MORTAGE BORROWING CAPS: LEVERAGE, DEFAULT, AND WELFARE*

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Abstract

We explore the transmission channels of macroprudential policy in the form of caps on household mortgage borrowing. We employ an overlapping generations model with uninsurable labor income risk, housing, and long-term defaultable loans to measure the long-run economic impact of loan-to-value (LTV) and debt payment-to-income (PTI) caps on mortgage contracts in an economy without aggregate risk. We calibrate the model to Portugal, which implemented a 90 percent LTV cap and a 50 percent PTI cap. We find that the leverage cap can lower mortgage debt to output by one-third and eliminate the default rate. However, this comes at the cost of a 2 percent reduction in household welfare, chiefly among income and wealth-poor agents. PTI limits reduce default by limiting debt service but increase indebtedness and household leverage. This mechanism stems from the interaction between labor market risk and the payment-to-income cap: Households fear future adverse income shocks may constrain their access to credit markets and borrow earlier with lower down payments. Finally, we find that the policymaker can achieve similar cuts in default with a smaller welfare cost by setting a less stringent LTV cap or a more restrictive PTI cap.

Keywords: Mortgage, Macroprudential Policy, Default, Recourse, LTV, PTI, House Prices.

JEL Classifications: D60, E21, E44.

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1 Introduction

High household debt burdens have been a persistent feature of advanced economies for the last few decades and are frequently identified as a drag on output growth (Demertzis et al., 2020, Mian et al., 2015). In response, policymakers introduced caps on household leverage and debt service ratios at mortgage loan origination. The goal of these policies is to reduce indebtedness, default risk, and dampen the effects of aggregate shocks on house prices and default.[1]

The use of household borrowing caps has become widespread. By 2018, roughly 3/4 of European Union Member States had enacted some form of limit on consumer loan contracts.[2] In the U.S., the Dodd-Frank act included an "Ability-to-Repay" rule, which increases the cost of originating high leverage loans (Defusco et al., 2020). Overall, a total of sixty economies have enacted some form of explicit limit on household lending standards since 1990 (Acharya et al., 2020).

Despite the prevalence in the adoption of these policies, research into their effects is in its early stages, and many questions remain open. What is the long-run impact of mortgage caps on household leverage and default? How is household welfare affected, and what are the distributional implications of these policies? Is the impact different depending on which cap is used?

We use the implementation of LTV and PTI caps in Portugal in 2018 as a case study to answer these questions. The goal of the policy was to reduce household indebtedness and lower default rates. Using the policy change as a backdrop, our paper proposes answers to the questions with six main findings.

First, we document that an LTV cap of 90 percent is binding for around 40 percent of new mortgage loans in Portugal, in contrast to only 25 percent for a PTI cap of 50 percent before the new policy was implemented. This implies that a significant number of new mortgage contracts are affected by the new regulation.

[1] Externalities associated with overborrowing have been described in Lorenzoni (2008) and Bianchi (2011). In a nutshell, in an economy with credit constraints linked to asset prices, agents make borrowing decisions without internalizing the general equilibrium effects of their individual decisions on prices. When debt is sufficiently high and an adverse shock occurs, agents reduce their consumption which depreciates the value of the assets posted as collateral. This triggers the classic Fisher debt-deflation channel, with mutually reinforcing drops in consumption and asset prices. A social planner can mitigate this by choosing a lower amount of borrowing *ex-ante*. For moral hazard of financial intermediaries, see Farhi and Tirole (2012). Whether mortgage borrowing caps are an effective tool to tackle these issues is outside the scope of this paper.

[2] LTV caps in the European Union ranged from 100 to 80 percent in 2018 for main residence buyers. PTI caps ranged from 100 to 40 percent. See ESRB (2019).

Second, using an overlapping generations model with uninsurable labor income risk, housing, and long-term defaultable loans we show that the specific policy implemented in Portugal can reduce mortgage debt by one-third and virtually eliminate default in the long-run. However, this comes at the cost of a 2 percent reduction in household welfare, concentrated at the bottom of the income and wealth distributions. We also find that setting PTI and LTV caps have only a very limited effect on house prices, as argued by Kaplan et al. (2020) for the U.S. economy. Thus, more affluent households benefit from the policy due to the reduction in property taxes and maintenance costs. However, it is not sufficient to offset the negative effects from constraining individual optimization in the welfare analysis. This observation does not necessarily imply that the policy is welfare reducing overall, given that the model does not take into account the intertemporal trade-off between *ex-ante* restrictions and lower crisis probability and severity *ex-post* due to a less vulnerable financial system.

Third, we show that these results are mainly driven by the leverage cap. The substantial drop in household debt, in particular, follows from the fact that a significant fraction of the aggregate mortgage credit flow is associated with younger agents who start their life with low wages and savings and choose loan contracts with lower down payments. Setting an LTV limit is equivalent to requiring a minimum down payment on new loans, forcing agents to either save up in order to meet the new requirements, buy a smaller house, or rent one instead of becoming homeowners, thus restricting the flow of high leverage loans and the future stock of debt.

Fourth, we find that the 50 percent PTI cap does not contribute to decreasing default or aggregate debt in the long-run in an environment where interest rates remain low and the fraction of constrained households is limited. However, when set in isolation from a cap on leverage, it puts upward pressure on aggregate debt and leverage. This is the result of the interaction between labor market risk, long-term loans, and the payment-to-income cap: Households fear future adverse income shocks may constrain their access to credit markets and borrow earlier with lower down payments, since the caps only need to be satisfied at loan origination. This can leave household balance sheets vulnerable to aggregate shocks if a PTI cap is implemented without an appropriate LTV cap to prevent the increase in leverage. The discovery of this mechanism, which we dub as *pre-emptive borrowing*, is one of our main contributions.

Fifth, depending on the weight that the policymaker assigns to reducing indebtedness, she may be able to cut the default rate at a lower welfare cost. For the baseline economy, setting the LTV cap at 100 percent cuts the default rate by 80 percent with two-thirds the welfare loss to households, at the cost of a lower reduction of total mortgage debt to GDP. Lowering the PTI cap to 0.45 instead of 0.5, the policymaker can reduce the default rate by three-fifths with one-tenth the welfare cost of the baseline policy. However, due to the interaction between labor market risk and the PTI cap this comes at the cost of a mild increase in aggregate debt relative to the baseline due to pre-emptive borrowing.

Finally, we test the response of the economy to shocks with and without the policy. We find that the imposition of PTI and LTV caps prevents a surge of defaults following a house price crash. However, this comes at the cost of a slower recovery of the housing market, given the restrictions on ownership introduced by the policy. This creates an argument for a counter-cyclical dynamic of mortgage borrowing caps to loosen conditions during house price recoveries.

To measure the effects of the policy and of the counterfactuals, we built a structural model in the tradition of Hatchondo et al. (2015), Favilukis et al. (2017), and Kaplan et al. (2020), which includes housing, long-term mortgages, the option to default, and rental markets. The setting is an open economy with overlapping generations of households subject to uninsurable idiosyncratic risk in labor income. They consume non-durable goods and housing services, and save in a risk-free bond which pays a fixed interest rate set by international markets. Housing services may be obtained by either renting or owning a house.

Ownership is attractive for three reasons: First, it provides the owner with extra utility with respect to renting a house of the same size. Second, housing markets are segmented such that consumption of higher housing services is only possible through ownership. Third, the rental sector is subject to frictions in the form of management costs and rental income taxation, which raise rents above the user cost of capital.

Households may finance their house purchase using long-term defaultable recourse mortgages provided by competitive financial intermediaries. Exogenous mortgage origination caps prevent lenders from providing a given contract to a borrower if he does not satisfy a minimum down payment requirement (the LTV cap) or a maximum ratio of scheduled debt payments to current after-tax labor income (the PTI cap).

If a household chooses to default on its mortgage payments, the financial intermediary repossesses the house in order to pay for the outstanding debt and the household is excluded from homeownership and credit markets in that period. This implies that the notion of default in our model corresponds to foreclosure of the household main residence.

If the foreclosure value is not sufficient for full debt repayment, the intermediary has a limited ability to extract recourse payments from the defaulting household during the default period. In the following period, the household regains access to all markets. In our framework there is no aggregate risk and no possibility of insolvency of the financial intermediaries.

The mechanics described above highlight the importance of leverage in the default decision. In case a household finds itself unable to fulfill the scheduled debt payment she always has the option to sell her house, collect the residual equity, and rent. It is only optimal to default in case home equity is negative. As the ability of the financial intermediary to garnish the household's income and assets is limited, default is a means to obtain debt relief.

By imposing a minimum down payment (i.e., an LTV cap), the policymaker can influence these incentives by reducing the probability that households have negative home equity following an adverse income shock. Likewise, setting a maximum debt service ratio limits access to credit for households at the bottom of the income distribution, which are those that actually default in the model.

Literature. This paper is tied to four strands in the literature. First, our paper builds on the macroeconomic research that studies housing choices in a model with idiosyncratic risk, housing markets, and mortgage financing, and competitive loan pricing in the tradition of Jeske et al. (2013), Chatterjee and Eyigungor (2015), Corbae and Quintin (2015), Hatchondo et al. (2015), Gete and Zecchetto (2018), and Kaplan et al. (2020), and Chen et al. (2020).

Second, our paper is closely related to the nascent theoretical literature which analyzes the impact of caps on household borrowing in incomplete markets models. Hatchondo et al. (2015) study the introduction of recourse mortgages and LTV caps in the U.S. economy. They find that LTV limits reduce welfare but can prevent an increase in defaults following an adverse house price shock. Hu (2019) studies the impact of the "ability-to-pay" rule of the Dodd-Frank Act in the U.S. mortgage market, which relaxes the existing Freddie Mac PTI limit for a subset of households with low probability of default. Our contribution to this strand is to analyze the impact of both LTV and PTI caps. Unlike Hatchondo et al. (2015) and Hu (2019), our framework incorporates endogenous house prices and rents, which allows us to account for the feedback between credit market restrictions, housing and rental markets.

Third, we contribute to the recent empirical literature on credit standards in Europe, as represented by Acharya et al. (2020) and van Bekkum et al. (2019). We document the empirical distribution of lending standards in Portugal, which features a non-trivial fraction of new loan contracts with a loan-to-value ratio above 100 percent and a lesser role for PTI caps, in contrast to the U.S. mortgage markets (Greenwald, 2016). We also find that borrowing caps have an impact on house prices, rents, and on the behavior of households which are not constrained by the policy, highlighting the challenges posed for the identifying assumptions of diff-in-diff strategies when measuring the impact of these policies.

Finally, this paper adds to the literature on representative agent DSGE models of credit markets and macroprudential policy, such as Mendicino (2012) and Greenwald (2016), by underlining the drawbacks of abstracting from idiosyncratic wage risk when studying the impact of these policies. In particular, we show that the interaction between the PTI cap and household labor income risk increases the leverage choice of households, a channel which is not fully captured in representative agent models as they stand.

Layout. The paper is organized as follows. Section 2 provides a short description of the Portuguese economy before the introduction of the mortgage borrowing caps by Banco de Portugal in 2018. Section 3 provides details on the policy and the assumptions made in order to approximate its effects with a calibrated structural model. Section 4 documents the distribution of LTV and PTI at mortgage loan origination before and after the policy was announced and implemented. Section 5 describes the theoretical model. Section 6 presents the calibration and model fit. Section 7 presents the main exercises and discusses the quantitative results and the transmission channels. Section 8 concludes.

2 The Portuguese financial crisis and mortgage debt

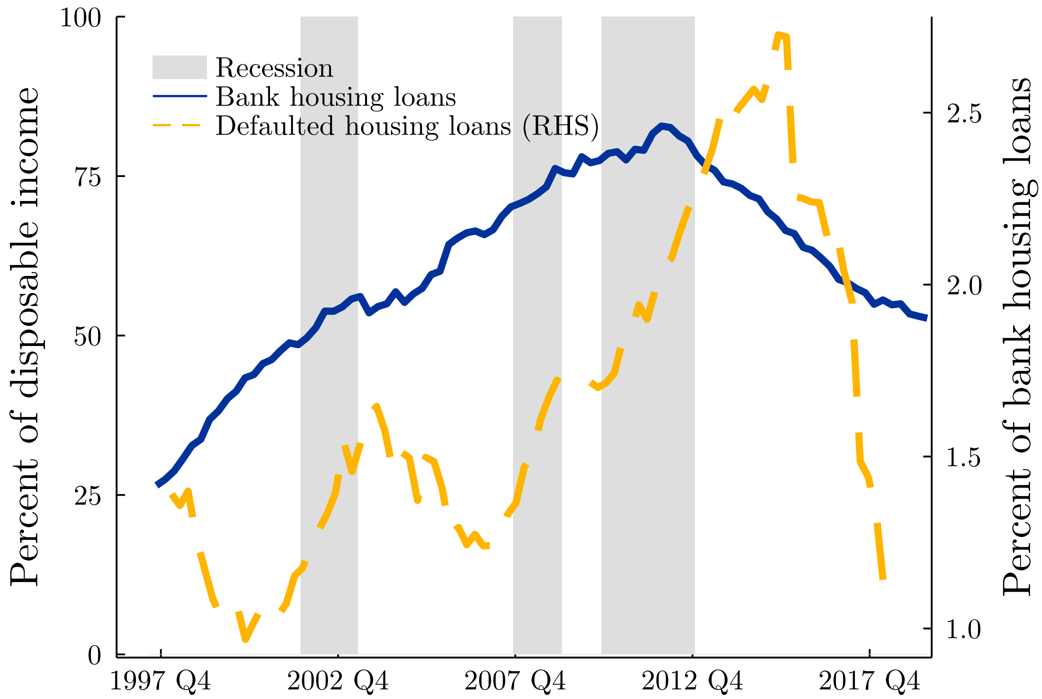
In this section, we provide information on the Portuguese economy prior to the decision to implement caps on household mortgage borrowing.

Following the pattern in many advanced economies, especially in the euro area, the Portuguese economy underwent a period of rapid debt accumulation from the 1990s until the early 2010s. In 2010, roughly two years after the onset of the Global Financial Crisis, Banco de Portugal (2010) noted that, like other euro area economies, the country was currently facing "significant and unforeseen increases in deficits and public debt" due to the global downturn. By this time, Portuguese 10-year government bonds yields had already breached a two percentage point premium with respect to German 10-year government bonds, prefacing a rating cut by Moody's during that summer.

A year later, facing rising risk premia on its debt and the prospect of bankruptcy, the Portuguese government requested financial assistance from the International Monetary Fund (IMF) and the European Financial Stability Facility. The main features of this period for euro area economies are discussed in detail in previous works such as Lane (2012), for the euro area in general, and Reis (2013), for the case of the Portuguese economy. One typical pattern in these analyses is the capital inflow to small euro area economies like Portugal to finance debt growth, which fueled internal demand and, in particular, strong dynamics in mortgage credit and housing markets

Figure 1 plots the evolution in the market for bank credit for house purchase in Portugal in the last two decades. The solid line indicates the stock of loans for house purchase granted by banks as a percentage of disposable income, while the dashed line corresponds to the fraction of the stock of loans for house purchase which is overdue. Between 1997 Q4 and 2012 Q1, the stock of loans for house purchase more than trebled, surging from 27 percent to a peak of 83 percent of disposable income.

The double recession that hit the Portuguese economy in 2008 and 2011, coupled with high household indebtedness resulted in a surge in defaulted loans. After a relatively modest increase from around 1 percent of the stock of housing loans in 2000 Q1 to 1.5 percent in 2004 Q1, it declined briefly until early 2007. However, starting in 2008 Q1, the Portuguese economy was hit by two contractions in economic activity in quick succession, resulting from the instability caused by the global financial crisis and, later,

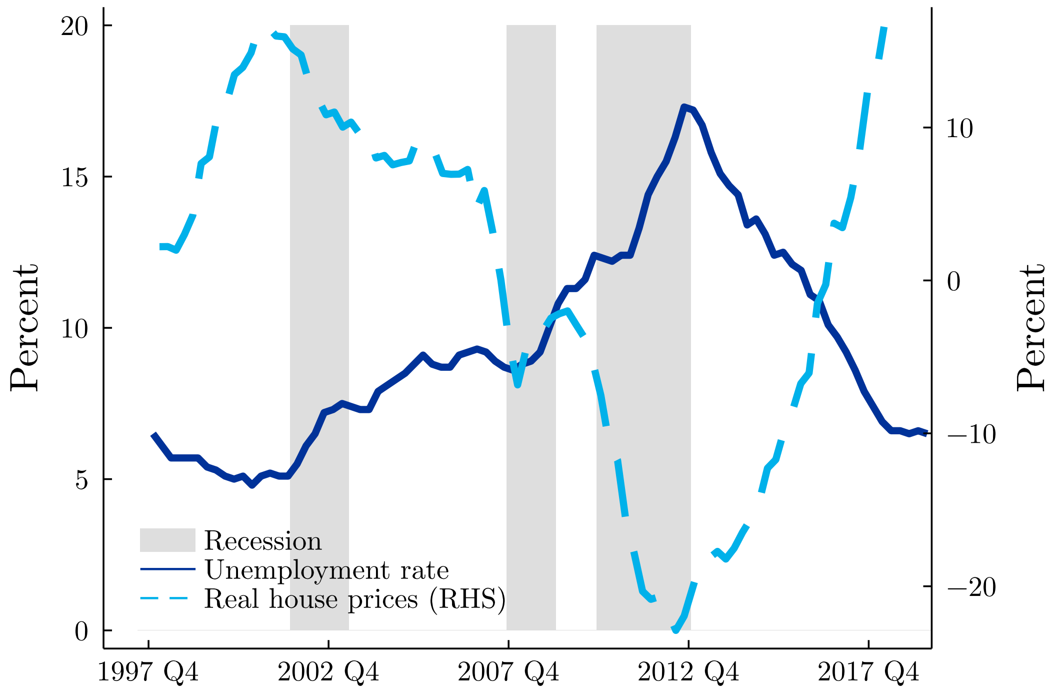


Note: Recessions dates for the Portuguese economy at a quarterly frequency are identified by Rua (2017). Housing debt and default data are from the Bank of Portugal. Disposable income data are from Statistics Portugal and are annualized. Data sources are provided in Appendix A.

Figure 1: Mortgage debt and default

the European sovereign debt crisis. The rate of defaulted loans climbed rapidly from 1.3 percent in 2008 Q1 and peaked at 2.7 percent in 2016 Q3, dropping sharply with the rebound in house prices and economic activity.

The surge in household default rates, which affected all types of consumer loans, contributed to the growing woes in the banking system, which was heavily exposed to the household sector, as recognized by Banco de Portugal (2017), and ailing from non-performing loans on its domestic corporate portfolio. By June 2012, three of the largest banks in the system were recapitalized with funds from both the financial assistance package and the general budget (Eichenbaum et al., 2016). In 2014 and 2015, two other banks were intervened, one being restructured with loans from the government and the other liquidated. Tribunal de Contas (2018), a report by the Portuguese Court of Auditors, estimated that between 2008 and 2017, net public expenses with the financial sector amounted to €16.8 billion, or 8.6 percent of GDP in 2017.



Note: The real house prices series is the ratio between the index of residential house prices and a consumer price index expressed as percentage deviations from its full-sample historical mean. The unemployment rate is from Statistics Portugal. The consumer price index and the house price data are from the Organization for Economic Cooperation and Development (OECD). Data sources are provided in Appendix A.

Figure 2: Unemployment and house prices

This evolution in credit markets and the financial sector was mirrored by developments in the labor and housing markets. Figure 2 plots labor market and house price dynamics in the Portuguese economy. The solid line indicates the unemployment rate, while the dashed line corresponds to the deviation of real house prices from their historical mean. Unemployment rose from roughly 5 percent in 2000 Q1 to more than 17 percent in 2012 Q4, tapering off afterward as GDP growth picked up. In the residential housing market, prices rose sharply between 1997 Q4 and 2000 Q4, and slowly declined until the end of 2007. Between 2007 Q4 and 2013 Q2, real house prices tumbled by almost 30 percentage points in relative deviations from the mean, in tandem with the rising unemployment rate and the mortgage default rate.

The mechanisms underlying these dynamics have been explored in the works of Corbae and Quintin (2015), Mian and Sufi (2015), and Kaplan et al. (2020) for the U.S., for example. While there are significant disagreements regarding the linkage between credit supply and house prices, the role of high leverage and debt service burdens generated by loose credit standards are thought to be at the heart of periods of high mortgage default rates.

In a nutshell, looser credit standards in the form of high LTV ratios at origination generate a loan stock where households have lower home equity. Given an adverse income shock, the lower the home equity, the greater the probability of default, as households have less to lose from a foreclosure. In the limit, with negative home equity, households use the decision to default as a means to obtain debt relief. High debt-service, measured by the PTI ratio, makes default more likely following an adverse income shock, especially for wealth-poor households. If labor income falls below the value of the loan installment, wealth-poor agents will either be forced to sell their housing or default.

In summary, in the years before Banco de Portugal enacted limits on mortgage lending criteria the economy was characterized by a highly indebted household sector. When adverse shocks hit the economy in 2008-2012, mortgage defaults ensued which contributed to the mounting losses in the financial sector, albeit more modestly than in other countries where the housing market was at the center of the financial crisis.

In the next section, we describe the policy enacted by Banco de Portugal in 2018, limiting leverage and debt service of household borrowing in the aftermath of the events described above.

3 Policy overview

On February 1st 2018, Banco de Portugal, as Portugal's macroprudential authority, issued a recommendation to all financial institutions granting consumer credit in Portugal introducing limits to some of the criteria used in assessing borrower creditworthiness at loan origination.[3] These criteria should be applied to all new loan contracts for house purchase, mortgages, and loans for consumption purposes signed by financial institutions operating in national territory from July 1st onward. Table 1 summarizes the main elements of the policy and their respective scope. The minimum criteria are as follows:[4]

[3]The summary, in English, of the policy measure is provided by the Banco de Portugal here. The legal text, in English, is available here.

[4]The following consumer credit contracts are exempted from fulfilling the minimum criteria: (i) contracts signed in order to prevent or address default situations; (ii) contracts under the framework for granting subsidized housing credit to the disabled; (iii) contracts with volume lower or equal to ten times the minimum wage (5,570€ in 2017); (iv) overdrafts and other credit with no defined payment schedule (such as credit cards or credit lines).

1. **Loan-to-value cap**. For all consumer loan contracts with a real estate guarantee whose purpose is to acquire the borrower's main residence, the ratio between the value of all of the borrower's outstanding loans secured by the same property and the value of the collateral should not exceed 90 percent. When the loan is granted for purposes other than acquiring a main residence, this cap drops to 80 percent. If the dwelling being used as collateral has been sold by a financial institution, the LTV cap is 100 percent. The value of the collateral is calculated as the minimum between the appraisal value and the transaction price.

2. **Payment-to-income cap**. For all consumer loan contracts (except credit card debt), the ratio between all of the borrower's monthly debt payments and labor income net of taxes and social security contributions should not exceed 50 percent. For floating or mixed rate contracts, an interest rate increase of 1 to 3 p.p. (depending on the loan maturity) should be assumed in the monthly payments when calculating this measure. Each financial institution may grant up to 10 percent of new loans with a PTI from 50 percent to 60 percent, and up to 5 percent higher than 60 percent. If the maturity of the contract extends beyond 70 years of age, a reduction of at least 20 percent of labor income should be considered when calculating the PTI.

3. **Maturity cap**. The maturity on loans for house purchase and mortgages should not exceed 40 years. The average maturity of new credit agreements should gradually converge to 30 years until the end of 2022. Consumer loans for the purpose of acquiring vehicles, financing education and investment in renewable energy are capped at a 10 year maturity. The maturity of consumer loans for other purposes is capped at 7 years.

4. **Regular payments requirement**. New credit agreements should be granted with regular payments of interest and principal.

The regulation is not intended to be binding in the sense that the limits described are not legally enforceable. However, any financial institution not complying with these limits must provide an explanation to the central bank, detailing its reasons for not doing so. The supervisor then evaluates the

Table 1: Borrowing cap summary

Regulation	Scope	Cap
LTV cap	Household permanent residence	$\leq$ 90%
	Other purposes	$\leq$ 80%
	Property owned by the financial institution	$\leq$ 100%
PTI cap	Loans (except credit cards)	$\leq$ 50%
Maturity cap	Housing	$\leq$ 40 years
	Auto loans, education, renewable energy	$\leq$ 10 years
	Other consumer credit	$\leq$ 7 years

justification provided by the institution and may take further action if it deems the explanation inadequate.

The goals of this policy, as spelled out in its summary, are to "*enhance the resilience of the financial sector and the sustainability of households' financing, thereby, minimizing defaults*." We interpret this to mean two things in practice: The goals of this policy are to (i) reduce household leverage, and (ii) to reduce default rates.[5]

Approach. The level of detail of the policy poses a number of tractability challenges. In order to allow for its analysis in a theoretical model, we reduce the scope of the evaluation and make a number of simplifying assumptions.

First, we narrow the focus to the direct impact of the restrictions on household decisions and welfare, without accounting for the effects of the policy on bank balance sheets, except when discussing its effect on the stock of high leverage loans and on the mortgage default rate.

Second, we assume the existence of a single type of mortgage debt contract available to consumers, i.e., a long-term contract with regular interest and principal payments which expires at death. Furthermore, as there are no changes in the level of reference rates in the environment, there is no difference between fixed or floating rate mortgages.

Third, the concept of default in our model is limited to foreclosure, which simplifies the computational

[5]The resilience of the financial sector to adverse shocks is beyond the scope of this paper, given the need for financial intermediary default to analyze this issue.

burden of the household problem. We will be using the word “default” and “foreclosure” interchangeably, from now on.

Fourth, we do not model loans for consumption or other purposes, and focus instead on the impact of the policy on mortgage loans for the purpose of purchasing a household’s main residence.

Fifth, we ignore the exceptions made to the LTV and PTI caps.

Sixth, we will not evaluate the impact of using the original transaction price when refinancing, as that would add another state variable to the problem, nor do we make a distinction between transaction price and bank evaluation.

4 Mortgage lending standards

In this section, we first describe the data sources. Second, we document the shape and changes to the joint distribution of mortgage loan characteristics at origination before and after the policy.

4.1 Data sources

We use two sources to describe the LTV and PTI distributions. First, the Central Credit Register (CCR), which began collecting income and collateral information at mortgage loan origination in July 2018. Second, the Conduct Supervision Department’s (CSD) supervisory data set on mortgage credit, collateral and income, which started in 2016.

The CCR provides detailed loan-level information on contract characteristics such as the amount outstanding, collateral value, interest rates, and original maturity. It also contains the demographic characteristics of the borrower, such as birth year, labor income, and education level. Information is collected on all mortgage loans granted to residents or non-residents in national territory by institutions headquartered in Portugal or local branches of foreign institutions.

The CSD data set provides information with a granularity level equivalent to the CCR, though and with similar coverage in terms of institutions. It allows us to characterize the LTV and PTI distributions prior to the policy, and before the CCR began collecting data on borrower income and collateral value.

It is limited by the fact that it collects a small number of the characteristics of the borrower, and there is no information regarding the purpose of the housing loan.

From the CCR, we extract mortgage loans whose purpose is to acquire or build the borrower's main residence, which form the object of the analysis conducted in this paper. The value of the collateral is calculated as the value of the residence or the underlying land. In order to do the same for the CSD's data set, we use the CCR's information on the outstanding loan stock in December 2019 to identify loans granted in December 2017 which are still outstanding. We then match those entries to the records in the CSD. The matching is done via the amount borrowed, amount outstanding in December 2019, date of origination date, bank identifier, and original maturity. The procedure allows us to fill in the mortgage loan's purpose and obtain demographic variables for the observations in the CSD data set.

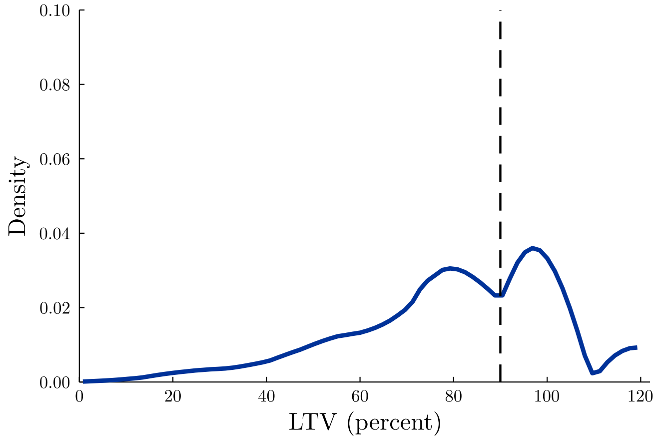
We consider the total amount borrowed and the total value of labor income reported for all contract records with more than one borrower. To define the demographic characteristics for loans with more than one borrower, if no male person is available, we consider the eldest female person. Henceforth, mentions to mortgage loans refer to loans for the purchase of the household main residence, unless stated otherwise.

Unlike the CCR, the CSD only reports pre-tax income of the borrower. To obtain after-tax labor income, we apply the income tax formula for unmarried individuals with no dependents living in continental Portugal in the respective year.[6] The employee Social Security tax is deducted from the pre-tax amount. We use this procedure for the entire sample, in order to maintain consistency in the way labor income is measured.

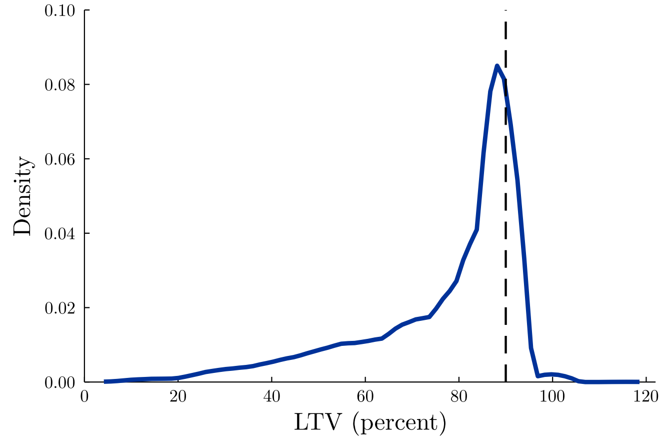
4.2 Distribution of LTV and PTI at loan origination

We start by showing the LTV and PTI distributions, and how they changed from December 2017 to December 2019. Figure 3 shows the distributions of the LTV and PTI of new mortgage contracts before and after the borrowing caps were implemented. Tables 2 and 3 show additional detail on the joint distribution of loan characteristics at origination for December 2017 and 2019, respectively. Each cell in

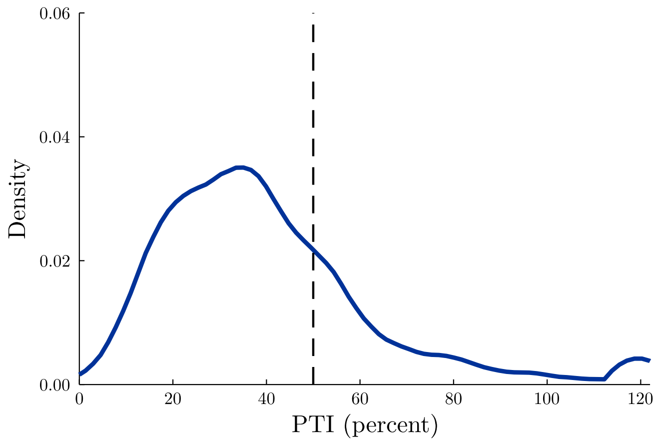
[6]The tables underlying the formula are available for several years in the Portuguese Tax Authority's website in Portuguese.



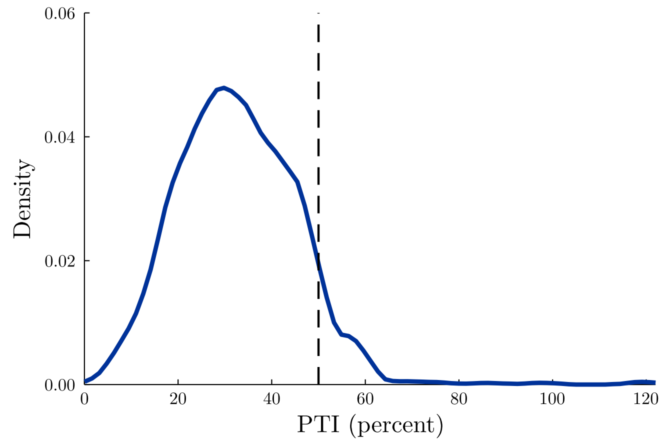
(a) LTV distribution (pre-policy)



(b) LTV distribution (post-policy)



(c) PTI distribution (pre-policy)



(d) PTI distribution (post-policy)

Note: The left hand side charts plot the distributions of LTV and PTI in December 2017, while the right hand side charts plot the same distributions in December 2019. For 2017, the sample represents 42 percent of the volume of new loans for house purchase, measured by Banco de Portugal's Monetary and Financial Statistics. For December 2019, this figure is 40 percent. The vertical axis in the charts is the relative frequency of the bins of the kernel density estimates. Values of LTV and PTI greater than 120 are replaced with 120. The vertical dashed line indicates the cap introduced by the policy. Source: Authors' calculations from CCR and CSD data.

Figure 3: LTV and PTI distributions before and after cap implementation. Half of new borrowers are constrained by the policy.

the table corresponds to the percentage of the value of total mortgage loans originated in that month for a given LTV and PTI bucket as indicated on the margins.

We estimate that contracts with an LTV above the cap accounted for roughly 40 percent of the number of new mortgages in December 2017, before the policy was announced (Figure 3a). Likewise, contracts with a PTI above the cap accounted for roughly one-quarter of the quantity of new mortgages in December 2017 (Figure 3c). In total, we estimate that half of new mortgage loans were associated with contracts with an LTV or a PTI ratio above the limits.

Table 2: New mortgage loans LTV and PTI distribution in December 2017

	PTI $\leq$ 50	50 $<$ PTI $\leq$ 60	PTI >60
LTV $\leq$ 80	38	4	6
80 $<$ LTV $\leq$ 90	10	2	2
90 $<$ LTV	27	5	7

Note: Each cell in the tables corresponds to the relative frequency of the number of mortgage loan contracts signed during that month for an LTV and PTI bucket, expressed in percent of the sample volume. The numbers may not add to 100 percent, given rounding error.

Table 3: New mortgage loans LTV and PTI distribution in December 2019

	PTI $\leq$ 50	50 $<$ PTI $\leq$ 60	PTI >60
LTV $\leq$ 80	39	3	0
80 $<$ LTV $\leq$ 90	53	3	1
90 $<$ LTV	1	0	0

Note: Each cell in the tables corresponds to the relative frequency of the number of mortgage loan contracts signed during that month for an LTV and PTI bucket, expressed in percent of the sample volume. The numbers may not add to 100 percent, given rounding error.

Figures 3b and 3d show the same distributions two years later. First, the quantity of loans above the caps drops sharply to 1 and 7 percent for the LTV and PTI, respectively. As described in section 3, 10 percent is the limit for new loans with a PTI greater than 50 percent by institution, which is consistent with the fraction of loans with a PTI above the limit. Second, more than half of new mortgages are clustered in the 80-90 percent LTV bucket in December 2019, in contrast with only 14 percent in December 2017. This is consistent with the results of van Bekkum et al. (2019), who find evidence of bunching against the LTV cap for the Netherlands. Third, the surge in the weight of 80-90 LTV bucket (+43 percentage points) is accounted for by a shift from above (38 p.p.) but also from below (6 p.p.). Fourth, three quarters of the value of new loans had a PTI of 40 percent or less. This indicates that though the cap is binding for a significant fraction of households, bunching is much more limited than in the case of the LTV.

In summary, we find that financial institutions complied with the recommendation issued by Banco de Portugal and that the policy affected a significant portion of borrowers. The evidence also suggests that the LTV cap is a binding constraint for a greater fraction of loans relative to the PTI cap.

5 A theory of housing and leverage choice

This section describes a model which can be calibrated to the Portuguese economy and used to evaluate the long-term impacts of mortgage borrowing caps, their welfare, and distributional implications.

5.1 Overview

We build an incomplete markets model with overlapping generations of households with partially uninsurable idiosyncratic risk to their labor efficiency units endowment. The setting is a small open economy endowed with technologies to produce non-durable goods and housing services. Households consume both, but the latter must be produced domestically, while the former can be imported from the rest of the world. Households can save in a risk-free annuity with an exogenous return, determined in international financial markets, and in housing, an illiquid asset requiring periodic maintenance, providing the owner with housing services. After retirement, endowment shocks cease, individuals have a positive probability of dying, and earn income from social security and their financial savings. Upon death, individuals leave a bequest from which they draw utility.

Housing services are obtained by either buying or renting a house. Homeownership is attractive compared to renting for three reasons: (i) it provides extra utility to homeowners for the same house size, (ii) the rental sector has to pay management costs on top of maintenance and taxes which translate into higher rental rates in equilibrium, and (iii) housing markets are segmented such that consumption of higher housing services is only possible through ownership. This is a reduced form method to include the many incentives to ownership relative to renting.[7] The illiquidity of houses is modeled by adding a transaction cost proportional to the sale value.

To finance house purchases, agents may borrow using defaultable mortgages with a long-term maturity and recourse in case of default. Contracts are signed with competitive financial intermediaries which aim to break even, in expectation, on each contract. Houses are traded in a market that includes households, the rental sector, financial intermediaries selling foreclosed properties, and a construction sector selling finished houses and maintenance. The production side of the economy is close to Boerma (2019), and Kaplan et al. (2020).

In this section, we present the main features of the problems of each sector. A detailed description of the household problems, the equilibrium definition, and the algorithm to compute it are presented in Appendix B, C, and D, respectively.

5.2 Households

Demographics. Time is discrete. The economy is populated by a continuum of finitely-lived households of measure one. Age is given by $j = 1, ..., J$. Households work during periods $j = 1, ..., J_{\text{ret}} - 1$ and retire at age $j = J_{\text{ret}}$, after which they are subject to stochastic debt. Households die with certainty after age J.

[7] Homeownership in Portugal in 2017, the year before the implementation of the policy, was 75 percent compared to a 66 percent average in the euro area (data from Eurostat, see Appendix A) and to a value of 65 percent in 1991 (Cardoso et al., 2019). In Portugal, measures fostering homeownership have changed across time and included: (i) mortgage payment tax deductions for contracts signed before 2012; (ii) a temporary exemption from property tax in the three years after buying the household main residence, and a permanent one for low-income families; (iii) grants for purchase or construction of houses by low income, low asset families; (iv) exemption from paying a transaction tax on the purchase of the household main residence (this exemption is removed if the house is rented out); (v) taxation of rental income (which is included in the model explicitly). Aside from regulatory incentives, homeowners also have greater freedom to dispose of their property as they see fit (e.g., repaint, rebuild) and do not have to leave their residence at the behest of their landlord, which is also captured by the extra utility term. There is also the issue of the option value of buying a house, in the sense that it can be partially rented out for additional income if necessary. This is not entirely captured by the extra utility term, as option values depend on fluctuations in house prices. We are indebted to Fernando Anjos for pointing this out to us.

Preferences. Expected lifetime utility of the households is given by:

$$\mathbb{E}_0\left[\sum_{j=1}^{J}\beta^{j-1}\left[S_j u_j(c_j,s_j)+(1-S_j)v(\flat)\right]\right], \tag{1}$$

where β is the discount factor, c_j is consumption of non-durable goods and services, s_j is the consumption of housing services, and S_j is the probability of surviving one more period after j periods alive, where $S_j = 1$ for $j < J_{\text{ret}}$. The expectation is taken over a sequence of idiosyncratic shocks to the labor productivity endowment. v measures the utility from leaving a bequest $\flat$. The utility function, u_j, is given by:

$$u_j=\frac{e_j[(1-\phi)c_j^{1-\gamma}+\phi s_j^{1-\gamma}]^{\frac{1-\vartheta}{1-\gamma}}-1}{1-\vartheta}, \tag{2}$$

where ϕ measures the relative taste for housing services, $1/\gamma$ is the elasticity of substitution between housing services and non-durable consumption, $1/\vartheta$ is the intertemporal elasticity of substitution, and e_j is an exogenous consumption equivalence scale which captures changes in households size and composition over time. I assume that the utility from bequests is given by:

$$v(\flat)=\nu\frac{(\flat-\underline{\flat})^{1-\vartheta}-1}{1-\vartheta}, \tag{3}$$

where ν measures the strength of the bequest motive, and $\underline{\flat}$ reflects the extent to which bequests are a luxury good as in De Nardi (2004).

Endowment. Age j active households have a labor income endowment, y_j^w, given by:

$$\ln y_j^w=\ln w+a+f_j+\epsilon_j, \tag{4}$$

where w is the wage rate per labor efficiency unit, and the set $\{a, f_j, \epsilon_j\}$ determines the household's efficiency unit endowment. a is an individual-specific permanent income component, f_j is the deterministic age profile of productivity, and ϵ_j is a persistent component following a first-order Markov process with autocorrelation parameter ρ_ϵ. Labor income after social security contributions is given by:

$$y_j = \frac{y_j^w}{1+\tilde{\tau}_{ss}}(1-\tau_{ss}),$$

where $\tilde{\tau}_{ss}$ is the employer contribution rate, and τ_{ss} is the employee contribution rate. $y_j^w/(1+\tilde{\tau}_{ss})$ are gross earnings received by households and equal taxable labor income before deductions.

Liquid bond. Households can save in a one-period risk-free bond, $b \geq 0$, with an exogenous fixed price q_b and implied interest rate $r_b = 1/q_b - 1$, determined in the world market.

Housing. A house is an asset that can be bought or rented by households to consume housing services. A single index summarizes housing characteristics, which includes several features ranging from location to size. We assume households use a common valuation scale of these characteristics. Owner-occupied housing quality is given by h, where $h \in \mathcal{H} = \{h^1, ..., h^N\}$ and $h^1 < h^2, ..., h^{N-1} < h^N$. Rentals are denoted by $\tilde{h} \in \tilde{\mathcal{H}} = \{\tilde{h}^1, ..., \tilde{h}^{\tilde{N}}\}$ and $\tilde{h}^1 < \tilde{h}^2, ..., \tilde{h}^{\tilde{N}-1} < \tilde{h}^{\tilde{N}}$. The unit price of housing is denoted by p_h, and the unit rental rate by ρ. The housing market is frictionless and competitive. In this formulation, we are making two key assumptions: (i) for housing markets to clear, it is enough that demand and supply of housing units be equal, e.g., higher quality houses can be subdivided and converted into smaller quality houses at no cost and then sold; (ii) both the rental sector and the construction sector will have no cost of adjusting supply.

Rental housing services are directly proportional to housing quality, i.e., $s = h$. In contrast, owning a house provides the household with more housing services per unit of size, i.e., $s = \omega h_j$, where $\omega > 1$, creating an incentive to homeownership. Every period, homeowners pay maintenance in terms of the non-durable good and a tax rate on the property value. Period expenses are given by:

$$(\delta_h + \tau_h)\, p_h h_j, \tag{5}$$

where δ_h is the housing depreciation rate, and τ_h is the property tax rate. To model housing as an illiquid asset, we assume that owners selling their house pay a fraction κ_h of the property's value. This implies that the total transaction cost is equal to $\kappa_h p_h h$.

Mortgages. Households can take out mortgages to finance their house purchase. Mortgages are liabilities with maturity until J and with the option to default. To obtain a mortgage, agents must pay a fixed origination fee κ^m, after which they receive a transfer of funds $q_j m_{j+1}$, where q_j is the individual-specific price of the mortgage and m' is the mortgage balance, which includes both the principal and the implicit spreads. Financial intermediaries lend funds at reference rate $r_m = r_b(1+\iota)$, where ι is an intermediation wedge. Since there are no aggregate shocks to the interest rate in this model, there is no distinction between fixed and adjustable-rate mortgages. The mortgage pricing function, $q \leq 1$, is the instrument that financial intermediaries use to set spreads. It depends on all available characteristics of the borrower: age, j, next period assets and liabilities, $\mathbf{x}_{j+1} := (b_{j+1}, h_{j+1}, m_{j+1})$, and the known elements of the labor productivity endowment process, $\mathbf{y}_j := (a, \epsilon_j)$. The down payment made by the households in terms of non-durable consumption goods is thus $p_h h_{j+1} - q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1}$.

At origination, loan contracts must comply with two constraints: (i) a cap on LTV and (ii) a cap on PTI. In the case of the LTV, the funds transferred must not exceed a fraction λ^m of the value of the collateral:

$$q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \leq \lambda^m p_h h_{j+1}. \tag{6}$$

In the case of the PTI cap, the scheduled mortgage payment must not exceed a fraction λ^π of after-tax labor income $y_j - \mathcal{T}(y_j)$:

$$\pi_j^{\min}(m_{j+1}) \leq \lambda^\pi \left(y_j - \mathcal{T}(y_j)\right), \tag{7}$$

where $\mathcal{T}$ is the labor income tax liability, and $\pi_j^{min}(m_{j+1})$ is given by:

$$\pi_j^{\min}(m_{j+1}) = m_{j+1} \frac{r_m(1+r_m)^{J-j}}{(1+r_m)^{J-j} - 1}, \tag{8}$$

the formula for the constant payment of an annuity with outstanding balance m_{j+1} and where the first payment is due next period. The borrower may pre-pay her mortgage by choosing $\pi_j > \pi_{j-1}^{\min}(m_j)$. The outstanding balance evolves according to the motion equation $m_{j+1} = m_j(1 + r_m) - \pi_j$. At any moment, the borrower may choose to refinance her mortgage, subject to paying the constant origination cost κ_m and complying with the LTV and PTI caps. She may also choose to sell her house, at which point she must pay the outstanding mortgage balance and interest $m_j(1 + r_m)$.

If the borrower defaults, the financial intermediary repossesses the house and sells it at $\Omega = (1 - \delta_h^d - \tau_h - \kappa_h)p_h h$, where $\delta_h^d > \delta_h$. The depreciation rate of the sale by the financial intermediary is higher to account for expenses associated with foreclosure and eviction procedures. If the residual equity is positive after the sale, the household is paid back the difference. If the proceeds from foreclosure are not enough to pay for outstanding debt, the household is subject to a recourse payment $\Phi = \min(\kappa_d[y_j - \mathcal{T}(y_j) + b_j], m^d)$, where κ_d is an attachment limit on cash-on-hand and m^d denotes the residual value of debt after foreclosure but before recourse. After a period in default, in which they are forced to rent, agents regain access to mortgage and housing markets. This formulation of the default problem implies that the reason why agents default in this model is to obtain debt relief.[8]

Household problem. Figure 4 summarizes the household dynamic program, described in greater detail in Appendix B. Households begin their lives as nonhomeowners and decide either to buy a house or rent. If they decide to buy a house, they face the problem of a homeowner in the following period. Homeowners may sell their house and rent, purchase a different house size, or pay the maintenance costs associated with their starting house size and move to the next period. If the household has a mortgage, she may also default, refinance, make the scheduled payment or pre-pay it. If she defaults, she becomes a nonhomeowner and chooses a rental size in the same period of default, only regaining access to credit markets in the following period.

[8] This point has also been made in Foote et al. (2008). For a proof, see proposition B.1 in Appendix B.

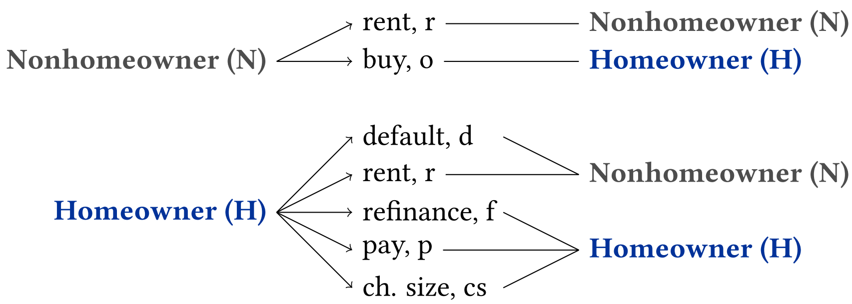


Figure 4: Household dynamic program.

5.3 Financial intermediaries

Financial intermediaries are owned by risk-neutral foreigners and operate in a competitive environment. The risk-neutrality assumption implies that the condition for pricing mortgage contracts is to break even in expectation. This allows us to price loan contracts through a zero-profit condition on a contract-by-contract basis. We assume that caps imposed on loan contracts cannot be avoided by asking for loans in a different country.

Let $g_j^n(\mathbf{x}_j, \mathbf{y}_j)$, $g_j^f(\mathbf{x}_j, \mathbf{y}_j)$, and $g_j^d(\mathbf{x}_j, \mathbf{y}_j)$ denote mutually exclusive indicators for the decisions to sell, refinance (or change house size), and default, respectively. For simplicity, in what follows, we suppress the dependence of indicator functions on the state variables. The price of a mortgage is expressed recursively as:

$$q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) = \frac{1}{(1+r_m)m_{j+1}} \mathbb{E}_\epsilon \{q_{\text{sell}} + q_{\text{default}} + q_{\text{pay}}\}. \tag{9}$$

The payoffs in each case are given by:

$$q_{\text{sell}} = \left[g_{j+1}^n + g_{j+1}^f\right](1+r_m)m_{j+1} \tag{10}$$

$$\begin{aligned} q_{\text{pay}} = &\left[1 - g_{j+1}^n - g_{j+1}^f - g_{j+1}^d\right] \cdot \\ &\left(\pi_{j+1}(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) + q_{j+1}(\mathbf{x}_{j+2}, \mathbf{y}_{j+1})\left[(1+r_m)m_{j+1} - \pi_{j+1}(\mathbf{x}_{j+1}, \mathbf{y}_{j+1})\right]\right) \end{aligned} \tag{11}$$

$$q_{\text{default}} = g_{j+1}^d \cdot \left[\min\left\{(1 - \delta_h^d - \tau_h - \kappa_h)p_h' h_{j+1}, m_{j+1}(1+r_m)\right\} + \right.$$

$$+\min\left\{\kappa_d(b_{j+1}+y_{j+1}-\mathcal{T}), m_{j+1}(1+r_m)-(1-\delta_h^d-\tau_h-\kappa_h)p_h' h_{j+1}\right\}\Bigg]. \tag{12}$$

In the first equation, if the household sells ($g^n = 1$) or refinances ($g^f = 1$) the payoff is the amount owed at the start of the period, i.e., $(1+r_m)m_{j+1}$. In the second, the household keeps the existing mortgage ($1 - g^n_{j+1} - g^f_{j+1} - g^d_{j+1} = 1$) and the intermediary receives a payment higher or equal to the scheduled repayment $\pi^{\min}_{j-1}$, plus the continuation value, conditional on the state variables and the individual choices. In the third, the household defaults ($g^d = 1$). In this case, the financial intermediary repossesses the house and either fully recoups the outstanding debt, or the entirety of the foreclosure value of the house. In the second case, residual debt after foreclosure is not enough to pay for the outstanding debt, and the financial intermediary may be able to garnish household cash-on-hand up to a fraction κ_d.

5.4 Rental sector

The housing stock in the rental sector is owned by a continuum of risk-neutral firms, who buy houses at unit price p_h and rent them out to tenants at a competitive rental price ρ.[9] Their opportunity cost of capital is equal to the interest rate, r_b, they incur management costs, ψ, maintenance costs, δ_h, pay property taxes on the value of housing at rate τ_h, and may sell housing capital next period at p_h'. I assume that the rental sector is able to sell houses without incurring in transaction costs. Therefore, in equilibrium, the rental price is given by:

$$\rho = \psi + p_h - \frac{1-\delta_h-\tau_h}{1+r_b}p_h' - \tau_r(\rho - \psi - \delta_h p_h' - \tau_h p_h'), \tag{13}$$

where τ_r is the tax rate on rental income net of management costs, depreciation, and property taxes. Kaplan et al. (2020) show how this equation can be derived from a general rental firm problem. As in their paper, we assume that deep-pocked foreigners own rental firms, i.e., the rental sector may take losses without going bankrupt and faces no financial constraints.

[9] In Portugal, the household sector owned 92 percent of the stock of residential housing in 2017. For simplicity, we abstract ourselves from household rental supply and attribute it to firms.

5.5 Construction sector

A continuum of firms in the construction sector produces new housing using a mix of the non-durable good, Z, and a fixed factor of production, L, as in Greenwald and Guren (2019). New homes are sold in a competitive market at unit price p_h. Following Davis and Heathcote (2005) and Favilukis et al. (2017), we interpret the fixed input L as a combination of new land and a flow of permits periodically issued by the government for the construction of new housing. The output of the construction sector is therefore given by:

$$Y_h = A_h L^{\varphi} Z^{1-\varphi}, \tag{14}$$

where Y_h is the construction of new housing, and φ is the share of land/permits in housing production. We assume a constant quantity $\bar{L}$ of new land/permits is made available by the government, which rents land/permits to construction firms each period at a competitive rental rate p_L. Like Favilukis et al. (2017) we make the assumption that $L = \bar{L}$. The firm problem is given by:

$$\max_{Z} \; p_h A_h \bar{L}^{\varphi} Z^{1-\varphi} - p_L \bar{L} - Z. \tag{15}$$

By replacing the first-order condition for Z in the production function, we obtain new housing as a function of the unit price of housing and land/permit flow:

$$Y_h = A_h^{\frac{1}{\varphi}} \left[p_h(1-\varphi)\right]^{\frac{1-\varphi}{\varphi}} \bar{L}, \tag{16}$$

which implies that the elasticity of new housing with respect to p_h is $(1-\varphi)/\varphi$. Likewise, the equilibrium price of land is its marginal product:

$$p_L = \varphi(1-\varphi)^{\frac{1-\varphi}{\varphi}} (p_h A_h)^{\frac{1}{\varphi}}.$$

5.6 Non-durable goods sector

A continuum of firms rent capital and labor to produce a non-durable good (the numeraire) using a Cobb-Douglas technology $F(K, N)$, where K is production capital and N the aggregate effective labor input:

$$F(K, N) = K^{\alpha} N^{1-\alpha}.$$

Given the absence of labor supply choice for households, effective aggregate labor is fixed and normalized to unity. The non-durable good can be used to satisfy non-durable consumption needs by households and the government, invest in business capital, used as an input for the construction sector to generate new housing, or exported to the rest of the world. In equilibrium, given interest rate r_b, firms choose capital such that $r_b = \alpha K^{\alpha-1} - \delta_k$, and the wage rate is $w = (1-\alpha)K^{\alpha}$, where δ_k is the depreciation rate of production capital. The law of motion is:

$$K' = K(1 - \delta_k) + I_k, \tag{17}$$

where I_k is investment in business capital, and K' is next period business capital.

5.7 Government

The government spends on goods and services not valued by households, G, manages a pay-as-you-go social security scheme, and provides public housing H^G. It collects revenues by taxing housing at a fixed rate τ_h, labor income using a progressive income tax function, consumption expenditure at rate τ_c, rental income, at rate τ_r, and by issuing a constant flow of new land/permits, $\bar{L}$. Social security is financed through employee and employer taxes. Deficits are covered by adjusting debt levels.

The functional form for labor income taxation is as in Benabou (2002), where the tax rate is given by:

$$\mathcal{T}\left(y_j, \tilde{h}_j\right) = \tau_y^0 \left(\max\left[\frac{y_j}{1-\tau_{ss}} - \min\{\tau_\rho \rho \tilde{h}_j, \bar{\tau}_\rho\}, 0\right]\right)^{-\tau_y^1}, \tag{18}$$

where τ_y^0 measures the tax level, and τ_y^1 the progressivity of the labor income tax schedule. Labor income tax incidence is on earnings before employee social security contributions. A fraction, τ_ρ, of the expenditure on rent is deducted from taxable income, up to a total of $\bar{\tau}_\rho$. After retirement, pension income before taxes is constant until death and given by:

$$y_{\text{ret}} = \rho_{ss} \frac{\bar{y}^w_{J_{\text{ret}}-1}}{1 + \tilde{\tau}_{ss}}, \tag{19}$$

where ρ_{ss} is the gross average replacement rate, and $\bar{y}^w_{J_{\text{ret}}-1}$ is the individual labor productivity in the last period before retirement with $\epsilon_{J_{\text{ret}}-1} = 0$. This formulation aims to approximate the average earnings of individuals in the years before retirement, which are used as the basis to calculate pension entitlements, without having to introduce additional state variables.

6 Calibration

In this section, we describe the parameter value choices and the model fit to data. The model is calibrated to match the Portuguese economy in 2017, just before the new policy on mortgage borrowing caps is announced. A set of parameter values is set externally, based on available evidence, and is shown in Table 4. The remaining parameter values, summarized in Table 5 are set by minimizing the distance between the moments obtained by solving the model equilibrium and their empirical counterparts. The loss function is defined as:

$$L(\theta) = ||M_m - M_d||,$$

where θ is the vector of parameters to be calibrated internally, M_m are model moments, and M_d are the data moments. All values are yearly, except if stated otherwise. Further details on data construction and sources are provided in Appendix A and E.

Demographics. Each model period is two years. Households enter the labor market at age 21 ($j = 1$), retire at 65 ($J_{\text{Jret}} = 23$), and die with certainty after age 80 ($J = 30$). After retirement, the probabilities

Table 4: External calibration summary

Description	Parameter	Value	Source
Demographics			
Maximum model age	J	30	-
Period of retirement	J_{Jret}	23	-
Survival probability by age	$\{S_j\}$	-	Statistics Portugal
Preferences			
Consumption equivalence scale	$\{e_j\}$	-	HFCS
EOS of housing/non-durable consumption	$1/\gamma$	1.250	Piazzesi et al. (2007)
Risk aversion	ϑ	2.000	Kaplan et al. (2020)
Endowment			
Life cycle profile of earnings	$\{\chi_j\}$	-	Brinca et al. (2021)
Auto-correlation (persistent component)	ρ_ϵ	0.335	Brinca et al. (2021)
Std. dev. (persistent component)	σ_ϵ	0.439	Brinca et al. (2021)
Financial instruments			
Risk-free interest rate	r_b	0.010	Assumption
Origination cost	κ_m	0.045	1000€ in the model
LTV cap	λ^m	1.200	Authors' calculation
PTI cap	λ^π	1.190	Authors' calculation
Housing			
Depreciation rate	δ_h	0.019	Penn World Table
Transaction cost	κ_h	0.089	Authors' calculations
Production			
Capital share	α	0.449	Statistics Portugal
Land share	φ	0.400	Assumption
Capital depreciation rate	δ_k	0.038	Penn World Table
Government and SS			
Consumption tax rate	τ_c	0.125	Statistics Portugal
Property tax rate	τ_h	0.007	Portuguese Tax Authority
Rental income tax rate	τ_r	0.280	Portuguese Tax Authority
Tax level parameter	τ_0^y	0.937	Brinca et al (2021)
Tax progressivity parameter	τ_1^y	0.136	Brinca et al (2021)
Fraction of rent which is deductible	τ_ρ	0.150	Portuguese Tax Authority
Maximum rent deduction	$\bar{\tau}_\rho$	-	Portuguese Tax Authority
Government consumption to output	g	0.169	Statistics Portugal
SS tax employee	τ_{ss}	0.110	Portuguese Social Security
SS tax employer	$\tilde{\tau}_{ss}$	0.238	Portuguese Social Security
Gross replacement rate	ρ_{ss}	0.547	OECD

Note: Additional details regarding the data are provided in Appendix A and E. One unit of consumption in the model equals 11,480€.

Table 5: Internal calibration summary

Description	Parameter	Value	Target	Model	Data
Discount Factor	β	0.982	NW to GDP	2.613	2.561
Housing utility weight	ϕ	0.131	Share of housing expenditures	0.215	0.209
Ownership extra utility	ω	1.005	Homeownership	0.776	0.747
Management costs	ψ	0.013	Homeownership < 35	0.411	0.419
Bequest motive strength	ν	55.58	Ratio of NW of 75/50	2.272	0.914
Bequests as luxury goods	$\bar{b}$	0.011	Fraction of retired with zero NW	0.0	0.05
S.D. permanent component	σ_a	0.370	S.D. of log household earnings	0.824	0.824
Housing grid	$\mathcal{H}$	-	Housing NW/NW		
			p10	0.195	0.252
			p50	0.396	0.751
			p90	0.946	0.993
Minimum rental size	$\tilde{h}_1$	0.01	Public housing as a share of housing stock	0.054	0.064
Rental grid size	$\tilde{N}$	4	Earnings homeowners/nonhomeowners	1.671	1.604
Depreciation rate	δ_h^d	0.201	Depreciation rate of foreclosed properties	0.250	0.250
Intermediation wedge	ι	0.140	Average rate on new mortgages	0.011	0.011
Attachment limit	κ_d	0.233	Foreclosure rate	0.005	0.005
Building permits	$\bar{L}$	0.146	Residential housing investment to GDP	0.027	0.028

Note: Details on the data are provided in Appendix A.

of dying in each period, $\{S_j\}$, are set using the life tables for the corresponding ages provided by Statistics Portugal. When calculating the model statistics, such as mortgage debt to GDP, we weight each household age cohort by its fraction in terms of the population of households using micro-data from the HFCS.

Preferences. The consumption expenditure equivalence scale is constructed based on micro-data from the HFCS. We calculate the average per-household consumption units for two-year buckets, set the value at age 21 as the base, invert, and fit a third-order polynomial to the resulting data. The predicted values are the vector $\{e_j\}$. The housing utility weight, ϕ, is calibrated to match the share of housing expenditures in private final consumption expenditures, which was 20.9 percent in 2017. The discount factor, β, is set to target a net worth to output ratio of 2.6, obtained from the national financial accounts produced by Banco de Portugal. The bequest motive strength, ν, is set to target a ratio of the average net worth of 75 to that of 50 year-olds, calculated using HFCS data.

In order to calibrate the extra utility from ownership, we target a homeownership rate of 75 percent, as per Eurostat data. The elasticity of substitution between non-durable consumption and housing services is set at 1.25, as estimated by Piazzesi et al. (2007).

Endowment. The endowment process is calibrated as in Brinca et al. (2021), which produce estimates for Portugal. We use their annual estimates of the life-cycle profile and the persistent component of earnings and convert them to bi-annual. f_j is a third-order polynomial with parameters $\{\chi_0, ..., \chi_3\}$. χ_0 is set such that individual labor inputs sum up to 1, consistent with the normalization of the aggregate labor input. The remaining parameters of the life-cycle are $\{0.340, -0.0160, 0.000\}$, respectively. The auto-correlation parameter is 0.335, and the standard deviation of the error term is 0.439. The standard deviation of the permanent component of the endowment process, σ_a, is set such that the model standard deviation of the log of household earnings matches its data counterpart from the HFCS, which we estimate at 0.824.

We initialize household liquid bond balance at labor market entry using the following procedure, adapted from Kaplan and Violante (2014): First, we assign each simulated agent to a quintile of the income distribution at job market entry. Second, we use HFCS data on inter-generational transfers to calculate two statistics: The median value of inheritances received by households in Portugal where the reference person is between 21 and 35 years of age, and the fraction of those households which received no transfers by quintile of the income distribution. Third, for each simulated household we generate a random number from the uniform distribution and check that figure against the fraction of households which receive zero transfers by quintile of the income distribution. For those with a random draw below that fraction, we assign zero liquid bonds. For those who draw a number above, we assign the median transfer in model euro.

Financial instruments. The interest rate on the risk-free liquid bond is set equal to 1.0 percent per *annum*. The origination cost is set equal to 1000€ in the model. The intermediation wedge, ι, is set to target the average interest rate on new mortgages of 1.13 percent. The attachment rate in case of default, κ_d, is set such that the foreclosure rate is equal to its data counterpart of 0.5 percent, which is the average annual rate of foreclosures in 2017, as computed by Fitch. In the baseline economy, we set the exogenous LTV and PTI requirements, λ^m and λ^π, to 120 and 119 percent, respectively. Both correspond to the $99th$

percentile of their corresponding distribution before the policy was implemented.

Housing. We follow the procedure of Kaplan et al. (2020) in order to calibrate the evenly spaced vector of house qualities $\mathcal{H}$. Specifically, we select the values of the minimum housing quality, h_1, the maximum housing quality, h_N, and the number of housing qualities, N, to target the 10th, 50th, and 90th percentiles of the distribution of homeowner housing net worth to total net worth, respectively. To pin down the rental housing grid, $\tilde{H}$, we assume $\tilde{h}^1 = h^1$ and set $\tilde{N}$ to target the ratio of the level of earnings of homeowners to nonhomeowners of 1.6, computed from the HFCS.

The depreciation rate is set to 1.9 percent yearly, the average depreciation rate of residential capital over 2000-2017 in Portugal, calculated from Penn World Table data. We set the value of the transaction cost, κ_h, such that it captures all costs associated with a house transaction, such as broker's fees and taxes. We estimate that broker's fees are, on average, 4.2 percent of the property's sale value. For taxes, we consider the main items associated with house sales: The real estate transaction tax and the stamp duty. The average transaction tax in 2015-2017 was 3.9 percent, and the stamp duty is charged at a flat rate of 0.8 percent. Therefore, we set the value of transaction costs to 8.9 percent.[10] The foreclosure depreciation rate, δ_h^d, is set such that the total depreciation of foreclosure properties in the model is 25 percent per year, consistent with the evidence from Pennington-Cross (2006). Management costs are set such that the homeownership rate of households before 35 years of age in the model is close to 42 percent, which is the data counterpart from the HFCS.

Production. The capital share parameter in the non-durable good production technology, α, is set to 0.45, which is the average share of capital income in 2000-2017. The business capital depreciation rate, δ_K, is set to 3.8 percent, which is the average yearly depreciation rate of the stock of non-residential capital in Portugal over 2000-2017, from the Penn World Table.

Government. The tax on consumption expenditures, τ_c, is estimated as the ratio of revenues from value added-type taxes (VAT) imputed to non-durables to private final consumption expenditures (see Appendix E) for 2012-2017. The property tax rate, τ_h, is set to 0.7 percent, which is the 2017 tax revenue

[10] Transaction tax, VAT on broker's fees, and stamp duties are estimated as costs for housing transactions but not included in the government budget constraint, nor explicitly written in the model, for simplicity.

from the local real estate tax divided by recorded property values. Public records of property value for tax purposes are often significantly lower than market transaction values, which makes this estimate an upper bound on the weight of property taxes in housing maintenance costs. The tax rate on rental income is set to 28 percent, which is the statutory rate. Tax level and progressivity parameters, τ_0^y, τ_1^y, for the labor income tax schedule are obtained from Brinca et al. (2021), which estimate them for Portugal. The rent tax deduction is set to a maximum of 15 percent of rental expenditure, or 500€. Government consumption expenditure to output, g, is set to 16.9 percent, its data analog. Employee and employer contribution rates to social security are equal to 11.0 percent and 23.8 percent, respectively, as per Social Security contribution tables. The gross replacement rate of pensions equals 54.7 percent, which is the gross replacement rate of average wage earners before retirement in 2018, as calculated by the OECD.

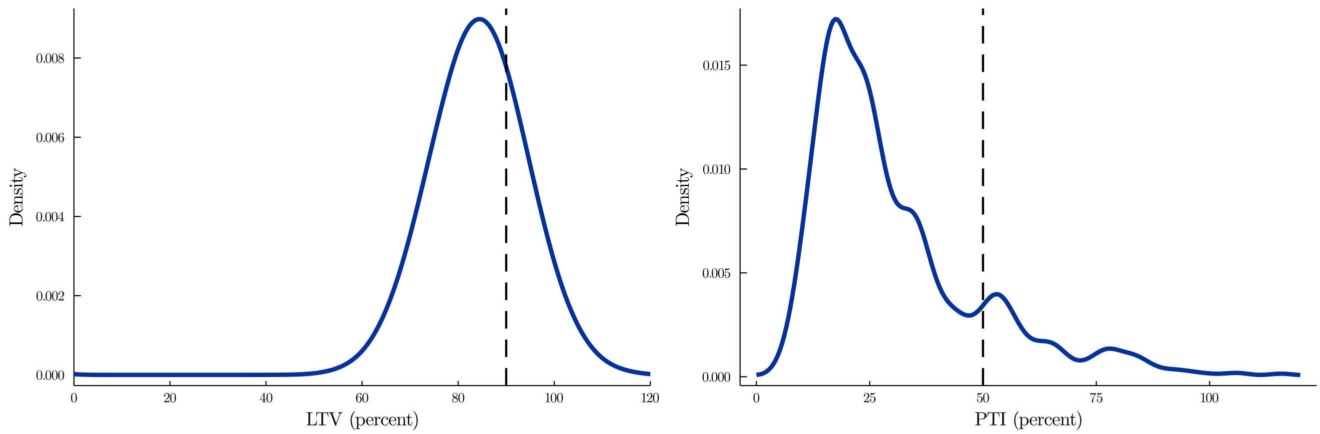
6.1 Model fit

In this section, we describe how key model statistics under the baseline calibration compare with non-target moments in the data.

Figure 5 shows model-generated distributions of LTV and PTI at mortgage loan origination, which are broadly consistent with their empirical counterparts. The LTV distribution is skewed to the left with a lump of mass in the 80-100 interval. The fraction of loans in the model above the LTV cap is 40 percent, compared to 39 percent in the data (see section 4).

The PTI distribution is skewed to the right, with most simulations centered around the 25 percent mark. The fraction of loans above the cap is 14 percent, compared to roughly one-quarter of the observations in the data. The disparity between model and data results from the assumption that mortgage loans have a maturity equal to J, implying lower minimum repayments than the data where loans typically have an average of 35 years of maturity at origination (CSD December 2017).

Figure 6 displays key household balance sheet statistics over the life-cycle. Figure 6a shows the homeownership rate during the working age. The share of households who own their home closely tracks its empirical counterpart across age cohorts during a household's early years, diverging around the age of 45 to 48 years old.



(a) LTV distribution at origination (b) PTI distribution at origination

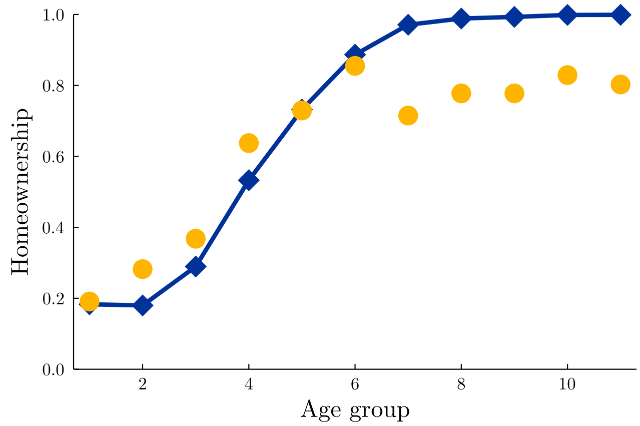
Note: The vertical axis in the charts is the relative frequency of the bins of the kernel density estimates. The vertical dashed line indicates the cap introduced by the policy.

Figure 5: Model generated LTV and PTI distributions at origination.

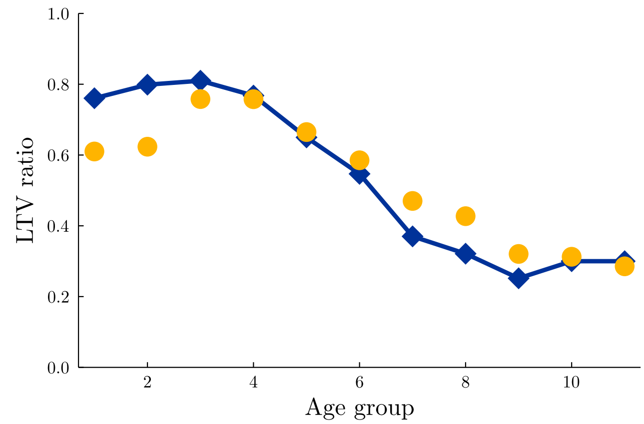
Figures 6b and 6c decompose aggregate mortgage debt across the working age. Figure 6b shows the LTV ratio for working-age households, i.e., the intensive choice of mortgages by homeowners. It starts at 60 to 80 percent on average for households younger than 40 years old and drops off until retirement. While the model matches the data from 29 years old onward, it overestimates the leverage of younger households. In contrast, the share of homeowners with a mortgage (i.e., the extensive margin of mortgage choice) is well approximated by the model almost until retirement, diverging around the age of 50. As households grow older, they repay their debt and exit mortgage markets, both in the data and in the model.

Finally, Figure 6d displays the accumulation of net worth relative to labor income. Qualitatively, the model can match the growing net worth accumulation by households through their working life. In the early years of life, the model underestimates net worth accumulation relative to the data. However, this difference should be viewed in light of the fact that survey responses to questions on the value of assets, such as the current value of a household's residence, are often biased upward, as argued in Bhandari et al. (2020) for the U.S.

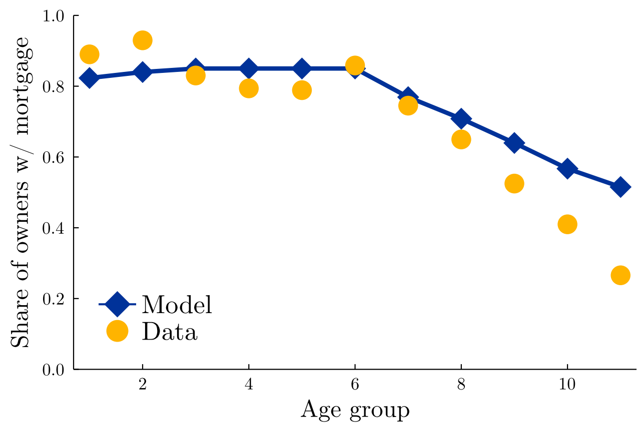
Table 6 shows the model fit to national accounts, as in Bhandari and McGrattan (2020). Appendix E describes the model national accounts and how to align them with the data. Briefly, model labor income



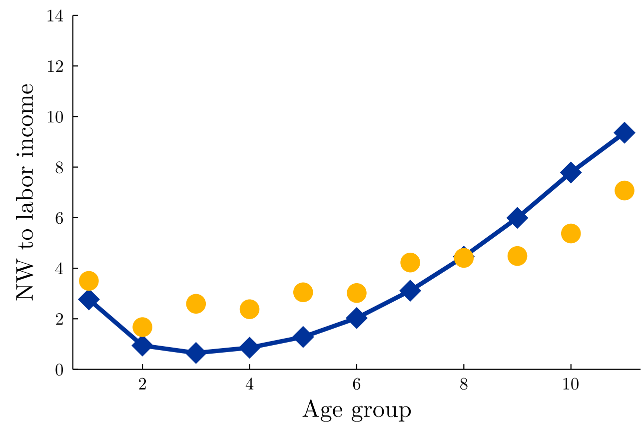
(a) Homeownership life-cycle



(b) LTV life-cycle



(c) Share of homeowners with mortgage across life-cycle



(d) Net worth life-cycle

Note: Age bins are defined as follows: 21-24 (1), 25-28 (2), 29-32 (3), 33-36 (4), 37-40 (5), 41-44 (6), 45-48 (7), 49-52 (8), 53-56 (9), 57-60 (10), 61-64 (11). The LTV ratio is calculated only for homeowners with a mortgage in each age bin. Data source: HFCS.

Figure 6: Model fit of non-targeted life-cycle profiles.

is composed of wages in non-durable and construction goods sectors. Capital income is the sum of the remuneration of business capital, the sale of land permits by the government, pre-tax profits of the rental sector, and rents imputed to homeowners.[11]

The construction of the product shares is as follows: Private consumption expenditure includes household expenses on non-durable goods, housing market transaction costs, mortgage origination costs, intermediation services, and housing rents. Government consumption is directly comparable to the data. Investment is divided into two categories, business and residential. Business capital is all non-residential

[11]The last adjustment is a convention of the European System of National Accounts (ESA).

Table 6: Model fit to national accounts

	Model	Data
Income shares		
Labor income	0.52	0.50
Capital income	0.48	0.50
Product shares		
Private nondurable consumption	0.42	0.60
Government consumption	0.17	0.17
Investment	0.37	0.23
Housing	0.03	0.03
Business capital	0.32	0.20
Net exports	0.04	0.01

Note: The main adjustments made to the National Accounts data are the subtraction of value-added taxes, and the reclassification of consumer durables as an investment. Further details on how to make model moments and data consistent are provided in Appendix E.

investment in the national accounts.

The most significant difference between the model and the data is the gap in private consumption and investment in business capital. Because the depreciation rate is close to standard values in the literature, the large share of business capital investment relative to output predicted by the model can only be explained by the low level of the world interest rate. However, due to the existence of fixed-rate mortgages in the model, it must be that $r_b > r_m$. Otherwise, households would find it optimal to borrow the maximum amount and invest in the risk-free bond. In order to generate a lower business investment share, a risky asset would be necessary, which would allow for a higher domestic return rate without violating the open economy assumption.

In summary, our model is able to broadly match the features of the data which will be more relevant for the evaluation of the policy, namely the main moments of the distribution of loans at origination, and the life-cycle profiles of homeownership and leverage. In the next section, we describe the use of the model calibrated to the Portuguese economy to produce predictions regarding the impact of LTV and PTI caps.

Table 7: Aggregate impact of mortgage borrowing caps compared with the pre-policy economy

	Baseline	**Both caps**	**LTV cap**	**PTI cap**
Leverage and foreclosure				
Mortgage debt to GDP	0.48	0.33	0.33	0.50
Share of homeowners w/ mortgage	0.51	0.46	0.46	0.54
LTV	0.41	0.30	0.30	0.42
Foreclosure rate (%)	0.53	0.03	0.03	0.55
Homeownership and prices				
Homeownership rate	0.78	0.71	0.70	0.81
House price	1.00	0.98	0.98	1.00
Mortgage interest rate (%)	1.11	1.13	1.13	1.11

Note: All statistics are computed based on the stationary distribution under the baseline calibration, with both caps activated, only the 90 percent LTV cap activated, and only the 50 percent PTI cap activated, as indicated in the top row of the table. LTV is the average LTV over the life-cycle. House prices are normalized by their level in the baseline economy.

7 Quantitative analysis

In this section, we use the model to predict the long-run impact of the policy, its welfare implications and to understand the role of LTV and PTI caps individually and in combination. The main experiment conducted is a simultaneous and unexpected tightening of both LTV and PTI caps, corresponding to the levels set in the policy enacted by Banco de Portugal:

$$\lambda^m : 1.2 \longrightarrow 0.9$$

$$\lambda^\pi : 1.2 \longrightarrow 0.5.$$

7.1 Impact of borrowing caps on leverage and default

Results of the main policy experiment are reported in Table 7. The columns indicate the level of aggregate variables under different mortgage market regulations. Compared to the baseline calibration, the economy with both borrowing caps has a 30 percent reduction in mortgage debt to GDP (15 percentage points). The reduction in aggregate indebtedness results from three sources. First, higher down payment requirements reduce the homeownership rate, which drops by 7 percentage points, as they require more time to save enough to buy a house. This reduces the total number of years that households are indebted and, therefore, the aggregate amount of debt in the economy.

Second, the share of homeowners with a mortgage drops by 10 percent (6 percentage points). This follows mainly from higher down payments: Households take out smaller mortgages, which are paid off quicker. Third, the LTV cap affects leverage choices, lowering average LTV by one-quarter (11 p.p.). Finally, we find that the policy is able to eliminate foreclosures in the long run, with only a minor impact on house prices.

The significant impact of the policy on the foreclosure rate is explained by the mechanics behind the default decision in the model: Because the option to sell the house is always available, default is only optimal in case the household has negative home equity. Setting an LTV cap amounts to raising the floor on home equity, eliminating the incentive to default in the stationary equilibrium of the economy.

The muted effect of the policy on house prices is the result of the coexistence of long-term mortgages and rental housing markets, as discussed in Kaplan et al. (2020). Because caps only bind at mortgage origination, only new borrowers are directly affected by the policy. This is in contrast to frameworks such as Favilukis et al. (2017), where households finance their housing choice with one-period bonds, and caps must be complied with every period. Thus, restricting LTV or PTI ratios would force an immediate deleveraging across all borrowers, which does not occur in our framework.

The inclusion of rental markets allows borrowers who become constrained by the policy to consume comparable levels of housing services without having to access the ownership market. This further dampens the linkage between house prices and credit market conditions. In simple terms, if a household becomes constrained in its housing size choice compared to the pre-policy economy, it may choose a rental with a similar size in the housing rental market. Thus, housing demand changes only slightly between economies with different credit market regulations.

The final two columns indicate the long-run impact of setting each cap in isolation. Due to the low fraction of households constrained by the PTI cap in the model, the LTV cap is the only driver behind the changes in aggregate variables. When set in isolation, the PTI cap is counterproductive in terms of the goals of the policymaker. It raises household borrowing, via the intensive and the extensive margins, and the foreclosure rate.

The reason for this result is the interaction between idiosyncratic risk, long-term mortgages, and the PTI cap: Because agents are subject to idiosyncratic earnings shocks, the introduction of the PTI cap implies that a negative labor income shock may constrain households in their access to credit markets. Because agents are risk-averse and caps can only bind at origination, households borrow earlier and with lower down payments, to insure themselves against this possibility, resulting in higher leverage. As leverage is a crucial determinant of the default decision, the foreclosure rate increases slightly. The discovery of this mechanism, which we dub as *pre-emptive borrowing*, is one of the main contributions of our paper.

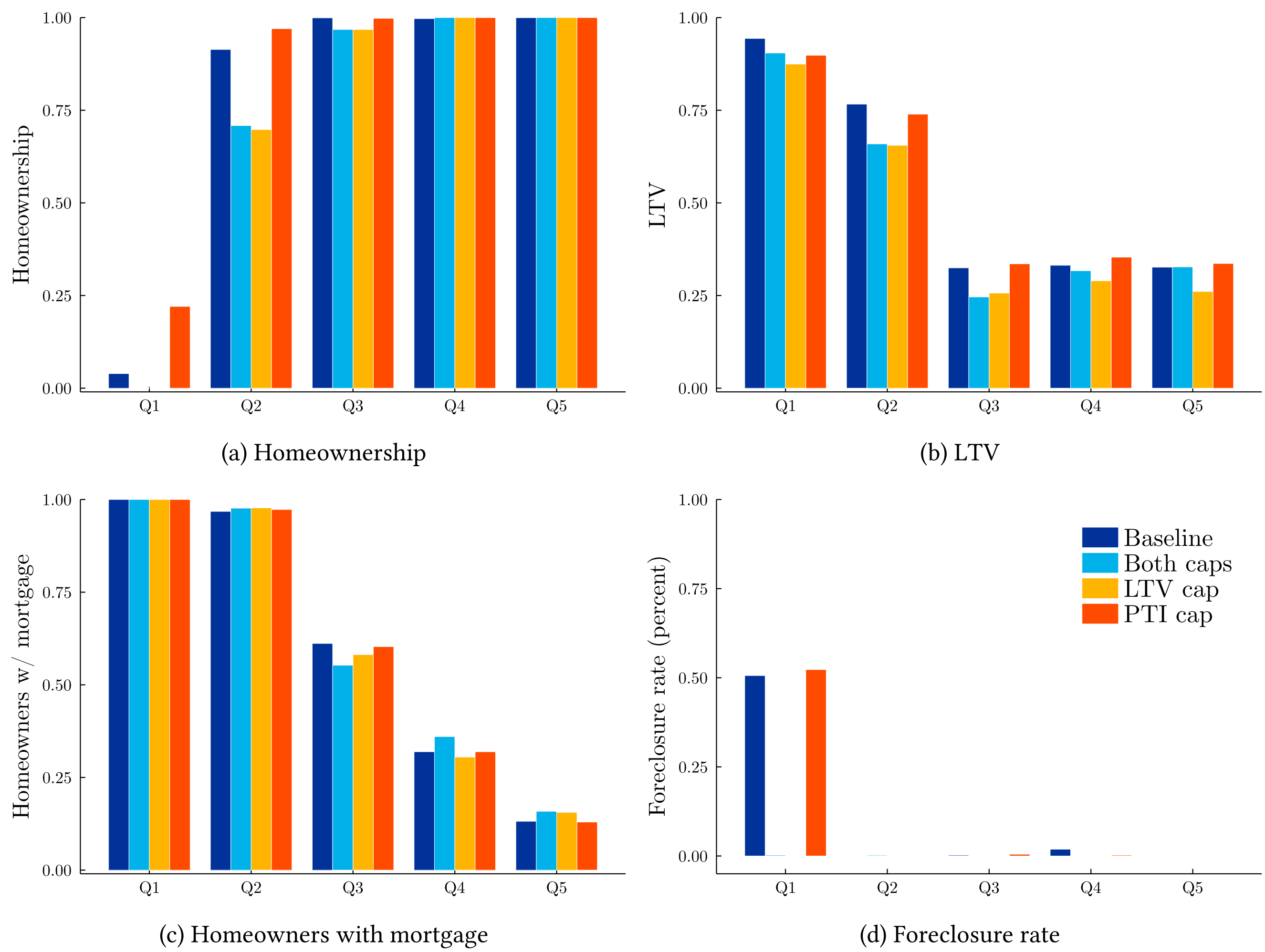
When the PTI cap is set in conjunction with an LTV cap, households are prevented from choosing higher leverage in mortgage contracts. This indicates that limits on leverage should accompany the introduction of PTI caps if policymakers wish to limit these effects.

Figures 7 and 8 show homeownership, indebtedness, and foreclosure rates across quintiles of the labor income and net worth distributions, respectively, under different credit market regulations.

Homeownership rates are lower for the bottom quintiles of the income and are reduced further when LTV caps are introduced. The reason for this reduction can be seen in Figure 7b, which displays the behavior of lifetime leverage for each quintile. Households in the second quintile of the labor income distribution have the most significant quantitative impact in terms of reducing overall indebtedness. They show high ownership rates before the policy is implemented, which are reduced substantially after introducing LTV caps, as these households delay home purchases.[12] Finally, foreclosures are limited to the first quintile (Figure 7d), indicating that households who default do so after very large adverse income shocks.

In terms of the net worth distribution, both homeownership and leverage drop across all quintiles whenever the LTV cap is implemented (Figures 8a and 8b). The share of homeowners with a mortgage drops substantially for the bottom quintiles (Figure 8c) as households borrow less from the outset and

[12] Households at the bottom quintile of the labor income distribution have a very high frequency of default, which explains why ownership is very low.

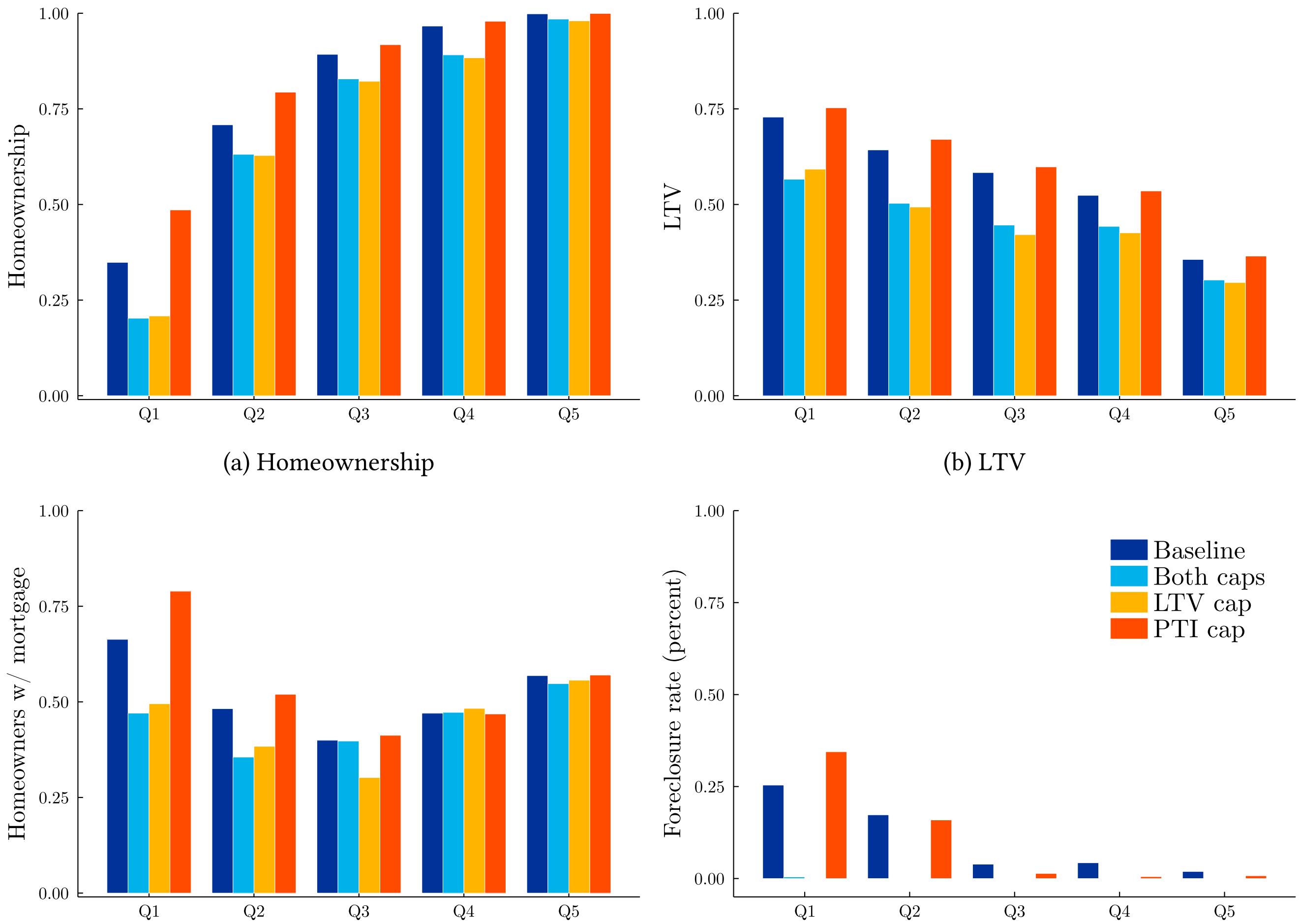


Note: Q1 to Q5 indicate the quantiles of the net worth distribution. LTV is the lifetime leverage of households. For the color blind, the bars are in the same order as the experiments indicated in the legend. The foreclosure rate is computed as the ratio between the value of defaulted loans per quantile and the value of total outstanding loans at the beginning of the period.

Figure 7: Impact of caps across the labor income distribution.

pay back their debt more quickly. In contrast, setting an PTI cap increases the fraction of homeowners with a mortgage for the bottom quintiles of the net worth distribution. This is due to the pre-emptive borrowing mechanism, which is stronger for wealth-poor households.

Finally, the foreclosure frequency is more severe at the bottom of the net worth distribution (Figure 8d) but is eliminated in all scenarios where the LTV cap is introduced. When the PTI cap is imposed, it remains nearly unchanged relative to the baseline calibration for most quintiles, and raises slightly for the bottom quintile, for the reasons argued in the previous paragraphs.



(a) Homeownership

(b) LTV

(c) Share of homeowners with mortgage

(d) Foreclosure rate

Note: Q1 to Q5 indicate the quantiles of the net worth distribution. LTV is the lifetime leverage of households. For the color blind, the bars are in the same order as the experiments indicated in the legend. The foreclosure rate is computed as the ratio between the value of defaulted loans per quantile and the value of total outstanding loans at the beginning of the period.

Figure 8: Impact of caps across the net worth distribution.

7.2 Impact of borrowing caps on welfare

In this section, we describe the aggregate and distributional welfare impacts of imposing mortgage borrowing caps.

Without accounting for its effects on aggregate risk, the trade-off involved in this policy can be summarized as follows. On the one hand, by constraining household behavior, the caps imply that individual choices will be sub-optimal with respect to the unconstrained equilibrium. In this case, income and wealth-poor households will have to pay more for the same housing services in the rental market due to the taxation of rental income and the management costs incurred by the rental sector. In order to regain access to credit markets, they have to save up for a down payment and purchase a house only later in their lives.

On the other hand, introducing a minimum down payment requirement reduces foreclosures, which are costly for the economy. This results from the higher depreciation rate associated with foreclosed properties, a friction that accelerates the depreciation of the housing stock and raises house prices. We find that, in practice, the upside of these policies is minimal compared to the cost if we abstract from the potential benefits from the reduction in aggregate volatility.

In order to measure the effects of imposing these policies in our model, we conduct two types of experiments. First, we compare the utility of the consumption streams under different policy combinations assuming that the economy moves instantly from the steady-state under the baseline calibration to an equilibrium with a given policy combination of LTV and PTI caps. Second, we redo the comparison by modeling the introduction of each policy as an unanticipated and permanent change in the maximum LTV and PTI limits.

Table 8 displays the change in household welfare measured in consumption equivalent variation for the main policy experiment and each of the caps separately. Consumption equivalent variation is measured using the formulation of composite consumption for models which include housing services in the utility function, as detailed in Gete and Zecchetto (2018).

The first row shows the effects of each policy combination for a household that is about to enter the labor market if the economy were to instantly transition from the baseline calibration to the final steady-state. We estimate that the introduction of this policy leads to a 1 percent drop in welfare and is fully explained by the limit on leverage at origination. The PTI cap has an insignificant effect in terms of welfare due to the low fraction of households that are constrained in the model.[13]

In the second row, we display the welfare analysis taking into account the transition. In this case, the welfare cost jumps to almost 2 percent in consumption equivalent variation. This further drop in welfare results from the process of transitioning to a lower equilibrium house price. Wealth and income-poor

[13] We investigate the consequences of choosing more restrictive PTI limits in section 7.3.

Table 8: Welfare impact of introducing caps in percent of consumption equivalent variation

	Both caps	LTV cap	PTI cap
Unborn	-1.1	-1.1	0.0
Unborn (transition)	-1.9	-1.9	0.0
Average	-0.1	-0.1	0.0
Average (transition)	-0.3	-0.3	0.0

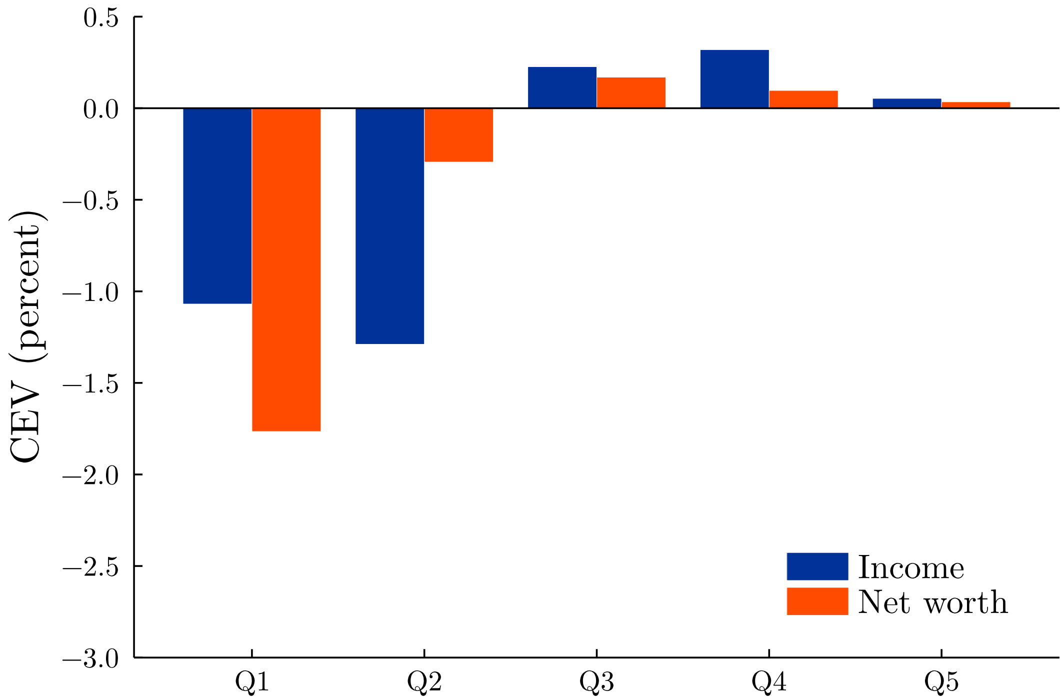
Note: Welfare costs are measured in percent of consumption-equivalent variation, using the method of Gete and Zecchetto (2018). "Unborn" indicates that the welfare change is measured for households about to enter the labor market and before they know their bequests and their permanent labor income component. "Average" indicates the average welfare change across all households. The "transition" annotation indicates whether the transition to a new steady state is taken into account. The transition period is 30 model periods, i.e., 60 years.

households are constrained in their access to higher housing services due to the LTV cap. However, the reduction in house prices alleviates this constraint. Because the transition to the new equilibrium price is not instantaneous, households entering the market the period after the policy is implemented do not immediately benefit from lower house prices and rents. Furthermore, as they become homeowners, the value of their house is still expected to fall in the future. Hence, unborn households prefer to transition to the new steady-state at once without experiencing the transition process.

The third row shows the average change in welfare for households already in the economy. Welfare costs are much lower for these agents, as most have already made their house purchase decisions and are thus less constrained by the caps. The reduction in house prices by 2 percent reduces rents and maintenance costs, but it is not enough to offset the average impact of the leverage constraint.

In the fourth row, we take the transition process into account. In this case, the welfare costs double. Once more, this is the result of the transition process, where income and wealth-poor households are constrained in their leverage choices and do not yet fully benefit from the drop in house prices.

Figure 9 shows the average welfare costs of the main policy experiment across the income and net worth distribution. The losers from the policy are located in the bottom two quintiles of the labor income and net worth distributions. As discussed previously, these are the households with the lowest savings or those with the lowest saving-generating capacity, who are most impacted by the new constraints.



Note: The figure shows the consumption equivalent variation computed for each quintile of the income and net worth distribution accounting for the transition to a new steady state. The transition period is 30 model periods, i.e., 60 years.

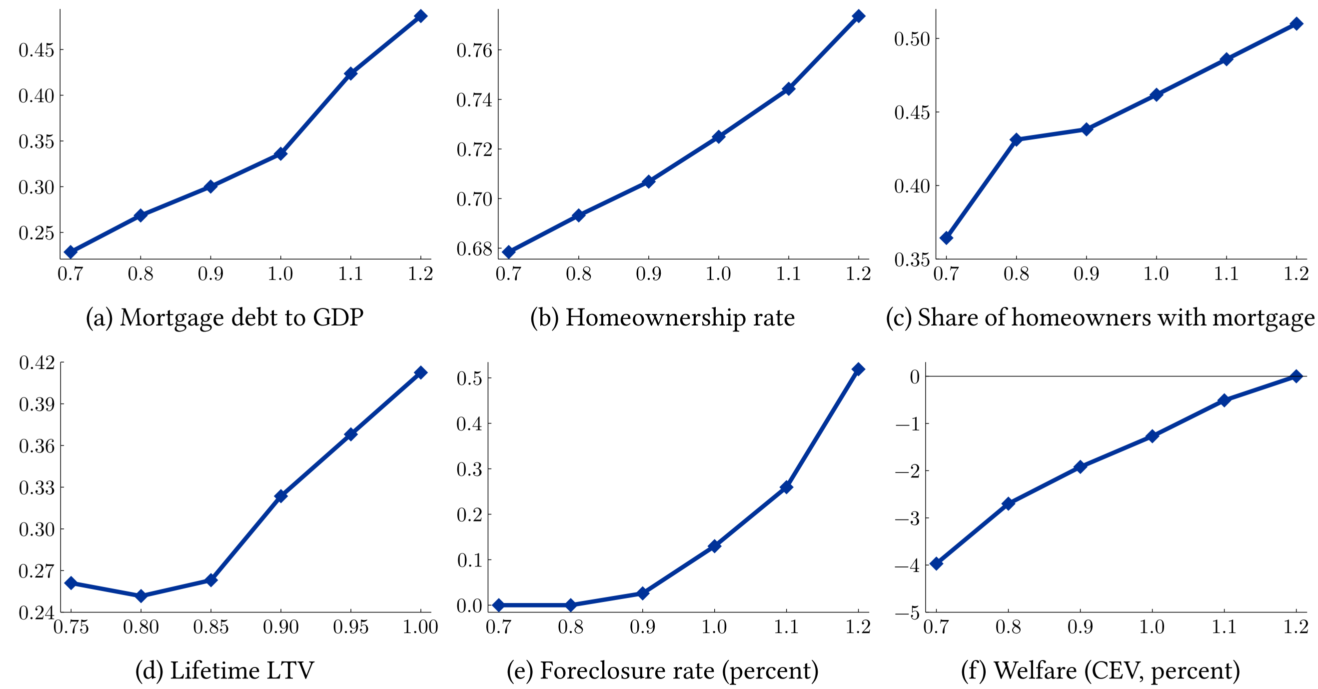
Figure 9: Welfare impact of the main policy experiment by labor income and wealth distribution quintiles. The income and wealth-poor households are negatively affected.

On the winner side are those in the top quintiles of the income and net worth distributions, who benefit from lower rents or maintenance costs on their house purchases. However, due to low observed property taxes and depreciation, and the slight impact of the caps on housing demand and house prices, the gains for these households are much more modest than the losses for those at the bottom.

7.3 Alternative cap levels

In this section we describe the partial effects of each cap on the long-run values of leverage, foreclosures, and welfare. This will allow us to identify cap combinations which achieve the goals of reducing households indebtedness and default, while reducing the welfare of households by the least possible amount. Figure 10 displays the impact of different levels of the LTV cap on the aggregate variables of interest.

In general, restricting leverage has a linear effect on homeownership, and the extensive and intensive margins of mortgage choice. Crucially, the model predicts that an LTV cap of 0.95 can eliminate



(a) Mortgage debt to GDP (b) Homeownership rate (c) Share of homeowners with mortgage

(d) Lifetime LTV (e) Foreclosure rate (percent) (f) Welfare (CEV, percent)

Note: The x-axis in each subplot is the value of the LTV cap. The interpretation of the y-axis is given in the title of each subplot. Welfare is measured as the expected welfare of a household about to enter the economy, taking into account the transition path.

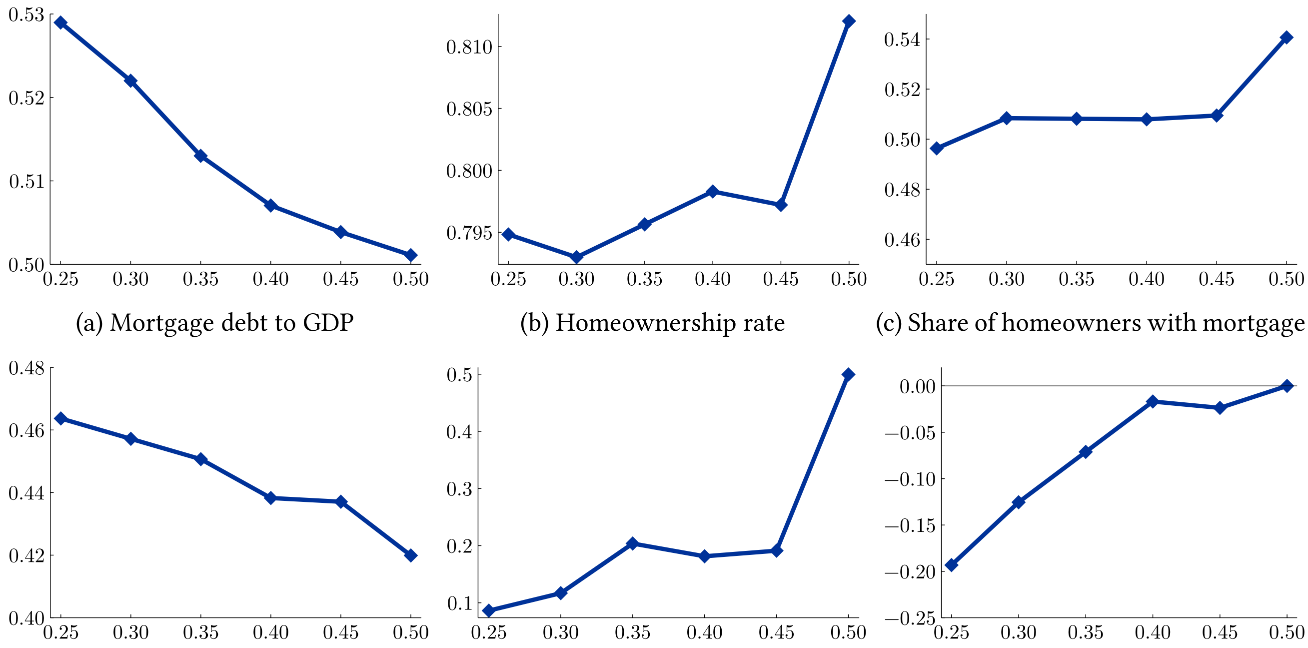
Figure 10: Sensitivity of aggregate variables to the LTV cap.

foreclosures at only half the welfare cost of the main policy experiment. If the policymaker allocates a greater weight to reducing foreclosures relative to lifetime leverage, she could still achieve her goals while minimizing welfare losses (Figure 10f). In addition, our findings indicate that caps on leverage have a limited effect on reducing overall leverage for an LTV cap between 0.75 and 0.85 (Figure 10d).

Figure 11 shows the partial effect of changing the PTI cap. The PTI limit displays a number of crucial differences with respect to leverage limits. First, it has a minimal impact on overall homeownership (Figure 11b) and on the extensive margin of mortgage choices (Figure 11b). This is unsurprising, as the PTI cap does not exclude households from the credit market altogether like the LTV cap but merely puts a limit on the debt service of a given contract.

Second, lowering the PTI cap increases total mortgage debt to GDP (Figure 11a) for the 50-25 percent band. This is the result of households increasing leverage choices at the start of their lives, which results in higher lifetime LTV (Figure 11d).

Finally, lowering the PTI cap reduces the foreclosure by three-fifths relative to the baseline calibration



(a) Mortgage debt to GDP (b) Homeownership rate (c) Share of homeowners with mortgage

(d) Lifetime LTV (e) Foreclosure rate (percent) (f) Welfare (CEV, percent)

Note: The x-axis in each subplot is the value of the PTI cap. The interpretation of the y-axis is given in the title of each subplot. Welfare is measured as the expected welfare of a household about to enter the economy, taking into account the transition path.

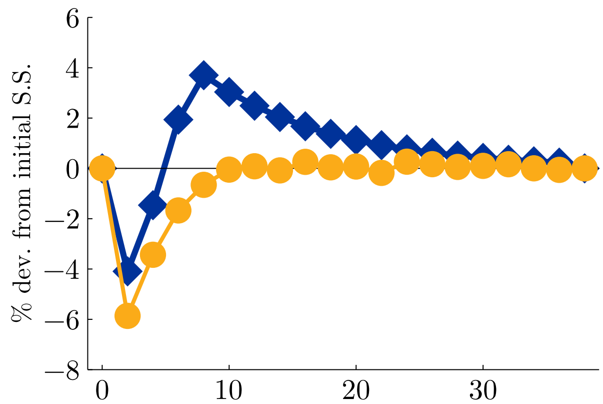
Figure 11: Sensitivity of aggregate variables to the PTI cap.

(Figure 11e) at only a fraction of the welfare cost of the LTV cap (Figure 11f). Although negative housing equity is a necessary condition for default, it is not a sufficient one. Most households will only default in case they are hit by a very adverse labor income shock. Limiting mortgage payments with respect to risky labor income ensures that the shock required to trigger a default decision in the future needs to be much larger, which limits foreclosures.

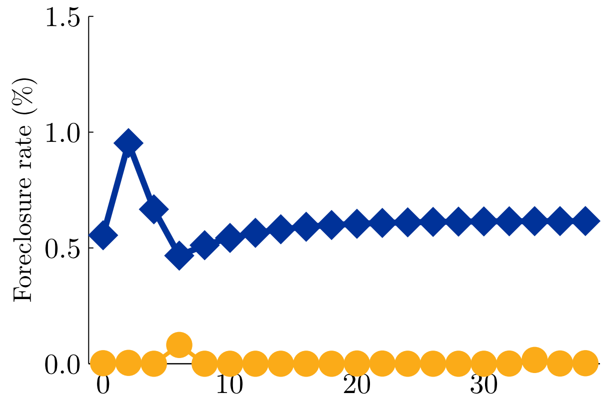
7.4 Response to aggregate shocks

One of the main arguments for the introduction of borrowing caps is their effectiveness as a means to dampen the effect of shocks to the economy. In this subsection, we compare the reaction of the economy to two different unexpected aggregate shocks with and without credit market regulations.

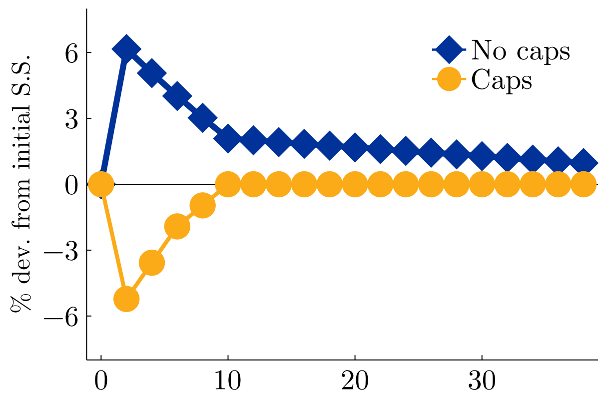
The first experiment is a temporary positive shock to total factor productivity in the construction sector, A_h. This results in an increased inflow of properties into the housing market, which results in



(a) House prices



(b) Foreclosure rate



(c) Mortgage debt

Note: The x-axis in each subplot are the periods, measured in years, since a 10 percent shock to A_h with persistence equal to 0.5. The interpretation of the y-axis is given in the title of each subplot.

Figure 12: House price crash.

a house price crash. This is akin to a sudden stop of foreign demand for domestic properties, which constituted about 10 percent of the value of transactions in Portugal in 2017.[14] Thus, we model the shock as a 10 percent increase in A_h with a persistence of 0.5. Figure 12 shows the impact of this shock on house prices, foreclosures, and credit.

In the case of the economy without caps, house prices drop on impact but recover quickly as households entering the economy resort to credit in order to take advantage of lower house prices before they return to their steady state value. Similarly, older households take the opportunity to upsize the quality of their homes. Thus, the housing market recovers quickly and total credit increases above the initial steady state level temporarily. Because the fraction of high leverage loans is significant, the drop in prices

[14]Source: Statistics Portugal.

leads to a temporary increase in the foreclosure rate. This reaction is transitory, as house prices quickly recover and the incentive to default is rapidly reduced.

Note that this experiment does not take into account the effect that house price drops and resulting foreclosures might have on financial intermediary balance sheets, which could lead to a credit crunch. Thus, the rapid recovery in house prices would only take place in case the financial sector is sufficiently capitalized to support the recovery.

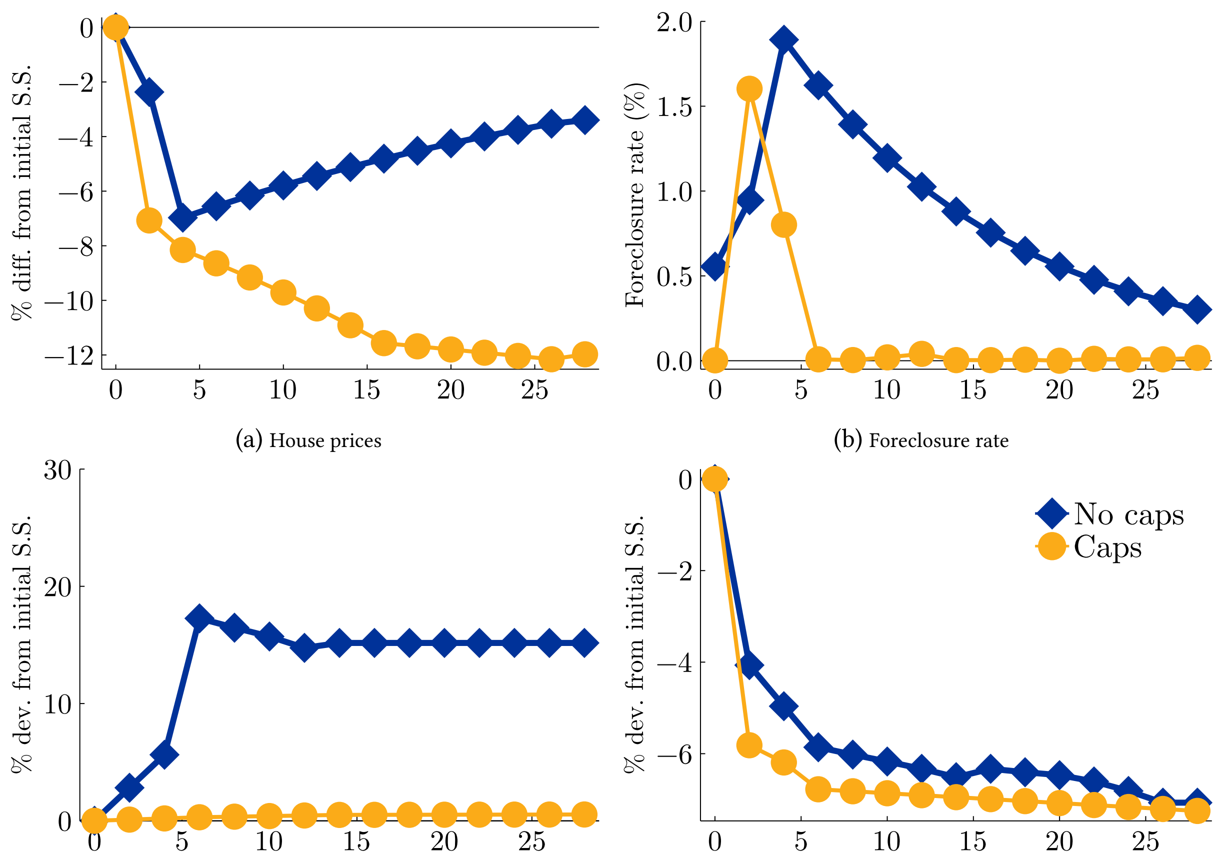
In the case of the economy with caps, the contrast is stark. The decline in house prices is more accentuated and persistent, as households are constrained in their access to credit by the caps. The foreclosure rate, however, is nearly unchanged as the stock of loans does not include mortgages with LTVs above 90 percent and, therefore, the incentive to default is much lower than in the economy without caps. This observation not withstanding, this experiment creates a case for the deactivation or relaxation of mortgage borrowing caps in the event of a house price crash, so as to allow for a more rapid recovery.

The second experiment we conduct is an increase in interest rates, i.e., a tightening of monetary policy at the euro area level. We model it as a permanent 1 percentage point shock to the risk-free rate r_b. The results are displayed on Figure 13.

An interest rate hike has a number of direct impacts in the economy: (i) raises the opportunity cost of consumption and house ownership for both households and the rental sector; (ii) leads to a reduction of wages, due to the flight of capital; and (iii) raises the debt payment burden of households.

In the economy without caps, the recovery of the housing market is much faster and to a higher level of house prices, dropping to only 4 percent below the initial steady state in the long-run. The reason for this is the same as in the previous experiment, i.e., the absence of the caps allows households to take advantage of the reduction of house prices, albeit to a lower degree. This is due to the higher opportunity cost of ownership and the increased debt burden of mortgages, which reduces the attractiveness of debt to households.

However, the rental sector is also subject to an increase in the opportunity cost of owning a housing stock. This implies that rents increase, leading households to turn to ownership. As a result, total debt increases, albeit via the extensive and not the intensive margin.



(a) House prices (b) Foreclosure rate

(c) Mortgage debt (d) GDP

Note: The x-axis in each subplot are the periods, measured in years, since a permanent 1 percentage point shock to r_b. The interpretation of the y-axis is given in the title of each subplot.

Figure 13: Monetary policy tightening

The permanent monetary tightening leads to a large increase in the foreclosure rate, to the tune of 1.5 percentage points above the value in the initial steady state. For reference, the recorded historical maximum was 1.4 percent in the fourth quarter of 2012, at the height of the European Sovereign Debt Crisis.[15] Foreclosures remain at very high levels, as lower prices keep home equity down for older households.

In contrast, in the economy with caps the housing market has a descending trajectory. House prices drop 12 percent below the initial steady state. Due to the existence of the caps, however, the stock of credit remains unchanged. Taking out mortgages is also less appealing due to higher rates and, given that

[15] Source: Fitch.

The most important result, however, is the lower amplitude and persistence of the effect of the shock on foreclosures. The foreclosure rate rises above 1.5 percent on impact but rapidly lowers to zero. This dampened response is the result of a low stock of high leverage loans, where borrowers have a much higher incentive to default.

In summary, the baseline policy is able to reduce the amplitude and persistence of aggregate shocks to the economy, although this comes at the cost of slower recovery of the housing market.

8 Conclusion

In this paper, we investigate the impact of mortgage borrowing caps on leverage, default, and welfare. To estimate the effects of this policy, we calibrate a structural model of mortgage debt and default to the Portuguese economy, where the central bank enacted loan-to-value and payment-to-income limits in 2018. Using the model as a laboratory with which to experiment different limits on household mortgages, we reach six main conclusions.

First, we document that an LTV cap of 90 percent is binding for around 40 percent of new mortgage loans in Portugal, in contrast to only 25 percent for a PTI cap of 50 percent before the new policy was implemented. This implies that a significant number of new mortgage contracts are affected by the new regulation.

Second, using an overlapping generations model with uninsurable labor income risk, housing, and long-term defaultable loans we show that the specific policy implemented in Portugal can reduce mortgage debt by one-third and virtually eliminate default in the long-run. However, this comes at the cost of a 2 percent reduction in household welfare, concentrated at the bottom of the income and wealth distributions. We also find that setting PTI and LTV caps have only a very limited effect on house prices, as argued by Kaplan et al. (2020) for the U.S. economy. Thus, more affluent households benefit from the policy due to the reduction in property taxes and maintenance costs. However, it is not sufficient to offset the negative effects from constraining individual optimization in the welfare analysis. This observation does not necessarily imply that the policy is welfare reducing overall, given that the model does not take into account the intertemporal trade-off between *ex-ante* restrictions and lower crisis probability and severity *ex-post* due to a less vulnerable financial system.

Third, we show that these results are mainly driven by the leverage cap. The substantial drop in household debt, in particular, follows from the fact that a significant fraction of the aggregate mortgage credit flow is associated with younger agents who start their life with low wages and savings and choose loan contracts with lower down payments. Setting an LTV limit is equivalent to requiring a minimum down payment on new loans, forcing agents to either save up in order to meet the new requirements, buy a smaller house, or rent one instead of becoming homeowners, thus restricting the flow of high leverage loans and the future stock of debt.

Fourth, we find that the PTI cap is able to restrict default if set at levels smaller than 50 percent for our baseline calibration, but raises aggregate debt and leverage. This is the result of the interaction between labor market risk, long-term loans, and the payment-to-income cap: Households fear future adverse income shocks may constrain their access to credit markets and borrow earlier with lower down payments, since the caps only need to be satisfied at loan origination. This can leave household balance sheets vulnerable to aggregate shocks if a PTI cap is implemented without an appropriate LTV cap to prevent the increase in leverage. The discovery of this mechanism, which we dub as *pre-emptive borrowing*, is one of our main contributions.

Fifth, depending on the weight that the policymaker assigns to reducing indebtedness, she may be able to cut the default rate at a lower welfare cost. For the baseline economy, setting the LTV cap at 100 percent cuts the default rate by 80 percent with two-thirds the welfare loss to households, at the cost of a lower reduction of total mortgage debt to GDP. Lowering the PTI cap to 0.45 instead of 0.5, the policymaker can reduce the default rate by three-fifths with one-tenth the welfare cost of the baseline policy. However, due to the interaction between labor market risk and the PTI cap this comes at the cost of a mild increase in aggregate debt relative to the baseline due to pre-emptive borrowing.

Finally, we test the response of the economy to shocks with and without the policy. We find that the imposition of PTI and LTV caps prevents a surge of defaults following a house price crash. However, this comes at the cost of a slower recovery of the housing market, given the restrictions on ownership introduced by the policy. This creates an argument for a counter-cyclical dynamic of mortgage borrowing caps to loosen conditions during house price recoveries.

In our view, several future strands of research are worth pursuing. First, our paper investigates the aggregate and distributional impacts of imposing borrowing caps, but it contains no relevant market failure that this policy can address. The next step is to determine whether quantitatively relevant externalities result from mortgage borrowing and whether caps can optimally address them.

Second, there is a single housing price in our model. In reality, there are multiple markets in an economy, which may respond differently to caps on leverage or debt service. Modeling them separately will allow us to make sharper predictions for the welfare consequences of this type of policy.

Third, the rental sector is entirely owned by foreigners. In practice, the rental housing stock is very often the property of domestic firms and households. Therefore, the income it generates directly impacts the welfare of households and may be affected by this policy. Introducing the options for households to rent part of their housing property (as in Jeske et al., 2013) can enrich our understanding of how this policy will impact rental markets.

Fourth, financial intermediaries in our model are a means to price mortgage contracts. They have no leverage, no probability of default, and no deposits. Typically one of the main reasons for introducing mortgage borrowing caps is to limit the amount of risk that banks can take, given that they can take advantage of the implicit subsidy provided by deposit insurance. Understanding whether this policy effectively mitigates this market failure remains an open question.

APPENDIX

The Appendix is organized as follows. Section A indicates data definitions and sources. Section B describes the household problems. Section C describes the equilibrium concept. Section D outlines the procedure for the computation of the equilibrium. Section E describes the model national accounts.

A Data

Bank housing loans: Stock of loans of other monetary financial institutions (OMFIs) to private individuals for housing purposes (all maturities).[16] *Bank of Portugal, Monetary and Financial Statistics, B.4.1.4, September 2020.*

Broker's fees: Total sales of real estate mediation firms (CAE REV code 68311) divided by the total value of real estate transactions (see information on the transaction tax below), plus VAT at 23%, in 2017. *Banco de Portugal, Statistics on Non-Financial Corporations from Central Balance-Sheet Database, Table G.5., May 2021.*

Capital depreciation rate: Average depreciation rate across assets in the capital detail files of the Penn World Table 10.0 (Feenstra et al., 2015) weighted by the stock of net current cost of each type of capital. The depreciation rate of each asset type is calculated as capital consumption of that asset type divided by the sum of net current cost of that asset type and capital consumption. The resulting depreciation rate is averaged over 2000-2017. The Penn World Table aggregates residential and non-residential structures, so we subtract the net current cost stock of residential structures (see below) and assume that all structures have the same depreciation rate. *Penn World Table 10.0, variables nc_struc, nc_mach, nc_traqeq, nc_other, dc_struc, dc_mach, dc_traqeq, and dc_other, April 2021.*

Consumer price index: Seasonally consumer price index (all items). *OECD, consumer price indices, variable cpaltt01.ixob.q, February 2021.*

[16] Monetary financial institutions (MFIs) are resident credit institutions as defined in European Union law, and other resident financial institutions whose business is to receive deposits or close substitutes for deposits from entities other than MFIs and, for their own account (at least in economic terms), to grant credits or make investments in securities. Definition provided by the ECB. OMFI are all MFI except central banks.

Consumption units: Consumption equivalence scale. Data for 2017. *European Central Bank, Eurosystem HFCS, 3rd wave, variable dh0002, May 2020.*

Defaulted housing loans: Stock of OMFI loans to private individuals for house purchase which are overdue. *Bank of Portugal, Monetary and Financial Statistics, Table B.4.1.4, September 2020.*

Disposable income: Seasonally adjusted nominal net disposable income at quarterly frequency, annualized. *Statistics Portugal, National Accounts, Table A.2.2, January 2020.*

Financial net worth: Financial of net worth of households and non-profit institutions serving households (NPISH). Data for 2017. Consolidated values. *Banco de Portugal, National Financial Accounts, Table F.2.1.4, August 2020.*

Government consumption expenditures: Annual government final consumption expenditures. Data for 2017. *Statistics Portugal, Table A.1.2.5.1, August 2020.*

Gross domestic product (GDP): Annual GDP, final consumption expenditure approach measured at current prices. Data for 2017. *Statistics Portugal, Table A.1.1.2, August 2020.*

Gross pension replacement rate: Value for 2018 of the average (male) gross pension entitlement divided by gross pre-retirement earnings of an individual who entered the labor market in 2018. *OECD, Pensions at a Glance, variable prt.pen3b, March 2021.*

Homeownership rate: Percentage of the population owning their primary residence in 2017. *Eurostat, Statistics on Income and Living Conditions, variable ilc_lvho02, February 2021.*

House price index: Seasonally adjusted index of residential house prices. *OECD, Analytical House Price Indicators, variable hpi, February 2021.*

Household earnings: Total annual labor earnings at the household level. Data for 2017. *European Central Bank, Eurosystem HFCS, 3rd wave, variable di1100, May 2020.*

Household weights: Sample weights of surveyed households, used to construct the relative weight of the population by age. Data for 2017. *European Central Bank, Eurosystem HFCS, 3rd wave, variable hw0010, May 2020.*

Housing net worth: Household-level difference between reported value of the household main residence and the value of all liabilities used to finance it. Calculated for homeowners only. Data for 2017. *European Central Bank, Eurosystem HFCS, 3rd wave, variables hb1701, hb1702, hb1703, hb2100, hb0900, May 2020.*

Housing share of expenditures: Sum of the values for the items "actual rentals for housing" (*041*), "imputed rentals for housing" (*042*), "maintenance and repair of the dwelling" (*043*), "Water supply and miscellaneous services related to the dwelling" (*044*), and "goods and services for routine household maintenance", divided by private final consumption expenditures as calculated in Appendix E. *Statistics Portugal, Table A.1.2.1.11. May 2021.*

Housing stock: Housing stock by institutional sector measured at current prices. Data for 2017. *Statistics Portugal, Capital Stock Accounts, Tables B.2.5, B.3.5, B.4.1.10, B.5.11, August 2020.*

LTV of new loans for house purchase: Percentage of new loans for house purchase by interval of LTV at origination. Data from Banco de Portugal (2020). *Bank of Portugal, August 2020.*

Net worth: Household-level net worth calculated as the difference between the value of all assets owned and the value of all outstanding liabilities. Data for 2017. *European Central Bank, Eurosystem Household Finance and Consumption Survey (HFCS), 3rd wave, variable dn3001, May 2020.*

PTI of new loans for house purchase: Percentage of new loans for house purchase by interval of PTI at origination. Data from Banco de Portugal (2020). *Bank of Portugal, August 2020.*

Residential housing investment: Annual gross residential housing investment by the private sector measure at current prices. Data for 2017. *Statistics Portugal, Tables B.2.5, B.3.5, B.4.1.10, and B.5.11, May 2020.*

Social Security tax rates: Social Security tax rates for for-profit entities and their employees. *Portuguese Social Security, Contribution Rate Tables, August 2020.*

Survival probabilities: Survival probability by age for both sexes for the years 2016-2018. Data for 2017. *Statistics Portugal, Life Tables, August 2020.*

Transaction tax: The transaction tax is calculated as the 2015-2017 average of the ratio between municipal transaction tax revenues and the value of real estate transactions. Tax revenues are obtained from the Portuguese Tax Authority statistics, available in their website in Portuguese only. Value of real estate transactions is obtained from the September 2020 bulletin on acquisitions of real estate by non-residents.

Property tax: The property tax is calculated as the ratio between revenues from local property taxes from urban properties to the total value of urban properties (taxable and exempt) in 2017. *Portuguese Tax Authority, Estate Tax Statistics, May 2021.*

Unemployment rate: Seasonally adjusted unemployment rate for population aged between 15 and 74 years old (2011 series). *Statistics Portugal, Labour Force Survey, January 2020.*

B Household problems

In this section, we detail the dynamic programs of each household type. $\Xi(\mathbf{y}_j)$ denotes the distribution of the labor income endowment, y_j, conditional on the vector of individual characteristics, $\mathbf{y}_j$. There are two types of households: non-homeowners, homeowners. Each household type can be active or retired. The latter bequeath their net worth upon death, which is distributed among households in the manner described in section 6. To simplify the exposition, I only present the problems of households in active life, with the exception of the last subsection which show the household problem in period J.

B.1 Non-homeowners

A household that enters the period with no outstanding mortgage debt and no housing has value function $\mathbb{V}_j^N$. This household type can choose between continuing to rent or buying a house:

$$\mathbb{V}_j^N(b_j, \mathbf{y}_j) = \max\left\{V_j^r(b_j, \mathbf{y}_j), V_j^o(b_j, \mathbf{y}_j)\right\},$$

where V_j^r is the value of renting and V_j^o the value of acquiring a house.

B.1.1 Rent

A household who chooses to rent will select: (i) consumption, c_j; (ii) the quantity of the liquid bond, b_{j+1}, and (iii) the size of the rental, $\tilde{h}_{j+1}$. The problem is given by:

$$V_j^r(b_j, \mathbf{y}_j) = \max_{c_j, \tilde{h}_{j+1}, b_{j+1}} u_j(c_j, s_j) + \beta\mathbb{E}_\epsilon\left[\mathbb{V}_{j+1}^N(b_{j+1}, \mathbf{y}_{j+1})\right] \tag{A-1}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + \rho\tilde{h}_{j+1} \leq b_j + y_j - \mathcal{T}(y_j, \rho\tilde{h}_{j+1})$$

$$c_j \geq 0, b_{j+1} \geq 0,\ s_j = \tilde{h}_{j+1} \in \tilde{\mathcal{H}},\ y_j \sim \Xi(\mathbf{y}_j).$$

B.1.2 Buy

A household who opts to buy a house and become a homeowner chooses: (i) consumption, c_j; (ii) the quantity of the liquid bond, b_{j+1}; (iii) housing size, h_{j+1}, and (iv) mortgage size, m_{j+1}. The problem is given by:

$$V_j^o(b_j, \mathbf{y}_j) = \max_{c_j, h_{j+1}, b_{j+1}, m_{j+1}} u_j(c_j, s_{j+1}) + \beta \mathbb{E}_\epsilon \left[\mathbb{V}_{j+1}^H(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) \right] \tag{A-2}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + p_h h_{j+1} + \kappa_m \mathbb{1}_{m_{j+1}>0} \leq b_j + y_j - \mathcal{T}(y_j, \rho \tilde{h}_{j+1}) + q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1}$$

$$q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \leq \lambda^m p_h h_{j+1} \tag{A-3}$$

$$\pi_j^{\min}(m_{j+1}) \leq \lambda^\pi (y_j - \mathcal{T}) \tag{A-4}$$

$$c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \omega h_{j+1},\ h_{j+1} \in \mathcal{H},\ y_j \sim \Xi(\mathbf{y}_j),$$

where the indicator $\mathbb{1}_{m_{j+1}>0}$ takes the value 1 if the household takes out a mortgage and zero otherwise, and $\mathbb{V}_{j+1}^H$ is the value function of a household that enters age $j+1$ as a homeowner. Equations A-3 and A-4 are the LTV and the PTI limits, respectively.

B.2 Homeowner

A household that enters the period as a homeowner has value function $\mathbb{V}_j^H$. This household type chooses between (i) paying his mortgage (if any exists); (ii) refinancing its current mortgage; (iii) selling his house and either buying another or renting; or (iv) defaulting on the mortgage:

$$\mathbb{V}_j^H(\mathbf{x}_j, \mathbf{y}_j) = \max \begin{cases} \text{Pay}: & V_j^p(\mathbf{x}_j, \mathbf{y}_j) \\ \text{Refinance}: & V_j^f(\mathbf{x}_j, \mathbf{y}_j) \\ \text{Sell}: & \mathbb{V}_j^N(b_j^n, \mathbf{y}_j) \\ \text{Default}: & V_j^d(\mathbf{x}_j, \mathbf{y}_j) \end{cases}$$

Note that in the case of the option to sell the house the homeowner problem collapses to that of a nonhomeowner where the liquid bond is given by:

$$b_j^n = b_j + (1 - \delta_h - \tau_h - \kappa_h) p_h h_j - (1 + r_m) m_j, \tag{A-5}$$

i.e., the starting bond holding plus the net-of-costs proceeds from the sale of the house after the outstanding mortgage is paid back.

B.2.1 Pay mortgage

A household who opts to make a mortgage payment (or keep the current house size with no outstanding mortgage balance) chooses: (i) consumption, c_j; (ii) the quantity of the liquid bond, b_{j+1} and (iii) the value of the mortgage payment, π_j. The problem is:

$$V_j^p(\mathbf{x}_j, \mathbf{y}_j) = \max_{c_j, b_{j+1}, \pi_j} u_j(c_j, s_j) + \beta \mathbb{E}_\epsilon \left[\mathbb{V}_{j+1}^H(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) \right] \tag{A-6}$$

$$s.t.:$$

$$c_j(1 + \tau_c) + q_b b_{j+1} + (\delta_h + \tau_h) p_h h_j + \pi \leq b_j + y_j - \mathcal{T}(y_j, 0)$$

$$\pi_{j-1}^{\min}(m_j) \leq \pi_j \leq (1 + r_m) m_j \tag{A-7}$$

$$m_{j+1} = (1 + r_m) m_j - \pi_j$$

$$c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \omega h_{j+1},\ h_{j+1} = h_j,\ y_j \sim \Xi(\mathbf{y}_j).$$

where equation A-7 indicates that mortgage payments cannot be below the scheduled contract payments.

B.2.2 Refinance mortgage

A household who opts to refinance its mortgage chooses: (i) consumption, c_j; (ii) the value of the liquid bond, b_{j+1}, and (iii) the new mortgage size, m_{j+1}. The problem is:

$$
\begin{aligned}
& V_j^f(\mathbf{x}_j, \mathbf{y}_j) = \max_{c_j, b_{j+1}, m_{j+1}} u_j(c_j, s_j) + \beta \mathbb{E}_\epsilon \left[\mathbb{V}_{j+1}^H(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) \right] \\
& s.t.: \\
& c_j(1+\tau_c) + q_b b_{j+1} + (\delta_h + \tau_h) p_h h_j + (1+r_m) m_j + \kappa_m \\
& \leq b_j + y_j - \mathcal{T}(y_j, 0) + q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \\
& q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \leq \lambda^m p_h h_j \\
& \pi_j^{\min}(m_{j+1}) \leq \lambda^\pi (y_j - \mathcal{T}) \\
& c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \omega h_{j+1},\ h_{j+1} = h_j, m_{j+1} > m_j,\ y_j \sim \Xi(\mathbf{y_j}).
\end{aligned}
\tag{A-8}
$$

B.2.3 Default

A household who opts to default chooses: (i) consumption, c_j; (ii) the quantity of the liquid bond, b_{j+1}, and (iii) the rental size, $\tilde{h}_{j+1}$. The problem is:

$$
\begin{aligned}
& V_j^d(\mathbf{x}_j, \mathbf{y}_j) = \max_{c_j, \tilde{h}_{j+1}, b_{j+1}} u_j(c_j, s_j) + \beta \mathbb{E}_\epsilon \left[\mathbb{V}_{j+1}^N(b_{j+1}, \mathbf{y}_{j+1}) \right] \\
& s.t.: \\
& c_j(1+\tau_c) + q_b b_{j+1} + \rho \tilde{h}_{j+1} \leq b_j + y_j - \mathcal{T}(y_j, \rho \tilde{h}_{j+1}) + \Phi \\
& \Phi = \max\{(1 - \delta_h^d - \tau_k - \kappa_h) p_h h_j - (1+r_m) m_j, -\kappa_d(b_j + y_j - \mathcal{T})\} \\
& c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \tilde{h}_{j+1} \in \tilde{\mathcal{H}},\ y_j \sim \Xi(\mathbf{y}_j),
\end{aligned}
\tag{A-9}
$$

where Φ is the recourse function. If the outstanding mortgage balance exceeds the net value of the foreclosed house, the household will have to pay the remainder up to a fraction κ_d of cash-on-hand. In practice, the household will never default with positive equity, as explained in Proposition B.1.

Proposition B.1. *Let m_j^d be residual debt after default. If a homeowner chooses to default, it implies that $m_j^d > 0$.*

Proof. Let $m_j^d := \max\{m_j(1+r_m) - (1-\delta_h^d - \tau_k - \kappa_h)p_h h_j - \kappa_d(b_j - y_j + \mathcal{T}), 0\}$ be the residual debt after liquidation and recourse, and $e_j := (1-\delta_h^d - \tau_k - \kappa_h)p_h h_j - (1+r_m)m_j$ be the residual equity in case of default. If $m_j^d = 0$ when the homeowner defaults, one of the following conditions must be true:

1. $e_j \geq 0$;

2. $e_j < 0$ and $e_j + b_j - y_j + \mathcal{T} \geq 0$.

In the case of (1), the household is able to pay all of its debt using the collateral. However, because of the assumption that $\delta_h^d > \delta_h$, were he to sell the house instead of defaulting, the household would be able to both pay off its debt and extract positive net proceeds from the house sale. Therefore, he would have a strictly larger amount to consume and rent. Thus, this condition can never be true if default is chosen.

In the case of (2), the household must use other resources in order to fully repay its debt. The same argument as before is used: Because $\delta_h^d > \delta_h$, selling the house would allow the household to increase his available resources to fully repay the debt, consume, and rent, which implies that default is not optimal in this situation. Therefore, default will never occur as long as $m^d > 0$. □

A corollary of this proposition is that a necessary condition for default is:

$$e_j < 0 \quad \text{and} \quad e_j + \kappa_d(b_j - y_j + \mathcal{T}) \leq 0,$$

meaning that leverage must be large enough for the household to find it optimal to default. For low κ_d, for example, there is a larger probability that the household will be able to discharge a greater fraction of its debt, making default a more attractive option.

B.3 Last period of life

In period $j = J$ the household decides on the size of the bequest it wishes to leave, from which it draws utility. For example, for a household with outstanding debt and housing the problem is:

$$V_J^p(\mathbf{x}_J, \mathbf{y}_J) = \max_{c_J, b_{J+1}, \pi_J} u_J(c_J, s_J) + \beta \nu(\flat) \tag{A-10}$$

$$s.t.:$$

$$c_J(1+\tau_c) + q_b b_{J+1} + (1+r_m) m_J \leq b_J + y_J - \mathcal{T}(y_J, 0)$$

$$\flat = b_{J+1} + (1 - \delta_h - \tau_k - \kappa_h) p_h' h_J$$

$$c_J \geq 0,\ b_{J+1} \geq 0,\ s_J = \omega h_J,\ h_J \in \mathcal{H},\ y_J \sim \Xi(\mathbf{y}_J).$$

In this case, the household pays off the remainder of his mortgage, the house is sold in the beginning of the following period and its net proceeds are bequeathed together with bond quantity b_{J+1}.

C Stationary equilibrium definition

Let $\mathbf{x}_j^N := (b_j, \mathbf{y}_j) \in \mathbb{X}^N$, and $\mathbf{x}_j^H := (b_j, h_j, m_j, \mathbf{y}_j) \in \mathbb{X}^H$ be the state vectors for individual non-homeowners, and homeowners, respectively. Also, let μ_j^N, μ_j^H be the corresponding measure of the three household types at age j, where $\sum_{j=1}^J \mu_j^N + \mu_j^H = 1$.

A recursive stationary competitive equilibrium is a set of value functions $\left\{\mathbb{V}_j^N(\mathbf{x}_j^N), V_j^r(\mathbf{x}_j^N), V_j^o(\mathbf{x}_j^N), \mathbb{V}_j^H(\mathbf{x}_j^H), V_j^p(\mathbf{x}_j^H), V_j^f(\mathbf{x}_j^H), V_j^d(\mathbf{x}_j^H)\right\}, \forall j \leq J$; policy functions $\left\{g_j^o(\mathbf{x}_j^N), g_j^n(\mathbf{x}_j^H), g_j^f(\mathbf{x}_j^H), g_j^d(\mathbf{x}_j^H), c_j^N(\mathbf{x}_j^N), c_j^H(\mathbf{x}_j^H), b_{j+1}^N(\mathbf{x}_j^N), b_{j+1}^H(\mathbf{x}_j^H), \tilde{h}_{j+1}^N(\mathbf{x}_j^N), h_{j+1}^N(\mathbf{x}_j^N), m_{j+1}^N(\mathbf{x}_j^N), m_{j+1}^f(\mathbf{x}_j^H)\right\}, \forall j \leq J$; a rental price, ρ, a house price, p_h, a mortgage pricing function, $q_j(\mathbf{x}_{j+1}, \mathbf{y}_j)$, an end-of-period property housing stock, H, an end-of-period rental housing stock, $\tilde{H}$, housing investment, Y_h, net exports, NX, and government debt, B^G, such that:

1. Households optimize, where value functions $\left\{\mathbb{V}_j^N, V_j^r, V_j^o, \mathbb{V}_j^H, V_j^p, V_j^f, V_j^d\right\}$ and policy functions $\left\{g_j^o, g_j^n, g_j^f, g_j^d, c_j^N, c_j^H, b_{j+1}^N, b_{j+1}^H, \tilde{h}_j^N, h_{j+1}^N, m_{j+1}^N, m_{j+1}^f\right\}, \forall j \leq J$, solve the household problems;

2. The price of land/permits p_L is equal to the marginal product of land:

$$p_L = (A_h p_h^{1/\varphi})\varphi(1-\varphi)^{\frac{1-\varphi}{\varphi}};$$

3. Firms in the construction sector maximize profits, where demand for non-durable goods, Z, and new housing, Y_h, solve problem (15);

4. Firms in the durable goods sector maximize profits, which implies factor prices equal their marginal products:

$$r_b = \alpha A_c K^{\alpha-1} - \delta_k$$

$$w = (1-\alpha)A_c K^{\alpha};$$

5. Mortgage credit markets clear at the loan level with pricing function $q_j(\mathbf{x}_{j+1}, \mathbf{y}_j)$ given by equation (9);

6. The equilibrium price, ρ, given by (13), clears the rental market, and the end-of-period rental housing stock, $\tilde{H}$, is given by:

$$\tilde{H} = \sum_{j=1}^{J} \Bigg[\underbrace{\int_{\mathbb{X}^H} \tilde{h}^N_{j+1} \left(b^n_j(\mathbf{x}^H_j), \mathbf{y}_j\right) \left[1 - g^o_j \left(b^n_j(\mathbf{x}^H_j), \mathbf{y}_j\right)\right] g^n_j(\mathbf{x}^H_j)\, d\mu^H_j}_{\text{Homeowners who choose to sell the house and rent}}$$
$$+ \underbrace{\int_{\mathbb{X}^H} \tilde{h}^H_{j+1}(b^d_j(\mathbf{x}^H_j), \mathbf{y}_j) g^d_j(\mathbf{x}^H_j)\, d\mu^H_j}_{\text{Homewoners who default}} + \underbrace{\int_{\mathbb{X}^N} \tilde{h}^N_{j+1}(\mathbf{x}^N_j) \left[1 - g^o_j(\mathbf{x}^N_j)\right]\, d\mu^N_j}_{\text{Non-homeowners who decide to keep renting}} \Bigg],$$

where the LHS is the total supply of housing units and the RHS is the demand for rental units by homeowners who sell their house and rent, homeowners who default, and non-homeowners who continue to rent. $b^n_j(\mathbf{x}^H_j)$ is the starting bond balance of a homeowner who decides to sell, and b^d is the starting bond balance of a homeowner who decides to default;

7. The equilibrium price $p_h = p'_h$ clears the property market:

$$\underbrace{Y_h}_{\text{Construction}} + \underbrace{\sum_{j=1}^{J} \left[\int_{\mathbb{X}^H} h^H_j(\mathbf{x}^H_j) \left[g^n_j(\mathbf{x}^H_j) + (1 - (\delta^d_h - \delta_h)) g^d_j(\mathbf{x}^H_j)\right] d\mu^H_j \right]}_{\text{House sales and foreclosures}} +$$
$$+ \underbrace{\sum_{j=J_{\text{ret}}}^{J} \hat{S}_j \int_{\mathbb{X}^H} h^H_{j+1}(\mathbf{x}^H_j)\, d\mu^H_j}_{\text{Bequests}} - \underbrace{\delta_h(H + \tilde{H})}_{\text{Depreciation}}$$
$$= \sum_{j=1}^{J} \Bigg[\underbrace{\int_{\mathbb{X}^N} h^N_{j+1}(\mathbf{x}^N_j) g^o_j(\mathbf{x}^N_j)\, d\mu^N_j}_{\text{House purchases by non-homeowners}} + \underbrace{\int_{\mathbb{X}^H} h^N_{j+1}(b^n(\mathbf{x}^H_j), \mathbf{y}_j) g^o_j(b^n(\mathbf{x}^H_j), \mathbf{y}_j) g^n(\mathbf{x}^H_j)\, d\mu^H_j}_{\text{House purchases by homeowners}} \Bigg],$$

where the LHS is the inflow of houses from the construction sector net of depreciation , plus sales by homeowners and financial intermediaries, and bequests. $\tilde{S}_j$ is the unconditional probability of surviving period j. The RHS are house purchases by non-homeowners, and homeowners who choose to sell their house;

8. Y_c is the equilibrium quantity of non-durable goods and is given by:

$$Y_c = \sum_{j=1}^{J} \Bigg\{ \underbrace{\int_{\mathbb{X}^H} c_j^H(\mathbf{x}_j^H) d\mu_j^H + \int_{\mathbb{X}^N} c_j^N(\mathbf{x}_j^N) d\mu_j^N}_{\text{Non-durable consumption expenditures}} + \underbrace{\kappa_h p_h \int_{\mathbb{X}^H} h_j^H(\mathbf{x}_j^H) [g_j^N(\mathbf{x}_j^H) + g_j^d(\mathbf{x}_j^H)]\, d\mu_j^H}_{\text{Transaction fees}}$$

$$+ \underbrace{\kappa_m \left[\int_{\mathbb{X}^N} g_j^o(\mathbf{x}_j^N)\, d\mu_j^N + \int_{\mathbb{X}^H} g_j^o(b^n(\mathbf{x}_j^H), \mathbf{y}_j) + g_j^f(\mathbf{x}_j^H)\, d\mu_j^H \right]}_{\text{Origination expenditures}} + \underbrace{\iota r_b \int_{\mathbb{X}^H} m_j(\mathbf{x}_j^H) d\mu_j^H}_{\text{Intermediation costs}} \Bigg\}$$

$$+ \underbrace{\sum_{j=J_{\text{ret}}}^{J} \hat{S}_j \kappa_h \int_{\mathbb{X}^H} h_{j+1}^H(\mathbf{x}_j^H) d\mu_j^H}_{\text{Transaction fees from wills}} + \psi \tilde{H} + \delta_k K + Z + G + NX,$$

where the first line is the aggregate non-durable consumption expenditures; The second are transaction costs associated with sales and foreclosures; The third are the expenditures from mortgage loan origination and refinancing, and intermediation costs; The fourth are transaction fees from executing wills, management costs of the rental sector, maintenance costs for business capital, intermediate inputs to the construction sector, government final consumption expenditures, and net exports, which are set to clear the resource constraint:

$$Y_c - NX = F(K, N);$$

9. The government budget constraint holds and is given by:

$$\underbrace{H^G \delta_h + G + r_b B^G + \int_{\mathbb{Y}^{\text{ret}}} y^{\text{ret}} d\mu^{\text{ret}}}_{\text{Public housing, consumption, debt service, and SS}} = \underbrace{\sum_{j=1}^{J} \left[\int_{\mathbb{X}^H} \mathcal{T}(y_j, 0)\, d\mu_j^H + \int_{\mathbb{X}^N} \mathcal{T}(y_j, \rho \tilde{h})\, d\mu_j^N \right]}_{\text{Labor taxes}}$$

$$+ \underbrace{\frac{\tilde{\tau}_{ss} + \tau_{ss}}{1 + \tilde{\tau}_{ss}} \sum_{j=1}^{J_{\text{ret}}-1} \left[\int_{\mathbb{X}^H} y_j^w d\mu_j^H + \int_{\mathbb{X}^N} y_j^w d\mu_j^N \right]}_{\text{Social Security contributions}}$$

$$+\underbrace{\tau_c \sum_{j=1}^{J} \left[\int_{\mathbb{X}^H} c_j^H(\mathbf{x}_j^H) d\mu_j^H + \int_{\mathbb{X}^N} c_j^N(\mathbf{x}_j^N) d\mu_j^N \right]}_{\text{Consumption taxes}} + \underbrace{p_L \bar{L}}_{\text{Land/permits}}$$

$$+\underbrace{\tau_h p_h (H + \tilde{H} - H^G)}_{\text{Property taxes}} + \underbrace{(\tilde{H} - H^G)(\rho - \psi - \tilde{\delta}_h p_h - \tau_h p_h)\tau_r}_{\text{Rental income taxes}},$$

where B^G is government debt, $\mathbb{Y}^{\text{ret}}$ is the space of retirement incomes, and μ^{ret} denotes the distribution of retired households over $\mathbb{Y}^{\text{ret}}$. The LHS of the equation are government expenditures on non-durable goods, debt payments, and Social Security pension payments to retirees. The RHS are labour income taxes collected by the government, Social Security contributions, consumption taxes, revenues from new land/permits issuance, income from property taxes and rental income taxes. B^G is adjusted so that the government budget constraint balances.

10. The measures μ_j^H, μ_j^N, and are invariant over the state spaces $\mathbb{X}^H$, and $\mathbb{X}^N$.

D Solution algorithm

D.1 Solving household problems

Household problems are solved by backward induction, as in Kaplan et al. (2020). The state spaces, $\mathbb{X}^H$, $\mathbb{X}^N$, are discretized by using grids on the permanent component of productivity, $\mathcal{A}$ (5 points), the persistent component, $\mathcal{E}$ (5 points), house sizes, $\mathcal{H}$, mortgages, $\mathcal{M}$ (21 points), and bonds, $\mathcal{B}$ (35 points). The bond grid is non-linearly spaced, with greater point density closer to the borrowing constraint. When taking out a mortgage, the choice of mortgage size is restricted to points belonging to grid $\mathcal{M}$. For households deciding to keep their mortgage, payment choice is allowed to be continuous within the admissible set $\pi_j \in [\pi^{\min}_{j-1}, (1+r_m)m_j]$, and is chosen jointly with the quantity of bonds b_{j+1}. For values of b_{j+1} and m_{j+1} between grid points, the value function is linearly interpolated. When solving for the homeowner choosing to keep his mortgage, bi-dimensional interpolation is used. When simulating the model, linear approximations to the policy functions are applied. We simulate the lifetimes of 12,000 agents, for a total population of 360,000 from which model statistics are computed. The model was constructed on Julia and ran on machine with an AMD Ryzen Threadripper 39070X processor with 64 logical cores.

D.2 Equilibrium computation

To calculate the equilibrium, we apply the following procedure:

1. Make a guess for the unit house price, p_h (outer loop);

2. Make a guess for the mortgage pricing function q (inner loop);

3. Obtain the rental price, ρ, from the rental sector equation (13);

4. Given prices, solve household problems by backward induction, and obtain policy and value functions;

5. Given policy and value functions, simulate the model and obtain aggregate quantities $\{H, \tilde{H}, K, Z, I_k, Y_c, Y_h, Y, NX, S^P, B^P, B^G, M, \theta\}$. Y is GDP, S^P are domestic private savings, B^P are domestic private liquid savings, M is total mortgage debt.

   (a) Given the equilibrium condition for business capital, the interest rate, r_b, determines K from which we obtain the wage rate w. From the law of motion for capital, we obtain $I_k = \delta_k K$. Given p_h, we obtain Z and p_L from the first order conditions of the construction sector. From these variables, we obtain Y;[17]

   (b) Given policy functions, prices, and the obtained quantities, net exports are the residual between consumption good expenditures and production, $NX = Y_c - F(K, 1)$;

   (c) The total domestic capital stock is the sum of business capital, K, and housing, $p_h(H + \tilde{H})$. Domestic savings are the difference between domestic private savings and government debt. Domestic private savings are the sum of household liquid bonds and housing owned. Given GDP, public debt is such that the government budget constraint holds.

6. Using policy functions, solve mortgage pricing functions recursively. Check if guesses matches the solution for given tolerance level. If yes, go to step 1. If not, update the guess as a convex combination between the previous guess and the solution and go to step 2;[18]

7. Update house prices and bequests using an homotopy rule. Check for convergence for given tolerance level. If yes, end. If not, go to step 1.

[17] See section E for the model definition GDP.

[18] We use a weight of 0.9 for the previous guess of the mortgage pricing function.

E National Accounts

In this section, I describe the model national accounts, and their relationship to their data analogue, as described in the European System of National Accounts (ESA).

Model. In the model economy, GDP is defined as:

$$Y = F(K, N) + p_h Y_h - Z + (\rho - \psi)\tilde{H} + \rho H,$$

where $F(K, N)$ is the output of the non-durable consumption good sector, $p_h Y_h - Z$ is the output of the construction sector minus intermediate expenses, and $(\rho - \psi)\tilde{H}$ is the the output of the rental sector minus intermediate expenses. To make model GDP consistent with its data analogue, we add imputed rents, ρH, to total production. The income and product shares are defined as follows:

Income shares:

Labor income	Nw/Y
Capital income	$[(r_b + \delta_k)K + p_L \bar{L} + (\rho - \psi)\tilde{H} + \rho H]/Y$
Non-durable goods sector	$(r_b + \delta_k)K/Y$
Construction sector	$p_L \bar{L}/Y$
Rental sector	$(\rho - \psi)\tilde{H}/Y$
Imputed rents	$\rho H/Y$

Product shares:

Private consumption	$[\int_{\mathbb{X}} c \, d\mu + \kappa_h p_h \int_{\mathbb{X}} (g^n + g^d) \, d\mu + \kappa_m \int_{\mathbb{X}} (m' g^o + m' g^f) \, d\mu$ $+ \iota r_b \int_{\mathbb{X}} m \, d\mu + \rho(\tilde{H} + H)]/Y$
Government consumption	G/Y
Investment	$[I_k + p_h Y_h]/Y$
Business capital	I_k/Y
Residential	$p_h Y_h/Y$

For simplicity, $\mathbb{X}$ is shorthand for the state space of homeowners and nonhomeowners, and μ the distribution of households over that space. We have also suppressed the dependence of $\{g^n, g^d, g^o, g^f\}$ on state variables. m' are end-of-period mortgage balances.

Data. In order to align the data with the model national accounts, we follow the procedure laid out in Bhandari and McGrattan (2020) and adapt it to the current setting.[19] The data used are publicly available on the website of Statistics Portugal, which is in charge of producing national accounts in Portugal. Table 9 summarizes the procedure for income, product, and their components in 2017.[20]

Starting from GDP at market prices, we make the following changes to obtain adjusted income:[21] (i) add consumer durable depreciation; (ii) add imputed capital services from consumer durables and government capital; and (iii) subtract value-added type taxes (VAT). Since consumer durables are classified as investment, both depreciation and imputed capital services must be included in adjusted income. The subtraction of VAT makes the data analogue of private consumption consistent with the model definition, which excludes consumption taxes, and must therefore be removed from both income and product.[22]

To estimate consumer durable depreciation, we assume that the stock is at its steady state value, which implies that household spending in consumer durables is equal to depreciation. Assuming a depreciation rate of 20%, as in Ahmad and Koh (2011), this implies that the stock of consumer durables in 2017 equals 58,030 million euro. The stock of government capital in 2017 is 414,186 million euro (national accounts table B.4.1.10). Assuming capital services amount to 4% of respective stocks at current prices, imputed capital services are 7,996 million euro. VAT in 2017 was 16,809 million euro.

Labor income is obtained by adding employee compensation and a fraction of gross mixed income of households, as in Boerma (2019). The latter item includes both capital and labour remuneration of owners of non-incorporated enterprises. For simplicity, I assume that the fraction of mixed income attributed to labour is half, which is the same assumption made by the Panel Study of Income Dynamics (PSID) in the U.S. (Heathcote et al., 2010).

[19] Unlike Bhandari and McGrattan (2020), I use ESA nomenclature in the description of the items. For example, “proprietor income” in the National Income and Product Accounts (NIPA) is “mixed income” in the ESA. For a description of how the System of National Accounts (SNA), on which the ESA is based, see Lequiller and Blades (2014).

[20] Information on data sources and methods applied in this section is self-contained and not repeated in section A of the present Appendix.

[21] GDP is the same as gross domestic income, given that the statistical recorded statistical discrepancy is virtually zero in every period.

[22] Unlike Bhandari and McGrattan (2020), I make no adjustment for misreported S-corporation income, nor for mismeasurement of intellectual property products, due to lack of data for Portugal.

Capital income is obtained by adding the gross operating surplus with the fraction of gross mixed income attributed to capital, depreciation of consumer durables, and imputed capital services. Finally, I add indirect business taxes, i.e., taxes on production and imports less subsidies. From this last item, we exclude VAT, to maintain consistency.

On the product side, we make similar adjustments. Starting with private final consumption expenditures (122,556 million euro in 2017), we subtract spending on durable goods, which were reclassified as an investment. VAT is imputed proportionally to the weight of durable good expenditure on private consumption expenditures and then subtracted. We add consumer durable depreciation, which, because of the assumption that the stock of consumer durables is at its steady state value, is equal to spending on consumer durables, whereby the two items cancel out. We then add imputed capital services from both consumer durables and government capital. Government consumption is simply the value of general government final consumption expenditure recorded in the national accounts. Finally, investment is the amount of Gross Capital Formation (GFC) adjusted to include spending on consumer durables, and the exclusion of the respective VAT amount. The accounts are closed by adding net exports.

Table 9: Adjusted income and product accounts in 2017 (million euro)

	Code	Value
Total adjusted income/product		198,740
GDP/GDI	A.1.3.4.1	195,947
+ Consumer durable depreciation	B.5.6	11,606
+ Imputed capital services		7,996
- VAT	B.4.3.6	16,809
Labour income		102,609
Employee compensation	A.1.3.4.1	86,097
+ Fraction of gross mixed income	A.1.3.2.1	16,512
Capital income		96,131
Gross operating surplus	A.1.3.4.1	49,634
+ Fraction of gross mixed income	A.1.3.2.1	16,512
+ Consumer durable depreciation	B.5.6	11,606
+ Imputed capital services		7,996
+ Indirect business taxes	A.1.3.4.1	27,191
- VAT	B.4.3.6	16,809
Consumption		149,008
Private final consumption expenditure	A.1.2.5.1	126,541
- Consumer durable expenditures	B.5.6	11,606
- VAT (proportional imputation)		15,218
+ Consumer durable depreciation	B.5.6	11,606
+ Imputed capital services		7,996
General government final consumption expenditure	A.1.2.2.1	33,673
Investment		43,820
GFC	A.1.2.5.1	33,755
+ Consumer durable expenditures	B.5.6	11,606
- VAT (proportional imputation)	B.4.3.6	1,542
Net exports	A.1.2.5.1	1,978

Note: The "Code" column indicates the respective national accounts table code in Statistics Portugal, when applicable.

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