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The impact of a macroprudential borrower based measure on households' leverage and housing choices

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Abstract
Banco de Portugal implemented new limits to the loan-to-value (LTV) ratio in July 2018. This paper investigates the impact of these new lending limits on households' leverage and housing choices. Using credit register data that covers the universe of loans granted to households, which allows us to account for loan and households' characteristics and bank heterogeneity, we document a decline in the LTV ratio after the implementation of the macroprudential measure. Importantly, using a difference-in-differences estimation strategy we estimate the impact of the policy change on households that were more likely to exceed the new LTV limits in the absence of the policy change. Our results show that the policy change was effective in reducing households' leverage as constrained households take out smaller loans and have lower loan-to-income ratios. These households pay higher interest rate spreads and have higher loan-service-to-income ratios than the control group. This paper also shows that the policy change affected households' housing choices as constrained households bought cheaper houses. Overall, our results highlight the improvement of the risk profile of households following the introduction of the LTV limits.

JEL: D14; E58; E61; G21; G28

Keywords: Macroprudential policy; LTV limit; Residential mortgages; Household leverage.

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1. Introduction

The Great Financial crisis highlighted how periods of high household credit growth coupled with the buildup of vulnerabilities in the financial sector can result in severe banking crisis (Büyükkarabacak and Valev 2010). Household debt becomes problematic if households fail to meet their debt obligations when faced with unexpected increases in interest rates or decreases in income, which can result in credit losses for banks. In the case of residential mortgages, credit losses become even more significant when households are highly leveraged in relation to the value of the immovable property (which serves as collateral to the loan) or when there are sudden downward corrections in housing prices (Svensson 2019). When these shocks disrupt financial intermediation activities undertaken by banks, household debt may pose significant risks to financial stability.

Recognizing the importance of cycles in credit supply, authorities have increasingly relied on macroprudential policies to mitigate the accumulation of systemic risk in the household credit sector and to improve the resilience of the financial sector to unexpected adverse shocks (Richter *et al.* 2019). In particular, macroprudential authorities have increasingly resorted to measures that directly affect lending standards to households, namely the introduction of maximum limits to the loan-to-value (LTV), debt-to-income (DTI), and debt-service-to-income (DSTI) ratios or maximum limits to maturity. While the specific policy motivation may differ across countries, these instruments are often introduced with the objective of strengthening the resilience of households and banks to unexpected income or interest rate adverse shocks and to curb credit growth during the upward phase of the credit cycle, ultimately dampening the severity of boom and bust cycles.

Against a background characterised by signs of easing of credit standards coupled with a high level of indebtedness and a low saving rate of Portuguese households, the Banco de Portugal, as the designated Portuguese macroprudential authority, adopted a measure targeting new loans for households including both residential mortgage and consumer credit. This macroprudential measure, announced on February 1st 2018, recommends setting limits to some of the credit criteria used by financial institutions in the assessment of the borrower's creditworthiness. The measure is comprised of limits to the LTV ratio, DSTI ratio, maturity of the new loans and a requirement of regular payments of interest and principal. The main objective of this measure is to ensure that credit institutions and financial companies do not take on excessive risk when granting credit to households, enhancing the resilience of the financial sector and the access of borrowers to sustainable finance (Leal and Lima 2018). The Recommendation is a type of macroprudential measure that acts directly on the borrower, generally restricting the quantity of credit by tightening borrowing constraints for certain groups of borrowers (the so-called borrower-based measures), in contrast to measures that promote the increase of capital requirements, applied

at the institution level (the so-called capital-based measures).[1] Limits to the LTV and DSTI ratios reduce, respectively, households' probability of default (PD) and the loss given default (LGD) that banks have to endure when adverse shocks hit the financial system, thus benefiting banks' capital and increasing their resilience during macroeconomic downturns (Gross and Población 2017; Jurča *et al.* 2020; Neugebauer *et al.* 2021).

Our primary objective is to understand the impact of the new lending limits set by the macroprudential Recommendation implemented by the Banco de Portugal on new mortgage loans.[2] We proceed with the analysis in two steps. First, crucial for the focus of our paper, we document the adjustment in the LTV ratio after the implementation of the macroprudential Recommendation. Second, we examine the micro-implications of the introduction of the LTV limits on new loans for house purchase. In particular, we explore the impact of the LTV limits on households' leverage (mortgage amounts and loan-to-income ratios), mortgage servicing costs (loan interest rate spreads and loan service-to-income ratio), monthly payments, and on borrowers' choices in the housing market (housing prices). For this purpose, we rely on a rich dataset at the loan level that covers the universe of new mortgage lending. The dataset includes detailed information on the loan, collateral, and borrowers' characteristics. The loan-level data allows us to account for banks' specific heterogeneity and borrowers' characteristics in the empirical analysis. In fact, to the best of our knowledge, this is the first paper to assess the micro-implications of the introduction of a borrower based measure on borrowers using credit register data that covers the universe of mortgage lending to households.

The specific design of the new limits to the LTV ratio makes it of particular interest. According to the Portuguese macroprudencial borrower-based measure, the LTV ratio for the construction or purchase of own and permanent residence should not be higher than 90 percent. Importantly, the new 90 percent limit to the LTV ratio was even stricter to the extent that the Recommendation sets that the LTV ratio of new loans corresponds to the ratio between the loan amount and the minimum between the purchase price and the appraisal value of the collateral. This was especially important because in the period before the implementation of the macroprudential measure, it was a standard practice to cap the LTV ratio between 80 and 90 percent of the appraisal value. However, given that the appraisal value was in general higher than the purchase price, there was a substantial share of credit financed at 100 percent of the purchase price. Since July 2018, the LTV of

1. Both macroprudential measures have the ultimate objective of improving the resilience of financial institutions. While capital-based measures raise institutions' resilience in an immediate and direct way, borrower-based measures improve institutions' resilience indirectly and over the medium term by mitigating the excessive risk of new credit, through the improvement of the risk profile of borrowers.

2. We evaluate the effects of the introduction of limits to the LTV ratio on new loans granted for purchase or construction of own and permanent residence, which represent the vast majority of new mortgages.Loans to households for house purchase accounted for approximately 60 percent of the new loans granted to households in the period between 2017 and 2019.

new mortgage loans is based on the minimum between the purchase price and the appraisal value of the collateral, translating into a decline in the risk assumed by institutions, given that the borrower has to make a downpayment of at least 10 percent of the immovable property's transaction price.

We use granular data from the Central Credit Register of the Banco de Portugal on new loans for house purchase between January 2017 and December 2019 and a difference-in-differences estimator to examine the impact of the LTV limit on households. We show that households most affected by the LTV limits reduce their leverage by taking on less mortgage debt than they would in the absence of the policy change. Households' leverage as measured by the loan-to-income (LTI) ratio decreased following the introduction of the LTV limits. Moreover, constrained borrowers have higher mortgage loan-service-to-income (LSTI) ratios than the control group. This is because affected borrowers pay higher loan interest rate spreads, which reflects the higher risk perception of banks following the introduction of the Recommendation. An alternative explanation is the lower bargaining power of constrained households after the introduction of the macroprudential measure. We also show that borrowers constrained by the new limit bought cheaper houses. Additionally, we do not find evidence that banks limited the supply of credit based on households' age or income after the policy change.

The focus of the analysis on the introduction of limits to the LTV ratio is rooted essentially on two explanations. First, the limits set to maturity were not restrictive in the sense that the great majority of the loans granted by institutions targeted by the macroprudential measure complied with the 40 years limit in the period before its introduction, with a very few exceptions. Nevertheless, whenever relevant, we control for loan maturity in the empirical analysis. Second, the exceptions foreseen for the DSTI limit do not allow us to accurately assess its micro-implications on borrowers' choices. We present a more thorough description of the macroprudential measure in Section 2.

The increasing importance of borrower based measures in applied policy settings has been followed by a growing number of studies that examine the effectiveness of this type of instruments.[3] The empirical literature on the impact of borrower based measures can be summarized along two general lines of research. The first line of research is comprised of studies that estimate the impact of the introduction of borrower based measures on aggregate macroeconomic and financial variables, typically by exploring cross-country data and constructing a counterfactual analysis. The results obtained in these studies show that limits to the LTV and DSTI ratios dampen the procyclicality of credit (Lim *et al.* 2011), lead to weaker households' credit growth (Price *et al.* 2014; Abreu and Passinhas 2021), and curb house prices growth (Cerutti *et al.* 2017; Igan and Kang 2011). In addition, these studies show that the growth rate of house prices and new mortgage lending is more sensitive to aggregate income shocks in countries with higher LTV and DSTI ratios. The

3. See Galati and Moessner (2018) for a comprehensive literature review.

effectiveness of the measures is more pronounced when growth rates are very high, as the limits become less countercyclical in busts (Cerutti *et al.* 2017). These results are in line with the theoretical literature based on Dynamic Stochastic General Equilibrium (DSGE) models that emphasizes the countercyclical characteristics of LTV limits (Lambertini *et al.* 2013; Mendicino and Punzi 2014; Gelain *et al.* 2013).

A second strand of the literature explores micro-level data to study the adjustments in housing and credit markets following the introduction of a borrower-based measure. The relative scant evidence shows that LTV limits are effective in reducing households' leverage as constrained households respond to the introduction of the policy by taking out smaller loans (De Araujo *et al.* 2020; Van Bekkum *et al.* 2019). Also, the introduction of LTV limits is associated with lower maturities (De Araujo *et al.* 2020), higher interest rates (De Araujo *et al.* 2020; Tzur-Ilan 2020), lower mortgage default rates (De Araujo *et al.* 2020; Van Bekkum *et al.* 2019) and the purchase of more affordable houses (De Araujo *et al.* 2020; Tzur-Ilan 2020). An important concern is whether these effects are disproportionally distributed across borrowers with different characteristics. Van Bekkum *et al.* (2019) show that the effects of the introduction of the LTV limit are more significant for lower income/wealth households while Acharya *et al.* (2020) finds that banks tend to reallocate credit from low to high income households. The introduction of tighter lending restrictions is also associated with a reduction in the number of transactions in the housing market (Igan and Kang 2011) and with the purchase of houses with lower quality and located further away from urban centers (Acharya *et al.* 2020; Tzur-Ilan 2020). In addition, LTV and DTI limits have been shown to curb the expectations on house price increases, thus leading to a postponement of house purchase decisions and limiting speculative behavior (Igan and Kang 2011).

A distinct set of papers has focused on the transmission of lender-based macroprudential policies targeting the residential mortgage credit. Auer and Ongena (2016) and Behncke (2020) study the transmission mechanisms of the Swiss sectoral countercyclical capital buffer (CCyB) on banks' lending and risk taking. Auer and Ongena (2016) use bank-level data and document that banks more exposed to the CCyB reduced their residential mortgage granting more strongly than other banks. Behncke (2020) combines data on new mortgage loans and LTI and LTV risk indicators with bank level supervisory data to study the effects of the sectoral CCyB and the LTV cap implemented in Switzerland and show that both measures led to a reduction of the share of new residential mortgages with high LTV ratios.[4] In a related work, Jiménez *et al.* (2017) study the impact of dynamic provisioning on credit supply and the associated spillovers on real estate activity on both good and bad times. The results show that dynamic provisioning mitigate cycles in credit supply. Camors *et al.* (2019) exploit a tightening of reserve

4. In related work, Basten and Koch (2015) examine the impact of the activation of the Swiss CCyB on mortgage pricing.

requirements in Uruguay and show that it led to a reduction of credit supply to firms.

Our paper is more closely related to Van Bekkum *et al.* (2019) and Tzur-Ilan (2020) but differs from them in two important aspects. First, like these authors, we explore the impact of the introduction of LTV limits on households' leverage and housing choices, but we capitalize on the very specific design of the Portuguese macroprudential measure, which introduces a new limit to the LTV ratio but also introduces a new and uniform definition for the LTV ratio: the LTV ratio is the ratio between the loan amount and the minimum between the purchase price and the appraisal value of the immovable property pledged as collateral. Second, we rely on a very rich database at the loan level that covers the universe of new mortgages and includes detailed information on the debt-contract, collateral, and borrower characteristics.

The paper proceeds as follows. In the next section we describe the macroprudential measure implemented in Portugal by the Banco de Portugal. This is followed by a discussion of the data used in the empirical analysis and the estimation procedure. Section 5 reports the results on the impact of the new LTV limit on borrowers' leverage and housing choices. Section 6 presents the results of the robustness analysis. Section 7 concludes.

2. Institutional Setting: The Borrower-Based Measure

The Banco de Portugal, as the designated Portuguese macroprudential authority, announced a macroprudential measure on February 1st 2018, which covers all new loans to households from July 1st 2018 onwards. The period of five months between the announcement and the implementation was meant to allow financial institutions to implement the required operational settings. The measure applies to all entities authorized to grant credit in Portugal, which include financial companies that have their head offices in Portugal as well as branches from foreign financial institutions operating in Portugal.

The macroprudential measure implemented by the Banco de Portugal recommends new limits to the LTV ratio, DSTI ratio, and maturity of new loans, and introduces a new requirement of regular payments of interest and principal for new loans for house purchase and consumption. The macroprudential measure takes the legal form of a recommendation that follows the "comply-or-explain" principle. This has not compromised the compliance of financial institutions with the limits set in the Recommendation, as they have broadly agreed on the benefits of the borrower-based measure for financial stability. The fast convergence of the most relevant financial institutions of the Portuguese financial system to the new lending limits tallies with the compliance with the macroprudential measure.

Forborne loans or credit intended to prevent or address default situations is out of the scope of the Recommendation, considering the high levels of non-performing loans in Portuguese banks' balance sheets when the Recommendation

was implemented. The Recommendation is also not applicable to credit agreements of an amount equal or lower than the equivalent to tenfold the guaranteed monthly minimum wage, given that, in these situations, institutions may estimate the borrower's income based on information they consider sufficient without requiring further evidence of their income. Finally, the Recommendation excludes credit agreements in the form of an overdraft facility and other credit with no defined repayment schedule (including credit cards and credit lines).

The macroprudential Recommendation designed by the Banco de Portugal defined the LTV ratio as the ratio of the total amount of credit agreements secured by an immovable property to the minimum between the transaction value and the appraisal value of the immovable property pledged as collateral. The macroprudential Recommendation defines new limits for the LTV ratio, according to the purpose of the loan: 90 percent for mortgages for own and permanent residence; 80 percent for mortgages for purposes other than own and permanent residence; and 100 percent for mortgages for the purchase of immovable properties held by credit institutions and for property financial leasing agreements. The Recommendation establishes a limit of 40 years for the maturity of a mortgage loan and sets a gradual convergence of the average maturity of new credit for house purchase to 30 years by the end of 2022.[5] In what concerns to the DSTI, the Recommendation introduces a limit of 50 percent that takes into account shocks to the interest rate and borrowers' income.[6] Limits to the DSTI ratio act as automatic stabilizers as they become tighter in the expansionary phase of the financial cycle. This is because in the expansionary phase real estate prices tend to adjust more rapidly than borrowers' income. Finally, the Recommendation introduced a requirement of regular payments of interest and principal. The completeness of the measure helps in reinforcing its effectiveness.

The reason to focus the analysis on the impact of the LTV limits is twofold: first, with a very few exceptions, financial institutions did comply with the 40 years limit to maturity before the introduction of the measure, meaning that these new lending limits are in general not binding (see Appendix Figures A.1 and A.2); second, the exceptions for the DSTI limit included in the macroprudential measure do not allow us to unequivocally identify the impact of DSTI limits on borrowers' leverage and housing choices. However, the introduction of year-month fixed effects in the estimated empirical models allows us to disentangle the impact of the LTV limits from that of other aggregate shocks.

In the next section we describe our data source ad lay out the definitions of the key variables considered in the empirical analysis.

5. In the case of credit for consumption, the maximum maturity is 7 years for personal loans and 10 years for car loans.

6. The DSTI is defined as the ratio between the total amount of monthly installments associated with the borrower's loans and income. Thus, the DSTI ratio considers the monthly installment associated with the new loan and the installments of credits already granted.

3. Data and Descriptive Statistics

In this section we describe our dataset and present the main descriptive statistics of key variables in our analysis.

3.1. Data description

Our main data source is the Portuguese Central Credit Register (*Central de Responsabilidades de Crédito* - CRC), a loan-level database at a monthly frequency, which covers the universe of loans granted to households by the domestic financial system, namely loans for consumption and mortgage loans. This dataset is managed by the Banco de Portugal. The sample we consider in the analysis is comprised of new loans for house purchase for own and permanent residence granted between January 2017 and December 2019, at a monthly frequency. Considering that the macroprudential Recommendation was implemented in July 2018, our sample includes one and a half years of observations before and after the policy change. This time frame is adequate to conduct the analysis as we have a reasonable number of observations after the introduction of lending limits on the LTV ratio, while the time frame is short enough to avoid other aggregate shocks that could have affected lending to households, thus hindering the identification of the impact of the policy change.

Loan-level data. The Banco de Portugal CRC data set is comprised of information on the debt contract, collateral, and borrower. For each loan, banks report the date of origination, loan maturity, amount, interest rate, interest rate spread, monthly payments, and the purpose of the credit. Banks also report the house transaction price and the appraisal value of the immovable property given as collateral for the new loan. This information allows us to compute the LTV ratio at the time of origination of the new loan as defined in the macroprudential Recommendation, which is the ratio of the mortgage amount to the minimum between the appraisal value and the transaction price of the property.

Borrower characteristics: Banks are required to report households' characteristics to the Banco de Portugal CRC dataset. In particular, for each loan, banks provide the household's age, education, employment status, and location. Information on the household's income is available only for new loans granted after July 2018. Therefore, we complement the credit register loan-level data with loan-level supervisory data on lending for house purchase, which includes borrowers' income.[7]

7. Even though both datasets cover information on mortgage loans granted by Portuguese banks and are both managed by the Banco de Portugal, they do not share a common loan identifier and, therefore, it is not possible to establish a direct correspondence of the data. We match the

Data filters. We apply minimal filters to the data to limit the impact of extreme values on the analysis, which arise from the granularity of the data. We drop loans with LTV ratios that are missing or unusually low (below 65) or high (above 110). We trim loan agreements at the 1st and 99th percentiles of the distribution of the key outcome variables due to unreasonable low or extremely high values. After matching the CCR data with the supervisory data and filtering the data, the number of observations in our sample of new loans for house purchase is approximately 103,000.

3.2. Descriptive Statistics

The main objective of this paper is to document the impact of the implementation of new lending limits on borrowers' leverage and housing choices.

As noted earlier, our sample is comprised of repeated cross-section observations that cover all mortgage loans for own and permanent residence granted to households from January 2017 to December 2019. The macroprudential Recommendation was implemented for new loans issued from July 2018 onwards.

Table 1 presents the descriptive statistics of the key variables in the analysis using observations on new loans granted before and after the introduction of the 90 percent LTV limit.

Loan-to-value. While the number of new loans granted after the policy change slightly decreased, the unconditional distributions of the loan amount, transaction prices and appraisal values shifted to the right. Loan amounts increased by less than transaction prices or appraisal values, suggesting that households had to use a higher amount of own funds to finance house purchase after the introduction of the LTV limit. The distribution of the LTV ratio shifted leftwards after the introduction of the new regulation. The median LTV decreased from 0.84 to 0.83, which suggests that the new LTV limit was binding for at least some of the households. As noted earlier, before the implementation of the new limits to the LTV ratio, the LTV ratio of loans for own and permanent residence stood commonly at between 80 and 90 percent of the appraisal value. Because the appraisal value was in general higher than the purchase price, this meant that a substantial share of credit was financed at 100 percent of the purchase price. Figure 1 shows the evolution of the LTV ratio calculated based on the transaction price and on the appraisal value in the period before the implementation of the macroprudential measure and according to the macroprudential measure in the period after the implementation of the new

observations in the datasets using the bank identifier, date of origination, maturity, and loan amount. Roughly 90 percent of the loan agreements are uniquevocally matched.

regulation. This figure shows that the average LTV ratio temporarily increased after the implementation of the new LTV limits.[8]

8. This temporary increase mainly reflects new loans for which the households' creditworthiness assessment was performed before the implementation of the policy.

	January 2017 - June 2018						*July 2018 - December 2019*					
	No. obs. (1)	Mean (2)	St. dev. (3)	Q1 (4)	Q2 (5)	Q3 (6)	No. obs. (7)	Mean (8)	St. dev. (9)	Q1 (10)	Q2 (11)	Q3 (12)
Loan amount (in euros)	54,393	108,736	53,308	70,000	97,750	135,000	49,605	114,959	54,632	75,193	104,000	141,611
Transaction price (in euros)	48,572	132,979	66,451	85,000	120,000	162,883	46,528	143,144	70,480	92,500	128,000	175,000
Appraisal value (in euros)	54,393	144,171	74,948	90,000	126,000	178,900	49,605	152,743	76,197	98,000	135,000	186,123
Loan-to-value (LTV)	54,393	0.84	0.11	0.75	0.84	0.96	49,605	0.84	0.09	0.79	0.83	0.90
Maturity (in years)	54,393	36.42	6.98	32.00	39.00	40.00	49,605	35.22	6.24	31.00	38.00	40.00
Loan interest rate (in %)	54,393	1.63	0.71	1.21	1.54	1.84	49,605	1.21	0.60	0.93	1.17	1.43
Loan spread (in pp)	47,498	1.72	0.59	1.25	1.70	2.00	42,940	1.39	0.34	1.15	1.30	1.55
Annual income (in euros)	54,393	27,752	18,749	15,927	22,380	33,646	49,605	30,082	21,159	15,866	23,198	37,735
Monthly instalment (in euros)	54,393	323	162	212	289.51	395	49,605	303	177	185	277	388
Loan-to-income (LTI)	54,393	4.81	2.51	3.03	4.37	6.07	49,605	4.86	2.48	2.92	4.61	6.33
Loan-service-to-income (LSTI)	54,393	0.20	0.11	0.13	0.18	0.25	49,605	0.18	0.11	0.10	0.18	0.25

Table 1. Main descriptive statistics for the periods before and after the introduction of the LTV limits.

Notes: The sample period goes from January 2017 to December 2019 and covers mortgage loans granted in this period. The loan-to-value ratio is defined as the ratio of the loan amount to the minimum between the transaction price and the appraisal value of the immovable property pledged as collateral. The sample is restricted to loans with LTV ratios between 0.65 and 1.1. The sample is split in the periods before the introduction of the new LTV limits (January 2017-June 2018) and after (July 2018-December 2019). Q1, Q2, and Q3 refer to the first, second, and third quartiles of the sample distribution of each variable, respectively.

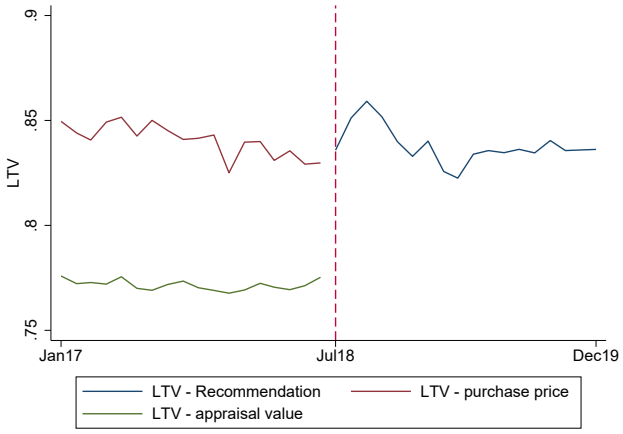


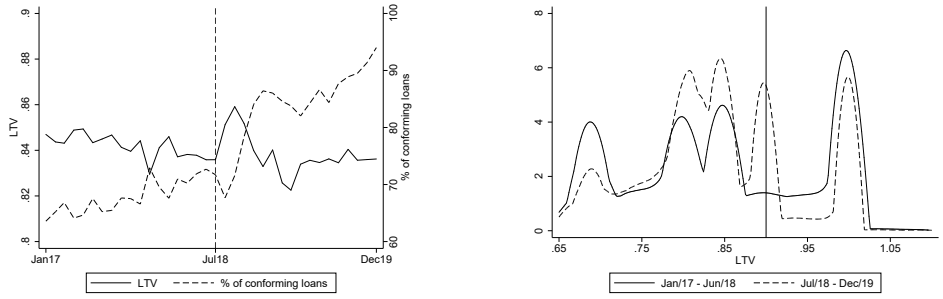
Figure 1: (Average) LTV ratio over time. The green line shows the evolution of the LTV ratio calculated as the ratio of the loan amount to the appraisal value of the property pledged as collateral. The red line shows the evolution of the LTV ratio calculated as the ratio of the loan amount to the transaction price. The blue line depicts the evolution of the LTV ratio calculated according to the macroprudential Recommendation, i.e., the ratio of the loan amount to the minimum between the transaction price and the appraisal value.

Panel A of Figure 2 presents the evolution of the (mean) LTV ratio over time calculated according to the macroprudential Recommendation. The time series of the average LTV ratio shows two different regimes before and after the introduction of the 90 percent LTV limit in July 2018. After the policy change, LTV ratios decreased to a lower value. The percentage of conforming loans, i.e. loans with an LTV ratio below or equal to 90, increased sharply after the implementation of the macroprudential Recommendation (from around 68.2 to 83.2 percent after the policy change).

Panel B of Figure 2 shows that the unconditional distribution of the LTV ratio shifted leftwards after the introduction of the LTV limit. Between January 2017 and June 2018, we observe a substantial concentration of the LTV ratio around 100 percent, i.e. new loans for house purchase were fully funded with bank credit. Before the introduction of the LTV limits, approximately 32 percent of the loans were granted with LTV ratios clearly above the 90 percent threshold while this percentage reduced to 17 percent after the introduction of the LTV limits. The percentage of loans granted with LTV ratios equal or above 100 percent decreased 6 percentage points in the period after the policy change (decreased from approximately 18.4 percent before the policy change to 12.0 percent after the policy change). From July 2018 to December 2019, the percentage of new loans with an LTV ratio around 100 percent decreased substantially and the LTV ratio became more concentrated around the 80 and 90 percent thresholds. Roughly 11.3 percent of the new loans are concentrated in the density of mortgages at 90

percent, which compares with 1.5 percent in the period before the introduction of the LTV limits.

The implementation of the new lending limits was gradual as we observe new loans with LTV ratios above the 90 percent limit in a few months following the policy change. This mainly reflects the new loans for which the households' creditworthiness assessment was performed before the implementation of the macroprudential Recommendation and to a lesser extent the difficulties in implementing the required operational procedures.



(a) (Average) LTV ratio over time and percentage of conforming loans.

(b) LTV ratio distribution before and after the introduction of the 90 percent LTV limit.

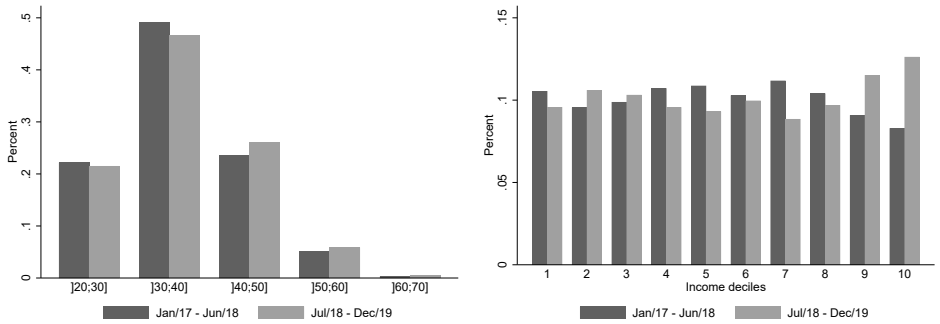
Figure 2: The distribution of LTV ratios before and after the introduction of the LTV limit.

Notes: Panel A) shows the time series of the average LTV ratio of new loans granted between January 2017 and December 2019 at the time of origination. The percentage of conforming loans (right axis) is the fraction of loan agreements with an LTV equal or below 90. Panel B) plots the distribution of the LTV ratio before and after the introduction of the LTV limit at 90, weighted by loan amounts.

Households' leverage. The unconditional distribution of households' income shifted rightwards after the introduction of the LTV limit, which indicates that in general new loans were granted to households with higher income. Households' leverage, as measured by the loan-to-income (LTI) ratio, is on average 0.05 percentage points higher in the period after the introduction of the LTV limit, which suggests that loan amounts increased more than households' income. In turn, the loan-service-to-income (LSTI) ratio is on average 0.3 percentage points lower. Interest rate spreads shifted leftwards and are less disperse after the introduction of the LTV limits, which partly explains the reduction in the LSTI ratio and in monthly instalments. The average (median) maturity after the policy change is approximately one year lower than before.

Households' income and age profiles. Panels A and B of Figure 3 show the distribution of new loans by households' age and income, respectively, before and after the implementation of the macroprudential Recommendation. In particular, Panel A shows that there are no significant changes in the distribution of loans

across age categories in the two periods. Panel B shows that the percentage of households in the two top deciles of the income distribution increased in the period after the policy change, which is in line with the improvement of the risk profile of households. In turn, there are no major changes in the percentage of loans in the remaining deciles of the income distribution.



(a) Borrower's age profile before and after the new LTV limit.

(b) Borrower's income profile before and after the new LTV limit.

Figure 3: New loans distribution by age and income deciles.

Notes: The period before the introduction of the LTV limit goes from January 2017 to June 2018 and the period after goes from July 2018 to December 2019.

In general, the descriptive analysis suggests an improvement in the risk profile of households associated with new loans for house purchase after the introduction of the measure. On average, households' income is higher, loan LTV ratios are lower (that reflects a higher percentage of own funds), and interest rate spreads are lower. Simultaneously, the average loan amount increased. Importantly for the objective of our paper, the descriptive statistics and the graphical evidence show a reduction in mortgage LTV ratios and a substantial shift of the OTV distribution to the left after the introduction of the 90 percent LTV limit in July 2018. However, understanding the micro-implications of the policy change on households' choices requires measuring the impact of the LTV limit on households more likely to be constrained by the new lending limits and to further account for aggregate time effects, borrower-specific characteristics, and bank-specific time-invariant heterogeneity.

In the next section we present the empirical strategy and the difference-in-differences model considered in the analysis. Section 5 discusses the results, and Section 6 presents the results of the robustness checks.

4. Empirical Methodology

In this section, we present the empirical models considered in this paper to explore the micro-implications of the introduction of the LTV limit on households. We begin by documenting the adjustment in the LTV ratio after the policy change and proceed by identifying borrowers who were more likely to be affected by the new lending limits. We then assess the impact of the policy change on this group of households' leverage and housing decisions.

4.1. Adjustment in the LTV distribution

Importantly for the objective of our study, we begin the analysis by documenting the adjustment in the LTV ratios following the implementation of the new LTV limits. For that purpose, we estimate the following regression model:

$$LTV_{lt} = \beta After_t + \theta' \mathbf{X}_{ht} + \omega_r + \delta_b + \varepsilon_{lt}, \tag{1}$$

where l denotes the loan granted to household h by bank b at time t. The variable $After_t$ equals one in the months after the introduction of the LTV limit (July 2018 to December 2019) and zero in the months before (January 2017 to June 2018). The vector $\mathbf{X}_{ht}$ is comprised of a set of borrower characteristics (income deciles, employment status, and education levels).[9] The terms ω_r and δ_b denote a set of location and bank fixed effects, respectively.[10] The term ε_{lt} is a zero mean disturbance term capturing all other omitted factors. In this regression model, β is the parameter of main interest and measures the change on households' average LTV ratio in the period following the policy change relative to the period before. We cluster standard errors at the location level.[11] Therefore, β is expected to be negative if the introduction of LTV limits was binding for some households.

The estimation results of equation (1) are presented and discussed in Section 5.1.

4.2. Difference-in-differences Model

The identification of β in equation (1) requires that the policy change was not anticipated by households and lenders and the absence of macroeconomic confounding effects that could drive both the macroprudential policy and the use of mortgage debt conditional on house purchase. To address these identification challenges, we proceed by estimating a difference-in-differences model, which

9. The employment status categorical variable includes as categories: business-owner, employee, unemployed.

10. In this regression model, location refers to the 306 Portuguese counties in the sample.

11. We also considered clustering standard errors at the month of origination of the loan and the statistical significance of the estimated coefficients remains unchanged.

allows us to estimate the impact of the introduction of LTV limits on households constrained by the policy change and to control for household and bank heterogeneity, and time effects. To formalize the impact of the new LTV limits on households' indebtedness and housing choices we consider the following regression model:

$$y_{lt} = \alpha_0 After_t + \alpha_1 Treated_h + \alpha_2 After_t \times Treated_h + \theta' \mathbf{X}_{ht} + \omega_r + \delta_b + \gamma_t + \varepsilon_{lt}, \tag{2}$$

where $Treated_h$ indicates whether the borrower was constrained by the introduction of the 90 percent LTV limit. The dependent variable y_{lt} assumes different loan level outcomes: LTV, loan amount, loan-to-income ratio, loan-service-to-income ratio, loan spread, and monthly payments. The term γ_t denotes a set of year-month fixed effects. In this specification, α_2 is the parameter of interest and measures the incremental policy response of affected households in comparison with the control group. We consider a slightly different empirical model to study the impact of the policy change on house transaction prices, which excludes bank fixed effects. Importantly, our identification assumption is that the constrained and the control group did not follow different trends in the period before the policy change (the parallel-trend assumption).

Estimating the counterfactual. To estimate the model presented in Equation (2) we need a control group (unconstrained households) and a treated group (constrained households). Due to the nature of the dataset, which is a repeated cross-section, the main challenge in this regression model is that the treatment status can be observed only before the policy change. After the policy change, we cannot distinguish affected (constrained) households by looking at their LTV ratios. However, based on data before the policy implementation, it is possible to predict the LTV ratio that the borrower would have chosen in the absence of the LTV limit (Van Bekkum *et al.* 2019; Tzur-Ilan 2020). We consider the following linear regression model to predict the household's LTV ratio:

$$LTV_{lt} = \beta_0 + \beta_1 Income_{ht} + \alpha_{r \times b} + \varepsilon_{lt}, \tag{3}$$

where $Income_{ht}$ denotes the borrower's annual income.[12] The estimated coefficients from this model are used to predict a counterfactual LTV ratio out-of-sample for each loan granted after the policy change. Then, households from both periods are classified as treated if the predicted LTV ratio is strictly above 90

12. In this regression model, r denotes a set of 20 Portuguese districts in the sample so that $\alpha_{r \times b}$ corresponds to the interaction terms between district and bank identifiers. We would end up with too many empty sets if we instead considered the interaction between the 306 Portuguese counties in the sample and bank identifiers.

percent ($d(\widehat{LTV}_{lt} > 90) = 1$), and are part of the control group otherwise.[13] According to the estimates, approximately 28 percent of the households were constrained by the introduction of the limits to the LTV ratio. We proceed by estimating equation (2) using this classification of constrained households.

Th estimation results of equation (2) are discussed in Section 5.2.

5. Impact of the LTV Limit on Households' Leverage and Housing Choices

In this section we discuss the estimation results of the difference-in-differences regression model. We begin by presenting the impact of the introduction of the 90 percent LTV limit on the distribution of LTV ratios (Section 5.1). We proceed by investigating the adjustment on households' leverage and housing decisions following the new LTV limits (Section 5.2).

5.1. Impact on LTV ratios

We begin by estimating the empirical model presented in Equation (1), which gives the adjustment in LTV ratios after the introduction of the LTV limit. The estimation results are reported in Table 2. The point estimates across the model specifications presented in columns (1) to (5), which include a different set of location, bank, and household control variables, show a reduction in the LTV ratios after the introduction of the LTV limits. According to the results reported in column (5), the LTV ratio was on average approximately 1.7 percentage points lower in the period after the introduction of the LTV limit. The estimated adjustment is statistically significant at 1 percent significance level. The change in the estimated coefficient and the increase in the adjusted R-squared when we account for bank fixed effects suggests that bank-specific time-invariant heterogeneity plays an important role in explaining the adjustment in the LTV ratios.

13. Including additional explanatory variables such as the borrower's age and education does not improve the explanatory power of our model as these variables are strongly correlated with the borrower's income. Some authors also consider a quadratic term on households' income (Van Bekkum *et al.* 2019; Tzur-Ilan 2020). In our estimated model, the quadratic term was not statistically significant. The coefficient of determination of the estimated model to predict "counterfactual" LTV ratios is approximately 46.3 percent.

	LTV_{ht} (1)	LTV_{ht} (2)	LTV_{ht} (3)	LTV_{ht} (4)	LTV_{ht} (5)
After	-0.0034***	-0.0035***	-0.0178***	-0.0023**	-0.0168***
	(0.0011)	(0.0011)	(0.0009)	(0.0011)	(0.0009)
Location fixed effects	No	Yes	Yes	Yes	Yes
Bank fixed effects	No	No	Yes	No	Yes
Borrower controls	No	No	No	Yes	Yes
N	102423	102423	102423	81039	81039
Adjusted R^2	0.000	0.006	0.439	0.013	0.465

Table 2. Impact of the LTV limit on LTV ratios: LTV measured continuously.

Notes: The table reports the estimation results of Equation (1). The dependent variable is the LTV ratio measured continuously. The sample period goes from January 2017 to December 2019. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** and ** denote statistical significance at 1% and 5%, respectively.

Table 3 shows the results of the estimation of Equation (1), considering a binary variable equal to one if the LTV ratio is above the 90 percent LTV threshold ($d(LTV > 90) = 1$) as dependent variable. The point estimates are stable across the regression specifications reported in columns (1) to (5) and statistically significant at 1 percent significance level. The estimates show that the probability of a LTV ratio above 90 percent is substantially lower after the introduction of the LTV limits. According to the estimates in column (5), the probability of being granted a loan with an LTV ratio that exceeds the 90 percent threshold is 15 percentage points lower after the policy change.

	$d(LTV > 90) = 1$ (1)	$d(LTV > 90) = 1$ (2)	$d(LTV > 90) = 1$ (3)	$d(LTV > 90) = 1$ (4)	$d(LTV > 90) = 1$ (5)
After	-0.1508***	-0.1498***	-0.1601***	-0.1422***	-0.1539***
	(0.0060)	(0.0060)	(0.0061)	(0.0058)	(0.0061)
Location fixed effecs	No	Yes	Yes	Yes	Yes
Bank fixed effects	No	No	Yes	No	Yes
Borrower controls	No	No	No	Yes	Yes
N	102423	102423	102423	81039	81039
Adjusted R^2	0.030	0.035	0.376	0.035	0.398

Table 3. Impact of the LTV limit on LTV ratios: LTV above 90.

Notes: The table reports the estimation results of Equation (1). The dependent variable is a binary variable equal to one if the LTV is above 90. The sample period goes from January 2017 to December 2019. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** denotes statistical significance at 1%.

The estimated adjustment in the LTV ratios following the policy change tally with the graphical evidence that shows a leftwards shift in the unconditional distribution of the LTV ratios and a substantial increase in the fraction of new

loans with LTV ratios below the 90 percent threshold after the implementation of the macroprudential Recommendation.

After documenting the adjustment in the LTV ratios, we proceed by exploring the impact of the policy change on households that are more exposed to the lending limits using a difference-in-differences framework.

Table 4 shows the results of the estimation of Equation (2), considering the LTV ratio measured continuously (LTV_{ht}) as dependent variable. This empirical specification allows us to analyse the impact of the LTV limit on households that would have exceeded the LTV limit in the absence of the macroprudential Recommendation. The coefficient of main interest is the coefficient of the interaction term, which tells us the adjustment in the LTV ratios of constrained households in the period after the policy change. The point estimates are negative, statistically significant at 1 percent significance level, and stable across the regression specifications presented in columns (1) to (3) of Table 4, which progressively account for time, bank, and location fixed effects, and borrower characteristics. According to the estimates in column (3), the LTV ratio of households more likely to exceed the new LTV limit was 5.9 percentage points lower due to the policy change. As expected, the reduction on LTV ratios of constrained households is stronger than the average estimated impact of the policy change.

Next we explore the mechanisms underlying the reduction of the LTV ratios of constrained households and the micro-implications on housing choices.

	LTV_{ht} (1)	LTV_{ht} (2)	LTV_{ht} (3)
Treated	0.1354***	0.1400***	0.0439***
	(0.0017)	(0.0017)	(0.0023)
After×Treated	-0.0865***	-0.0888***	-0.0586***
	(0.0017)	(0.0017)	(0.0017)
Year-month fixed effects	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes
Bank fixed effects	No	No	Yes
Borrower characteristics	No	Yes	Yes
N	94217	74233	74233
Adjusted R^2	0.269	0.289	0.457

Table 4. Impact of the LTV limit on LTV ratios - DID specification.

Notes: The table reports the estimation results of Equation (2). The dependent variable in columns (1), (2), and (3) is the LTV ratio measured continuously. The sample period goes from January 2017 to December 2019. All specifications include year-month fixed effects. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** denotes statistical significance at 1%.

5.2. Impact on households' leverage and housing choices

The documented adjustment in the LTV ratios following the introduction of the 90 percent threshold for the LTV ratio, in particular the estimated reduction for more vulnerable households, is consistent with the idea that the lending limits were binding for some of the households. Therefore, a crucial question is whether the introduction of the LTV limit led to an adjustment on leverage and housing choices, especially for households that were more likely to have LTV ratios that would exceed the new lending threshold in the absence of the new regulation. In particular, by requiring a higher downpayment, constrained households may take out smaller loans, either because they are able to find alternative sources of funding or because they purchase cheaper houses.

In order to understand these effects, we estimate Equation (2) considering the (logarithm of the) loan amount and the (logarithm of the) house transaction price, separately, as dependent variables. The estimation results are reported in Table 5. Columns (1) to (4) report the estimated impacts of the LTV limits on loan amounts. The estimates show that constrained households load on less mortgage debt due to the policy shock. According to the estimates reported in column (3), constrained households borrowed on average 6.9 percent smaller loans than they would have borrowed in the absence of the policy shock. The impact is even stronger when we control for loan maturity in column (4). According to the estimates in column (4), constrained borrowers load up on average 7.5 percent smaller loans than the borrowers in the control group. A possible explanation for the reduction on mortgage amounts rely on the larger downpayments that households are required to make after the introduction of the limits to the LTV ratio.

In what concerns to house transaction prices, the estimates in columns (5) and (6) of Table 5 show that, on average, households more likely to exceed the new LTV limit bought cheaper houses after the introduction of the macroprudential measure. The results reported in column (6) show that the interaction term - the treatment effect - is statistically significant at 5 percent significance level and that house transaction prices of households that would exceed the 90 percent threshold in the absence of the macroprudential measure are on average 2.1 percent lower than those of the control group.

Taken together, these results suggest that constrained households adjusted to the introduction of the new limits to the LTV ratio by taking out smaller mortgage loans and buying cheaper houses.

	Loan amount (1)	Loan amount (2)	Loan amount (3)	Loan amount (4)	House price (5)	House price (6)
Treated	0.0912***	0.1126***	0.0264***	0.0251***	-0.0886***	-0.0579***
	(0.0081)	(0.0049)	(0.0093)	(0.0094)	(0.0079)	(0.0053)
After×Treated	-0.1265***	-0.0905***	-0.0688***	-0.0746***	-0.0485***	-0.0208**
	(0.0093)	(0.0078)	(0.0080)	(0.0075)	(0.0095)	(0.0082)
Year-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	No	No	Yes	Yes	No	No
Borrower characteristics	No	Yes	Yes	Yes	No	Yes
Maturity control	No	No	No	Yes	No	No
N	94217	74233	74233	74233	85526	67064
Adjusted R^2)	0.066	0.313	0.331	0.368	0.088	0.331

Table 5. Impact of the LTV limit on loan amounts and house transaction prices.

Notes: The table reports the estimation results of Equation (2). The dependent variable in columns (1), (2), (3), and (4) is the (logarithm of the) loan amount. Column (4) controls for loan maturity quartiles. The dependent variable in columns (5) and (6) is the (logarthm of the) house transaction prices. The sample period goes from January 2017 to December 2019. All specifications include year-month fixed effects. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** and ** denote statistical significance at 1% and 5%, respectively.

Next we further explore the impact of the introduction of the limit to the LTV ratio on households' leverage by re-estimating the empirical model presented in Equation (2) considering the LTI and the LSTI ratios as outcome variables. The estimation results reported in Table 6 show that households constrained by the new lending limits have a lower LTI ratio in comparison with the control group. According to the estimates reported in column (4), the LTI ratio of constrained households is on average 0.31 percentage points lower due to the policy change. This result tallies with the reduction in loan amounts taken out by constrained households following the new lending limits.

	LTI (1)	LTI (2)	LTI (3)	LTI (4)
Treated	0.7568***	0.5081***	0.3334***	0.3217***
	(0.0561)	(0.0239)	(0.0403)	(0.0401)
After×Treated	-0.2311***	-0.3331***	-0.2841***	-0.3035***
	(0.0659)	(0.0374)	(0.0379)	(0.0362)
Year-month fixed effects	Yes	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects	No	No	Yes	Yes
Borrower characteristics	No	Yes	Yes	Yes
Maturity control	No	No	No	Yes
N	94217	74233	74233	74233
Adjusted R^2	0.025	0.461	0.471	0.495

Table 6. Impact of the LTV limit on loan to income (LTI) ratios.

Notes: The table reports the estimation results of Equation (2). The dependent variable is the loan to income ratio (LTI). The sample period goes from January 2017 to December 2019. All specifications include year-month fixed effects. Column (4) controls for loan maturity quartiles. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** denotes statistical significance at 1%.

Table 7 presents the estimates of Equation (2) considering the LSTI ratio as outcome variable. Interestingly, according to these estimates, the LSTI ratio of households affected by the introduction of the LTV limit is higher than that of the borrowers in the control group. According to the estimates reported in column (4), the LSTI ratio of constrained households is approximately 1.9 percentage points higher than that of the households in the control group. It is important to note that the design of the Portuguese macroprudential measure includes a limit to the DSTI ratio of 50%[14], which contributes to ensure borrowers' debt servicing capacity.

To understand the mechanisms underlying the impact of the limits to the LTV ratio on LSTI ratios, we next analyse the adjustment in interest rate spreads following the policy change. The results reported in columns (1) to (3) of Table 8 show that while in the aggregate new loan interest rate spreads are lower after the introduction of the LTV limits, constrained households pay higher spreads relative to the control group. The increase in interest rate spreads is consistent with the documented increase in LSTI ratios of contrained households relative to the control

14. The calculation of the DSTI ratio should assume that the installments of the new credit agreement are constant and consider the impact of an interest rate rise according to the maturity in the case of variable and mixed interest rate agreements and a reduction in income in the case of a borrower aged 70 and over at the planned expiry of the agreement, except if at the time of the creditworthiness assessment the borrower is already retired.

group.[15] When we consider location and bank fixed effects and borrower-specific controls in the estimated model, the interest rate spread of loans taken out by constrained households is 0.03 percentage points higher relative to the control group. In the aggregate, the downward adjustment in the LTV ratio in response to the introduction of the new LTV limits is associated with an improvement in the risk profile of households and therefore lower interest rate spreads. However, constrained households actually pay a higher interest rate spread, despite the reduction in the LTV ratio which, among other factors, contributes to a lower expected loss via the reduction in the LGD. One possible explanation for this outcome is that the introduction of a macroprudential measure by the macroprudential authority is a strong signal for banks about the buildup of systemic risk in the financial system and this may have changed banks' risk perception. Then, the pricing of new loans granted to constrained households reflects the higher risk perception (Tzur-Ilan 2020; De Araujo *et al.* 2020).[16] An alternative explanation is the lower bargaining power of constrained households when negotiating a new loan with a bank after the introduction of the macroprudential Recommendation.

	LSTI (1)	LSTI (2)	LSTI (3)	LSTI (4)
Treated	0.0216***	0.0120***	0.0001	0.0007
	(0.0022)	(0.0009)	(0.0018)	(0.0017)
After×Treated	0.0147***	0.0107***	0.0191***	0.0193***
	(0.0026)	(0.0017)	(0.0017)	(0.0018)
Year-month fixed effects	Yes	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes	Yes
Bank fixed effects	No	No	Yes	Yes
Borrower characteristics	No	Yes	Yes	Yes
Maturity control	No	No	No	Yes
N	94217	74233	74233	74233
Adjusted R^2	0.034	0.422	0.475	0.482

Table 7. Impact of the LTV limit on loan service to income (LSTI) ratios.

Notes: The table reports the estimation results of Equation (2). The dependent variable is the loan service to income ratio (LSTI). The sample period goes from January 2017 to December 2019. All specifications include year-month fixed effects. Column (4) controls for loan maturity quartiles. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** denotes statistical significance at 1%.

15. Even though the 40-year maturity limit was not binding for most of the financial institutions and we are accounting for year-month fixed effects in the empirical models, this result could be partly driven by the new maturity limits recommended in the measure. We include loan maturity quartiles in the estimated regression models in order to account for this possibility.

16. A similar result is documented in Tzur-Ilan (2020). The author shows that affected households by the imposition of a strict LTV limit in Israel paid higher interest rates than the control households.

Columns (4) to (7) of Table 8 report the impact of the introduction of the new lending limits on monthly instalments paid by households. The estimates are statistically significant at 1 percent significance level and show that monthly instalments of constrained households are on average 40 euros higher compared to the control group. This result is consistent with the increase in the LSTI ratio of constrained households, which stems from the higher interest rate spreads associated with loans borrowed by these households.

	Spread (1)	Spread (2)	Spread (3)	Instalment (4)	Instalment (5)	Instalment (6)	Instalment (7)
Treated	-0.1514***	-0.1605***	0.0455***	12.8828***	20.3728***	-30.0739***	-29.1741***
	(0.0104)	(0.0101)	(0.0135)	(2.5602)	(1.4335)	(3.7736)	(3.7119)
After×Treated	0.0310***	0.0202*	0.0336**	8.9591**	20.5477***	39.4100***	40.1995***
	(0.0101)	(0.0112)	(0.0130)	(3.7002)	(2.8363)	(3.0223)	(3.1431)
Year-month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	No	No	Yes	No	No	Yes	Yes
Borrower characteristics	No	Yes	Yes	No	Yes	Yes	Yes
Maturity controls	No	No	No	No	No	No	Yes
N	82399	65366	65366	94217	74233	74233	74233
Adjusted R^2	0.194	0.247	0.347	0.067	0.229	0.314	0.327

Table 8. Impact of the LTV limit on loan interest rate spreads and monthly instalments.

Notes: The table reports the estimation results of Equation (2). The dependent variable in columns (1), (2), and (3) is the loan interest rate spread. The dependent variable in columns (4), (5), (6), and (5) is the monthly instalment. The sample period goes from January 2017 to December 2019. All specifications include year-month fixed effects. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses.*** denotes statistical significance at 1%.

All in all, our results suggest that the introduction of a limit to the LTV ratio of new mortgage loans contributed to improve the risk profile of households through the reduction of the LTV ratio. This adjustment seems to be driven by a reduction in the loan amounts taken out by households, especially by households that were more likely to exceed the new limits to the LTV ratio. Also, constrained households bought cheaper houses following the introduction of the policy change. Additionally, our analysis suggests that constrained households paid higher interest rate spreads relative to the control group, which are associated with higher LSTI ratios and monthly instalments.

The next section presents robustness checks that adress possible endogeneity concerns that would compromise the validity of the estimated treatment effects, namely the possibility of anticipation effects and the presence of location-specific effects.

6. Robustness Checks

An imediate concern with the estimated models is the presence of policy anticipation effects that would cause the coefficient estimates of the treatment effects to be biased. The macroprudential measure was announced in February 2018 but implemented in July 2018. Selection effects could arise if some households or credit institutions behave strategically and anticipate the introduction of the new LTV limits. To address these endogeneity concerns, we excluded from the analysis mortgages originated after the policy announcement in February 2018 and before the implementation of the policy in July 2018. The estimation results are reported in columns (1) to (3) of Table 9. The estimated coefficients are negative and statistically significant at 1 percent significance level across the three empirical specifications. The point estimate for the interaction term reported in column (3) is -0.056, which is virtually the same we obtained in Table 4. Therefore, these results suggest that households' strategic behaviour (if any) does not drive the estimation results.

An additional concern with the estimation is whether location-specific economic conditions could play a role in the adjustment of the LTV ratios. We address this potential source of endogeneity by introducing a new set of fixed effects that allows us to account for location-specific time effects. Columns (4) to (6) of Table 9 present the estimates of the adjustment of the LTV ratios accounting for the possibility of differential macroeconomic trends that could disproportionately affect the treated group. According to the estimates reported in column (6), the LTV ratios of constrained households are on average 6.1 percentage points lower than those of the control group. This result suggests the absence of location-specific trends.

	LTV_{ht} (1)	LTV_{ht} (2)	LTV_{ht} (3)	LTV_{ht} (4)	LTV_{ht} (5)	LTV_{ht} (6)
Treated	0.1337***	0.1381***	0.0471***	0.1375***	0.1416***	0.0437***
	(0.0010)	(0.0011)	(0.0015)	(0.0009)	(0.0010)	(0.0014)
After× Treated	-0.0853***	-0.0875***	-0.0560***	-0.0914***	-0.0930***	-0.0607***
	(0.0014)	(0.0016)	(0.0015)	(0.0015)	(0.0017)	(0.0016)
Year-month×location fixed effects	No	No	No	Yes	Yes	Yes
Year-month fixed effects	Yes	Yes	Yes	No	No	No
Location fixed effects	Yes	Yes	Yes	No	No	No
Bank fixed effects	No	No	Yes	No	No	Yes
Borrower characteristics	No	Yes	Yes	No	Yes	Yes
N	76471	60180	60180	94217	74233	74233
Adjusted R^2	0.253	0.274	0.442	0.268	0.288	0.456

Table 9. Impact of the LTV limit on LTV ratios - robustness checks.

Notes: The table reports the estimation results of Equation (2). The dependent variable is the LTV ratio measured continuously. The sample period goes from January 2017 to December 2019. Loans granted between the announcement (February 2018) and the implementation (July 2018) of the LTV limits are excluded from the sample in columns (1), (2) and (3). Columns (1) to (3) include year-month fixed effects and columns (4) to (6) include year-month times location fixed effects. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** denotes statistical significance at 1%.

In Section 5 we documented that banks adjusted progressively to the new lending limits, with some loans with LTV ratios above the 90 percent threshold granted after July 2018. Therefore, a natural question is whether there might be delayed effects to the policy change. We re-estimated equation (2) and splitted the sample considering that the macroprudential measure was instead implemented in October 2018. The estimation results are reported in Table 10. The point estimates are very similar to the point estimates reported in Table 4 and suggest that the adjustment on average LTV ratios does not differ substantially.

	LTV_{ht} (1)	LTV_{ht} (2)	LTV_{ht} (3)
Treated	0.1343***	0.1385***	0.0390***
	(0.0008)	(0.0008)	(0.0013)
After× Treated	-0.0828***	-0.0845***	-0.0537***
	(0.0014)	(0.0016)	(0.0014)
Year-month fixed effects	Yes	Yes	Yes
Location fixed effects	Yes	Yes	Yes
Bank fixed effects	No	No	Yes
Borrower characteristics	No	Yes	Yes
N	97196	76644	76644
Adjusted R^2	0.277	0.297	0.460

Table 10. Impact of the LTV limit on LTV ratios - robustness checks

Notes: The table reports the estimation results of Equation (2). The dependent variable is the LTV ratio measured continuously. The sample period goes from January 2017 to December 2019. The after period goes from October 2018 to December 2019. All specifications include year-month fixed effects. The set of borrower-specific controls is comprised of income deciles, education levels, and employment status. Ordinary Least Squares estimates with robust standard errors clustered at the location level in parentheses. *** denotes statistical significance at 1%.

7. Final remarks

Although borrower-based measures have become increasingly more important in macroprudential authorities' toolkit, there is still little evidence on the micro-implications of these policies on borrowers. We study the effects of the introduction of a macroprudential Recommendation by the Banco de Portugal in July 2018, which is comprised of new lending limits. In particular, we explore the response of households to the introduction of a new limit to the LTV ratio with a new standardized definition. We use credit register data that covers the universe of new loans to households and is comprised of loan-level information, borrower characteristics, and information on the immovable property pledged as collateral.

We rely on a difference-in-differences regression model and find that the introduction of the new lending limits was effective in reducing households' leverage through a reduction of the LTV ratios of loans borrowed after the policy change, especially of loans borrowed by constrained households. This result is consistent with an improvement of the risk profile of households following the introduction of the new lending limits. We find that this adjustment seems to be driven by the reduction in the loan amounts of loans taken out by constrained households and in households' leverage as measured by the loan-to-income ratio. This is related to the fact that households are requested to make larger downpayments after the introduction of the LTV limit. Our results also show that on average constrained households bought cheaper houses in relation to a no-policy scenario.

An interesting result is that constrained households paid on average higher interest rate spreads, despite the reduction in the LTV ratio which, among other factors, contributes to a lower LGD. This result may be explained by the perception of higher risk by the credit institutions and the lower bargaining power of the

households more likely to exceed the new lending limits. This increase in interest rate spreads is associated with higher monthly instalments and loan service to income ratios of constrained households after the policy change.

We also show that the explanatory power of the estimated models increase substantially when we account for bank-specific time-invariant heterogeneity, which is evidence of considerable heterogeneity in banks' pricing and lending strategies.

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Appendix: Loan maturity

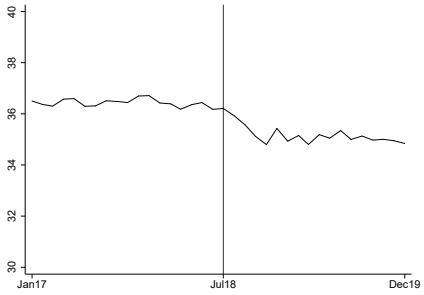

Figure A.1: Loan maturity (in years) over time.

Notes: The period before the introduction of the limits to maturity goes from January 2017 to June 2018 and the period after goes from July 2018 to December 2019. The loan maturity is measured in years.

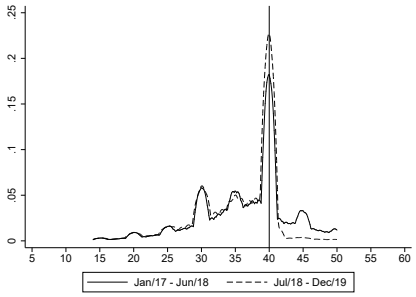

Figure A.2: The distribution of loan maturity (in years) before and after the introduction of the limits to the maturity.

Notes: The period before the introduction of the limits to maturity goes from January 2017 to June 2018 and the period after goes from July 2018 to December 2019. The loan maturity is measured in years.

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