how low interest rates influence deposits holdings, lending and banks' profitability. In particular, I focus on the functioning of the deposits channel proposed by Drechsler, Savov e Schnabl (Drechsler et al. (2017)). According to the deposits channel hypothesis, central banks can influence the deposits holdings and the loan supply by changing the policy rate. When the central bank increases this rate, banks gain market power in the deposits market, charge a higher deposit spread, and households substitute part of their deposits holdings by other assets. Therefore, there is a negative relationship between the interest rate level and deposits holdings. But two questions remained unanswered by Drechsler et al. (2017). What happens if the interest rates

are low enough to erode banks' market power in the deposits market? Can we assume that the deposits holdings increase, with low-interest rates? In this essay, I discuss the generality of the deposits channel and show that low interest rates may turn this channel off. I also show that low interest rates may lead to reductions on lending and on banks' profitability, due to the reduction of banks' main source of funding—deposits.

In the second essay, Chapter 3, I study how mortgage law influences loan characteristics at origination. Borrower-friendly laws impose higher costs and risks for lenders and, thus, induce effects on mortgage pricing and leverage. However, we cannot assume that all borrower-friendly laws generate the same effects. In this study, I take advantage of mortgage law heterogeneity in the U.S. to empirically assess the effects of judicial foreclosure requirements and non-recourse restrictions on mortgage interest rates and collateralization level. By using a loan-level dataset for the U.S. mortgage market between 2001 and 2011, I find that judicial foreclosure requirements imply higher mortgage interest rates, as a reflection of higher recovery costs incurred in a judicial process. I also find that the non-recourse restrictions imply higher loan collateralization, as a consequence of the fewer recovery opportunities in case of borrowers' default.

Finally, in the third essay, Chapter 4, I study how low interest rates and households' behavior influence mortgage risk-taking. Market interest rates have been low for more than a decade. Understanding how low interest rates affect risk attitudes towards credit is critical to prevent the next financial crisis. A large empirical literature documents this effect on credit to firms but, to my knowledge, this is the first study on mortgage credit. I use loan-level data for the Portuguese mortgage market between 2007 and 2010. I find that with low interest rates, households do not behave rationally. When getting a mortgage, households neglect potential changes in the interest rate level. They end up borrowing larger amounts than they would have if interest rates were high. By acting myopically, they take more risk.

Chapter 2

Does the deposits channel work under a low interest rate environment?

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2.1 Introduction

Drechsler, Savov and Schnabl (2017) (DSS) have proposed the deposits channel of monetary policy. Unlike the conventional bank lending channel, it relies on banks' market power in the deposits market, and not on required reserves. The key idea is that the central bank influences deposits by changing the policy rate. When the central bank increases this rate, banks charge a higher spread on deposits, leading to a reduction in the banks' main source of funding. With fewer funds, the supply of bank lending contracts. In DSS's theoretical model, imperfect competition in the deposits market gives rise to a negative response of deposits and

loans to interest rate. They document the impact of changes in the Fed funds rate on the deposits market for the United States from 1994 to 2013.

Figure 2.1. Deposits Growth and Monetary Policy



This figure plots the evolution of the Fed funds rate in levels (Panel A), and the year-over-year changes in core deposits (Panel B) against year-over-year changes in the Fed funds rate. The shaded area represents the period of low interest rates. Core deposits are the sum of checking, savings, and small time deposits. The data are from the Federal Reserve Board's H.6 release. The sample is from January 1986 to May 2019 and considers non-seasonally adjusted data.

The question that remains unanswered is how general is the deposits channel hypothesis. Does it operate for all interest rate levels? To look into this question, we extend DSS's Figure II by adding data for a period with low interest rates. Figure 2.1 plots the evolution of the Fed funds rate (Panel A), and the year-over-year changes in core deposits (Panel B) against year-over-year changes in the Fed funds rate. According to DSS one would expect that for the shaded area—in which the Fed funds rate decreased and remained at a very low level—deposits would have become relatively less expensive, more attractive and would flow into the banking

system. However, the relationship that was once clear and striking, becomes unclear as the growth rate of deposits falls for a significant part of the low interest rate period. In mid-2017 as the Fed funds rate started to increase, the deposits channel was apparently restored. While the low interest rate is not the single factor that characterizes the shaded area, the puzzling behavior of deposits calls for closer inspection.

This paper explores the limitations of the deposits channel model, especially in a low interest rate environment. We use DSS's theoretical model complemented with numerical solutions, and present the policy implications of our findings.

2.2 Theoretical framework under a low interest rate environment

2.2.1 The baseline model

As in DSS, there exists a one period economy without risk, where the central bank exogenously sets the interest rate f according to its objectives of monetary policy, and thus influences the return on financial assets.

There are three assets: cash M is liquid and returns zero, deposits D are less liquid than cash and return $f - s$ (where s is the deposit spread charged by banks), and bonds B are illiquid and return f .

When deciding the portfolio composition, the representative household maximizes a three-level nested CES utility function. At the top level are the complements wealth W and liquidity

services ℓ , subject to a share parameter λ ,

$$u(W_0) = \max \left(W^{\frac{\rho-1}{\rho}} + \lambda \ell^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{\rho-1}}, \text{ with } 0 < \rho < 1. \quad (2.1)$$

At the middle level are the substitute assets that provide liquidity services, subject to a share parameter δ that represents the liquidity of deposits,

$$\ell(M, D) = \left(M^{\frac{\epsilon-1}{\epsilon}} + \delta D^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}, \text{ with } \epsilon > 1. \quad (2.2)$$

At the bottom are the imperfect substitute deposits produced by N banks,

$$D = \left(\frac{1}{N} \sum_{i=1}^N D_i^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \text{ with } \eta > 1. \quad (2.3)$$

Utility maximization is subject to a budget constraint, where the final wealth W is the result of investing the initial wealth W_0 in the three assets,

$$W = W_0(1 + f) - Mf - Ds. \quad (2.4)$$

Bank i maximizes profit by raising deposits at rate $f - s_i$ and investing them in bonds at rate f ,

$$\Pi_i = s_i D_i. \quad (2.5)$$

Banks are able to sustain non-zero profits, since imperfect substitutability of deposits gives them market power. In the symmetric equilibrium, the deposits market clearing condition is

$$\left[\frac{1}{1 + \delta^\epsilon \left(\frac{f}{s} \right)^{\epsilon-1}} \right]^\epsilon + \left[\frac{\delta^\epsilon \left(\frac{f}{s} \right)^{\epsilon-1}}{1 + \delta^\epsilon \left(\frac{f}{s} \right)^{\epsilon-1}} \right] \left(\frac{\rho + \frac{\ell s_\ell}{W}}{1 + \frac{\ell s_\ell}{W}} \right) = N - \eta(N - 1) \equiv \mathcal{M}, \quad (2.6)$$

where s_ℓ represents the weighted average premium paid for liquidity services, and $\mathcal{M}$ rep-

resents the banks' market power measured by the number of banks N and the elasticity of substitution of deposits across banks η .

In the limiting case of $\lambda \rightarrow 0$, the deposit spread s is positive and increasing in the interest rate f if the banks' market power is sufficiently high, and zero otherwise. Formally

$$s = \begin{cases} \beta f & , \text{ if } \mathcal{M} > \rho \\ 0 & , \text{ if } \mathcal{M} \leq \rho \end{cases} \quad (2.7)$$

with $\beta = \delta^{\frac{\epsilon}{\epsilon-1}} \left(\frac{\mathcal{M}-\rho}{\epsilon-\mathcal{M}} \right)^{\frac{1}{\epsilon-1}} > 0$ and $\frac{\partial \beta}{\partial \mathcal{M}} > 0$. The case $s = \beta f$ describes the mechanism proposed by DSS. When the central bank increases f , the opportunity cost of holding cash also increases. Deposits become more attractive which gives more market power to banks. As a result, banks charge a higher deposit spread s and deposits D contract. The intensity of this mechanism increases with banks' market power $\mathcal{M}$.

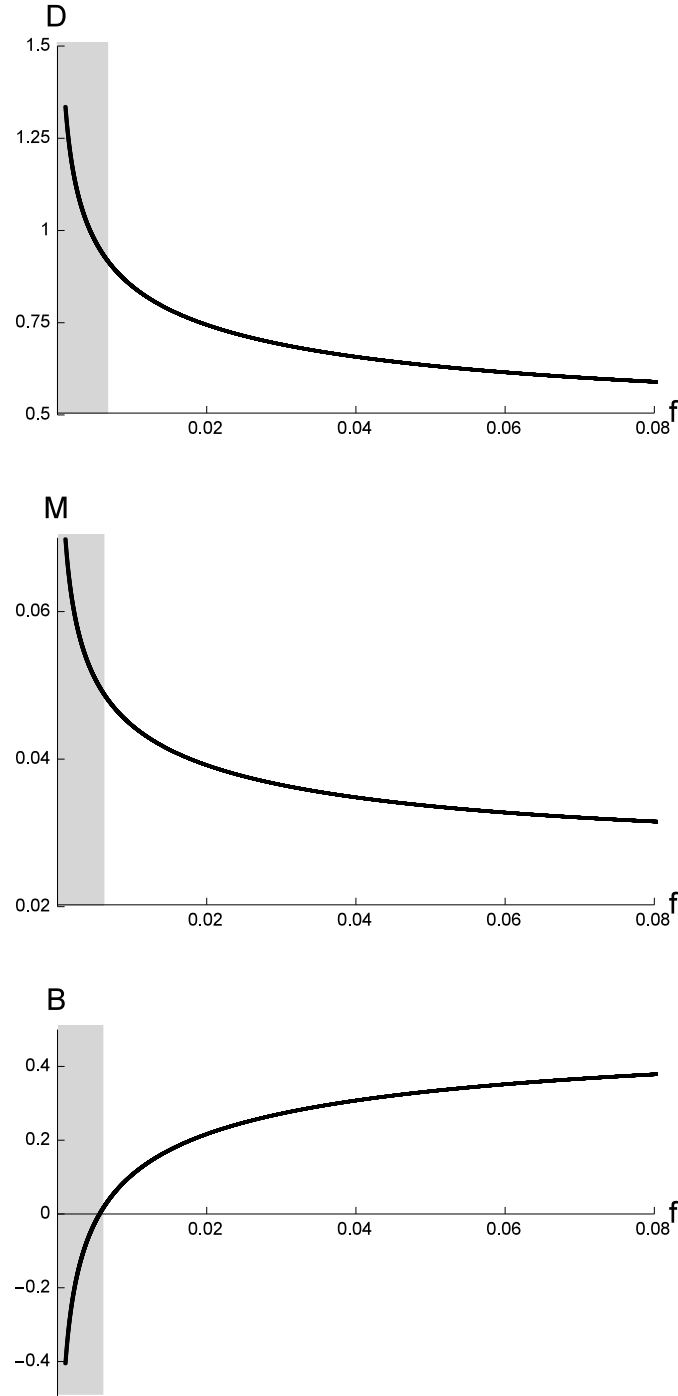
Regarding this we show that this mechanism may not apply in a low interest rate environment. When the return on bonds f (or its relative return to deposits s) is close to zero, bonds lose their attractiveness and households often short sell bonds to invest the proceeds in deposits—an asset with similar return, but which provides liquidity. The shaded area in Figure 2.2 illustrates this argument for an initial wealth normalized to unity and for specific values of the parameters.

As short selling can be substantial, a realistic solution for the model requires a short selling restriction. When this restriction binds, the deposits channel proposed by DSS does not work.

2.2.2 The extension with lending and wholesale funding

In DSS's extended version, the profit function of bank i in Equation (2.5) is redefined as

Figure 2.2. Baseline model equilibrium solutions for deposits D , cash M , and bonds B as a function of interest rate f



Parameters in this example are $W_0 = 1$, $\lambda = 0.00125$, $\rho = 0.2$, $\delta = 0.8$, $\epsilon = 2$, $N = 5$, $\eta = 1.1$, $l_0 = 0.001$, $l_1 = 0.00175$, and $h = 0.002$.

$$\Pi_i = \left(f + l_0 - \frac{l_1}{2} L_i \right) L_i - \left(f + \frac{h}{2} H_i \right) H_i - (f - s_i) D_i, \quad (2.8)$$

where $L_i = H_i + D_i$ is the total lending of bank i , H_i is the wholesale funding, $l_0, l_1 > 0$ are parameters defining the decreasing marginal returns of bank loans and $h > 0$ is the parameter defining the increasing marginal costs of wholesale funding. For a finite number of banks with non-zero profits and for the elasticity of demand of bank i 's deposits e_i , the optimality condition is

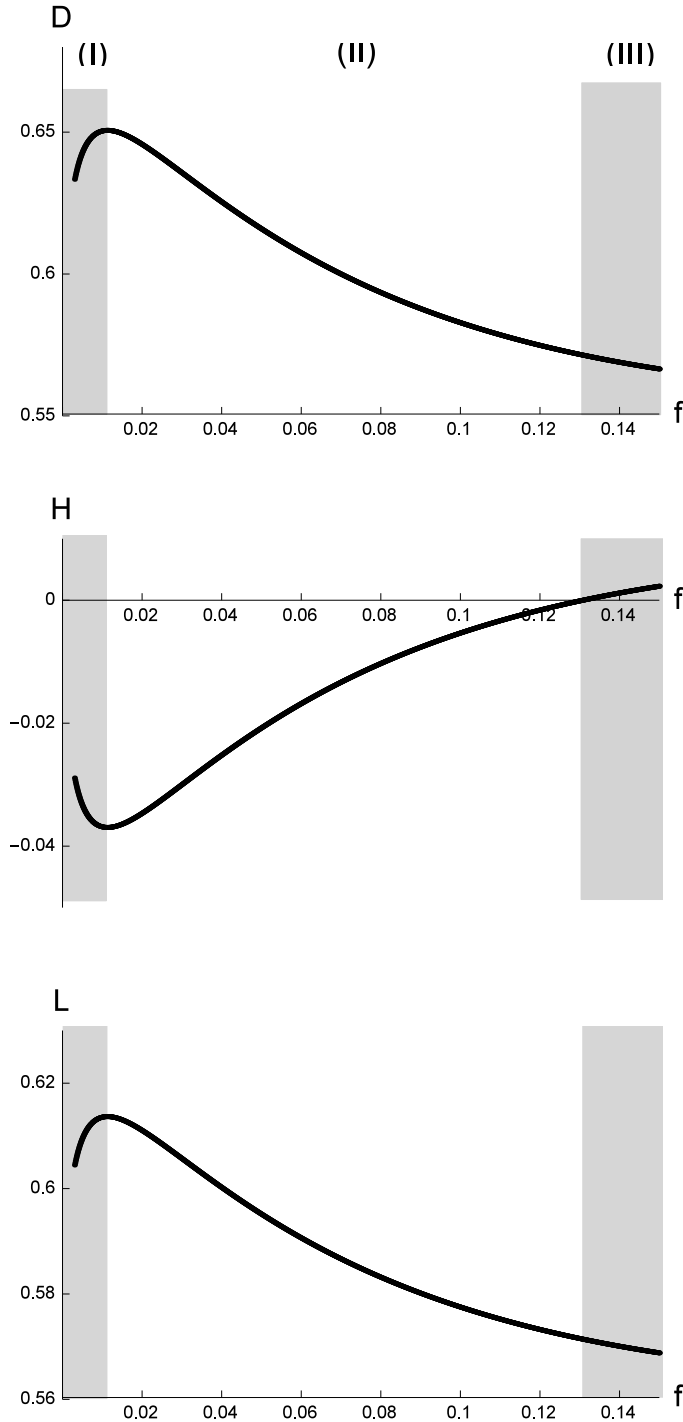
$$\left(\frac{h}{l_1 + h} \right) (l_0 - l_1 D_i) + s_i \left(1 - \frac{1}{e_i} \right) = 0, \quad (2.9)$$

where the first term on the left-hand side is the marginal lending profit the bank earns from raising another dollar of deposits and the second term is the marginal profit from raising this dollar of deposits. Equation (2.9) is equivalent to $hH_i + s_i \left(1 - \frac{1}{e_i} \right) = 0$, which shows explicitly that the marginal lending profit depends on the wholesale funding H_i .

DSS focus on the specific case when the bank's deposits are insufficient to fund its lending and the bank obtains additional funding in the wholesale market ($H_i > 0$). The intuition is that with profitable lending opportunities, there is cross-subsidization of loans by deposits, with the bank giving up some of its deposit rents, so as to increase its lending. Given the positive marginal lending profit from raising another dollar of deposits ($hH_i > 0$), the bank fixes a deposit spread in the inelastic part of the demand curve for deposits, where the marginal profit from raising this dollar of deposits is negative ($s_i \left(1 - \frac{1}{e_i} \right) < 0$).

Regarding this we show that an alternative case is also possible. The bank collects more deposits than makes loans, with the central bank draining the extra funds ($H_i < 0$). Without cross-subsidization of loans by deposits, the bank fixes a deposit rate in the elastic part of the deposits curve, where the marginal profit from raising another dollar of deposits is positive. Although the deposit spread increases with the interest rate f , deposits may either decrease or

Figure 2.3. Extended model equilibrium solutions for deposits D , wholesale funding H , and lending L as a function of interest rate f



Parameters in this example are $W_0 = 1$, $\lambda = 0.00125$, $\rho = 0.2$, $\delta = 0.8$, $\epsilon = 2$, $N = 5$, $\eta = 1.1$, $l_0 = 0.001$, $l_1 = 0.00175$, and $h = 0.002$.

increase; the response depends on the interest rate level.

Figure 2.3 depicts a numerical example showing the equilibrium solutions for deposits, wholesale funding, and lending as function of interest rate f . In shaded area *III*, the deposits channel operates as in DSS; the bank obtains funding in the wholesale market, and both deposits and lending contract with the interest rate f . In area *II*, the bank has a long position in the wholesale market, but the response of deposits and lending to changes in the interest rate f remains as suggested by DSS. In shaded area *I*, the bank has a long position in the wholesale market and, contrary to the deposits channel hypothesis, deposits and lending expand with the interest rate f .

Figure 2.3 reveals that the DSS framework embeds a set of sufficient conditions for the existence of the deposits channel. Yet, the necessary and sufficient condition for an active deposits channel is the existence of banks' market power over deposits, and thus the deposits channel also prevails in area *II*. Market power only appears when the return on deposits ($f - s$) is sufficiently larger than zero (the return on cash). For the low interest rates represented in area *I*, the market power is negligible thereby rendering the deposits channel silent.¹ In this situation, a loose monetary policy may lead to a reduction in the banks' main source of funding and to unintended consequences on lending.

Besides contributing to understanding the deposits channel, this result also recognizes the influence of monetary policy on banks' profitability. More specifically, a loose monetary policy conducted under a low interest rate environment may lead to a simultaneous decrease in price (deposit spread) and in quantities (deposits and lending), compromising the banks' activity.

¹In the model deposit rates are mainly positive, but negative deposit rates are possible if we include a percentage cost of holding cash that increases banks' market power. This change would shift the shaded area *I* leftwards but would not have qualitative changes in the relationship between deposits and the interest rate f . Still, including the cost of holding cash can help to calibrate the model and expand its applicability.

2.3 Policy implications and conclusions

We show that the deposits channel hypothesis is not general, as it often is silent under a low interest rate environment. This finding has two major implications: first, it shows that monetary policy may have unintended consequences on lending, and second, it emphasizes bank profitability issues.

We contribute to the recent literature on the effect of interest rates on commercial bank profitability, which can be divided into three strands. The first strand suggests that low interest rates may have an adverse impact on bank profitability, with the impact depending on banks' heterogeneity as well as on the persistence of low interest rates (e.g. Jiménez et al. (2014), Alessandri and Nelson (2015), Borio et al. (2017), or Arce et al. (2018), or Claessens et al. (2018)). The second strand questions the positive correlation between interest rates and bank profitability, since the stance of monetary policy depends on forecasts about macroeconomic activity creating endogeneity concerns (e.g. Altavilla et al. (2018)). Finally, the third strand highlights additional identification issues such as banks' risk taking incentives (e.g. Rajan (2006), Hanson and Stein (2015), Bonfim and Soares (2018), or Demiralp et al. (2019)), zombie lending practices (e.g. Caballero et al. (2008), or Freixas et al. (2015)), or other measures taken to mitigate the negative effect of falling interest rates (e.g. Albertazzi and Gambacorta (2009), Sääskilahti (2018), or Altavilla et al. (2019)).

Particularly, our contribution fits in with recent studies that emphasize that the effects of interest rates in bank profitability are more pronounced for banks that heavily rely on deposits (e.g. Ampudia and Van den Heuvel (2018), English et al. (2018), Bottero et al. (2019), Amzallag et al. (2019), or Heider et al. (2019)).

Nonetheless, some challenges remain. How to define what is a low interest rate? More specifically, what is the threshold below which interest rates erode banks' market power and turn off the deposits channel? Does this threshold depend on the specific characteristics of the

banking system? An interesting direction for future research is to examine these challenges through the comparative analysis of different banking systems.

Chapter 3

To change or not to change: The impact of the mortgage law on loan origination

3.1 Introduction

Do changes in the law influence the mortgage market and loan characteristics? The intuitive answer might be yes, but there is little evidence on how mortgage law affects mortgage price and leverage. If the law imposes higher costs or risks for lenders, it is fair to assume that lenders may transfer the costs to the borrower or demand higher loan collateralization. Moreover, not all aspects of mortgage law induce the same effects. While some aspects may change the borrower's probability of default, others may only lead to higher recovery costs or longer processes. When deciding to change or not to change the law it is, thus, important to have a reasonable knowledge of its different impacts. Many authors, at least since Pence (2006), have analyzed the influence of the law on mortgage credit, but few approach other outcomes rather than loan amounts. This paper addresses this gap in the literature. By using loan-level data for the U.S. mortgage market, I trace how two aspects of the law—foreclosure procedure and deficiency judgments—influence the mortgage interest rate and the loan-to-value ratio at

origination.

Like a large empirical literature (see, for example, Ghent and Kudlyak (2011), Mian et al. (2015), and Milonas (2017)), I start by taking advantage of mortgage law heterogeneity across states in the United States. I classify each state according to two aspects of the law: foreclosure procedure and deficiency judgments. On the one hand, the law might require a court's approval to initiate the foreclosure, which delays the process and makes it more costly. In these cases, I classify states as judicial. On the other hand, the law might not allow for deficiency judgments, which means that, if the house sale price is lower than the debt value, the lender cannot seize other assets or income of the borrower to recover the debt. Besides limiting the recovery opportunities, it might also affect the borrower's probability of default by encouraging strategic defaults. In these cases, I classify states as non-recourse.

One critical concern on the mortgage heterogeneity is the verification of the desirable orthogonality properties along with state-level economic and social conditions. To address this issue, I check if states with distinct law classifications vary among other attributes that might influence the determination of the mortgage interest rate or the loan-to-value ratio at origination like, for example, demographic factors. After inspecting the period from 2000 to 2016, I conclude that the orthogonality condition is not valid from 2012 onward. By combining this result with the loan-level data availability, I restrict the study to the period between 2001 and 2011.

I continue by developing a simple theory of mortgage origination to provide guidance on the impact of mortgage law on loan characteristics. The motivation of lenders and borrowers, while interacting in the mortgage market, is different. Lenders call for compensation that adequately prices the risk of the loan, whereas borrowers look for the loan that allows them to buy the house that best fits their preferences at the lowest cost. As a result, the market clearing process can be described by the joint determination of two variables. First, the mortgage interest rate, as it reflects the price of the loan. Second, the loan-to-value ratio, as it measures the loan risk for lenders, and represents borrowers' simultaneous choice of house and loan

amount. If the law implies differences in the cost and risk assessment of a mortgage, then the equilibrium solution may also show differences at the mortgage interest rate (price channel) or the loan-to-value ratio (collateral channel).

Under this framework, three questions arise: (i) If judicial states impose higher foreclosure costs, are their mortgage outcomes at origination different from the nonjudicial ones? (ii) If non-recourse states impose a smaller debt recovery and a bigger propensity to default, are their mortgage outcomes at origination different from the recourse ones? and (iii) Does the mortgage market adjust to differences in the law through mortgage interest rate (price channel) or loan-to-value ratio (collateral channel)?

To answer these questions, I study the differences in the mortgage interest rates and the loan-to-value ratio for more than 3 million observations on fixed-rate mortgages originated between 2001 and 2011. I find that the mortgage interest rate is 4.3 to 4.7 basis points higher in judicial states and, therefore, lenders transfer, at least, part of the extra costs to borrowers. I also find that the loan-to-value ratio is 0.42 to 0.58 percentage points lower in non-recourse states, meaning that lenders require more collateral to compensate for the lower recovery perspectives. The two aspects of the law lead to differences in loan characteristics but operate through different channels. While the foreclosure procedure activates the price channel, the deficiency judgment activates the collateral one.

But, if the effects of the law only appear in a scenario of default, should we expect that the impact on loan characteristics is the same for credit constrained and not credit constrained borrowers? In particular, if lenders ask for higher collateralization in non-recourse states as a way to deter strategic default, should the impact be the same for credit constrained and not credit constrained borrowers? To expand the results obtained, I study the law impacts along the conditional distribution of the loan-to-value ratio. The results show that the impact of law for the different types of borrowers is not much different from the mean results, implying that the higher collateralization in non-recourse states is not due to the probability of strategic default. In other words, if lenders asked for more collateral to deter strategic defaults, then the

impact would be stronger for credit constrained borrowers, as they are more close to an event of negative equity. I complete the study by running some robustness checks and conclude that both impacts are fairly robust.

A large empirical literature explores the relationship between mortgage law heterogeneity in the United States and the credit supply but, to my knowledge, this is the first study to analyze price and collateral effects using a large mortgage loan-level dataset. Most authors measure the impact of the law on credit supply through loan size, and the result is not consensual. Pence (2006) applies a regression-discontinuity design at state boundary to loans originated between 1994 and 1995 and finds that loan sizes are 3% to 7% smaller in judicial states. He only considers house values at county-level and does not include interest rate or collateralization data. Mian et al. (2015) report a similar methodology, but use loans originated in 2005 and data averaged at zip code. They find no evidence that average loan sizes or total lending are significantly lower in judicial states and argue that the effect described by Pence (2006) diluted over time. As for the impact of the law on credit supply through loan prices, most of the results arise from aggregate data at the state level. Ghent and Kudlyak (2011) and Pruszkowski (2017) find no difference in mortgage interest rates between recourse and non-recourse states and do not consider differences at the foreclosure procedure. Ambrose et al. (2004) use loan-level data from 1995 to 1997 provided by a national lender and with information on 26,179 loans. Although the central question is not the effect of law on prices and collateralization, the authors find puzzling results with lower interest rates and higher loan-to-value ratios in non-recourse states.

Another strand of literature emphasizes the role of mortgage law heterogeneity in the default and foreclosure rates. Mian et al. (2015) find that states that did not require judicial foreclosures were twice as likely to proceed with the foreclosure during the 2007 mortgage crisis. The effect was not driven by different default rates and does not persist after 2011. Desai et al. (2013) study the impact of judicial requirement and non-recourse laws on default and foreclosures rates across different segments of the mortgage market. They conclude that

the effects are stronger on subprime mortgages and adjustable rate mortgages. Gerardi et al. (2013) state that judicial requirements do not prevent foreclosures, and only delays the process. Melzer (2017) argues that the delay in foreclosing the house creates a debt-overhang problem with the deterioration of the property condition and consequent reduction in the collateral value. For the case of non-recourse law, many authors inspect whether or not negative equity is a sufficient condition to default in non-recourse states (strategic default) or if, on the contrary, liquidity constraints are the only source of default. Ghent and Kudlyak (2011) find that borrowers facing negative equity are more likely to default in non-recourse states, but for home values above \$200,000. Guiso et al. (2013) find some evidence of strategic default and conclude that morality and fairness also plays a role in the decision. Demiroglu et al. (2014) inspect how judicial foreclosures and non-recourse interact in the likelihood of default on residential mortgages and conclude that it has a significant effect conditional on having negative equity.

Finally, mortgage law also relates to housing prices. Calomiris et al. (2013) find different responses in judicial and nonjudicial states for employment shocks and house price shocks to foreclosure start shocks. Mian et al. (2015) document the link between foreclosures and house prices, and use as an instrument the differences in the foreclosure rate in judicial and nonjudicial states. All in all, mortgage law heterogeneity generates a lot of research interest, but the conclusions on the impact at origination are not always obvious.

The paper is organized as follows. In Section 2, I describe the mortgage law heterogeneity in the United States. Section 3 presents a simple theoretical model of mortgage origination and the impact of the law. Section 4 presents the data and empirical strategy. Section 5 provides results and Section 6 the robustness checks. Section 7 concludes.

3.2 Mortgage law heterogeneity in the U.S.

A mortgage contract gives the lender the right to foreclose the home in case of borrowers' default. In the U.S., the foreclosure procedure is governed mostly by state law and reveals a significant heterogeneity among states. After a depth review of the U.S. mortgage law history, Ghent (2014) concluded that the roots of its heterogeneity go back to the nineteenth century and have no connection with economic factors. Despite several attempts to uniform the mortgage law at a national level, the cross-state variation existing today still influences both the borrower-lender relationship and the foreclosure outcome.¹

Following the National Mortgage Servicer's Reference Directory (NMSRD) published by USFN (2018), I characterize the state-level differences in two aspects of the law: foreclosure procedure, and deficiency judgments.² First, as for the *foreclosure procedure*, when a borrower becomes delinquent on his mortgage and the lender wants to proceed with the foreclosure, the law may require a court's approval or allow a nonjudicial procedure. In states with judicial foreclosure, the average time and transaction costs to foreclose the property are generally higher. In states that allow procedures that do not require courts' approval (for example, power-of-sale foreclosures), lenders often choose a nonjudicial option to speed up the process and increase the recovery value. Thus, states that demand judicial procedures are more pro-borrower (Ghent (2014)).

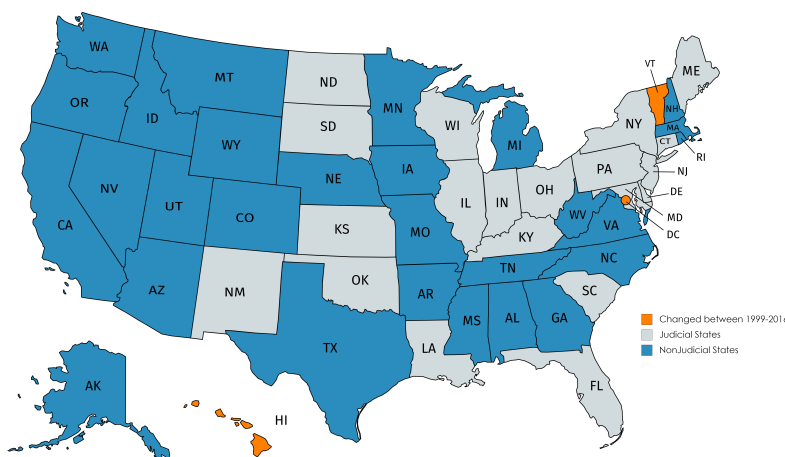
The dummy variable *Judicial* describes the foreclosure procedure classification. If a

¹According to Ghent (2014), the bulk of laws developed through case law shows "remarkable persistence" along time, as they require changes to the civil code of procedures and cannot be promptly adjusted to the economic conditions. The few changes observed in the U.S. mortgage laws are frequently pro-borrower and relate to changes in statute law (like changes in the redemption periods).

²The NMSRD is a reference in the mortgage industry and provides information on state foreclosure processes and regulations. Although it does not systematically organize the changes that have occurred in the U.S. mortgage law, it is possible to identify the most relevant changes in the last years for each state. For the desegregation of state-level differences, I consider the 50 U.S. states plus the federal District of Columbia (for simplicity, the District of Columbia is a *state*). Appendix A presents state classification for each mortgage law aspect. Appendix B presents differences in the classification across different sources and studies.

state requires a court's approval to proceed with foreclosure, then it is classified as judicial (*Judicial* = 1). All other cases are classified as nonjudicial (*Judicial* = 0).³ Figure 3.1 shows a distribution map of judicial and nonjudicial states and emphasizes the changes registered between 2000 and 2016.⁴ The distribution is balanced.

Figure 3.1. Distribution of judicial and nonjudicial states



This figure presents the distribution of judicial and nonjudicial states classified based on USFN (2018) data. States in light color require judicial foreclosures. For more details on the classification and changes occurred between 2000 and 2016, see Appendix A and Appendix B. Map created with *mapchart.net*.

Second, as for the *deficiency judgments*, when the debt value exceeds the market value of the property, the lender may collect a deficiency judgment to pursue the borrower personally. With a deficiency judgment, the lender can seize the borrower's unsecured personal assets and future income to recover the debt value (Harris and Meir (2015)). This possibility is usually known as recourse and might be automatic, require a judicial decision, or even be forbidden. States that do not allow recourse are more pro-borrower (Ghent (2014)).

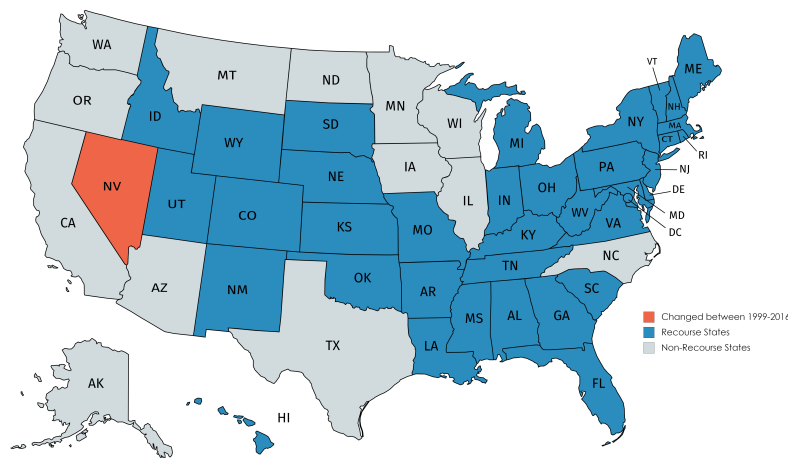
The dummy variable *NonRecourse* describes the restrictions on deficiency judgments

³Including states that allow both judicial and nonjudicial foreclosures, but where nonjudicial are more common.

⁴During this period, only three cases—District of Columbia, Hawaii, and Vermont—justified changes in the classification and all of them in the direction of judicial foreclosure.

classification. If a state allows deficiency judgments through a process that has no major obstacles, then it is classified as recourse ($NonRecourse = 0$). All other cases are classified as non-recourse ($NonRecourse = 1$).⁵ Figure 3.2 shows a distribution map of recourse and non-recourse states. The majority of states are recourse states.

Figure 3.2. Distribution of recourse and non-recourse states



This figure presents the distribution of recourse and non-recourse states classified based on USFN (2018) data. States in light color do not allow recourse. For more details on the classification and changes occurred between 2000 and 2016, see Appendix A and Appendix B. Map created with *mapchart.net*.

3.2.1 Orthogonality of mortgage law differences to economic and social conditions

Relying exclusively on the distribution presented in Figure 3.1 and Figure 3.2 to explain the differences in the mortgage interest rate and the collateralization level might not be sufficient.

⁵Exceptionally, the classification of the state of Nevada does not follow the NMSRD information. For the particular case of primary residence single-family mortgages, the state of Nevada passed a new law that abolished deficiency judgments for loans originated after October 1, 2009 (Li and Oswald (2017)).

One of the critical questions that arise is how distinct are judicial and nonjudicial states on other important dimensions. For example, differences in mortgage pricing in judicial states may not be driven by law if households in judicial states also happen to have a lower income. The same might apply when comparing non-recourse to recourse states.

To ensure that the mortgage law differences are orthogonal to relevant economic and social conditions, one needs to show that states with different law classifications do not differ along with another attribute that independently influences the mortgage interest rate and the collateralization level.⁶ I follow an approach similar to Mian et al. (2015) and test if judicial (non-recourse) states are significantly different in a set of economic and social attributes grouped into four categories: (1) demographic and income; (2) GDP; (3) housing market; and (4) mortgage market variables. By covering a substantial period from 2000 to 2016, I test the time consistency of the results.⁷ Table C1 in Appendix C presents the results for the univariate regressions on whether a state requires judicial foreclosures. For most of the attributes from 2000-2011, judicial states do not significantly differ from the nonjudicial ones. The only exception is the fraction of population with 65 or more years that is, on average, one percentage point higher in judicial states. As for 2012-2016 there are significant differences in the housing and mortgage market, which suggests that the assumption of orthogonality may not be valid during this period.

Table C2 in Appendix C presents the results on whether a state imposes non-recourse. For most of the attributes from 2000-2011, non-recourse states also do not significantly differ from the recourse ones. As exceptions are: the fraction of population with 65 or more years that is, on average, one percentage point lower in non-recourse states; the fraction of population that is black, which is, on average, six percentage points lower in non-recourse states; and the mortgage delinquency rate in 2004 and 2006, which is, on average, 30 basis points lower in non-recourse states. As for 2012-2016 there are also some signs of orthogonality assumption

⁶Several studies assume the orthogonality of the differences in mortgage law, at least for specific time periods (see, for example, Ghent (2014), Mian et al. (2015) and Milonas (2017)).

⁷This approach excludes states where the law has changed between 2000 and 2016.

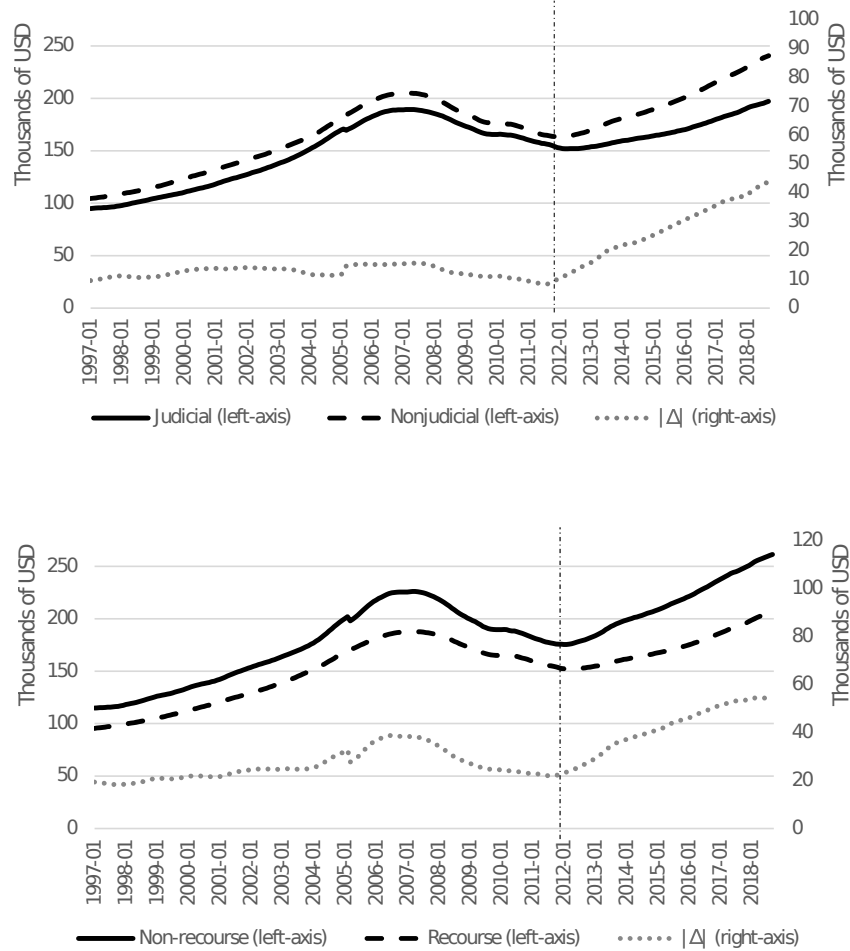
violation in the real GDP annual growth and in the housing and mortgage market.

Taken together, these results suggest that differences in mortgage law are fairly independent of other attributes from 2000-2011. However, the same does not apply from 2012-2016. To better understand this distinctive pattern, I inspect the evolution of the average price of a single-family residence by aspect of law. Figure 3.3 shows that prices in judicial states follow a parallel trend to those in nonjudicial states, at least up to 2011. From 2012 onward, there is a trend detachment that might independently influence the mortgage interest rate and the collateralization level. Figure 3.3 also shows similar results when comparing prices in non-recourse states to those in recourse states. Even if the break in the trend is not as evident as for the judicial foreclosure requirement, it is sufficient to question the validity of orthogonality. As a result, to securely assess the impact of mortgage law on the mortgage interest rate and the collateralization level, I strict the analysis up through 2011.

3.3 A simple theory of mortgage origination

The basic idea behind the fundamentals of a market clearing process is that agents interact in the simultaneous determination of equilibrium price and quantities. When it comes to credit, and mortgage credit in particular, the dynamics are more complex. The obligations between borrower and lender do not end with the settlement of the mortgage contract. In fact, the loan origination is only the beginning of a commitment that will only end with the debt repayment, and that usually lasts for a long period. To reduce the risk of the contract, lenders grant a secured loan, introducing a third variable in the simultaneous determination problem—the collateral value, which for mortgages is the house value. Instead of a standard price and quantities decision, there is a three-variable solution where the loan amount, the interest on the loan, and the house value are jointly determined (see, for example, Stiglitz and Weiss (1981) and Cerqueiro et al. (2016)). Recognizing these dynamics of mortgage credit, and to the

Figure 3.3. Average price for a single-family residence



This figure shows the evolution of the simple-average price for a single-family residence according to the aspect of law based on Zillow data available on <https://www.zillow.com/research/data/>. The dotted line in the upper figure represents the difference between the average price in nonjudicial vs. judicial states. The difference is relatively stable up to 2012 and is consistent with the idea of parallel trends. After 2012, the trends detach. The dotted line in the lower figure represents the difference between the average price in non-recourse vs. recourse states. Although with a lower magnitude, the trends also detach after 2012.

extent of this simple theory of mortgage origination, I redefine the problem through a different perspective.

Let's start by considering the lender's maximization problem. Lenders seek to maximize profits for a certain risk level. The *price* of a loan is the mortgage interest rate. The *costs* of a loan are mainly the funding costs and capital charges. The *risk* of a loan is its expected loss. All elements included in *price*, *costs*, and *risk* are in percentage values that do not depend on the loan amount. It is therefore reasonable to assume that lenders base their choices according

to a risk-return per dollar lent, where the risk of a loan is not measured by the loan amount and house values individually, but rather by the ratio of both. From this perspective, the relevant decision variables for mortgage supply are the mortgage interest rate r^m , and loan-to-value ratio LTV .

And what about households? Can we assume that the decision variables are also the interest rate and the loan-to-value ratio? In a theoretical model of mortgage decision, Brueckner (1994) states that households simultaneously decide the loan amount and the house value. The loan-to-value ratio LTV is, thus, a relevant decision variable because households choose a house depending on how much the lender is willing to lend. The decision also depends on mortgage cost r^m , income level, savings, housing needs, and preferences.

For the purpose of this simple theory of mortgage origination, the demand and supply dynamics are redefined as a function of two variables— r^m and LTV . But, to understand the role of the law at mortgage origination, one need to take a step back and break up the concept of loan risk for the lender. The expected loss is the product of the probability of default (PD), and the loss given default (LGD).⁸ The former reflects how likely is a borrower's default event. It is a function of the borrower's credit score and the borrower's incentives to default, which might emerge along with the life of the contract. The latter represents the amount per dollar that the lender expects not to recover if the borrower defaults. It is a function of the loan-to-value ratio, the possibility to seize other assets, and the expected costs to be incurred in debt recovering (which might include operating, judicial, time, and other costs).⁹ Hence, loan risk depends on loan and borrower's characteristics. All the other elements influencing the mortgage supply—like capital charges, funding cost, or operating costs—do not depend on the loan characteristics, but rather on time and lender-specific factors.¹⁰

⁸The exact definition of the expected loss includes the exposure at default (EAD). For mortgages at origination it represents the full loan amount (100%), and is therefore irrelevant.

⁹As a reference, Repullo and Suarez (2004) derive a loan pricing equation where the equilibrium interest rate increases with the PD and the LGD . They also find that the equilibrium interest rates increase with the required level of capital and with the exposure to systematic risk, which, for the present study, are treated as time and lender-specific.

¹⁰Capital charges represent the unexpected loan loss and, depending on the regulatory setting, might be loan-specific. For example, Basel III recommends that the capital charges on mortgages must consider the loan-to-value ratio (Basel Committee

3.3.1 The impact of law

Mortgage law influences loan risk and cost, therefore, it generates direct effects on the mortgage demand and supply. From the interaction of both, one observes the total effects through the market equilibrium.

3.3.1.1 Direct effects: changes in the demand and supply

Stiglitz and Weiss (1981) argued that, in a loan contract, while firms focus on what happens under the no bankruptcy scenario, lenders pay attention to how the actions of the firm will influence its probability of default, and how can the lender recover the debt in case of default. Even though firms and households have different incentives, it is possible to establish some analogy as to the direct effects of mortgage law in the expected behavior of borrowers and lenders.

Consider a household that looks for funding to buy a house for primary residency. As the house satisfies a basic need, the borrower will have a strong commitment to pay the installments on time. Besides, failing the payment shatters the credit score, and makes it doubtful to get another mortgage. As a result, at origination the default event is not a credible scenario, and he will not acknowledge the impact of mortgage law in a potential foreclosure process.¹¹ But, even if the borrowers' decision process would acknowledge law criteria, it would only be binding if he was available to change his residency to another state.¹² It is, thus, reasonable to assume a limited influence of law heterogeneity on the mortgage demand. Contrarily, on the supply side, the effects are not negligible and dependent on the type of law.

Foreclosure procedure: In states that require judicial foreclosure procedures, lenders face on Banking Supervision (2017)). In the U.S case, the Federal Reserve decided not to include this recommendation in the adoption of the Basel III criteria (see Department of Treasury and Federal Reserve System (2013)).

¹¹Exceptionally, one might assume that the non-recourse option could influence the mortgage demand by relaxing the household concerns in case of default.

¹²Exceptionally, law differences can be binding for households that live near the border of a state with different laws.

additional costs and will, on average, take more time to conclude the foreclosure. Different authors recognize this increase in the foreclosure costs (like Pence (2006), Mian et al. (2015), Shibut and Singer (2015), and others) which can go as high as 10% of the loan balance, according to Pence (2006). In a more general approach, Cerqueiro et al. (2016) also recognize that the legal mechanisms influence the value of the collateral as they determine when and how can the secured assets be seized. The higher costs in recovering the debt imply, *ceteris paribus*, a higher loss given default when compared to nonjudicial states. On the borrowers' side, judicial foreclosure procedures provide more protection and delay the foreclosure process, but it should not change borrowers' incentives to default. Overall, for loans with similar characteristics, I anticipate that the mechanism through which the expected loss increases in judicial states operates mainly through loss given default.

Restrictions on deficiency judgments: When recourse is not allowed, the value of the house given as collateral limits the debt recovery. The lender cannot seize other assets of the borrower, neither his income. With lower recovery opportunities, lenders face a higher loss given default, *ceteris paribus*, when compared to recourse states. Further, when recourse is not allowed, borrowers have more incentives to default when the loan balance exceeds the value of the house (negative equity). This event is well documented in the literature and is known as strategic default. Ghent and Kudlyak (2011) find that borrowers with properties appraised at more than \$200,000 are 30% more likely to default in non-recourse states. Overall, for loans with similar characteristics, I anticipate that the mechanism through which the expected loss increases in non-recourse states operates both through the probability of default and the loss given default.

With a higher expected loss in judicial and non-recourse states (borrower-friendly laws), one will expect that lenders adjust the pricing of mortgages by requiring, *ceteris paribus*, a higher risk premium. The more skin in the game, the more the lender calls for risk compensation. If mortgage law influences loan risk, then there should be a direct effect on the mortgage supply.

3.3.1.2 Total effects: changes in the mortgage market equilibrium

Direct effects determine how borrowers and lenders change their behavior in the presence of different law contexts, whereas total effects are the result of their interaction. Due to the joint determination of r^m and LTV , the adjustment mechanism might operate through two channels:

- Price channel, when the mortgage interest rate increases to reflect the higher risk and cost in borrower-friendly states (higher r^m);
- Collateral channel, when the collateral requirements increase to compensate for the increased risk in borrower-friendly states (lower LTV).

3.4 Data and empirical strategy

3.4.1 Data and descriptive statistics

This paper combines a variety of data sources. Besides the NMSRD for the mortgage law, I use the Freddie Mac's Single Family Loan-Level Dataset¹³ for data on individual mortgages, and FRED Economic Data for data on market interest rates.

Freddie Mac Single Family Loan-Level Dataset comprises a portion of single family mortgages acquired or guaranteed by Freddie Mac. The data is publicly available for research purposes, which guarantees reproducibility and allows for study extension. It includes fully amortizing fixed-rate mortgages and has the comparative advantage of having information on interest rates.¹⁴

¹³Available in http://www.freddiemac.com/research/datasets/sf_loanlevel_dataset.page as of August 2018

¹⁴It excludes government-insured mortgages, affordable mortgages, adjustable-rate mortgages, mortgages with credit

I restrict the sample period to loans originated between 2001 and 2011, to comply with the orthogonality assumption discussed in Section 3.2.1. The loan origination information is available by quarter/year. The selected sample includes mortgages granted for the purchase of a single-family primary residency, with a fixed interest rate, minimum amount of \$50,000 and original term between 25 and 35 years, and whose associated property locates in one of the states considered in Section 3.2.¹⁵ In addition to the variables directly provided, I compute the borrower's monthly income (*Income*) through the monthly installments and the decomposition of the debt to income ratio. I also compute the loan-to-income ratio as the loan amount per dollar of monthly income (*LTI*).

All loans in the sample are fixed rate mortgages. To compare fixed interest rates from different periods and isolate the credit risk premium, I follow an approach similar to Basten et al. (2018) and compute the *Spread* as the difference between the mortgage interest rate and the refinancing costs under full hedging of interest rate risk. In their work, the interest rate risk immunization strategy contemplates the repricing period of the mortgage as reference for the interest rate swap maturity. However, in the U.S., fixed rate mortgages have no interest rate resetting and no prepayment penalty, meaning that the fixed interest rate is valid up to the maturity date (25 to 35 years) or the loan prepayment, whichever one is first.¹⁶ Given that the loan prepayment is unknown at origination, I assume that the quarterly average 30-Year Interest Rate Swap is the most adequate hedging instrument to compute the *Spread*.¹⁷ Since mortgage rates are usually defined in advance of closing the deal, I lag the 30-Year Interest Rate Swap one quarter.

Table 3.1 presents summary statistics of the loan-level data used.¹⁸ The 3,145,276 loans are enhancements other than primary mortgage insurance, and mortgages with not verified documentation.

¹⁵Minor adjustments were made due to the presence of data inconsistencies. For further details please contact the author.

¹⁶To immunize interest rate risk, lenders match the duration of assets and liabilities. In the determination of the mortgage duration, it is important to account for the possibility of principal prepayment. However, as it is an uncertain event that varies with the interest rate level and economic environment, the computation of the duration will depend on the specification of the option exercise (Mattey (2000)).

¹⁷As a robustness check, I assume that the prepayment occurs after 10 years and compute the *Spread* as the difference between the mortgage interest rate and the 10-Year Treasury Yield. This approach is presented in Section 3.6.1.

¹⁸Summary statistics by Year presented in Appendix Appendix D.

distributed along 11 years and 44 quarters. The average loan has a *Spread* of 78 basis points, an *Amount* of \$180,557, and a *LTV* of 79.38%. On average the borrower has a *CreditScore* of 730 and a *Income* of \$3,391. The sample is well distributed among judicial and nonjudicial states, with 46% of loans subject judicial foreclosure. It is also fairly distributed among recourse and non-recourse states, with 37% of loans subject to non-recourse regime. Table 3.2 and 3.3 present the summary statistics by aspect of law: judicial foreclosure requirement and non-recourse law.

Table 3.1. Summary Statistics

	mean	sd	min	max	Description
Spread	78	47	-304	496	Mortgage spread to previous period 30Y swap rate (bps)
Amount	180,557	92,792	50,000	1,403,000	Mortgage amount (\$)
Value	238,181	144,902	50,000	5,214,286	House value (\$)
LTV	79.38	13.75	6.00	105.00	Loan-to-value ratio (pp)
LTI	59.16	18.72	1.24	132.13	Loan-to-income ratio
CreditScore	730	54	300	850	Credit score
Income	3,391	2,693	413	298,465	Borrowers' monthly income (\$)
DFirstTime	0.27	0.44	0	1	=1 if First-Time Homebuyer
DSingleBorrower	0.42	0.49	0	1	=1 if Single Borrower
Judicial	0.46	0.50	0	1	=1 if in a judicial state
NonRecourse	0.37	0.48	0	1	=1 if in a non-recourse state
Observations	3,145,276				

3.4.2 Data caveats and opportunities

The use of Freddie Mac dataset is not without caveats. First, the dataset only includes loans acquired or secured by Freddie Mac, which might form a biased representation of the

Table 3.2. Summary Statistics by Judicial Foreclosure Requirement

	Judicial		Nonjudicial	
	mean	sd	mean	sd
Spread	81	47	76	47
Amount	175,120	90,239	185,171	94,660
Value	230,047	139,253	245,084	149,181
LTV	79.65	13.71	79.15	13.77
LTI	58.69	18.64	59.57	18.77
CreditScore	729	54	731	54
Income	3,316	2,591	3,455	2,774
DFirstTime	0.27	0.44	0.27	0.44
DSingleBorrower	0.42	0.49	0.42	0.49
NonRecourse	0.19	0.39	0.53	0.50
Observations	1,443,938		1,701,338	

Table 3.3. Summary Statistics by Non-Recourse Law

	NonRecourse		Recourse	
	mean	sd	mean	sd
Spread	77	47	79	47
Amount	188,946	96,638	175,598	90,074
Value	251,139	154,399	230,521	138,413
LTV	78.99	13.80	79.61	13.71
LTI	60.11	18.66	58.60	18.73
CreditScore	731	54	730	55
Income	3,475	2,696	3,342	2,690
DFirstTime	0.28	0.45	0.27	0.44
DSingleBorrower	0.41	0.49	0.43	0.49
Judicial	0.23	0.42	0.59	0.49
Observations	1,168,552		1,976,724	

market. If the lender took advantage of having more information about the loans and, thus, sold only the lower quality ones, than the dataset entails a problem of adverse selection. Second, both government-sponsored enterprises (GSE) and purchasers of securitized mortgage-backed securities might not differentiate the risk of mortgage laws—intentionally or for lack of due diligence. For example, the Freddie Mac’s Single-Family Seller/Servicer Guide that establishes the requirements relating to the purchase of mortgages, makes no distinction on

foreclosure procedure or deficiency judgments (Freddie Mac (2020)). In this case, it might be argued that, at origination, lenders may disregard the risk derived by mortgage law differences, if they intend to sell the mortgage in the secondary market. As a cross reference of this caveat, Mian et al. (2015) use this risk blindness argument to justify that the credit supply effects in nonjudicial states, that were initially shown by Pence (2006), have weakened over time as a consequence of the intensified presence of GSEs in the mortgage market.

These two critiques, however, do not jeopardize this study. At the moment of the origination, the lender may not have yet the intention to sell the mortgage to a third party. While some lenders proceed with the loan underwriting with the clear intention to sell the mortgage very soon after closing on the contract, others postpone the decision. It is, therefore, not definite that all loans on the dataset have different characteristics at origination than the loans kept on the lenders' balance sheet. Moreover, the sale of mortgages to Freddie Mac does not necessarily mean that the risk is fully transferred to the third party. For example, loans with a LTV ratio in excess of 80% sold to Freddie Mac must comply with one of three options: (i) have a mortgage insurance provided by the lender or other entity on the portion that exceeds the 80% LTV ratio; (ii) keep all risks and costs of a borrower default on the lenders/seller-side; or (iii) be sold on a participation basis (Freddie Mac (2020)).

From another perspective, Pence (2006) argues that lenders and third parties interact in a repeated game, which deters lenders from disregarding risk differences. If lenders imposed loose requirements on loans, with the expectation of later selling it, they would be putting at risk the continuation of the business with the third party. A history of bad risk assessment might have led third parties to refuse to buy loans.

But, most of all, even under the hypothesis that loans sold to Freddie Mac enclose loose credit standards, any evidence of differences derived by mortgage law heterogeneity found with this dataset implies that the effects on the entire market should be at least equal, but probably stronger.

The use of Freddie Mac dataset is also an opportunity. To my knowledge, former studies on the impact of law on mortgage outcomes disregard the impact on mortgage pricing (see, for example, Pence (2006) and Mian et al. (2015)), evaluate the price effects at aggregate level (see, for example, Ghent and Kudlyak (2011) and Pruszkowski (2017)), or use small private datasets (see, for example, Ambrose et al. (2004)). The lack of loan-level data with interest rate information makes it difficult to assess the price effects of mortgage law.¹⁹ That is where the Freddie Mac dataset emerges as an opportunity. By providing information on interest rate, collateral value, borrower's risk, borrower's income, and others, the Freddie Mac dataset broadens the research opportunities.

As a final and general critique, that applies to any dataset on U.S. mortgage data, is the strong presence of secondary market institutions and mortgage insurance companies, and the possible distortion that they might cause in the market outcomes, and in the loan characteristics. For example, Green and Wachter (2005) argue that these institutions blur the difference in the mortgage supply for high-risk and low-risk borrowers, while providing a solution for the Stiglitz and Weiss (1981) pooling problem. If this is the case, then any study on the impact of mortgage law heterogeneity in the U.S. must acknowledge that the mortgage risk assessment and pricing might be biased.

3.4.3 Empirical strategy

To identify the impact of mortgage law on loan characteristics, one would ideally want to observe the effects of an exogenous and not policy-oriented change in the law. In the absence of that event, I could alternatively study the interactions between borrowers and lenders at

¹⁹The most comprehensive source of publicly available information on loan origination in the United States is the Home Mortgage Disclosure Act (HMDA) data but, up to 2018, it does not include loan price information. The information on the interest rate, loan term, introductory rate period, and others were only available after the 2018 Home Mortgage Disclosure Act (effective in January 2018 for submissions due in March 2019) (FFIEC (2018)).

origination in different law contexts (from loan applications to bank responses) to disentangle the effects of law on mortgage demand and supply. Neither of both is possible. First, no event proxies a randomized experiment of a change in the law.²⁰ Second, the U.S. is the most representative example of mortgage law heterogeneity, but no dataset includes simultaneously loan applications, loan pricing, and loan collateralization for a significant period.²¹ Even for other geographic regions, detailed mortgage-level information that allows for a clear separation of mortgage demand and supply with price information is usually not publicly available. Some exceptions include Basten et al. (2018) and Basten (2020) that use a sample of the Swiss mortgage market and Michelangeli and Sette (2016) that make use of simulations.

Given the availability of data, the solution includes a baseline model and a detailed approach that considers the conditional distribution of the LTV ratio.

3.4.3.1 Baseline model

The identification strategy departs from the observation of the mortgage law heterogeneity across U.S. states and the assumption of orthogonality to other economic and social factors from 2001 to 2011. If the mortgage law is randomly assigned, then there are no confounding factors in the treatment assignment, and the multivariate analysis is an appropriate method to evaluate the impact of the law. A second econometric challenge is the joint determination of the mortgage interest rate and the collateralization level, as discussed in Section 3.3. To deal with this endogeneity issue, I estimate the reduced-form equations for the spread on the mortgage interest rate *Spread*, and the loan-to-value ratio *LTV*. This approach is similar to the one followed by Gambacorta and Mistrulli (2014). Equation (3.1) sets the estimation for *Spread* and Equation (3.2) for the *LTV*

²⁰As set in Section 3.2, Nevada passed a legislation on October 1, 2009 that abolish recourse on mortgages granted with the purpose of purchasing a single-family home. However, this change in the law emerged as a response to the mortgage crisis and cannot be considered a random (not policy-oriented) change in law.

²¹See footnote 19.

$$\begin{aligned}
Spread_{i,j,t} = & \beta_{10} + \beta_{11}Log(Income)_i + \beta_{12}Log(Income)_i^2 + \beta_{13}LTI_i \\
& + \beta_{14}CreditScore_i + \beta_{15}DSingleBorrower_i + \beta_{16}DFirstTime_i \\
& + \beta_{17}Judicial_{i,t} + \beta_{18}NonRecourse_{i,t} \\
& + \Phi_{1t} + \Omega_{1j} + \epsilon,
\end{aligned} \tag{3.1}$$

$$\begin{aligned}
LTV_{i,j,t} = & \beta_{20} + \beta_{21}Log(Income)_i + \beta_{22}Log(Income)_i^2 + \beta_{23}LTI_i \\
& + \beta_{24}CreditScore_i + \beta_{25}DSingleBorrower_i + \beta_{26}DFirstTime_i \\
& + \beta_{27}Judicial_{i,t} + \beta_{28}NonRecourse_{i,t} \\
& + \Phi_{2t} + \Omega_{2j} + \epsilon,
\end{aligned} \tag{3.2}$$

for loan i , seller j , and year t . The Φ are year fixed-effects to control for year nationwide shocks that might influence demand or supply. The Ω are seller fixed-effects to control for heterogeneity in interest rate setting and collateral requirements, which might arise due to specific characteristics of bank liquidity, capitalization, and relationship lending (Gambacorta (2008)). As the error terms can display a potentially time-varying seller component from changes in seller's strategies, I cluster the residuals by seller.

Mortgage laws have a direct impact on the probability of default, loss given default, and expected loss, as discussed in Section 3.3. Yet, the mechanism through which they influence the mortgage market equilibrium can be distinct. The judicial foreclosure requirement implies higher costs in case of default (both time and monetary costs), but it is not expected to change the borrower's probability of default. As a result, in the market equilibrium, lenders might require a risk premium to compensate for the higher recovery costs ($\beta_{17} > 0$, price channel), or

might input the extra recovery costs in the collateral value and require more collateral ($\beta_{27} < 0$, collateral channel). Both mechanisms are coherent with Cerqueiro et al. (2016) empirical evidence on collateral functions and the impact of legal tools.

The way through which non-recourse enforcement increases the expected loss is different. First, the probability of default might be higher due to the lack of borrower's incentives to comply with the contract in the presence of a scenario of negative equity caused by a downward housing market. Second, the loss given default might be higher, if lenders consider realistic expectations to seize the borrower's other assets and income in recourse states. As a result, in the market equilibrium, lenders might require a risk premium to compensate for the higher expected loss ($\beta_{18} > 0$, price channel) or require higher collateralization ($\beta_{28} < 0$, collateral channel), both to compensate for the higher loss given default or to decrease the probability of a negative equity scenario.²² Table 3.4 summarizes the foreseen differences in the expected loss for the different mortgage laws, as well as the expected changes in the mortgage market equilibrium (total effects).

Table 3.4. Expected effects of mortgage law

Mortgage Law	Expected Loss		Mortgage Market Equilibrium	
	Prob. of default (PD)	Loss given default (LGD)	Price channel (Spread)	Collateral channel (LTV)
Judicial	no effect	+	β_{17} 0 / +	β_{27} 0 / -
Non-recourse	no effect / +	+	β_{18} 0 / +	β_{28} 0 / -

²²The lower the *LTV* ratio, the less probable is a negative equity event.

3.4.3.2 Law effects dependent on conditional distribution of the *LTV* ratio

The baseline approach focuses on the average effect of the law on mortgage pricing and collateralization level. It does not consider that the impact might diverge according to the conditional distribution of the *LTV* ratio. Put differently, the baseline approach ignores that the impact of the law might be different for credit constrained borrowers and not credit constrained ones.

For example, it assumes that the impact of non-recourse law in the collateral requirements is the same for a not credit constrained borrower that asks for a loan with a *LTV* ratio of 40%, and a credit constrained borrower that asks for a loan with a *LTV* ratio of 85%. Yet, the impact of non-recourse law induced by the probability of strategic default is quite different. While for the not credit constrained borrower the occurrence of a negative equity event requires a decrease in house value of more than 60%, for the credit constrained borrower it only requires a decrease of more than 15%. The scenario of strategic default is, therefore, highly unlikely when the credit constrained is not bidding. If lenders require more collateral to deter strategic default, then one would expect that the not credit constrained borrower would not be affected.

To fix ideas, one should start by defining what is a credit constrained borrower in the framework of the U.S. mortgage market. Usually, lenders prefer to grant conforming loans, as these loans are easily traded in the secondary market.²³ The Federal Housing Finance Agency (FHFA) sets, annually, the limits on the loan amount for conforming loans, and Freddie Mac and Fannie Mae set the guidelines on loan characteristics. Loans with *LTV* ratios above 80% can classify as conforming loans and be sold to Freddie Mac, but require additional protection in case of borrowers' default.²⁴ This criteria sets the mode for the typical loan, as going above 80% implies increasing costs. As a result, it is possible to classify each loan according to the conditional distribution of the *LTV* ratio and to the type of borrower:

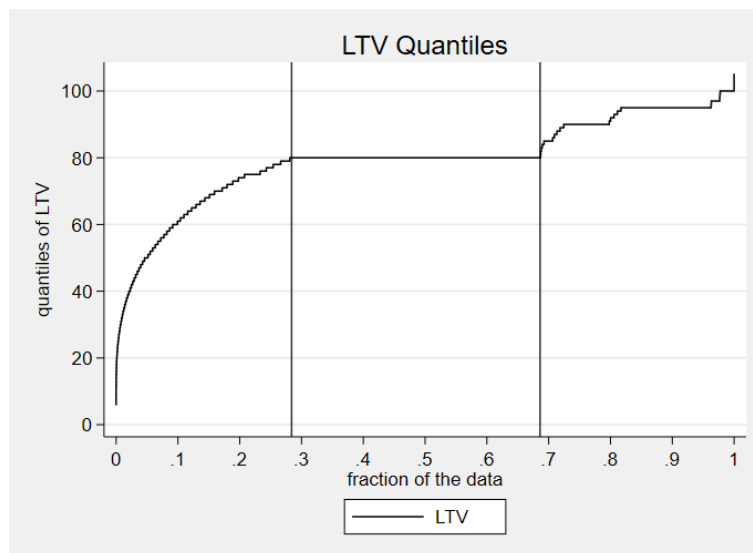
²³ Either through a government-sponsored enterprise or a private issue of mortgage-backed securities.

²⁴ As set in Section 4.4.2.

- Type I (*LTV* ratio below 80%) - the borrower is not credit constrained, and could ask for a higher loan.
- Type II (*LTV* ratio of 80%) - the borrower might be credit constrained, and asks for the maximum loan amount that does not require additional protection to classify as conforming.
- Type III (*LTV* ratio above 80%) - the borrower is credit constrained, and chooses to obtain a higher loan, even if that means paying for private mortgage insurance.

Figure 3.4 presents the empirical cumulative distribution function of the *LTV* ratio for the loans included in the data. It shows pattern breaks around 30th and 70th quantiles, consistent with the above classification. Up to around the 30th quantile, mortgages have a *LTV* ratio below 80% and show a concave distribution. From the 30th quantile to a little before the 70th quantile, mortgages have a *LTV* ratio of 80%, and reflect a flat distribution. Afterwards, mortgages have a *LTV* ratio mostly between 80% and 95%, with higher values as exceptional cases.

Figure 3.4. Cumulative Distribution of the *LTV* ratio



This figure presents the empirical cumulative distribution function of the *LTV* ratio. Approximately, 30% of the mortgages have a *LTV* ratio below 80% (Type I borrowers - not credit constrained), 40% have a *LTV* ratio of 80% (Type II borrowers - might be credit constrained), and 30% have a *LTV* ratio above 80% (Type III borrowers - credit constrained).

If the effects of the law are intrinsically related with the occurrence of a default event, is it reasonable to rely only on average effects estimated by Equation (3.2)? Or should we consider that the law effects depend on the conditional distribution of the *LTV* ratio and the type of borrower? To test these hypothesis, I follow Koenker and Bassett (1978) and start by inspecting if the assumption of normality of residuals in Equation (3.2) is strictly satisfied.²⁵ If the distribution of the *LTV* ratio residuals does not approximate a normal distribution, I proceed by applying a quantile regression method. Besides not making assumptions on the parametric distribution of residuals, the quantile regression method allows for the estimation of explanatory variables' effects at different points of the *LTV* conditional distribution. It is also more robust in the presence of outliers as it considers median regression, rather than mean regression.

For the Type I borrowers, I analyze intratype effects at the 10th, 15th, 20th, and 25th quantiles, whereas for the Type II and III, I analyze the mid-points set by the 50th and 85th quantiles. I apply a quantile method with the same rationale as the baseline model.^{26,27}

²⁵OLS methods model the conditional mean and assume a normal distribution of residuals, which ignores that responses can vary across the conditional distribution of the dependent variable. The violation of the normality assumption renders OLS estimators that are valid, but inefficient. In that case the use of an alternative approach is justified.

²⁶I use the STATA module *xtqreg* to estimate quantile regressions according to the method proposed by Machado and Santos Silva (2019) with seller and year fixed effects. Instead of clustering the errors by seller, I use bootstrap standard errors as recommended by Baum (2013).

²⁷I do not study the conditional distribution of the *Spread* because there is no fundamental argument to do it. While the distribution of the *LTV* ratio relates to the credit constraints of the borrower, the same does not apply to the price of mortgages.

3.5 Results

3.5.1 Baseline model results

Table 3.5 presents the OLS estimation of the reduced-form equations in (3.1) and (3.2), with and without seller fixed-effects. As for the price channel, judicial requirements significantly increase the mortgage spread ($\beta_{17} > 0$), whereas non-recourse law does not affect the price ($\beta_{18} = 0$). Lenders require a monetary compensation for the increased foreclosure costs but not for the lower recovery opportunities and increased probability of default. On average, the mortgage interest rate on judicial states is approximately 4.3 to 4.7 basis points higher than in nonjudicial ones.

As for the collateral channel, judicial requirements do not significantly decrease the *LTV* ($\beta_{27} = 0$), whereas non-recourse law implies a lower *LTV* ratio ($\beta_{28} < 0$). Lenders require more collateralization given the lower recovery opportunities and increased probability of default but not for the increased foreclosure costs. On average, the loan-to-value ratio is approximately 0.42 to 0.58 percentage points lower in non-recourse states.

Why is the collateral channel silent in judicial states, and why is the price channel functioning? According to the evidence gathered by Cerqueiro et al. (2016), both should be active. But, if only the price one is effective, one can conclude that lenders consider the extra cost from judicial foreclosures as an operational limitation that makes the loan activity more expensive, rather than a devaluation of the collateral value per se. Lenders do not input the judicial cost to the collateral value.

Why is the price channel silent in non-recourse states, and why is the collateral channel functioning? One possible reason for a silent price channel is that lenders in recourse states usually face judicial costs to seize borrower's other assets and income. These costs can offset

the value of the recovery opportunities and apparently silence the price channel. As for an effective collateral channel, there are two possible reasons. First, non-recourse laws imply a zero recovery beyond the house value, therefore lenders require a lower *LTV* ratio to, *ceteris paribus*, increase the protection against default. Second, lenders might want to avoid strategic defaults by reducing the probability of an event of negative equity. With higher collateralization, it is less probable that the debt value will exceed the house value during the life of the contract.

The latter argument provides one of the motivations for the next subsection. If lenders require more collateral in non-recourse states as a way to deter strategic default, then the effect of law should differ for different points of the *LTV* ratio conditional distribution.

3.5.2 Law effects dependent on the conditional distribution of the *LTV* ratio

Figure 3.5 presents the distribution of the residuals of Equation (3.2) with year and seller fixed-effects. The distribution of the residuals on the *LTV* ratio regression violates the normality assumption.²⁸ As a result, OLS estimators in Table 3.5 are valid but inefficient, which justifies the use of a quantile regression method.²⁹

Table 3.6 presents the estimation results for the *LTV* ratio quantile regression with seller and year fixed effects. As expected, the effects of explanatory variables vary across quantiles, and the differences are particularly relevant for the variable *Income*. On the other hand, the effect of non-recourse law shows little divergence across quantiles, and not in the expected

²⁸Normality tests, like Shapiro-Wilk *W* or Shapiro-Francia, are not valid for large samples. The normality of residuals distribution can only be validated through visual inspection.

²⁹The conditional distribution of *Spread* is not relevant for Section 3.4.3.2 argument. Nevertheless, Appendix E presents the distribution of the residuals of Equation (3.1) with year and seller fixed-effects. There is no evidence of normality assumption violation for the *Spread* regression.

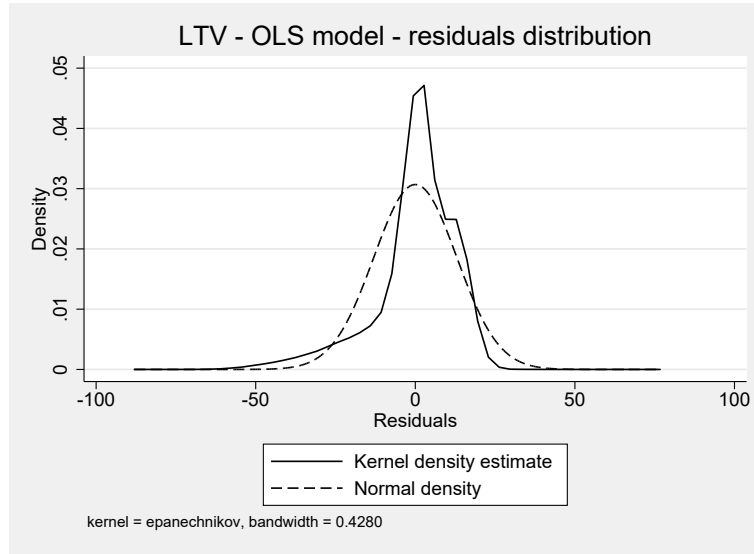
Table 3.5. Effects of law on Spread and LTV

	Spread	Spread	LTV	LTV
LogIncome	-28.709** (9.617)	-27.960** (9.058)	49.094*** (2.717)	49.327*** (2.709)
LogIncome ²	1.131* (0.540)	1.108* (0.502)	-3.066*** (0.165)	-3.063*** (0.166)
LTI	-0.286*** (0.015)	-0.281*** (0.014)	0.041*** (0.006)	0.046*** (0.006)
CreditScore	-0.133*** (0.009)	-0.132*** (0.009)	-0.055*** (0.002)	-0.055*** (0.002)
DSingleBorrower	3.646*** (0.493)	3.566*** (0.474)	1.995*** (0.081)	2.015*** (0.075)
DFirstTime	1.746* (0.693)	2.512* (0.917)	3.700*** (0.225)	4.066*** (0.162)
Judicial	4.698*** (0.249)	4.305*** (0.207)	0.303 (0.186)	0.167 (0.170)
NonRecourse	-0.050 (0.170)	0.219 (0.234)	-0.583*** (0.129)	-0.421** (0.138)
FE Year	yes	yes	yes	yes
FE Seller	no	yes	no	yes
<i>N</i>	3,145,276	3,145,276	3,145,276	3,145,276
<i>R</i> ²	0.327	0.332	0.096	0.106

This table presents coefficients of the OLS specification for *Spread* and *LTV* on law dummies—*Judicial* and *NonRecourse*. Standard errors are clustered by seller. Coefficients marked with ***, **, * and + are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively

direction. The collateral requirements due to non-recourse law are higher for not credit constrained borrowers than for credit constrained ones. This result overrules the hypothesis that lenders require a lower *LTV* ratio in non-recourse states to deter borrowers from strategic de-

Figure 3.5. Residuals distribution on the *LTV* ratio regression



This figure presents the distribution of the residuals on the estimation of Equation (3.2) with year and seller fixed effects. The estimated residuals (Kernel density estimate) violate the assumption of normality distribution represented by the dash line.

fault. If it was true, the effects should be stronger for credit constrained borrowers (Type III) because they are the first to strategic default in a scenario of a falling housing market. For Type III borrowers, the *LTV* ratio is 0.30 percentage points lower in non-recourse states, whereas for Type II borrowers, it is 0.41 percentage points lower. The results are even more striking for differences within the Type I borrowers. If lenders demand more collateral to deter strategic default, then the effect of non-recourse on not credit constrained borrowers with loans with low *LTV* ratios should be almost negligible. Yet, the impact of non-recourse within the Type I borrowers is decreasing with the quantiles. For borrowers belonging to the 10th quantile, the *LTV* ratio is 0.58 percentage points lower in non-recourse states, whereas for borrowers belonging to the 20th quantile, it is 0.49 percentage points lower.

If the argument of strategic default avoidance is not valid to justify the higher collateralization level in non-recourse states, then it only remains the justification that lenders might require less collateral in recourse states because they have realistic expectations of seizing the borrower's other assets and income.

Table 3.6. Effects of law on the conditional distribution of LTV

	OLS	Type I Q(0.10)	Type I Q(0.15)	Type I Q(0.20)	Type I/II Q(0.25)	Type II Q(0.50)	Type III Q(0.85)
LogIncome	49.327*** (2.709)	119.644*** (4.688)	95.423*** (3.459)	79.919*** (2.252)	69.671*** (2.421)	42.610*** (1.630)	-2.516 (1.599)
LogIncome2	-3.063*** (0.166)	-7.163*** (0.291)	-5.750*** (0.216)	-4.847*** (0.137)	-4.249*** (0.150)	-2.671*** (0.099)	-0.040 (0.098)
LTI	0.046*** (0.006)	0.148*** (0.008)	0.113*** (0.007)	0.090*** (0.008)	0.075*** (0.005)	0.036*** (0.005)	-0.029*** (0.005)
CreditScore	-0.055*** (0.002)	-0.069*** (0.002)	-0.064*** (0.002)	-0.061*** (0.002)	-0.059*** (0.002)	-0.054*** (0.001)	-0.045*** (0.002)
DSingleBorrower	2.015*** (0.075)	3.538*** (0.160)	3.013*** (0.129)	2.677*** (0.085)	2.455*** (0.093)	1.869*** (0.069)	0.892*** (0.058)
DFirstTime	4.066*** (0.162)	7.520*** (0.375)	6.330*** (0.232)	5.569*** (0.216)	5.065*** (0.165)	3.736*** (0.138)	1.519*** (0.207)
Judicial	0.167 (0.170)	0.221 (0.234)	0.203 (0.218)	0.190 (0.169)	0.183 (0.186)	0.161 (0.137)	0.126 (0.153)
NonRecourse	-0.421** (0.138)	-0.582** (0.200)	-0.526** (0.175)	-0.491** (0.190)	-0.467*** (0.136)	-0.405*** (0.120)	-0.302*** (0.073)
FE Year and Seller	yes	yes	yes	yes	yes	yes	yes
N	3,145,276	3,145,276	3,145,276	3,145,276	3,145,276	3,145,276	3,145,276

This tables presents coefficients of the OLS and the Quantile Regression specification for LTV on law dummies—*Judicial* and *NonRecourse*. Quantiles defined according to the type of borrower. Standard errors are bootstrapped by seller with 100 repetitions. Coefficients marked with ***, **, * and + are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively

As for the impact of judicial foreclosures, there are no differences across quantiles and the effect is null. This means that the collateral channel is not activated to compensate for judicial foreclosure requirement, independently of the type of borrower.

3.6 Robustness tests

As robustness checks, I run three additional models. First, I use an alternative definition of *Spread* that considers the hypothesis of prepayment of principal. Second, I test if the effects previewed in the baseline model prevail when we consider the secondary mortgages associated with the same property. Third, I test the time dependency of the results obtained.

3.6.1 Alternative definition of Spread

The definition of *Spread* used in this study assumes that by deducting the refinancing costs under full hedging of interest rate to the mortgage interest rate, one obtains the credit risk premium. By using the 30-Year Interest Rate Swap as reference rate, it does not consider the possibility of mortgage prepayment in the hedging strategy. Yet, in the U.S mortgage prepayment is frequent and motivated by a variety of reasons.³⁰

To address these concern, I redefine *Spread* as the difference between the mortgage interest rate and the lagged quarterly average 10-Year Treasury Yield and name it *Spread2*. I use the 10-Year Treasury Yield for three reasons: first, several studies use treasury rates as a reference

³⁰Chernov et al. (2018) study the mortgage prepayment risk in the US for the period between 1998 and 2014. They find that the average implied prepayment rate is 25.13% and the average empirical prepayment rate is 20.96%. Hall and Maingi (2019) point out some of the reasons that lead to mortgage termination, which include: refinancing with a new mortgage with better conditions; refinancing with a new mortgage with a higher balance; paying off the mortgage as the better strategy when comparing alternative savings investments; paying off the mortgage to exchange the house; defaulting, and homeowner's death.

for computing credit risk premium (for example, Krainer and LeRoy (2010)); second, lenders use treasury securities as benchmarks to set up mortgage rates (Justiniano et al. (2016)); and third, borrowers usually repay the mortgage before the maturity and ten years is a good proxy for principal prepayment (Ambrose et al. (2004)).

This approach, however, does not control for the co-movement between mortgage and Treasury rates, neither controls for the term structure. To account for the pattern of the expectations for interest rates, I follow an approach similar to Justiniano et al. (2016) and control for four additional variables—*Level*, *Slope*, *Curvature*, and *Volatility60d*. The first three represent the quarterly average of the term-structure factors for Treasuries (*Level*, *Slope*, and *Curvature*), and are obtained through principal components analysis. The latter represents the quarterly average of a volatility indicator (*Volatility60d*) and is computed as the realized volatility of the daily 2-Year Treasury Yield over a rolling 60-day window.

Table F1 in Appendix F presents the results of the estimation of the baseline model for the *Spread2*. The results are qualitatively similar to the ones presented on Table 3.5, which confirms Section 3.5.1 conclusions.

3.6.2 Combined LTV ratio

At the origination of a purchase mortgage loan, borrowers occasionally ask for a secondary mortgage that is associated with the same property as the primary mortgage, but that can have different characteristics, such as interest rate and maturity. In this case, it is reasonable to assume that lenders evaluate the risk by considering the entire exposure associated with the mortgaged property. To test if the impact of law remains the same when we consider the entire exposure, I re-estimate Equation (3.2) by using the combined loan-to-value ratio (*CLTV*) at origination instead of the *LTV* ratio.

Table F2 in Appendix F presents the OLS results for the *CLTV* regression. The results are consistent with the ones presented on Table 3.5. Judicial foreclosure requirements do not impact the collateralization level, whereas the non-recourse law leads to a lower *CLTV* ratio of approximately 0.42 to 0.50 percentage points. These results confirm the conclusions presented in Section 3.5.1.

3.6.3 Law effects dependent on the time frame

The baseline approach includes year fixed effects that control for nationwide shocks, and captures time-specific dynamics of the mortgage market. Nevertheless, to inspect Mian et al. (2015) argument that the credit supply effects related to judicial foreclosures requirement found by Pence (2006) have weakened over time³¹, I re-estimated the reduced-form equations by interacting law with year dummies.

Table F3 in Appendix F presents the OLS results for the *Spread* and *LTV* regressions with year-law interactions. As for the price channel, judicial requirements significantly increase the mortgage spread for most of the years, and the effect varies from 1.5 to 6.5 basis points. The only exceptions are 2010 and 2011, for which the effect is not significantly different from zero. As for the collateral channel, the impact of non-recourse on the *LTV* ratio is also significant for most of the sample, and varies from 0.33 to 0.78 percentage points. The only exceptions are 2001, 2009 and 2010.

Despite the evidence of a price and collateral channel for most of the sample period, one cannot disregard the hypothesis that, in some periods, lenders might assign a low probability to scenarios of substantial house prices declines (Gerardi et al. (2013)) and, thus, not penalize judicial foreclosures and non-recourse. By inspecting the evolution of Case-Shiller U.S. National Home Price Index, there is anecdotal evidence that points to the coincidence of a

³¹Mian et al. (2015)'s argument focus on the period between 2000 and 2005.

depressed housing market with the verification of silent price and collateral channels.³²

3.7 Conclusions

Mortgage laws influence the debt recovery process in case of default and, thus, impact the cost and risk of mortgages for lenders. Depending on the type of law, the effects might materialize in a higher probability of default, a higher loss given default, or both. By focusing on the U.S. mortgage market, I analyze the judicial foreclosure requirement and the non-recourse, as borrower-friendly laws that increase the mortgage cost and risk. I use a loan-level dataset to assess how the law influences loan characteristics at origination, and consider two possible channels: price and collateral channel.

I find that judicial foreclosures activate a price channel, with the mortgage interest rate being 4.3 to 4.7 basis points higher in judicial states. The results suggest that lenders charge a premium to compensate for higher monetary and time costs incurred in judicial processes. This effect is fairly robust, even if it shows some variation over time. On the other hand, there is no evidence that judicial foreclosures lead to higher collateral requirements.

As for the non-recourse law, I find that it activates a collateral channel, with mortgages in non-recourse states having a lower loan-to-value ratio of about 0.42 to 0.58 percentage points. I also find that the collateral requirements in non-recourse states are not higher for credit-constrained borrowers, which means that they do not arise as a way to deter strategic default. Higher collateralization levels in non-recourse states derive from lower opportunities to recover the debt as the lender cannot seize other borrower's assets and income, rather than the house given as collateral.

³²Figure F1 in Appendix F shows the evolution of Case-Shiller U.S. National Home Price Index and emphasizes the years 2009, 2010 and 2011.

Chapter 4

Do low interest rates spur risk-taking in mortgage underwriting? An empirical study

4.1 Introduction

The effects of low interest rates on credit risk-taking have been intensely debated, particularly after the 2007 financial crisis. In an innovative empirical approach, Jiménez et al. (2014) show that low interest rates induce low capitalized banks to relax their lending standards to firms, both by conceding loans to previously risky firms and by lowering the collateral requirements. Many other studies follow similar approaches and support that, in low interest rate environments, banks have incentives to take more risk while lending to firms (see, for example, Dell’ariccia et al. (2017), Delis et al. (2017), Paligorova and Santos (2017), or Bonfim and Soares (2018)).

Yet, the increasing evidence on the credit risk-taking channel neglects an important part of the story: How do low interest rates impact the risk of household credit? Do households

have incentives to take more risk when credit is cheap? In particular, what are the effects of low interest rates on residential mortgage risk-taking at underwriting (ex-ante risk-taking)?¹ Mortgages are different from firm loans, and thus, it is reasonable to consider that the effects of low interest rates are not identical. This paper aims to reduce part of this gap in the literature by studying how the reduction in the market interest rates influences households behavior towards mortgage risk. I use data on the Portuguese mortgage market from 2007 to 2010, and, to my knowledge, this the first paper to empirically assess the effect of interest rates on mortgage risk-taking with loan-level data.

A mortgage is a special kind of credit. I start by exploring the mortgage underwriting decision under low interest rates while focusing on the particular case of adjustable-rate mortgages (ARM) — the type of mortgage more exposed to interest rate risk. When tempted with low borrowing costs, households might overspend, get larger loan amounts, and buy more expensive houses. And, if that is true, they will end up with riskier loans, as the monthly payments might increase above their ability to pay.

There are, at least, three reasons why households might overspend and take more risks. First, they may not know how much the mortgage payment can change because they lack financial knowledge. Second, they may underestimate the interest rate risk and be over-optimistic about the future. Lastly, they may have a preference for present consumption. The common factor is that households neglect the potential impact of changes in interest rates. Deluded by the current ability to pay, they, ultimately, act myopically. The myopia in assessing the future impact of interest rates is the risk-taking mechanism identified in this study.

I proceed by asking the following question: How can we measure mortgage risk-taking? One of the most used measurements of household's ability to pay is the debt-service ratio (DSR). It compares the household's required monthly payments to its disposable income. However, by itself, it is not suitable for measuring risk-taking in ARM because the DSR is sensitive to interest rate level, and does not indicate the future ability to pay.

¹Hereafter, residential mortgage is referred to as mortgage.

Throughout an example, I demonstrate that it is possible to compare risk-taking under different interest rate scenarios if we use the DSR combined with an alternative indicator—the stressed debt service ratio (SDSR). The latter is not sensitive to interest rate level and represents the DSR that the household would have observed if interest rates were high.

Why study the Portuguese mortgage market? First, most mortgages are ARM and indexed to Euribor rates. Second, when interest rates fell by the end of 2008, the Portuguese mortgage market was still resilient, notwithstanding the financial crisis. Portugal had no exposure to subprime mortgages, and the major drop in the market only happened in 2011 as a consequence of the sovereign debt crisis. As a result, I can analyze risk-taking effects on the period between 2007 and 2010.

I use mortgage-level data from European DataWarehouse (ED). I find, that in the period of low interest rates, the DSR is relatively lower, which reflects the lower borrowing costs. However, for the same period, the SDSR is relatively higher, which means that households assume more risk, and would have a reduced ability to pay the mortgage if interest rates were to be high. This finding is compatible with the argument that households behave myopically and disregard changes in the interest rates.

This paper relates to three strands of literature. First, the empirical contributions on the risk-taking channel that, as above mentioned, focus on loans to firms. Different studies use different identification strategies and risk measurements but, most of them find evidence of an increased ex-ante risk taking under low interest rates. Jiménez et al. (2014) study the Spanish market and evaluate the risk effects on loan applications and collateralization level. On the U.S. corporate market, Dell’ariccia et al. (2017) use the rating of new loans as risk measurement, while Delis et al. (2017) and Paligorova and Santos (2017) study the spread on the loans. For the Portuguese market, Bonfim and Soares (2018) evaluate risk-taking through changes in loans amounts.

Second, the empirical studies on financial literacy and the impact on financial decisions.

Most of the empirical evidence points to the influence of household knowledge on mortgage decisions. Bucks and Pence (2008) studies how well do households know their mortgage terms, and they find that borrowers with ARM are more likely to underestimate risks. Bajo and Barbi (2018) study a change in the Italian law that provides an opportunity to refinance fixed-rate mortgages with important gains. Only a small part of households took advantage of it, and they attribute this fact to the lack of financial knowledge. Other authors conclude that, when different types of mortgages are available, more financially literate households choose more complex mortgage types (Cox et al. (2014), van Ooijen and van Rooij (2016), and Gathergood and Weber (2017)). Applied to a different market, but equally relevant, is the study by Behrman et al. (2012), which finds that financial literacy influences peoples' likelihood of contributing to their pension savings.

Third, contributions on household's myopic behavior. The hypothesis of myopia contrasts with the idea of rationality, and emerges in different contexts. For example, Busse et al. (2013) analyze the choices of car buyers and the relationship with the future fuel costs. They conclude in favor of consumer myopia. Imas et al. (2016) study the investment decisions, and conclude that the past experience of the investor will define if he takes more or less risk. In particular, for realized losses, investors are more prudent, while for paper losses, they tend to act myopically. For the case of mortgages, Basten et al. (2018) study the mortgage decisions for the Swiss market, and find that households are not prudent managers, in the sense that they tend to neglect future interest rate changes when deciding the fixation periods. The case for myopic households is also approached by Mian and Sufi (2014) as one of the causes of overspending, excessive borrowing, and irrational behavior.

The paper is organized as follows. Section 2 discusses the mortgage underwriting under low interest rates. Section 3 presents the case for Portugal and the interest rate decrease in 2008. Section 4 presents the data and empirical strategy. Section 5 provides results and Section 6 concludes.

4.2 Mortgage underwriting, low interest rates and risk-taking

Getting a mortgage is probably the most important financial decision for a household. On the one hand, the choice of the family home depends on how much the bank is willing to lend. On the other hand, for the typical household, mortgage credit will represent the largest debt in the portfolio and will last for most of its life. As a result, when deciding to get a mortgage, households have to balance the willing to get the family home of their dreams and the ability to comply with the set up payments.

In their decision, rational households account for two factors. First, they formulate expectations on their income, the housing market, and the interest rates. Second, they evaluate the contract terms and what it might imply for future mortgage payments. Processing and gathering all this information requires a certain level of financial knowledge that might be difficult for the average household to have. It is, thus, reasonable to assume that, under some circumstances, households might underestimate the loan risk, and get a mortgage with higher risk than initially intended.

Besides household's preferences and the ability to assess mortgage risk, the prevailing market conditions in the country of loan provision also influence mortgage terms. For example, in the U.S, the most common mortgage loan is a fixed-rate mortgage, whereas, in Portugal, most mortgages are adjustable-rate ones with short interest rate adjustment periods. The mortgage supply and predominant loan contracts in the market limit the households' choices.

4.2.1 Mortgage terms, low interest rates and myopic households

Knowing and understanding the mortgage terms is key for proper risk-taking. But how well do households know their mortgage terms? The answer is geographically specific, but is it

possible to gather some insights from the empirical work of Bucks and Pence (2008). Focusing on the U.S. market, the authors compare the distribution of mortgage terms as reported by borrowers to the distributions as reported by lenders. They conclude that most borrowers have a reasonable knowledge about their mortgage terms, but borrowers with ARM seem to underestimate interest rate risk or not know how much the mortgage payment might change. These findings suggest that ARM are more associated with an increased risk-taking, whether due to the complexity of the product or due to the downplay of potential interest rate increases.

And how do households react to low interest rates? According to Mian and Sufi (2014), households tend to overspend in the presence of cheap credit. With low interest rates, the debt burden is apparently lower, and they get more credit to satisfy their preference for present consumption. Many authors recognize this behavior as myopic because households neglect the future impact of their decisions (see, for example, Fabozzi and Modigliani (1992), or Busse et al. (2013)). For the purpose of this paper, I define myopic households in a broader sense that includes: (1) the ones that have a desire to consume immediately; (2) the ones that do not realize how much the mortgage payment can change if interest rates increase; or (3) the ones that are over-optimistic about the future and disregard the long maturity of the loan. In any of the three cases, myopic households tend to borrow excessively and, therefore, assume higher levels of risk. With overspending, households will probably regret their choices in the future, which means that their initial decision is not rational (Mian and Sufi (2014)).

For low interest rates and under the hypothesis of myopic behavior, households borrow excessively independently of the type of mortgage. However, if the predominant mortgage in the market is adjustable-rate, then the consequences of myopia on risk-taking are a bigger motive of concern. With an ARM, myopic households are more exposed to the risk of rising interest rates and, therefore, their probability of default is higher.

The combination of ARM, low interest rates, and myopic households creates the perfect conditions for an increased risk-taking in mortgage underwriting. Nonetheless, this is only possible if, on the supply-side, banks are willing to accept riskier loans. The explanation for

this reaction lies in the argument that, with low interest rates, banks search for yield in the short-term, even if it might lead to higher risk in the future (Jiménez et al. (2014)).

4.2.2 The debt-service ratio and risk-taking

A simple way to evaluate the ability of the household to comply with the mortgage payments is to analyze the ratio of the required monthly payments to its disposable income. This indicator, known as DSR, ideally includes the debt payments and the disposable income of all members of the household.^{2,3} It is frequently used in the loan underwriting process (Johnson and Li (2010)), and has the advantage of being easily understood by households—even by poor financially literate individuals. The downside of using the DSR as a risk metric is that, for an ARM, it is highly sensitive to changes in the interest rates. Moreover, as Johnson and Li (2010) point out, it is difficult to determine a threshold above which borrowing constraints are binding.

In the case of ARM, when interest rates are low, the DSR overestimates the ability of the household to keep up with the payments, as it does not account for the potential increase in interest payments along with the life of the contract. In other words, when the interest payment is relatively small, households might think that they can get a larger loan than they would get if interest rates were high. But, as mortgages have long maturities, interest rates will probably increase during the contract, threatening households' ability to keep up with their monthly payments.

I take advantage of this fragility in the DSR for ARM contracts to analyze mortgage risk-taking. I compare the DSR at underwriting with the alternative DSR under high-interest rates. The next subsection presents the hypotheses development explained through Jane's example.

²The DSR is sometimes referred to as debt-service to income ratio or back-end ratio.

³There are different ways to compute the ratio but the logic is always the same. The debt payments of the household might include automobile loans, consumption loans, mortgages on secondary residences, and others.

4.2.3 Jane's example and hypothesis development

Consider a world with only two possible market interest rate scenarios, $s = \{high, low\}$, and two moments, $t = \{0, 1\}$. At the moment of mortgage origination ($t = 0$), households and banks observe the interest rate in t and do not know the interest rate in $t + 1$. Assume that the interest rate process is i.i.d, meaning that the probability of observing a high or low interest rate in $t + 1$ does not depend on the interest rate observed in t . Both types of agents are risk-neutral.

At $t = 0$, Jane wants to buy a house and asks for an ARM loan. She has to simultaneously decide the house to buy and the loan amount to get. Jane's decision depends on her perceived ability to comply with the monthly payments—which at maximum corresponds to a debt service ratio of 50%. It also depends on whether Jane makes a rational or myopic decision.

Jane gets a mortgage loan: the rational version

Suppose that the market interest rate is *high* and that Jane gets an ARM of €100,000, indexed to the market interest rate plus a spread of 1%, and a debt service ratio of 50%. At $t = 1$, if the interest rate is *high*, Jane's debt service ratio will still be 50% but, if the interest rate is *low*, the debt service will drop to 30%. In either case, Jane does not expect to default.

Alternatively suppose that the market interest rate is *low*, at $t = 0$. If Jane knows that the interest rate might equally be *low* or *high* at $t = 1$, she will get a loan in $t = 0$ such that the potential payment in $t = 1$ does not exceed her maximum monthly capacity. As a result, Jane gets the same €100,000 mortgage indexed to the market interest rate plus a spread of 1% and a debt service ratio of 30%, at $t = 0$. Independently of the initial market interest rate scenario, Jane will always have a debt service ratio of 30% when $s = low$, and of 50% when $s = high$. But, what happens if Jane neglects potential changes in the market interest rates?

Jane gets a mortgage loan: the myopic version

Suppose that the market interest rate is *high*. Jane cannot go above her means so, even if she wants to get a higher mortgage, she can only get a €100,000 mortgage indexed to the market interest rate plus a spread of 1%, and a debt service ratio of 50%.

Now, suppose that the market interest rate is *low*. Jane knows that, if she gets a mortgage of €100,000, indexed to the market interest rate plus a spread of 1% and a debt service ratio of 30%, she will be far from reaching her maximum ability to pay the mortgage in the present. If she neglects the impact of the potential increase in interest rate in $t = 1$, she might be tempted to get a larger mortgage that corresponds to, for example, a debt service ratio of 40%. This allows her to buy a more expensive house that better fits her preferences. At $t = 1$, if the interest rate is *low*, Jane will continue to pay the mortgage but, if the interest rate is *high*, the debt service ratio will exceed the 50% barrier and she will default.

By acting myopically, Jane neglects the potential increase in the cost of the mortgage. She chooses a mortgage that might be above her means, takes more risk and gets over-indebted.

From Jane's example to hypothesis definition

Table 4.1 summarizes the behavior of *Rational Jane* and *Myopic Jane* under the two interest rate scenarios. Column DSR presents Jane's debt service ratio at origination in each scenario. Column SDSR presents Jane's stressed debt service ratio, which corresponds to the maximum debt service ratio that she can observe during the mortgage contract. From this example emerges the strategy to test if households act myopically and succumb to the temptation of cheap credit.

Table 4.1. Jane's behavior in different interest rate scenarios

	<i>s=high</i>		<i>s=low</i>	
	DSR	SDSR	DSR	SDSR
Rational Jane	50%	50%	30%	50%
Myopic Jane	50%	50%	40%	>50%

Let's start with a scenario of *high* interest rates. Both rational and myopic households get similar loans, thus we cannot distinguish them. Now, suppose that there is a change in the market, and interest rates are now *low*:

Rational households: will get mortgages with a SDSR within their maximum ability to keep up with the payments. With cheaper credit, the DSR at origination will be lower. I label this as cash flow effect.

Myopic households: will partially neglect scenarios of *high* interest rates and will want to take advantage of cheap credit in the present. They will get larger amounts and ignore that the SDSR is above their ability to keep a performing loan. I label this as risk effect. Yet, with cheaper credit, the DSR at origination can still be lower. The cash flow effect also shows.

The main hypotheses of the paper derive from the assumption that households are rational and that, in a credit commitment that lasts for approximately thirty years, any change in interest rates level is mostly temporary. Even if households expect that the interest rates will not increase in the short term, they should not disregard the long maturity of the loan. As so:

Hypothesis 1 [H1]: *When the market interest rates decrease, rational households get mortgages with lower debt service ratios. There is a cash flow effect.*

Hypothesis 2 [H2]: *When the market interest rates decrease, rational households get mortgages with similar risk, thus similar stressed debt service ratios. There is no risk change.*

4.3 An outline of the Portuguese mortgage market from 2007 to 2010

Two reasons make Portugal a good case for studying mortgage risk-taking. First, almost 75% of households own a primary residence house, of which 43% have a mortgage.⁴ The most common type of mortgage is an ARM indexed to Euribor rates, and with interest rate adjustments occurring each three to twelve months. Second, in late 2008 and early 2009, the European Central Bank (ECB) significantly reduced the key interest rates, leading to a sharp decrease in Euribor rates.⁵ Portugal was showing the first signs of an economic recession, but, as Portuguese banks had no direct exposure to the subprime crisis, the housing market was still exhibiting some resilience.

One of the critical questions that arise is how independent is the 2008 interest rate cut from the Portuguese housing market dynamics? By 2007 the volume of new mortgage loans was at its historical high. There were some indications that the housing and mortgage markets were slowing down but not dramatically, as the volume of total mortgages continued to increase up to 2011, and the average value of the houses given as collateral did not decrease.⁶ It was only in 2011 and 2012 that the sovereign crisis severely hit Portugal, and the mortgage market almost froze.

This interpretation is in line with the identification of business cycles for the Portuguese economy. Rua (2017) shows that there was a first recessionary period from the first quarter of 2008 to the first quarter of 2009 and a second one starting in the third quarter of 2010.

⁴Source: 2017 Portuguese Household Finance and Consumption Survey by Bank of Portugal.

⁵Before October 15, 2008, the minimum bid rate for the main refinancing operations was 4.25%. From October 2008 to May 2009, the ECB made progressive cuts in the interest rates up to 1% and changed the refinancing operations regime to fixed rate tenders. Changes in the key interest rates led to changes in the Euribor rates. Figure G1 in the Appendix G presents the evolution of the main refinancing operations rate and the 3-month Euribor rate.

⁶In Appendix H, Figure H1 presents the evolution of the volume of total and new mortgages from 2003 to 2013. Figure H2 presents the average value of the houses given as collateral.

Lourenço and Rodrigues (2017) show that the real housing prices declined with the first recessionary period, but slightly correct before the end of 2008. The big fall in housing prices only happened in 2011. As a result, even if the interest rate cut of late 2008 is not the best example of an exogenous event, we can still assume that the Portuguese housing market was sufficiently robust for a couple of years after. For this reason, this study focuses on the period between 2007 and 2010. In 2007-2008 interest rates were high, and in 2009-2010 interest rates were low.⁷

4.4 Data and empirical strategy

4.4.1 Data and descriptive statistics

This paper combines two data sources. I obtain data on mortgage loans from the European DataWarehouse, and data on banking indicators from Moody's Analytics BankFocus.

European DataWarehouse (ED) is a centralized securitization repository for asset-backed securities that stores loan-level data, provided by the ECB, and which includes information on interest rates. Among the different portfolios included in ED's data are asset-backed securities portfolios of Portuguese mortgages. The data represent a sample of the Portuguese mortgage market and are the most comprehensive source of information on mortgage credit. The data include performance details but, to the purpose of this paper, I focus only on loan's characteristics at origination. Due to data quality issues identified in ED database, the selected sample was subject to a previous exercise of standardization.⁸

⁷I could not have studied other events of interest rate decrease (like, for example, the year 2000), because there is no loan level data available.

⁸There are different reasons for data quality issues and some of them are highlighted by European Datawarehouse (2016). For more details, see Section 4.4.2.

To capture the interest rate decrease discussed in Section 4.3, I restrict the sample period to adjustable rate loans indexed to Euribor interest rates and originated between 2007 and 2010. The sample includes loans granted by five Portuguese banks and loan origination information on borrower identifier, loan identifier, origination date, maturity date, term, amount, house value, property identifier, index rate, interest rate spread, and borrower's primary income.⁹ To complement the information directly provided by ED, I calculate the monthly installments at origination and the correspondent maximum monthly installment previewed according to the European Parliament Directive 2014/17/EU.^{10,11} With these two additional variables, I compute the DSR and the SDSR. The first corresponds to the monthly installment per euro of monthly primary income, and the second corresponds to the maximum monthly installment per euro of monthly primary income. I also compute the loan-to-value (LTV) as the ratio of the loan amount to house value, and the loan-to-income ratio (LTI) as the loan amount per euro of annual primary income.¹²

Table 4.2 presents summary statistics of the 55,804 mortgages included in the sample. On average the loan amount is €117,780, the house value is €136,287, and the original contract term is 39 years. With an average annual primary income of €27,950, borrowers agree on a average DSR of 39.61%, and SDSR of 65.12%. On average the loan amount corresponds to 88.61% of the house value and to 9 times the primary income.¹³

Are securitized mortgages a representative sample? The distribution of data among the four

⁹The banks included in the sample are Banco BPI, Banco Santander, Banco Espírito Santo, Caixa Geral de Depósitos, and Montepio Geral.

¹⁰As the credit decision is prior to the origination of the mortgage, I lag the indexed rate one month and consider the average monthly rate in $t - 1$.

¹¹As a reaction to the concerns on irresponsible lending and borrowing practices on residential mortgage credit, the European Parliament has adopted the Directive 2014/17/EU. This Directive sets a framework for certain aspects of the laws, regulations, and administrative provisions, which includes the communication of pre-contractual information through the European Standardized Information Sheet (ESIS). For ARM, the ESIS sets that the lender shall inform the household about the sensitivity of the installments to changes in interest rates, namely the simulation of its value with the highest rate in the last twenty years, or the longest period possible.

¹²Ideally, one would want to include the income of all members of the household. However, given that many banks do not report borrower's secondary income, I decide to compute the DSR, the SDSR, and the LTI based on borrower's primary income.

¹³For more details on summary statistics by year, see Appendix I.

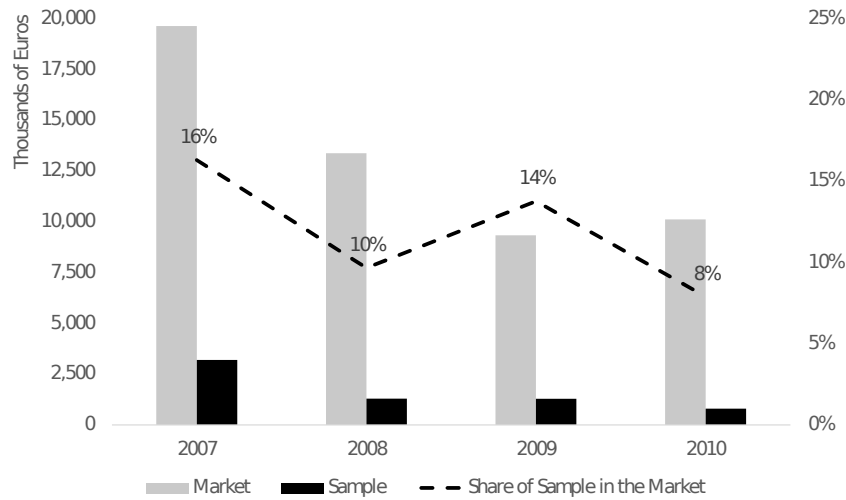
Table 4.2. Summary statistics

	mean	median	Description
DSR	39.61	33.88	Debt service ratio (pp)
SDSR	65.12	57.97	Stressed debt service ratio (pp)
Amount	117,780	106,000	Mortgage amount (€)
House Value	136,287	120,000	House Value (€)
Term	469	481	Term (months)
Primary Income	27,950	17,663	Borrower's annual primary income (€)
LTV	88.61	90.16	Loan-to-value ratio (pp)
LTI	9.33	7.01	Loan-to-income ratio
Observations	55,804		
	sd	min	max
DSR	27.75	0.04	596.28
SDSR	42.42	0.06	760.73
Amount	58,010	25,000	1,500,000
House Value	72,968	50,000	4,480,000
Term	106.01	48.00	610.76
Primary Income	100,386	5,642	11,606,201
LTV	18.13	2.42	429.17
LTI	11.37	0.01	417.32

years reveals a fair approximation to the Portuguese mortgage market as it includes around 13% of the volume of new mortgages in the period. Figure 4.1 compares the volume of the new mortgages included in the sample in each year with the volume of mortgages granted in the entire market. The share in the sample varies from 8 to 16% of the volume granted in each year.

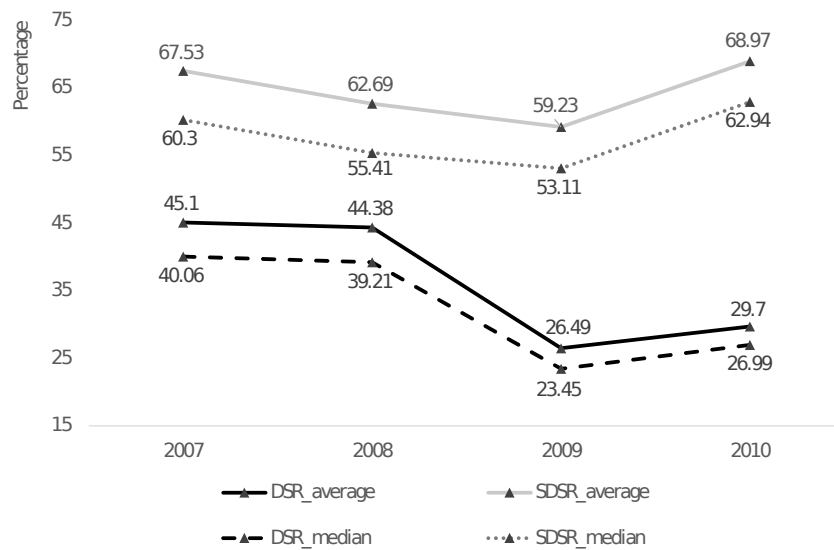
Figure 4.2 shows a first inspection on the trend of DSR and SDSR by year. Both the average and median DSR dropped in 2009 and 2010, which is consistent with the idea of a cash flow effect for low interest rates. The average and median SDSR dropped in 2009 and increased

Figure 4.1. Volume of new mortgages in the sample vs. the market



This figure compares the volume of new mortgages included in the sample (black) to the volume of new mortgage granted in Portugal (light gray). The dash line is the respective share that varies between 8 to 16%.

Figure 4.2. Yearly average and median values of the DSR and SDSR



This figure presents the yearly average and median values of the DSR and SDSR for the mortgages in the sample. In the low interest rate period (2009 and 2010) the DSR dropped more than one third of its value, while the SDSR does not show a clear pattern.

considerably in 2010. The latter suggests that households took more risks.

As for the second data source, Moody's Analytics BankFocus, I collect banking indicators on the five Portuguese banks to control for lender characteristics.¹⁴ With these data, I compute:

¹⁴The low number of banks considered results from the combination of few financial institutions operating in the Portuguese mortgage market, of which only part securitize mortgages and have loan data on ED. There are also some restrictions

(1) the equity ratio as equity over total assets (equity ratio); (2) the liquidity ratio as cash and balances with central banks over total assets (liquidity ratio); (3) the deposits ratio as customer's deposits over total assets (deposits ratio); and (4) the loans-to-deposits ratio as gross loans over customer's deposits (loans to deposits).

4.4.2 Data caveats and opportunities

ED dataset provides a unique opportunity to study mortgage level data that usually are not available for research. Despite the ED's effort in improving the quality of the submitted data, some drawbacks in the standardization of data still make it difficult to use loan level data.¹⁵ The first obstacle is that ED provides information by residential mortgage-backed securities (RMBS) deal and, to create an origination dataset, one needs to combine all ED reports and keep only one record for each loan. The second obstacle is that ED does not integrate the historical information on each RMBS deal, meaning that the standardization of information is not assured.¹⁶ A third obstacle is that, at least for Portugal, mortgages often split into more than one operation for the same collateral. In the ED database, no identifier allows merging into a single exposure.

There are other issues in the standardization of information. Although ECB provides the submission templates with detailed instructions for banks, not all banks have interpreted it in the same way. After a complex exercise of standardization that follows strict rules, I have managed to create a loan origination dataset from 2007 to 2010.¹⁷

on the availability of data on Moody's Analytics BankFocus.

¹⁵ED collects, validates, and distributes loan-level data for residential mortgage-backed securities (RMBS). Mortgage data are grouped by RMBS deal and is frequently updated to allow the valuation of the traded securities

¹⁶For example, consider a RMBS issued by bank A. At a point in time, bank B merges with bank A and changes the format of the bank's A Loan Id to bank's B format. ED does not standardize this Loan Id, so it not possible to immediately follow the loan.

¹⁷Details on the standardization process available in the online appendix at <https://anaisabeldesa.wordpress.com/40-2/research/research/>.

4.4.3 Empirical strategy

Do low interest rates spur risk-taking in mortgage underwriting? To discuss this question, the first thing that one needs to keep in mind is that most empirical strategies that apply to the study of credit to firms are no valid for studying mortgage credit. While the firm's credit exposure includes various loans and changes according to the firm's needs, the household's exposure to mortgage credit emerges from a single loan. As a result, instead of having a panel data on firms that allows the study of changes in loan volumes, I have a combination of cross-section data on households and panel data on banks and time. This means that the empirical strategy usually followed for studying the risk-taking channel with firm data does not suit this paper (see, for example, Jiménez et al. (2014) and Bonfim and Soares (2018)).¹⁸

The novelty of this paper is how it takes advantage of mortgage credit specificity to establish the identification.¹⁹ The empirical strategy follows the hypotheses presented in Section 4.2.3, and considers that the main variables for assessing the households behavior towards risk are the DSR and the SDSR. Ideally, one would want to observe the two ratios from the moment of the loan application to the final outcome of loan denial or origination, so as to disentangle mortgage demand and supply effects. However, given the unavailability of data, I can only assess the overall effect of interest rates on mortgage risk-taking.

The following two subsections detail the baseline model and the extension with banks' characteristics.

4.4.3.1 Baseline model

The time frame of the study includes two years of high interest rates and two years of low interest rates. The identification strategy departs from a risk threshold that allows the

¹⁸The empirical strategy of these papers departs from three-dimensional panel data: firm, bank, and time.

¹⁹Buying a house is simultaneously associated with basic needs fulfillment and life goals. Thus, the demand for a mortgage is different from the ones of any other loan. Besides, mortgages have long maturities, and (in Portugal) are mainly ARM.

comparison of loan risk across the time frame. The objective of this risk threshold is not to provide information on the absolute risk of the loan, but rather on its comparative risk.

Many studies suggest the existence of a DSR threshold above which loans become too risky (see, for example, Greninger et al. (1996), Quercia et al. (2003), Georgarakos et al. (2010), and May and Tudela (2011)). However, it is not definite what that threshold is, and, ultimately, it depends on how the ratio was determined.²⁰ To overcome this difficulty, I determine the threshold as the median value in the sample. The median is the measure of central tendency that best fits the purpose of defining comparative risk without being affected by outliers.

Given the uneven distribution of data among years, I compute the median DSR and the median SDSR by year, and aggregate it as a simple average. The threshold for the DSR is 32.43% and the SDSR is 57.94%.²¹ I then create two dummy variables—dDSR and dSDSR—that take the value one when the ratio of the loan is above the threshold, and zero otherwise. With these binary variables, I classify the risk of each loan relative to the sample and apply a logit model to estimate the probability of a loan being above each threshold, conditional on loan characteristics.

As some loan characteristics might be jointly determined, I previously inspect multicollinearity issues. Table 4.3 presents the correlation matrix of the loan characteristics available in the dataset. The bold values are problematic for the model specification.²² From the six variables available, I choose to include only three: the Log(Primary Income), the LTV ratio, and the LTI ratio.

²⁰For example, the DSR can include only the mortgage payment or the mortgage payments plus any other loan of the household.

²¹With this approach I avoid over-representation bias. As robustness checks, I have also computed two alternative thresholds: (1) the median value of the entire sample; and (2) the weighted average of the median value by year. Both alternatives produce similar qualitative results.

²²I consider as problematic any correlation with an absolute value above 0.3.

Table 4.3. Loan characteristics: correlation matrix

	Log (Amount)	Log (House Value)	Term	Log (Primary Income)	LTV	LTI
Log(Amount)	1.000					
Log(House Value)	0.750	1.000				
Term	0.181	-0.040	1.000			
Log(Primary Income)	0.229	0.323	-0.193	1.000		
LTV	0.438	-0.224	0.303	-0.083	1.000	
LTI	0.146	0.057	0.157	-0.079	0.135	1.000

Equation (4.1) sets the specification of the binary logit model on the probability of a loan being above the DSR threshold, and Equation (4.2) sets the equivalent for SDSR threshold

$$P(dDSR_{i,j,t} = 1 | \Theta_i) = F_L(\beta_{10} + \beta_{11}LowInterest_t + \beta_1\Theta_i + \Omega_{1j}), \quad (4.1)$$

$$P(dSDSR_{i,j,t} = 1 | \Theta_i) = F_L(\beta_{20} + \beta_{21}LowInterest_t + \beta_2\Theta_i + \Omega_{2j}), \quad (4.2)$$

for loan i , bank j , and year t . F_L is the cumulative logistic distribution function, $LowInterest_t$ is a dummy variable equal to one if the loan was originated in a period of low interest rates, Θ_i is a vector of loan characteristics, and Ω_j are bank-fixed effects to control for heterogeneity in banks' characteristics and respective influence in credit decision (Gambacorta (2008)).²³ I cluster the residuals by bank because the error terms can exhibit a potentially time-varying bank component from changes in bank's strategies.

Under H1, when the market interest rates decrease, rational households get mortgages with lower debt service ratios (cash flow effect). This means that in periods of low interest rates ($LowInterest = 1$) the probability of being above the DSR threshold should be lower

²³Following the events described in Section 4.3 and Appendix G, I consider 2007 and 2008 as a high interest rate period ($LowInterest = 0$) and 2009 and 2010 as a low interest rate period ($LowInterest = 1$).

($\beta_{11} < 0$). On the other hand, under H2, when the market interest rates decrease rational households get mortgages with similar risk and similar stressed debt service ratio (no risk change). This means that the interest rate regime (*LowInterest*) should not influence the probability of the loan SDSR being above its threshold ($\beta_{21} = 0$). Table 4.4 summarizes the expected results under the assumption that households are rational.

Table 4.4. Hypothesis testing

	H1 (cash flow effect)	H2 (no risk change)
Rational households	$\beta_{11} < 0$	$\beta_{21} = 0$

4.4.3.2 Interaction with banks' characteristics

The baseline approach focuses on households' behavior and accounts for time-invariant bank heterogeneity through bank-fixed effects. Yet, it is silent on how a specific characteristic of a bank may influence the mortgage risk-taking, as a consequence of searching for yield in a low interest rate environment.

As disclosed before, with the data available it is not possible to disentangle the demand and supply effects, so that one cannot take conclusions on the search for yield. Nonetheless, it is possible to present some insights into how differences in banks' characteristics may restrict (or not) the baseline results. I interact the low interest rate dummy with bank characteristics associated with traditional channels of monetary-policy transmission, while keeping the bank-fixed effects. Equations (4.3) and (4.4) set the specification with the interaction with banks' characteristics

$$P(dDSR_{i,j,t} = 1|\Theta_i) = F_L(\alpha_{10} + \alpha_{11}LowInterest_t \times BankCharacteristic_j + \alpha_1\Theta_i + \Omega_{1j}), \quad (4.3)$$

$$P(dSDSR_{i,j,t} = 1|\Theta_i) = F_L(\alpha_{20} + \alpha_{21}LowInterest_t \times BankCharacteristic_j + \alpha_2\Theta_i + \Omega_{2j}), \quad (4.4)$$

for loan i , bank j , and year t . The variable *BankCharacteristic* measures the bank's exposure prior to the change to low interest rates. I consider four key bank characteristics: (1) the equity ratio; (2) the liquidity ratio; (3) the deposits ratio; and (4) the loans-to deposits ratio.²⁴

4.5 Results

4.5.1 Baseline model results

Table 4.5 presents the logit estimation of Equations (4.1) and (4.2), with and without loan characteristics. As for the cash flow effect in periods of low interest rates, the probability of being above the median DSR is lower than in periods of high interest rates ($\beta_{11} < 0$), meaning that, we cannot reject H1 (i.e. we cannot reject that households are rational). As for the no risk change, in periods of low interest rates, the probability of being above the median SDSR is higher than in periods of high interest rates ($\beta_{21} > 0$), therefore, we reject H2 (i.e. we reject that households are rational). With lower interest rates, households take more risk.

²⁴Appendix J presents the correlation between each bank characteristic and the bank-fixed effects. With the exception of the liquidity ratio, there is no reason to suspect of multicollinearity issues.

Table 4.5. Effect of low interest rate

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Low Interest Rate	-1.2490*** (0.0594)	-2.2366*** (0.0961)	0.1044* (0.0470)	0.4345*** (0.1022)
Log(Primary Income)		-3.8429*** (0.0837)		-3.9682*** (0.1008)
LTV		0.0379*** (0.0059)		0.0428*** (0.0052)
LTI		0.0386** (0.0141)		0.0559*** (0.0157)
Bank FE	yes	yes	yes	yes
Observations	55,804	55,804	55,804	55,804
Pseudo R^2	0.0990	0.5225	0.0371	0.4988

Standard errors clustered by bank in parentheses

⁺ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4.6. Marginal effects of low interest rate at the means

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Low Interest Rate	-0.2873*** (0.0128)	-0.2516*** (0.0118)	0.0247* (0.0111)	0.0475*** (0.0107)

Standard errors clustered by bank in parentheses

⁺ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

To better understand the estimation results, Table 4.6 presents the marginal effects of low interest rates taken at the means of the other variables. For two hypothetical mortgages with average values on Primary Income, LTV, and LTI, the predicted probability of being above the DSR median is 25 to 29 percentage points lower for the mortgage originated in a period of low interest rates than for the one granted in a period of high interest rates. Yet, for the same two hypothetical mortgages, the predicted probability of being above the SDSR median is 2 to 5

percentage points greater for the mortgages originated in a period of low interest rates.

Recall Jane's example described in Section 4.2.3. Both rational and myopic Jane would look for loans with lower DSR when interest rates were low. By not rejecting H1, we cannot say if households behave rationally or myopically. In the end, the decrease in DSR is a direct effect of the reduction in the cost of borrowing, which implies lower monthly payments in the present.

Rejecting H2 is the key result of the paper, which allows distinguishing *Rational Jane* from *Myopic Jane*. If households increase the SDSR when interest rates are low, this means that they are taking more risk, and not equally considering that, during the long life of the contract, interest rates can increase. In this scenario, the monthly payment might become too high in the future. This finding rejects the hypothesis of keeping the same risk level under different interest rate environments and suggests that households behave myopically when tempted with cheap credit.

Nevertheless, the results do not explain why households behave in this way. Is it because they prefer present consumption and are myopic in the strict sense of the word? Or is it because they lack financial knowledge and disregard the potential increase in interest rates? A survey-based study applied to both high and low interest-rate environments would be the best approach to answer these questions.

4.5.2 Interaction with banks' characteristics results

As for the logit estimation of Equations (4.3) and (4.4), with and without loan characteristics, Table 4.7 presents the marginal effects of low interest rates taken at the means of the other variables.²⁵ When considering the interaction with banks' characteristics, I obtain sim-

²⁵Appendix K presents the regression results for each interaction.

ilar qualitative results to the baseline model, as for the lower (higher) probability of the DSR (SDSR) being above the threshold, under low interest rates. In particular, banks with high equity, high liquidity ratios, high deposits ratios, and high loans to deposits are more likely to provide mortgages with SDSR above the threshold, when interest rates are low.

Table 4.7. Marginal effects of the banks' characteristics interactions at the means

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Equity Ratio x Low Int	-0.0520*** (0.0026)	-0.0445*** (0.0027)	0.0043 ⁺ (0.0023)	0.0091*** (0.0021)
Liquidity Ratio x Low Int	-0.1193** (0.0419)	-0.1048*** (0.0311)	0.0160** (0.0053)	0.0245*** (0.0033)
Deposits Ratio x Low Int	-0.0053*** (0.0004)	-0.0046*** (0.0003)	0.0006* (0.0002)	0.0010*** (0.0002)
Loans to Deposits x Low Int	-0.0017*** (0.0002)	-0.0015*** (0.0002)	0.0001 ⁺ (0.0001)	0.0003*** (0.0001)

Standard errors clustered by bank in parentheses

⁺ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Regardless, the small number of banks and years requires caution in the interpretation of these results. Ideally, one would want to include in the same regression the *BankCharacteristic*, the *LowInterest*, the *LowInterest* $\times$ *BankCharacteristic*, and the bank-fixed effects. With this approach I could disentangle the effects of the bank characteristics before and after the interest rate cut. However, given the small number of banks and years, I could not rely on the coefficient estimates due to multicollinearity issues. The strategy followed in Section 4.4.3.2 is the best possible for the sample size. But it does not provide a definite answer on the impact of bank characteristics on mortgage risk-taking.

4.6 Conclusions

In this paper, I analyze the effect of a decrease in the interest rates on mortgage risk-taking at underwriting. Low interest rates might tempt households to overspend, ask for higher loans, and buy more expensive houses. If they give in to temptation, they will be more indebted and will take more risks. I focus on the case of Portugal because most mortgages are indexed to Euribor rates, which makes Portuguese households more exposed to changes in the interest rates.

I find that, under low interest rates, the debt-service ratio of new mortgages is lower, which reflects the reduction in the cost of borrowing. In particular, the probability of having a ratio greater than the sample median is 25 to 29 percentage points lower for loans originated in a low interest rate period. On the other hand, I find that the stressed debt-service ratio is higher under the same environment, which reflects a higher exposure to future increases in the interest rates. In particular, the probability of having a ratio greater than the sample median is 2 to 5 percentage points higher for loans originated in a low interest rate period.

These results indicate that households take more risk under low interest rates and suggest that the mortgage decision might not be rational. With cheap credit, households behave myopically, whether due to preference for present consumption or lack of knowledge about the terms and risks of the contract.

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Appendices

Appendix A - Classification of states by mortgage law aspect

This appendix presents the current classification of states by mortgage law aspect, as well as the changes from 2000 to 2016. The column *Judicial* describes the foreclosure procedure classification, where *Judicial* = 1 represents mandatory judicial foreclosures. The column *NonRecourse* describes the restrictions on deficiency judgments, where *NonRecourse* = 1 means that deficiency judgments are not allowed.

Table A1. Mortgage law by state

State		Time	Judicial	NonRecourse
ALABAMA	AL	all	0	0
ALASKA	AK	all	0	1
ARIZONA	AZ	all	0	1
ARKANSAS	AR	all	0	0
CALIFORNIA	CA	all	0	1
COLORADO	CO	all	0	0
CONNECTICUT	CT	all	1	0
DELAWARE	DE	all	1	0
DIST. OF COLUMBIA	DC	up to 2010	0	0
DIST. OF COLUMBIA	DC	2011 onward	1	0
FLORIDA	FL	all	1	0
GEORGIA	GA	all	0	0
HAWAII	HI	up to 2010	0	0
HAWAII	HI	2011 onward	1	0
IDAHO	ID	all	0	0
ILLINOIS	IL	all	1	1
INDIANA	IN	all	1	0

Table A1. Mortgage law by state (cont.)

IOWA	IA	all	0	1
KANSAS	KS	all	1	0
KENTUCKY	KY	all	1	0
LOUISIANA	LA	all	1	0
MAINE	ME	all	1	0
MARYLAND	MD	all	1	0
MASSACHUSETTS	MA	all	0	0
MICHIGAN	MI	all	0	0
MINNESOTA	MN	all	0	1
MISSISSIPPI	MS	all	0	0
MISSOURI	MO	all	0	0
MONTANA	MT	all	0	1
NEBRASKA	NE	all	0	0
NEVADA	NV	up to 2009	0	0
NEVADA	NV	2010 onward	0	1
NEW HAMPSHIRE	NH	all	0	0
NEW JERSEY	NJ	all	1	0
NEW MEXICO	NM	all	1	0
NEW YORK	NY	all	1	0
NORTH CAROLINA	NC	all	0	1
NORTH DAKOTA	ND	all	1	1
OHIO	OH	all	1	0
OKLAHOMA	OK	all	1	0
OREGON	OR	all	0	1
PENNSYLVANIA	PA	all	1	0
RHODE ISLAND	RI	all	0	0
SOUTH CAROLINA	SC	all	1	0
SOUTH DAKOTA	SD	all	1	0

Table A1. Mortgage law by state (cont.)

TENNESSEE	TN	all	0	0
TEXAS	TX	all	0	1
UTAH	UT	all	0	0
VERMONT	VT	up to 2006	0	0
VERMONT	VT	2007 onward	1	0
VIRGINIA	VA	all	0	0
WASHINGTON	WA	all	0	1
WEST VIRGINIA	WV	all	0	0
WISCONSIN	WI	all	1	1
WYOMING	WY	all	0	0

Appendix B - Comparison of classification of states by mortgage law aspect

This appendix presents the comparison of classification of states by mortgage law aspect across different sources and studies, namely Mian et al. (2015), Ghent and Kudlyak (2011), and RealtyTrac.com²⁶. Table B1 shows the differences in the classification of foreclosure procedure. Table B2 shows the differences in the classification of restrictions on deficiency judgments.

²⁶Data available on <https://www.realtytrac.com/real-estate-guides/foreclosure-laws/> as of January, 28 2020.

Table B1. Differences in the classification of Judicial Foreclosure

State		This study	Mian et al (2015)	Ghent and Kudlyak (2011)	Realty Trac.com	Justification
DIST. OF COLUMBIA	DC	0/1	0	0	0	The change in the judicial foreclosure requirement in the District of Columbia started with the "Saving D.C. Homes from Foreclosures Emergency Amendment Act of 2010" effective on November, 17 2010. During the discussion period the majority of residential foreclosure activity become judicial due to the risks involved. After some changes, the Act became law on November 4, 2013.
HAWAI	HI	0/1	0	0	0	With the "Act48" SLH 2011 of May, 5 2011, lenders were discouraged to pursue nonjudicial foreclosures. Most foreclosures become judicial.

Table B1. Differences in the classification of Judicial Foreclosure (cont.)

MASSACHUSETTS	MA	0	1	0	1	Foreclosures in Massachusetts require a two-stage procedure. First, a judgment from the land court declaring that the mortgagors are not under protection of the Service members Civil Relief Act (SCRA). Second, a nonjudicial or judicial foreclosure depending on the existence of a power of sale clause. I consider the first stage as not significant for the classification of judicial and nonjudicial foreclosure, meaning that, following the criteria on the other states I classify Massachusetts as a state that does not require judicial foreclosure.
NEBRASKA	NE	0	1	0	1	Nebraska allows for nonjudicial foreclosures for a deed of trust, but requires judicial foreclosure for mortgages. As in this paper I use a broad definition of mortgage that includes the deeds of trust, and following the criteria on the other states, I classify Nebraska as a state that does not require judicial foreclosure.
OKLAHOMA	OK	1	0	0	1	Oklahoma allows for nonjudicial foreclosures but are extremely rare, due to certain restrictions. As most foreclosures are judicial, I classify Oklahoma as a state that requires judicial foreclosure.

Table B1. Differences in the classification of Judicial Foreclosure (cont.)

SOUTH DAKOTA	SD	1	0	0	1	South Dakota allows for nonjudicial foreclosures but are frequently not used, due to uncertainty in the foreclosure process. As most foreclosures are judicial, I classify South Dakota as a state that requires judicial foreclosure.
VERMONT	VT	0/1	1	1	1	After 2006, nonjudicial foreclosures were discouraged in Vermont due to a revision of the foreclosure statute. The 2006 foreclosure statute establishes that nonjudicial foreclosures are only possible if there is no equity in the subject property, which is burdensome to prove. I classify Vermont as a state that does not require judicial foreclosure up to 2006 and as a state that requires judicial foreclosure from 2007 onward.
WISCONSIN	WI	1	0	1	1	Although Wisconsin allows for nonjudicial foreclosures, most foreclosures are judicial.

Table B2. Differences in the classification of Non-recourse

State		This study	Ghent and Kudlyak (2011)	Justification
ILLINOIS	IL	1	0	Ghent and Kudlyak (2011) recognize that deficiency judgments are rarely granted, but classify the state as recourse by arguing that the possibility of personal recourse may be enough to deter strategic default. I do not follow their argument because the judicial approval of the property sale frequently implies that the lender waves her right to a deficiency judgment. If the sale is conditional on waving the deficiency judgments, then the lender is not protected by personal recourse.
TEXAS	TX	1	0	Ghent and Kudlyak (2011) recognize that the state law allows deficiency judgments, even if the large homestead exemption may be an obstacle. I do not follow their argument because besides the almost unlimited homestead exemption, deficiency judgments are frequently noncollectable due to the fact that the borrower is "judgment proof".

Appendix C - Orthogonality of mortgage law differences to social and economic conditions

This appendix presents the results of the univariate regressions of a set of state attributes on the mortgage law aspects. Table C1 shows if judicial states also significantly differ in other economic and social attributes. Table C2 shows if non-recourse states also significantly differ in other economic and social attributes.

Table C1. Orthogonality of Judicial Foreclosure Requirement

	Judicial	N	R^2
<i>Demographics and Income Variables</i>			
Fraction with 65 years or more, 2008-14	0.0106 * (0.0043)	47	0.108
Fraction with less than high school, 2008-14	-0.0058 (0.0077)	47	0.011
Black fraction, 2008-14	0.0270 (0.0282)	47	0.020
Hispanic fraction, 2008-14	-0.0054 (0.2979)	47	0.001
Poverty fraction, 2008-14	-0.0005 (0.0090)	47	0.000
Fraction with personal income less than \$25k, 2008-14	-0.0060 (0.1070)	47	0.007
Fraction with household income less than \$25k, 2008-14	0.0039 (0.0120)	47	0.002
Fraction with income less than \$25k, 2008-14	0.0029 (0.0119)	47	0.001
Unemployment rate, 2008-14	-0.0025 (0.0045)	47	0.006

Table C1. Orthogonality of Judicial Foreclosure Requirement (cont.)

	Judicial	N	R ²
<i>GDP Variables</i>			
Real GDP per capita annual growth, 2000	-0.0029 (0.0077)	47	0.003
Real GDP per capita annual growth, 2002	0.0042 (0.0068)	47	0.011
Real GDP per capita annual growth, 2004	-0.0008 (0.0050)	47	0.001
Real GDP per capita annual growth, 2006	-0.0021 (0.0065)	47	0.002
Real GDP per capita annual growth, 2008	0.0041 (0.0074)	47	0.007
Real GDP per capita annual growth, 2010	0.0050 (0.0065)	47	0.013
Real GDP per capita annual growth, 2012	0.0093 (0.0104)	47	0.022
Real GDP per capita annual growth, 2014	0.1039 (0.0052)	47	0.089
Real GDP per capita, 2000	1326 (2614)	47	0.006
Real GDP per capita, 2002	1850 (2581)	47	0.012
Real GDP per capita, 2004	1888 (2635)	47	0.012
Real GDP per capita, 2006	1367 (2808)	47	0.005
Real GDP per capita, 2008	1219 (2870)	47	0.004
Real GDP per capita, 2010	1916 (2909)	47	0.009
Real GDP per capita, 2012	2601 (3122)	47	0.015

Table C1. Orthogonality of Judicial Foreclosure Requirement (cont.)

	Judicial	N	R^2
Real GDP per capita, 2014	2748 (3048)	47	0.018
Real GDP per capita, 2016	1951 (2922)	47	0.010
<i>Housing Market Variables</i>			
House price growth, 2000	0.0046 (0.1251)	47	0.003
House price growth, 2002	0.0105 (0.0142)	47	0.012
House price growth, 2004	0.0101 (0.0200)	47	0.006
House price growth, 2006	-0.0070 (0.1329)	47	0.005
House price growth, 2008	0.0097 (0.0163)	47	0.008
House price growth, 2010	0.0089 (0.0095)	47	0.019
House price growth, 2012	-0.0277 ** (0.0091)	47	0.161
House price growth, 2014	-0.1372 * (0.0064)	47	0.087
House price growth, 2016	-0.1044 (0.0081)	47	0.034
Manufactured housing shipping annual growth, 2000	0.0578 (0.0521)	47	0.024
Manufactured housing shipping annual growth, 2002	0.0566 (0.0389)	47	0.046
Manufactured housing shipping annual growth, 2004	0.0184 (0.0576)	47	0.002
Manufactured housing shipping annual growth, 2006	0.0397 (0.0539)	47	0.010
Manufactured housing shipping annual growth, 2008	0.0474 (0.0622)	47	0.013

Table C1. Orthogonality of Judicial Foreclosure Requirement (cont.)

	Judicial	N	R^2
Manufactured housing shipping annual growth, 2010	0.0893 (0.1133)	47	0.016
Manufactured housing shipping annual growth, 2012	-0.2223 (0.3176)	47	0.012
Manufactured housing shipping annual growth, 2014	0.2395 (0.2948)	47	0.019
Manufactured housing shipping annual growth, 2016	-0.0561 (0.0813)	47	0.010
<i>Mortgage Market Variables</i>			
Mortgage debt balance per capita (excl. HELOC), 2004	-3060 (2332)	47	0.034
Mortgage debt balance per capita (excl. HELOC), 2006	-3469 (30594)	47	0.024
Mortgage debt balance per capita (excl. HELOC), 2008	-4245 (35645)	47	0.029
Mortgage debt balance per capita (excl. HELOC), 2010	-3176 (3115)	47	0.022
Mortgage debt balance per capita (excl. HELOC), 2012	-2755 (2993)	47	0.018
Mortgage debt balance per capita (excl. HELOC), 2014	-2842 (2756)	47	0.022
Mortgage debt balance per capita (excl. HELOC), 2016	-2965 (2731)	47	0.024
Mortgage delinquency rate, Q42004	0.0020 (0.0017)	47	0.031
Mortgage delinquency rate, Q42006	0.0023 (0.0014)	47	0.059
Mortgage delinquency rate, Q42008	0.0044 (0.0063)	47	0.013
Mortgage delinquency rate, Q42010	0.0114 (0.0098)	47	0.034
Mortgage delinquency rate, Q42012	0.0186 * (0.0077)	47	0.140

Table C1. Orthogonality of Judicial Foreclosure Requirement (cont.)

	Judicial	N	R^2
Mortgage delinquency rate, Q42014	0.0133 ** (0.0043)	47	0.213
Mortgage delinquency rate, Q42016	0.0074 *** (0.0018)	47	0.304

This tables presents coefficients of the univariate regression for x_i variable on *Judicial* dummy. Standard errors are heteroskedasticity robust. Coefficients marked with ***, **, * and + are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively.

States subject to changes in the mortgage law not included in the regressions. Data sources: Demographics and income variables from Current Population Survey (CPS), GDP variables from Bureau of Economic Analysis (BEA), house price growth from Zillow - (Single Family Residence), manufactured housing shipping annual growth from Institute for Building Technology & Safety (IBTS), and mortgage market variables from State Level Household Debt Statistics 2003-2017, Federal Reserve Bank of New York.

Table C2. Orthogonality of Non-recourse law

	Non-recourse	N	R^2
<i>Demographics and Income Variables</i>			
Fraction with 65 years or more, 2008-14	-0.0104 + (0.0055)	47	0.085
Fraction with less than high school, 2008-14	-0.0046 (0.0109)	47	0.006
Black fraction, 2008-14	-0.0613 * (0.0243)	47	0.083
Hispanic fraction, 2008-14	0.0520 (0.0399)	47	0.054
Poverty fraction, 2008-14	-0.0047 (0.0095)	47	0.005

Table C2. Orthogonality of Non-recourse law (cont.)

	Non-recourse	N	R^2
Fraction with personal income less than \$25k, 2008-14	-0.0120 (0.0110)	47	0.022
Fraction with household income less than \$25k, 2008-14	-0.0150 (0.1132)	47	0.027
Fraction with income less than \$25k, 2008-14	-0.0082 (0.0111)	47	0.008
Unemployment rate, 2008-14	0.0019 (0.0055)	47	0.003
<i>GDP Variables</i>			
Real GDP per capita annual growth, 2000	0.0018 (0.0091)	47	0.001
Real GDP per capita annual growth, 2002	0.0031 (0.0057)	47	0.005
Real GDP per capita annual growth, 2004	0.0017 (0.0058)	47	0.002
Real GDP per capita annual growth, 2006	0.0087 (0.0066)	47	0.029
Real GDP per capita annual growth, 2008	-0.0006 (0.0084)	47	0.000
Real GDP per capita annual growth, 2010	-0.0007 (0.0077)	47	0.000
Real GDP per capita annual growth, 2012	0.0256 + (0.0144)	47	0.137
Real GDP per capita annual growth, 2014	0.0042 (0.0061)	47	0.012
<i>GDP Variables (cont.)</i>			
Real GDP per capita, 2000	1266 (2575)	47	0.005
Real GDP per capita, 2002	1261 (2641)	47	0.004

Table C2. Orthogonality of Non-recourse law (cont.)

	Non-recourse	N	R^2
Real GDP per capita, 2004	1468 (2529)	47	0.006
Real GDP per capita, 2006	2290 (2746)	47	0.012
Real GDP per capita, 2008	3064 (2886)	47	0.020
Real GDP per capita, 2010	3146 (3071)	47	0.021
Real GDP per capita, 2012	5392 (3536)	47	0.054
Real GDP per capita, 2014	5576 (3372)	47	0.061
Real GDP per capita, 2016	5206 (3047)	47	0.056
<i>Housing Market Variables</i>			
House price growth, 2000	-0.0074 (0.0162)	47	0.005
House price growth, 2002	-0.0071 (0.0139)	47	0.004
House price growth, 2004	0.0106 (0.0213)	47	0.005
House price growth, 2006	-0.0018 (0.0139)	47	0.000
House price growth, 2008	-0.0135 (0.0214)	47	0.012
House price growth, 2010	-0.0065 (0.0121)	47	0.008
House price growth, 2012	0.0272 * (0.0133)	47	0.127
House price growth, 2014	0.0104 (0.0071)	47	0.041
House price growth, 2016	0.0088 (0.0105)	47	0.020

Table C2. Orthogonality of Non-recourse law (cont.)

	Non-recourse	N	R^2
<i>Housing Market Variables (cont.)</i>			
Manufactured housing shipping annual growth, 2000	-0.0027 (0.0562)	47	0.000
Manufactured housing shipping annual growth, 2002	0.0067 (0.0355)	47	0.001
Manufactured housing shipping annual growth, 2004	-0.0742 (0.0553)	47	0.030
Manufactured housing shipping annual growth, 2006	0.0347 (0.0575)	47	0.007
Manufactured housing shipping annual growth, 2008	-0.0274 (0.0788)	47	0.004
Manufactured housing shipping annual growth, 2010	0.2103 (0.1582)	47	0.072
Manufactured housing shipping annual growth, 2012	0.2080 (0.3176)	47	0.008
Manufactured housing shipping annual growth, 2014	-0.2128 (0.1777)	47	0.012
Manufactured housing shipping annual growth, 2016	0.0543 (0.0863)	47	0.008
<i>Mortgage Market Variables</i>			
Mortgage debt balance per capita (excl. HELOC), 2004	2851 (2794)	47	0.024
Mortgage debt balance per capita (excl. HELOC), 2006	4234 (3886)	47	0.030
Mortgage debt balance per capita (excl. HELOC), 2008	5199 (4339)	47	0.036
Mortgage debt balance per capita (excl. HELOC), 2010	4249 (3583)	47	0.032
Mortgage debt balance per capita (excl. HELOC), 2012	3573 (3323)	47	0.025

Table C2. Orthogonality of Non-recourse law (cont.)

	Non-recourse	N	R^2
Mortgage debt balance per capita (excl. HELOC), 2014	3887 (2958)	47	0.034
Mortgage debt balance per capita (excl. HELOC), 2016	4149 (2936)	47	0.039
Mortgage debt balance delinquency rate, Q42004	-0.0034 * (0.0015)	47	0.077
Mortgage debt balance delinquency rate, Q42006	-0.0029 * (0.0013)	47	0.078
Mortgage debt balance delinquency rate, Q42008	-0.0014 (0.0065)	47	0.001
Mortgage debt balance delinquency rate, Q42010	-0.0016 (0.0097)	47	0.001
Mortgage debt balance delinquency rate, Q42012	-0.0077 (0.0064)	47	0.020
Mortgage debt balance delinquency rate, Q42014	-0.0084 * (0.0034)	47	0.069
Mortgage debt balance delinquency rate, Q42016	-0.0053 (0.0015)	47	0.130

This tables presents coefficients of the univariate regression for x_i variable on *NonRecourse* dummy. Standard errors are heteroskedasticity robust. Coefficients marked with ***, **, * and + are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively.

States subject to changes in the mortgage law not included in the regressions. Data sources: Demographics and income variables from Current Population Survey (CPS), GDP variables from Bureau of Economic Analysis (BEA), house price growth from Zillow - (Single Family Residence), manufactured housing shipping annual growth from Institute for Building Technology & Safety (IBTS), and mortgage market variables from State Level Household Debt Statistics 2003-2017, Federal Reserve Bank of New York.

Appendix D - Summary statistics by year

Table D1. Summary statistics by year from 2001 to 2011.

	Year 2001				Year 2002			
	mean	sd	min	max	mean	sd	min	max
Spread	63	40	-183	368	65	40	-304	496
Amount	149,984	61,564	50,000	578,000	157,388	67,663	50,000	650,000
Value	192,617	93,729	50,000	2,500,000	202,706	103,228	50,000	2,500,000
LTV	80.84	13.44	6	100	80.81	13.44	6	105
LTI	51.91	15.68	1.40	109.88	54.91	17.11	1.24	115.42
CreditScore	717	55	300	839	717	56	300	842
Income	3,218	2,386	480	212,338	3,266	3,284	474	200,256
DFirstTime	0.23	0.42	0	1	0.24	0.43	0	1
DSingleBorrower	0.37	0.48	0	1	0.40	0.49	0	1
Judicial	0.43	0.50	0	1	0.45	0.50	0	1
NonRecourse	0.39	0.49	0	1	0.39	0.49	0	1
Observations	445,097				395,960			

	Year 2003				Year 2004			
	mean	sd	min	max	mean	sd	min	max
Spread	61	42	-197	487	43	37	-192	457
Amount	166,905	73,920	50,000	749,000	169,673	76,714	50,000	642,000
Value	216,086	113,133	50,000	2,083,333	224,934	121,196	50,000	3,340,000
LTV	80.46	13.19	7	102	78.91	13.61	7	102
LTI	59.62	18.57	1.56	126.31	61.28	18.69	1.56	124.61
CreditScore	723	52	300	841	723	53	300	850
Income	3,149	2,560	434	230,512	3,069	2,219	429	264,417
DFirstTime	0.22	0.42	0	1	0.22	0.41	0	1
DSingleBorrower	0.39	0.49	0	1	0.40	0.49	0	1
Judicial	0.48	0.50	0	1	0.50	0.50	0	1
NonRecourse	0.36	0.48	0	1	0.34	0.47	0	1
Observations	346,957				313,324			

	Year 2005				Year 2006			
	mean	sd	min	max	mean	sd	min	max
Spread	81	39	-161	405	100	39	-160	381
Amount	178,777	83,738	50,000	800,000	186,532	92,168	50,000	802,000
Value	241,732	135,431	50,000	2,571,429	251,380	144,694	50,000	3,878,572
LTV	77.76	14.37	7	104	77.76	14.12	7	105
LTI	62.51	19.48	1.48	122.83	59.66	18.55	1.41	117.71
CreditScore	730	55	300	850	729	56	300	850
Income	3,183	2,292	431	219,423	3,467	2,490	456	182,283
DFirstTime	0.24	0.43	0	1	0.26	0.44	0	1
DSingleBorrower	0.42	0.49	0	1	0.42	0.49	0	1
Judicial	0.48	0.50	0	1	0.46	0.50	0	1
NonRecourse	0.34	0.47	0	1	0.35	0.48	0	1
Observations	352,502				301,679			

	Year 2007				Year 2008			
	mean	sd	min	max	mean	sd	min	max
Spread	93	38	-212	429	119	49	-161	389
Amount	189,786	96,030	50,000	802,000	211,741	109,237	50,000	802,000
Value	248,262	147,835	50,000	3,207,692	281,890	180,192	50,000	4,369,231
LTV	80.11	14.62	6	103	79.39	14.57	8	105
LTI	59.81	18.96	1.45	122.69	61.62	19.87	1.54	126.31
CreditScore	728	57	300	850	741	50	333	850
Income	3,535	2,700	482	254,811	3,834	3,056	425	298,465
DFirstTime	0.31	0.46	0	1	0.33	0.47	0	1
DSingleBorrower	0.45	0.50	0	1	0.49	0.50	0	1
Judicial	0.46	0.50	0	1	0.43	0.49	0	1
NonRecourse	0.35	0.48	0	1	0.40	0.49	0	1
Observations	269,851				212,152			

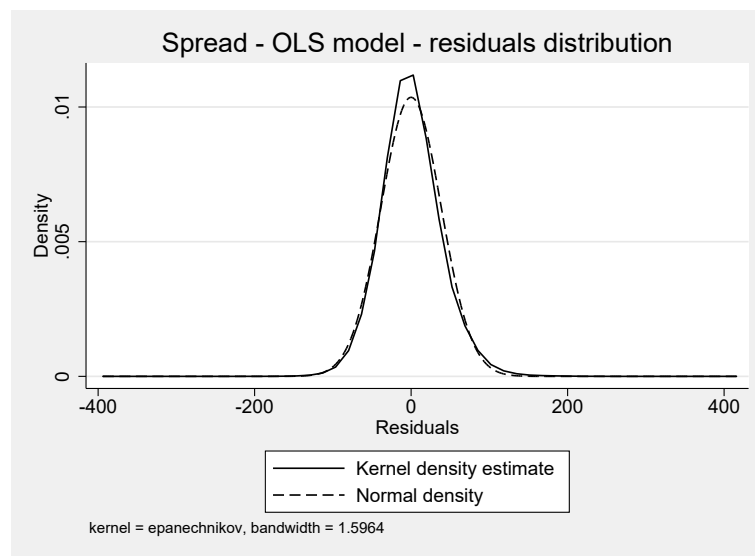
	Year 2009				Year 2010			
	mean	sd	min	max	mean	sd	min	max
Spread	136	46	-56	430	66	29	-73	304
Amount	218,730	123,981	50,000	1,403,000	218,706	124,904	50,000	1,129,000
Value	294,424	199,038	50,000	4,464,286	292,898	193,982	50,000	5,214,286
LTV	77.80	12.96	9	100	77.78	12.70	8	100
LTI	62.07	19.70	1.81	132.13	63.33	18.59	1.76	111.80
CreditScore	758	40	461	843	760	40	527	832
Income	3,908	3,012	413	220,680	3,777	2,843	461	249,622
DFirstTime	0.38	0.48	0	1	0.39	0.49	0	1
DSingleBorrower	0.48	0.50	0	1	0.47	0.50	0	1
Judicial	0.44	0.50	0	1	0.45	0.50	0	1
NonRecourse	0.40	0.49	0	1	0.40	0.49	0	1
Observations	208,588				162,476			

	Year 2011			
	mean	sd	min	max
Spread	64	34	-95	243
Amount	228,012	127,644	50,000	1,333,000
Value	298,860	193,853	50,000	3,037,500
LTV	79.47	12.69	10	100
LTI	64.87	18.27	1.81	127.77
CreditScore	760	39	562	835
Income	3,823	2,793	487	284,937
DFirstTime	0.37	0.48	0	1
DSingleBorrower	0.46	0.50	0	1
Judicial	0.44	0.50	0	1
NonRecourse	0.40	0.49	0	1
Observations	136,690			

Appendix E - Distribution of residuals on the *Spread* regression

This appendix presents the residuals inspection for the estimation of Equation (3.1) with year and seller fixed effects. In the absence of normality tests valid for large samples, the

Figure E1. Residuals distribution on the *Spread* regression



This figure presents the distribution of the residuals on the estimation of Equation (3.1) with year and seller fixed effects. The estimated residuals (Kernel density estimate) follow a distribution close to the assumption of normality distribution represented by the dash line.

Appendix F - Robustness checks

This appendix presents the main estimation results for the robustness tests. Table F1 shows the results for the alternative definition of *Spread2*. Table F2 shows the results for the estimation on the combined loan-to-value ratio. Table F3 shows the results when considering time dependency. Figure F1 shows the evolution of Case-Shiller U.S. National Home Price Index.

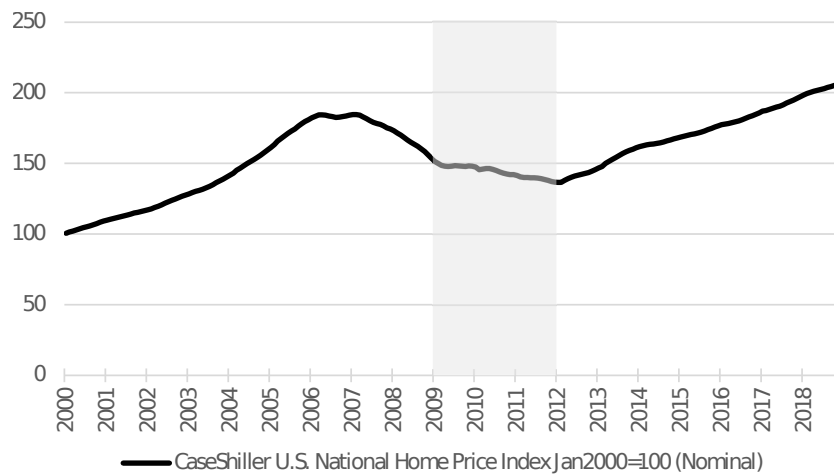
Table F1. Effects of law on Spread2

	Spread2	Spread2
LogIncome	-29.023** (9.104)	-28.293** (8.531)
LogIncome ²	1.140* (0.504)	1.112* (0.467)
LTI	-0.304*** (0.017)	-0.300*** (0.014)
CreditScore	-0.137*** (0.010)	-0.136*** (0.009)
DSingleBorrower	3.753*** (0.499)	3.642*** (0.487)
DFirstTime	1.846* (0.678)	2.600** (0.861)
Judicial	4.799*** (0.228)	4.414*** (0.203)
NonRecourse	-0.133 (0.181)	0.141 (0.244)

Table F1. Effects of law on Spread2 (cont.)

	Spread2	Spread2
Level_lag1	-0.419*** (0.012)	-0.422*** (0.013)
Slope_lag1	-0.793*** (0.025)	-0.798*** (0.026)
Curvature_lag1	-1.046*** (0.057)	-1.055*** (0.056)
Vol60d_lag1	0.610*** (0.077)	0.597*** (0.076)
FE Year	yes	yes
FE Seller	no	yes
<i>N</i>	3,145,276	3,145,276
<i>R</i> ²	0.338	0.344

This tables presents coefficients of the OLS regression for *Spread2* on law dummies—*Judicial* and *NonRecourse*. Standard errors are clustered by seller. Coefficients marked with ***, **, * and + are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively.

Figure F1. Case-Shiller U.S. National Home Price Index

This figure shows the evolution of the Case-Shiller U.S. National Home Price Index data available on <https://fred.stlouisfed.org>. The shaded area emphasizes the years 2009, 2010 and 2011, for which the mortgage law have lower or no impact on the mortgage interest rate and on the LTV ratio. It coincides with a depressed housing market where lenders might attribute a low probability to the default scenario.

Table F2. Effects of law on CLTV

	CLTV	CLTV
LogIncome	53.162*** (4.053)	52.461*** (4.023)
LogIncome ²	-3.284*** (0.255)	-3.227*** (0.254)
LTI	0.053*** (0.004)	0.055*** (0.005)
CreditScore	-0.050*** (0.003)	-0.050*** (0.003)
DSingleBorrower	1.524*** (0.185)	1.567*** (0.196)
DFirstTime	4.525*** (0.310)	4.706*** (0.275)
Judicial	0.013 (0.208)	-0.060 (0.188)
NonRecourse	-0.496** (0.147)	-0.424*** (0.109)
FE Year	yes	yes
FE Seller	no	yes
<i>N</i>	3,145,276	3,145,276
<i>R</i> ²	0.088	0.096

This table presents coefficients of the OLS regression for *CLTV* on law dummies—*Judicial* and *NonRecourse*. Standard errors are clustered by seller. Coefficients marked with ***, **, * and + are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively.

Table F3. Effects of law on Spread and LTV by Year

	Spread	Spread	LTV	LTV
LogIncome	-28.423** (9.584)	-27.714** (9.038)	49.087*** (2.716)	49.316*** (2.706)
LogIncome ²	1.109* (0.539)	1.090* (0.501)	-3.066*** (0.165)	-3.062*** (0.166)
LTI	-0.288*** (0.015)	-0.282*** (0.014)	0.041*** (0.006)	0.046*** (0.006)
CreditScore	-0.133*** (0.009)	-0.132*** (0.009)	-0.055*** (0.002)	-0.055*** (0.002)
DSingleBorrower	3.626*** (0.495)	3.551*** (0.476)	1.994*** (0.082)	2.014*** (0.075)
DFirstTime	1.711* (0.691)	2.489* (0.914)	3.700*** (0.225)	4.066*** (0.160)
2001xJudicial	6.461*** (0.454)	6.095*** (0.432)	0.036 (0.310)	-0.081 (0.353)
2002xJudicial	3.284*** (0.589)	2.770*** (0.651)	0.189 (0.240)	-0.024 (0.303)
2003xJudicial	5.037*** (0.601)	4.533*** (0.539)	0.433* (0.171)	0.246 (0.193)
2004xJudicial	5.949*** (0.527)	5.370*** (0.480)	0.498* (0.241)	0.312 (0.230)
2005xJudicial	4.971*** (0.699)	4.417*** (0.607)	0.566 (0.325)	0.389 (0.247)
2006xJudicial	5.946*** (0.696)	5.564*** (0.634)	0.278 (0.305)	0.207 (0.263)

Table F3. Effects of law on Spread and LTV by Year (cont.)

	Spread	Spread	LTV	LTV
2007xJudicial	5.697*** (0.603)	5.468*** (0.613)	0.195 (0.366)	0.129 (0.318)
2008xJudicial	3.699*** (0.999)	3.599** (1.011)	0.172 (0.370)	0.159 (0.267)
2009xJudicial	3.798** (1.289)	3.493** (1.095)	0.359 (0.326)	0.211 (0.215)
2010xJudicial	1.544* (0.660)	1.071 (0.808)	0.536 (0.384)	0.441 (0.345)
2011xJudicial	0.470 (0.659)	0.516 (0.931)	0.127 (0.389)	-0.013 (0.393)
2001xNonRecourse	0.130 (0.333)	0.621 (0.373)	-0.331 ⁺ (0.181)	-0.193 (0.195)
2002xNonRecourse	-0.797 (0.571)	-0.397 (0.602)	-0.692*** (0.184)	-0.491* (0.213)
2003xNonRecourse	-0.556 (0.462)	-0.125 (0.483)	-0.553*** (0.124)	-0.377** (0.133)
2004xNonRecourse	-0.775* (0.306)	-0.414 (0.367)	-0.465*** (0.115)	-0.326* (0.120)
2005xNonRecourse	-1.156* (0.509)	-0.707 (0.587)	-0.608** (0.212)	-0.452* (0.218)
2006xNonRecourse	0.022 (0.400)	0.460 (0.426)	-0.672** (0.227)	-0.498* (0.187)
2007xNonRecourse	-0.690 (0.786)	-0.421 (0.804)	-0.784* (0.306)	-0.594* (0.236)
2008xNonRecourse	0.556 (0.825)	0.245 (0.731)	-0.686* (0.301)	-0.535 ⁺ (0.273)

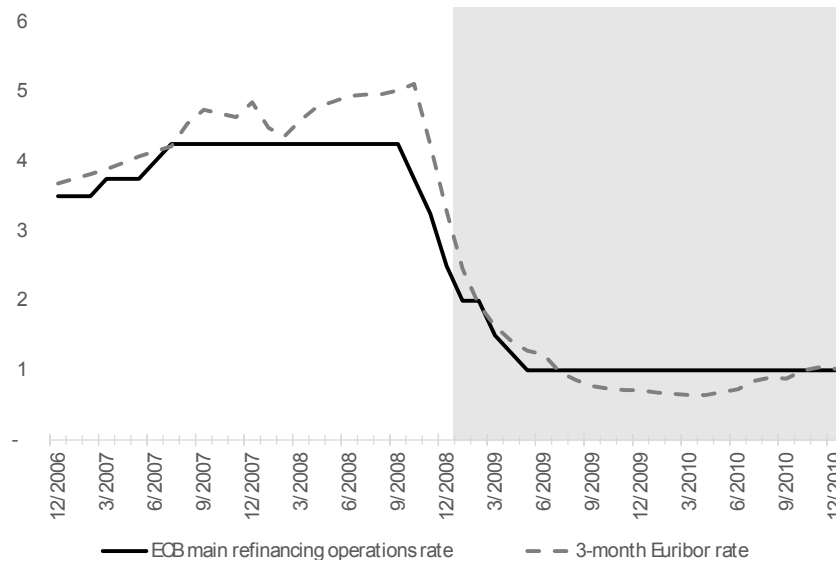
Table F3. Effects of law on Spread and LTV by Year (cont.)

	Spread	Spread	LTV	LTV
2009xNonRecourse	2.130 ⁺ (1.093)	2.008 ⁺ (1.049)	-0.668* (0.279)	-0.505 (0.299)
2010xNonRecourse	1.358 (0.931)	1.279 (0.891)	-0.538 ⁺ (0.288)	-0.383 (0.300)
2011xNonRecourse	1.529 (1.073)	1.383 (1.067)	-0.645* (0.297)	-0.554 ⁺ (0.288)
FE Year	yes	yes	yes	yes
FE Seller	no	yes	no	yes
<i>N</i>	3,145,276	3,145,276	3,145,276	3,145,276
<i>R</i> ²	0.327	0.333	0.096	0.106

This table presents coefficients of the OLS regression for *Spread* and *LTV* on law dummies—*Judicial* and *NonRecourse*—interacted with year dummies. Standard errors are clustered by seller. Coefficients marked with ***, **, * and ⁺ are statistically different from zero at the 0.1%, 1%, 5%, and 10% confidence level, respectively.

Appendix G - Interest Rates

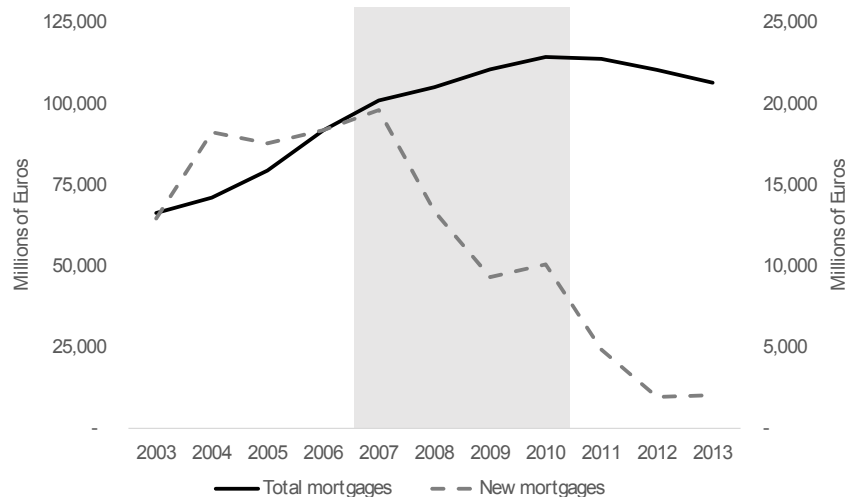
Figure G1. Interest rates from 2007 to 2010



This figure presents the evolution of the ECB main refinancing operations rate (black line) and the 3-month Euribor rate (dash line) from 2007 to 2010. By the end of 2008 and beginning of 2009, the ECB cut significantly the interest rates of the main refinancing operations, which influenced the interbank market and lead to a sharp decrease in the Euribor rates. The gray area represents the period of low interest rates.

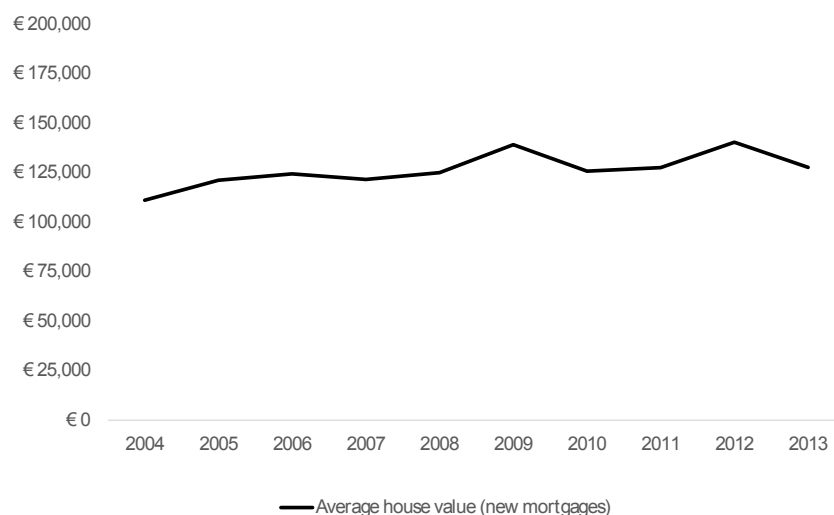
Appendix H - Portuguese Mortgage Market

Figure H1. Mortgage credit in Portugal: stock vs. flow



This figure presents the evolution of mortgage stock (black line) and mortgage flow (dashed line). The gray area represents the period in analysis from 2007 to 2010. While the new mortgages dropped after 2007, the stock of mortgages continued to increase up to 2010. The great fall in the Portuguese mortgage market only happened in 2011, when the market froze.

Figure H2. Average house value in new mortgages



This figures presents the evolution of the average house value of new mortgages. It shows that there were no substantial changes from 2007 to 2010.

Appendix I - Summary statistics by year

Table II. Summary statistics by year from 2007 to 2010.

	Year 2007				
	mean	median	sd	min	max
DSR	45.10	40.06	30.02	0.04	596.28
SDSR	67.53	60.30	44.64	0.06	760.73
Amount	117,128	105,000	58,450	25,000	1,500,000
House Value	137,210	120,020	75,440	50,000	4,480,000
Term	465	481	107	55	611
Primary Income	29,660	16,730	141,380	5,642	11,606,201
Loan to Value	87.55	90.00	17.45	5.56	429.17
Loan to Income	9.86	7.47	11.70	0.01	382.05
Observations	27,302				
	Year 2008				
	mean	median	sd	min	max
DSR	44.38	39.21	29.30	1.64	445.67
SDSR	62.69	55.41	41.36	2.29	652.80
Amount	113,675	100,000	56,120	25,000	722,397
House Value	135,304	118,400	72,729	50,000	1,551,096
Term	471	481	114	60	601
Primary Income	25,271	17,415	24,013	5,964	553,190
Loan to Value	86.82	90.00	18.70	6.00	244.38
Loan to Income	9.06	6.88	10.28	0.25	252.76
Observations	11,369				

Year 2009					
	mean	median	sd	min	max
DSR	26.49	23.45	16.65	1.51	237.22
SDSR	59.23	53.11	37.20	2.81	454.03
Amount	119,825	110,000	59,242	25,000	900,000
House Value	137,589	125,000	71,446	50,000	2,595,000
Term	479	481	107	48	601
Primary Income	27,591	20,276	24,765	6,300	1,011,109
Loan to Value	88.75	90.00	18.61	7.85	260.00
Loan to Income	7.81	5.96	9.55	0.20	237.19
Observations	10,716				
Year 2010					
	mean	median	sd	min	max
DSR	29.70	26.99	17.93	1.78	178.48
SDSR	68.97	62.94	41.49	3.41	407.82
Amount	124,415	115,000	56,634	25,000	740,000
House Value	131,929	120,000	64,555	50,000	1,650,000
Term	466	480	78	48	601
Primary Income	26,020	17,927	22,781	6,650	262,213
Loan to Value	96.03	100.00	17.32	2.42	239.47
Loan to Income	10.11	7.41	13.98	0.34	417.32
Observations	6,417				

Appendix J - Correlation and collinearity issues

Table J1. Pairwise Correlation with Bank FE

	Bank FE
Equity Ratio x Low Int	-0.023
Liquidity Ratio x Low Int	-0.328
Deposits Ratio x Low Int	-0.052
Loans to Deposits x Low Int	0.023

Appendix K - Interaction with banks' characteristics results

Table K1. Effect of low interest rate interacted with equity ratio

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Equity Ratio x Low Int	-0.2400*** (0.0132)	-0.4274*** (0.0238)	0.0182 ⁺ (0.0095)	0.0822*** (0.0197)
Log(Primary Income)		-3.8403*** (0.0877)		-3.9674*** (0.0995)
Loan to Value		0.0378*** (0.0057)		0.0428*** (0.0052)
Loan to Income		0.0383** (0.0142)		0.0559*** (0.0157)
Bank FE	yes	yes	yes	yes
Observations	55,804	55,804	55,804	55,804
Pseudo R^2	0.0990	0.5223	0.0371	0.4987

Standard errors clustered by bank in parentheses

⁺ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table K2. Effect of low interest rate interacted with liquidity ratio

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Liquidity Ratio x Low Int	-0.5430** (0.2046)	-0.9787** (0.3174)	0.0676** (0.0226)	0.2226*** (0.0326)
Log(Primary Income)		-3.7799*** (0.0911)		-3.9660*** (0.0989)
Loan to Value		0.0358*** (0.0067)		0.0433*** (0.0048)
Loan to Income		0.0381** (0.0138)		0.0556*** (0.0157)
Bank FE	yes	yes	yes	yes
Observations	55,804	55,804	55,804	55,804
Pseudo R^2	0.0898	0.5099	0.0374	0.4991

Standard errors clustered by bank in parentheses

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table K3. Effect of low interest rate interacted with deposits ratio

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Deposits Ratio x Low Int	-0.0245*** (0.0022)	-0.0441*** (0.0033)	0.0023* (0.0010)	0.0086*** (0.0023)
Log(Primary Income)		-3.8330*** (0.0771)		-3.9676*** (0.1017)
Loan to Value		0.0377*** (0.0061)		0.0428*** (0.0051)
Loan to Income		0.0388** (0.0140)		0.0559*** (0.0157)
Bank FE	yes	yes	yes	yes
Observations	55,804	55,804	55,804	55,804
Pseudo R^2	0.0975	0.5209	0.0372	0.4988

Standard errors clustered by bank in parentheses

+ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table K4. Effect of low interest rate interacted with loans to deposits

	dDSR (1)	dDSR (2)	dSDSR (3)	dSDSR (4)
Loans to Deposits x Low Int	-0.0080*** (0.0009)	-0.0141*** (0.0017)	0.0006 ⁺ (0.0003)	0.0028*** (0.0006)
Log(Primary Income)		-3.8125*** (0.0929)		-3.9693*** (0.0997)
Loan to Value		0.0380*** (0.0057)		0.0426*** (0.0053)
Loan to Income		0.0380** (0.0141)		0.0559*** (0.0157)
Bank FE	yes	yes	yes	yes
Observations	55,804	55,804	55,804	55,804
Pseudo R^2	0.0983	0.5199	0.0371	0.4987

Standard errors clustered by bank in parentheses

⁺ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$