Mortgage Design, Repayment Schedules, and Household Borrowing*

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Abstract

We study how debt repayment schedules affect household borrowing. We exploit a Swedish policy reform that eliminated interest-only mortgages for loan-to-value ratios above 50%. We document substantial bunching at the threshold, leading to a 5% reduction in borrowing. Wealthy, unconstrained borrowers drive the results, challenging liquidity constraints as the main explanation. A standard life-cycle model and a model with fixed one-time cost of amortizing fail to match key empirical results. We instead find support for an ongoing flow disutility to amortization. Our results suggest that interest-only mortgages products may increase household borrowing and the lifetime cost of debt.

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1 Introduction

One of the most important features of the mortgage contract is the repayment schedule. Most mortgages force the borrower to gradually repay the mortgage and build wealth in the form of home equity. Mandatory saving through mortgage repayment represents a large share of household savings, similar in aggregate magnitude to pension contributions (Bernstein & Koudijs, 2023). While historically households have had very little choice over the repayment schedule, financial innovation during recent decades has generated a wide variety of alternative mortgage products that allow households to delay mortgage repayment. Perhaps the most famous example is the *interest-only mortgage*, which surged in popularity during the mid-2000s, jumping to roughly 25% of originations in the United States and contributing substantially to the run-up of mortgage debt prior to the financial crisis (Amromin *et al.* , 2018). Financial regulators have taken drastically different approaches, with some prohibiting and others encouraging such mortgages. For instance, while the US has strongly discouraged interest-only mortgages, the UK has recently encouraged banks to offer mortgages with longer maturities and lower payments. Many countries continue to grapple with the question of whether to regulate this important feature of the mortgage contract.

Despite the important role of the repayment schedule, we have little evidence of how this key feature of the mortgage contract affects household borrowing. This paper seeks to fill this gap in the literature. To do so, we exploit a policy reform in Sweden that eliminated interest-only mortgages for borrowers with loan-to-value ratios above 50 percent. In response to the reform, households make larger downpayments or extract less equity to avoid amortization. The reduction in borrowing is similar for both constrained and unconstrained borrowers and is driven by relatively wealthy households, thus ruling out credit constraints as the primary driver of our results. Motivated by the empirical evidence, we develop a theoretical framework to clarify the mechanisms that may lead wealthy households to avoid amortization payments. We argue that much of the response arises from households suffering an ongoing flow disutility to amortization payments. Identification is driven by the fact that most of the bunching is generated without a missing mass, indicating a kink rather than a notch in household preferences. Our results are consistent with theories of "NPV neglect" in household decision-making, which we discuss later, and imply that new mortgage products may substantially increase household debt and the lifetime costs of debt.

The policy reform that we exploit is the amortization requirement. Before 2016, interest-only mortgages constituted the majority of mortgage contracts in Sweden. The amortization requirement is designed to reduce debt levels over time and features two loan-to-value (LTV) thresholds where minimum mandatory mortgage payments exhibit a discontinuous jump. As a result of this policy, mortgage borrowers with LTV ratios above 50 percent cannot get interest-only mortgages but must repay at least 1 percent of their original loan per year. Borrowing more than 70 percent of the home value requires a repayment of at least 2 percent annually. Borrowers can reduce amortization payments once they get below the statutory threshold. We estimate the response to the requirement using a bunching analysis, using pre-requirement years to form the counterfactual LTV distribution. We document significant bunching at both LTV thresholds. New borrowers reduce their LTV ratios by 5 percent in response to a one percentage point higher average amortization rate. The reduction in borrowing is driven by wealthy and unconstrained borrowers, who make up 86 percent of households who decide to bunch at the lower threshold. These borrowers are also far from the regulatory LTV constraint of 85%. The primary credit constraint that binds borrowers at the lower threshold is a regulatory payment-to-income (PTI) constraint that includes amortization payments. Borrowers facing a binding PTI constraint account for only 14 percent of borrowers at the lower threshold. Unconstrained borrowers could borrow at least an additional 2 million kronor (approximately $250,000, more than the average loan size in our data) before facing binding payment constraints. Credit constraints are thus unlikely to explain our results.

We assess the validity of our empirical approach and the robustness of our results along several key dimensions. First, we confirm the validity of our empirical strategy using various placebo tests, which show that previous years indeed provide a valid counterfactual LTV distribution. Estimating the counterfactual distribution using a polynomial approach (Kleven, 2016) yields larger estimates. Second, we find similar results for households that purchase a property compared to those who refinance, thus alleviating concerns about housing choices. For refinancers, the bank sets the home value exogenously based on their (model-based) assessment of the collateral value. These results support our interpretation that the observed decline in LTV ratios comes from lower loan demand (the numerator in the LTV) and not from changes in housing choices (the denominator). Third, we investigate various supply-side factors (mortgage approval, collateral assessments, and refinancing costs) but find none can explain our results. Most importantly, the interest rate is flat over the LTV threshold in each year.

Motivated by the empirical evidence, we develop a theoretical framework to clarify the mechanisms that lead wealthy households to prefer to avoid amortization payments. We begin with a standard life-cycle model of consumption, housing, and mortgage decisions in the spirit of Campbell & Cocco (2003) and Cocco (2005), where credit-constrained households borrow to purchase housing while faced with idiosyncratic and uninsurable income risk. Households are allowed to borrow using long-term mortgage contracts with mandatory minimum payments. We allow for two policy regimes: the first with interest-only mortgages and the second with mandatory amortization payments for households above the 50% LTV threshold. These two policy regimes broadly represent the institutional framework in Sweden before and after the 2016 reform. We show that this model cannot replicate the observed bunching behavior of wealthy households at the 50% LTV threshold. We verify this result by looking at the expected discounted utility of households purchasing homes with different LTV ratios, which we find is smooth around the 50% threshold. Since interest-only mortgages provide greater flexibility to smooth consumption (Cocco, 2013), all households would prefer to live in a world with interest-only mortgages. However, there is no discontinuous change in their utility at the threshold that would cause them to bunch. The lack of bunching for wealthy households is robust to a wide variety of alternative assumptions related to preference parameters, asset returns, and refinancing costs.

If the standard model does not generate bunching for wealthy, unconstrained households, what potential extensions can help the model replicate our empirical results? Kleven (2016) explains that four mechanisms may generate bunching: notches or kinks in the budget constraint, or notches or kinks in household preferences. As mentioned previously, we find a very limited role for mechanisms operating through the budget constraint, as only 14% of bunching households face binding PTI constraints, and we find no evidence of other supply-side factors generating notches or kinks in the budget constraint. We therefore extend the model with two broad classes of mechanisms that may generate either a notch or kink in household preferences. We adopt a reduced-form approach to behavioral modeling, remaining agnostic about the specific behavioral biases that may generate the wedge in household preferences, following Mullainathan *et al.* (2012).

The first mechanism is that households may experience a one-off disutility that applies when borrowers turn off amortization payments. This mechanism generates a notch in household preferences, as taking out a mortgage just above the 50% LTV threshold is discontinuously worse than being just below the threshold. This mechanism may occur if households experience a cost to mortgage renegotiation when calling the bank to turn off amortization payments when eligible. We model this as a utility cost, as monetary refinancing costs are low in Sweden. We discuss refinancing costs extensively when discussing the robustness of the empirical results. That said, various other behavioral factors could generate a similar one-off cost, and our approach allows us to remain agnostic about the particular reason. For instance, if households are uncertain about their ability to turn off amortization, this would create a one-off cost. Similarly, if the statutory threshold serves as a target that agents strive to achieve, then reference dependence could also generate a notch in household preferences (Kleven, 2016).

The second option is that households may experience ongoing flow disutility from amortization payments. This mechanism generates a kink in household preferences and may occur for various reasons. For instance, households may perform "monthly payment targeting," where they focus on targeting a specific monthly mortgage payment rather than minimizing the lifetime cost of the loan, in the spirit of Argyle *et al.* (2020). Alternatively, households may view amortization payments as a cost rather than a form of saving, in the spirit of Camanho & Fernandes (2018). In Swedish survey evidence, 38 percent of respondents state that amortization payments are a cost, 44 percent state that amortization payments are a form of savings, and 18 percent does not know (SBAB, 2018). In either case, such preferences generate "NPV neglect," where households do not fully consider the net present value of future mortgage payments when choosing between mortgage contracts with alternative repayment schedules, as proposed by Shu (2013).

The distinction between notches and kinks allows us to disentangle the relative contribution of these two very different mechanisms.[1] More specifically, notches generate bunching due to a dominated region with missing mass directly above the threshold. In contrast, kinks generate bunching by altering the incentives for all households above the threshold, thus generating excess mass without missing mass. In the data, we find that less than 15 percent of bunching is explained by missing mass directly above the threshold. The lack of missing mass is difficult to rationalize with optimizing frictions since borrowers can choose the LTV value directly and

[1] The use of bunching to identify behavioral preferences has received attention in Kleven (2016) and DellaVigna (2018). See Lacetera *et al.* (2012); Allen *et al.* (2017); Strulov-Shlain (2021); Andersen *et al.* (2022). Most of these studies focus on reference dependence or loss aversion rather than the theories in the present paper.

since the consequences of choosing a higher LTV are highly salient. We therefore conclude that while both mechanisms play a role, most of the response is driven by households suffering an ongoing flow disutility to amortization, consistent with the theory of "NPV neglect."

The above results have important implications for understanding the link between financial innovation and aggregate household borrowing. In a world with "NPV neglect," introducing new mortgage products with longer maturities or interest-only payments can have large aggregate effects on household borrowing. Crucially, any large aggregate response depends on the kink rather than notch in household preferences. Had the observed bunching behavior been driven by a notch, there would have been only a local effect on household borrowing and thus only a small increase in aggregate debt after introducing IO mortgages. Empirically, we see a decline in the growth rate of mortgage debt in Sweden following the amortization requirement. This decline is consistent with the flow disutility channel, although it is difficult to rule out other factors.

Taking stock, we believe that our findings have important implications for macroprudential policymakers concerned about aggregate household debt and consumer protection agencies concerned about potential exploitative contracting by financial institutions.[2] We see three main contributions of this paper. First, we provide novel evidence that amortization payments affect household borrowing for both constrained and unconstrained borrowers. To our knowledge, we are the first to document this behavior in mortgage markets. In related studies, Argyle *et al.* (2020) find that consumers manage total payment size instead of interest payments when making car-loan decisions, even in subsamples of unconstrained borrowers. Shu (2013) documents "NPV-neglect", the tendency of borrowers to target total payment size instead of the interest rate. Similarly, Camanho & Fernandes (2018) find experimental evidence that homebuyers compare the monthly rental payment and the monthly mortgage installment, including amortization payments, implicitly using the total mortgage payment instead of the interest cost to decide on whether to buy a house. Our results thus suggest a role for consumer protection and financial education to avoid exploitative contracting and suggest that we need to examine all features of the mortgage contract, including amortization payments, when thinking household borrowing decisions.

[2] Although we do not model bank incentives, it would be easy to extend our model to include the optimization problem faced by banks, who might have an incentive to increase lending by offering longer loan maturities. Note that in a Swedish context with full recourse mortgages, the increases in credit risk inherent in interest-only mortgages are likely limited, especially for the low LTV values in our baseline analysis.

Second, we contribute to the growing literature on mortgage design, which has recently focused on the mortgage repayment schedule. Bernstein & Koudijs (2023) show that amortization payments are crucial for building wealth, Campbell *et al.* (2020) study how lower amortization payments in a recession can stabilize consumption, Amromin *et al.* (2018) show that interest-only mortgage were used by prime borrowers in the US housing boom, and Garmaise (2013) show that increased flexibility in mortgage borrowing led to higher borrowing.[3] We also note that amortization payments represent a *de-facto* constraint on savings and borrowing for payment-constrained borrowers. In our setting, this turns out to not be a large contribution factor, but it may matter in other settings. Amortization payments have recently been included in several theoretical models that incorporate realistic features of the mortgage contract (Greenwald, 2017; Kaplan *et al.* , 2020; Gorea & Midrigan, 2017), but the interaction with credit constraints has received less attention.

Finally, our results are relevant for understanding the role played by mortgage innovation in the financial crisis. Lower amortization payments in the first years after origination were a common feature of interest-only mortgages, option ARMs, and balloon mortgages in the run-up to the Great Recession in the United States (Amromin *et al.* , 2018; Barlevy & Fisher, 2020; Justiniano *et al.* , 2021). Internationally, Scanlon *et al.* (2008) report that Australia, Denmark, Finland, Greece, Korea, and Portugal introduced interest-only mortgages between 1995 and 2005. Our results suggest that the increased availability and subsequent disappearance of non-traditional mortgages with lower amortization payments can make up at least a part of the unexplained movements in household debt in the United States. Looking forward, policymakers looking into adjusting amortization rates should be aware that such a reform could have large consequences for credit growth as borrowers adjust their leverage. Our results, therefore, also contribute to the growing literature on the effect of macroprudential policies (e.g. Cerutti *et al.* , 2017; Laufer & Tzur-Ilan, 2019; Peydró *et al.* , 2020; Guren *et al.* , 2021).

The paper is organized as follows. Section 2 provides background on the Swedish mortgage market and the amortization requirement. Section 3 presents the data and discusses the empirical strategy. Section 4 provides the main empirical results. Section 5 develops a theoretical framework to understand household borrowing decisions when faced with mandatory amortization. Section 6 concludes.

[3]For see also seminal contributions from Cocco (2013) and Piskorski & Tchistyi (2010). Recent papers on the topic also include Vihriälä (2023) on debt-repayment flexibility and liquidity constraints.

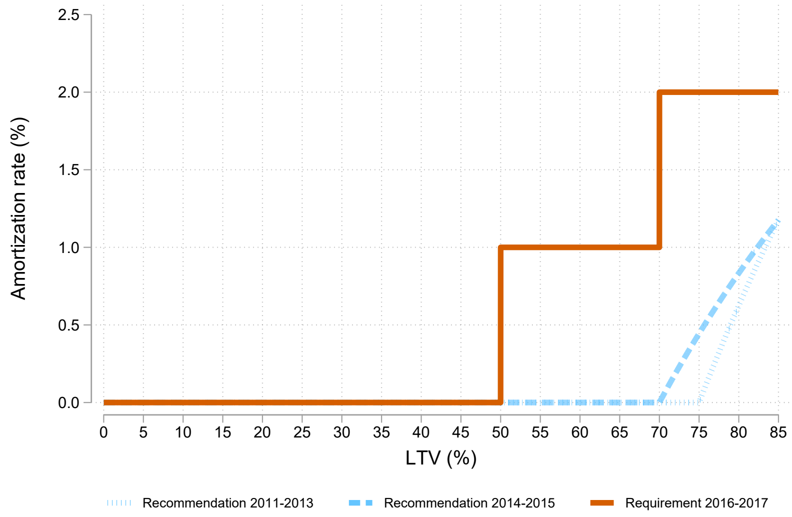


Figure 1. Required Amortization Rates for new mortgages

Notes: The figure plots required or recommended amortization rates by LTV ratios for different periods. The blue lines plot the non-binding recommendations from the Swedish Bankers' Association.

2 The Amortization Requirement

The Swedish housing and credit markets experienced rapid growth in the early 2010s. House prices increased by 31 percent between 2011 and 2015, and credit growth increased from 5 percent in 2012 to over 8 percent in 2015. Concerned with financial and macroeconomic stability, the Swedish Financial Supervisory Authority (*Finansinspektionen*) announced that they would propose new regulation in November 2014, intending to reduce debt levels over time – the amortization requirement. The purpose was to limit macroeconomic risks posed by high household debt levels. The FSA considered households with higher LTV ratios a higher risk; consequently, regulation targeted this group. The requirement came on top of the current recommendation by the Swedish Bankers Association (SBA), which recommended that borrowers amortize if their LTV values exceeded 70 percent. The amortization requirement was finally proposed in December 2015, and the law went into effect in June 2016. The FSA introduced an additional amortization requirement in March 2018, which mandates that any mortgage where the debt-to-income ratio is above 4.5 is to be amortized by an additional percentage point.

The Swedish amortization requirement mandates that all new mortgages issued after June 1st, 2016, with LTV ratios above 50 percent must be amortized. New mortgages with LTV ratios below 50 percent are exempt. Borrowers switching banks with no change in contract terms are also exempt. The requirement, along with the previous recommendations from the SBA, is summarized in Figure 1. Before 2016, the SBA recommended that borrowers amortize loans with an LTV ratio above 75 percent (2011-2013, blue dotted line) and 70 percent (2014-2015, blue dashed line), respectively. Compared to the requirement introduced in 2016, the recommended rates were lower and implied an increase in the *marginal* amortization rate. The implemented amortization requirement instead mandates that new borrowers must amortize at least 1 percent per year on any mortgage where the initial LTV ratio exceeds 50 percent and at least 2 percent per year on any mortgage where the LTV ratio exceeds 70 percent. Since continuous re-valuation of property values could have pro-cyclical effects, the law states that the valuation can only be made every five years. Moreover, any re-valuation must be based on changes to the property value due to renovation or rebuilding of the property, not due to house price changes. A borrower can be granted an exception from amortizing after the origination of the loan, due to extenuating circumstances, such as unemployment, illness, or a death in the family.[4]

Once a borrower has amortized down to a threshold, the borrower is legally allowed to reduce the amortization rate. We contacted all banks in our sample to ask for clarification on how reducing amortization payments would work for their customers. All banks state that the borrowers need to contact the bank to ask for a reduction in amortization payments. No bank except one offers a contract where the amortization rate is reduced automatically. While the mortgage contract specifies the amortization rate or repayment plan, no new mortgage contract is required. Instead, a phone call or a request made on the bank's online portal is sufficient to reduce the amortization rate once the customer reaches the threshold. There is no fee for reducing the amortization rate, except for one bank that charges 1500 SEK (approximately USD 150). Finally, there is no new credit check, and banks rarely deny a request for a reduced amortization rate once the borrower hits the threshold. Several banks state that a customer is never denied a lower amortization rate. For banks stating that denials happens, the denial was related to being delinquent or having missed mortgage payments.

The requirement had a large impact on amortization rates for new borrowers. From the data, which we discuss in detail in Section 3, Figure 2 plots the share of interest-only mortgages among new mortgages against LTV values for different years.[5] In the pre-requirement years between

[4]Due to the spread of the Coronavirus in 2020, the FSA allowed exceptions to the requirement for all borrowers until June 2021. See https://www.fi.se/en/published/press-releases/2020/banks-may-grant-all-mortgagors-amortisation-exemption/. For an analysis of the exemption, see Andersson & Aranki (2021).

[5]Figure A2 plots the average rate of amortization rate against LTV values

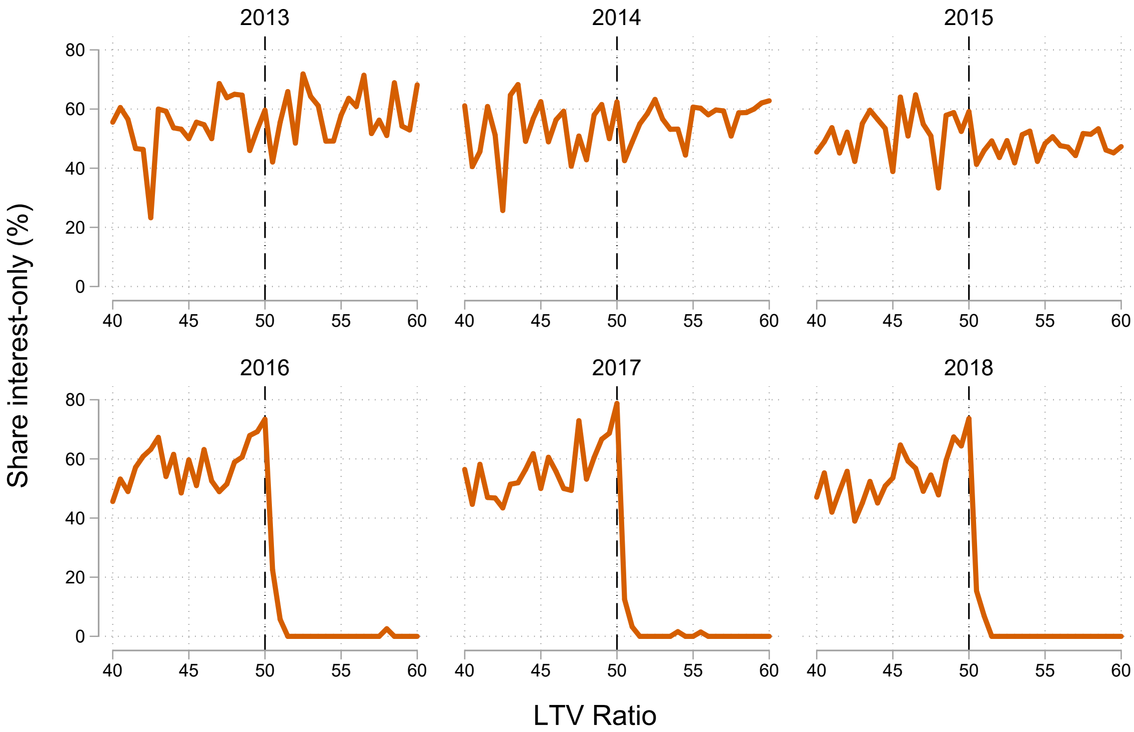


Figure 2. Share interest-only mortgages at the lower threshold

Notes: The orange line plots the share of interest-only loans by LTV for the lower (panel a) and upper threshold (panel b). Panel b) also plots the share of borrowers who amortize up to 1 percent in blue. The blue line consists of borrowers with an interest-only mortgage and with amortization rates below 1 percent.

2013 and 2015, around 60 percent of mortgages around the lower threshold were interest-only. In the post-requirement years between 2016 and 2018, the interest-only share is still around 60 percent to the left of the threshold. To the right of the threshold, the interest-only share is zero, as required by the policy. We also see a spike in interest-only mortgages precisely at the threshold, consistent with borrowers deliberately moving to the threshold to qualify for interest-only mortgages.

Several studies examine the effect of the Swedish amortization requirement. Andersson & Aranki (2017) use a difference-in-difference strategy to show that the amortization requirement reduced household borrowing. Andersson & Aranki (2019) analyze the additional amortization requirement introduced in 2018 that mandated that mortgages with a debt-to-income ratio above 4.5 had to be amortized by an additional percentage point. The authors show that households are borrowing, on average, 8.5 percent less than they otherwise would have done and that they are also buying less expensive homes. Wilhelmsson (2022) finds that the amortization requirement led to a 7 percent reduction in house prices.

2.1 Swedish mortgages

The Swedish mortgage market system works as follows (see, e.g. Riksbank, 2014). Banks provide mortgage credit to borrowers directly, subject to a credit assessment. Mortgage debt is full recourse, with unlimited liability of the borrowers and lifetime wage garnishing to compensate lenders in case of default. This feature is important as it limits the benefits provided by interest-only mortgages when borrowers wish to speculate on rising house prices (Barlevy & Fisher, 2020). All Swedish mortgages are subject to a maximum loan-to-value ratio of 85 percent as of 2010, and 30 percent of interest payments are deductible against capital gains and labor income. The banks set mortgage rates. Several Swedish banks use (or have used) a system where the portion of the mortgage with an LTV ratio above 75 percent has a higher interest rate (a so-called "top loan").[6]

Importantly, Swedish mortgages are *not* annuity contracts. Instead, total mortgage payments consist of the sum of interest payments and amortization payments. Total interest payments are the interest rate on the mortgage times the outstanding mortgage debt. Similarly, total amortization payments are the amortization rate times the mortgage debt *at origination* (i.e., the loan is repaid linearly over time). The increase in mortgage payments at the threshold is then fully due to higher amortization payments.

Swedish banks are required to assess the borrower's financial status. Banks assess financial status through a *discretionary income limit*, which requires the household to have enough disposable income to afford basic consumption and housing (including amortization payments). This limit, functionally equivalent to a payment-to-income constraint (Grodecka, 2020), is calculated using a stressed interest rate to ensure that borrowers' finances are resilient to higher interest rates. When applying for a mortgage, Swedish borrowers first seek a "borrowing pledge" from their preferred bank. On the pledge, the bank states the maximum amount they are willing to lend to the borrower, given, for example, household income and household size. Importantly, banks give this pledge *before* the borrower makes a housing purchase, which makes manipulation of the LTV ratio from the bank unlikely.

[6] Top loans refer to the slice of the mortgage loan not eligible for funding with covered bonds. Covered bond regulation in Sweden puts a maximum LTV ratio of 75 percent for residential real estate.

3 Data and Empirical Strategy

3.1 Data

We use data from the Mortgage Survey (Bolåneundersökningen) from 2011 until 2018. The FSA collects this data directly from the eight largest Swedish banks as part of its micro- and macroprudential mandate. The dataset contains information on all new mortgages issued by these banks during certain days between August and October. The FSA varies the exact dates and announces the dates afterward to surprise banks and prevent them from applying different credit standards during these survey dates.[7] The survey includes household-level data on (gross and disposable) incomes, total debt divided into secured and unsecured loans, and certain household characteristics, as well as loan-level data on loan size, interest rates, monthly amortization payments, and value of the collateral. The data also includes the bank's calculation of discretionary income, evaluated at a stressed interest rate. Collateral values are usually based on banks' internal valuation models using previous transaction prices and local hedonic price indices. The transaction price is typically used for new home buyers. We use the total mortgage debt divided by collateral value to calculate LTV ratios. We are unable to link our mortgage data to other register data as households are reported anonymously. Table B1 provides summary statistics for the full sample and for groups based on financial constraints.

3.2 Empirical strategy

We now describe our approach to estimating the counter-factual distribution and the amount of bunching induced by the amortization requirement.

Our empirical strategy hinges on estimating the counter-factual LTV distribution that would have occurred without the amortization requirement. We exploit the availability of repeated cross-sections to estimate the counter-factual distribution. In other words, we compute a *difference-in-bunching* estimate, where the distribution observed in the years before the requirement will serve as the counter-factual distribution in the post-requirement years. Our identifying assumption is that for each bin, the *fraction* of loans in the post-reform period would have been equal to the fraction of loans in the pre-reform period in the absence of the policy: no other change or policy caused the distribution of LTV ratios to shift between the

[7] The number of days and exact dates vary per year. Typically, banks report all issued mortgage loans for five days in late August and another five days in early October. To the extent the chosen days are representative of the rest of the year, the sample is representative of the flow of new mortgage loans.

pre-and post-reform periods. We note that this is a different assumption than in the empirical bunching literature, where it is more common to assume that the counter-factual distribution is smooth in the absence of the policy change (see, e.g. Kleven & Waseem, 2013). Our approach can account for any spikes in the distribution at the thresholds related to, e.g., round number bunching or supply-side factors that would generate bunching. Our identifying assumption is that such spikes are constant across time. We conduct several robustness checks and rule out several potential mechanisms to ensure that this assumption is plausible in Section 4.4. For completeness, we provide results using the standard polynomial approach and show that our results are conservative. Since the spike at 50 is larger than the spikes at other potential round numbers in pre-requirement years, it is more conservative to use the difference-in-bunching approach. Appendix C.3 provides details on the flexible polynomial approach.

We group borrowers into LTV bins with a width of half a percentage point. The goal is to estimate the counter-factual fraction of borrowers in each LTV bin j in the post-requirement period had the amortization requirement not been introduced, denoted $\hat{n}_j$.][8] We measure the amount of bunching $\widehat{B}$ as the difference between the observed and counter-factual bin fractions in the region at and to the left of the threshold located at R:

$$\widehat{B} = \sum_{j=L}^{R} (n_j - \hat{n}_j) \tag{1}$$

The amount of bunching is equal to the fraction of additional borrowers who place themselves at the threshold, beyond what the counter-factual distribution based on previous years would predict. We also report the excess mass at the threshold relative to the counter-factual distribution:

$$\widehat{b} = \sum_{j=L}^{R} (n_j - \hat{n}_j) / \sum_{j=L}^{R} \hat{n}_j \tag{2}$$

Similarly, but to the right of the threshold, the amount of missing mass is equal to:

$$\widehat{M} = \sum_{j>R}^{U} (n_j - \hat{n}_j) \tag{3}$$

Missing mass is equal to the difference between the observed and counter-factual distribution in

[8]We calculate the fraction of borrowers in each LTV bin instead of using the count of borrowers since we have different sample sizes for each year. Since the sample size reflects the number of days the mortgage survey collects data runs, the count is uninformative. And as we are using the previous years to form the counter-factual distribution, using the count instead may result in level differences solely due to differences in sample size. We have verified that using the fraction instead of the count does not affect our empirical estimates.

the region to the right of the threshold. Note that borrowers making up the missing mass could either shift towards the threshold (intensive margin) or exit the market completely (extensive margin). If all borrowers in the region defining the missing mass bunch at the threshold, the intensive margin effect equals the amount of bunching. If some borrowers drop out of the market because of the requirement, this is equivalent to stating that not all borrowers shift toward the threshold.

We use the bunching estimate $\widehat{B}$ to calculate the behavioral response to the requirement, ΔLTV (DeFusco & Paciorek, 2017). The equation states that the response to the requirement by the marginal borrower, ΔLTV, is equal to the amount of bunching $\widehat{B}$ divided by the counterfactual density around the notch:

$$\widehat{\Delta LTV} = \frac{\widehat{B}}{\widehat{g_{linear}}(\overline{LTV})} \tag{4}$$

We calculate bootstrapped standard errors for all parameters by drawing 500 random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate the parameters at each iteration.

We use the estimated change in LTV from the reform to estimate the amortization elasticity of mortgage demand. The semi-elasticity of borrowing with respect to the amortization rate is equal to

$$e^{\alpha} = \frac{\Delta LTV/\overline{LTV}}{\alpha^{*}(\overline{LTV} + \Delta LTV) - \alpha_0} \tag{5}$$

where we relate the percent change in the LTV ratio (calculated as the behavioral response, ΔLTV, divided by the LTV at the threshold, $\overline{LTV}$), to the change in the marginal amortization rate $\alpha^{*} - \alpha_0$ for the marginal buncher. Appendix C.1 provides further details behind the computation.

Our estimates captures the intensive margin response to the amortization requirement – the response of borrowers who still choose to borrow after the requirement was implemented. This margin sufficiently demonstrates our main goal, which is to identify the effect of higher amortization payments on credit demand. Identifying the extensive margin response to the reform convincingly would require strong assumptions over the distribution to the right of the threshold and extrapolation from the threshold up until the maximum borrowing limit of 85 percent (see DeFusco *et al.* , 2020). As the Swedish amortization requirement affected 90 percent of the new mortgage flow, we lack a counter-factual and instead focus on the intensive margin response.

4 Empirical results

This section presents the main results of the analysis. Our main results focus on the lower threshold, located at LTV ratios of 50. Although all our results are consistent across both the lower and upper threshold, the lower threshold provides cleaner identification for a number of reasons. First, some new borrowers may already choose an LTV ratio of 70 percent in the pre-requirement years because of a previous recommendation that households amortize on the portion of the mortgage in excess of a 70 percent LTV ratio. The previous recommendation represents a potential downward bias in our estimates, as borrowers may bunch even in the pre-requirement period. Second, several banks offer mortgages with a higher marginal interest rate on the part of the mortgage with an LTV above 75 percent (a so-called "top loan"). This incentive was phased out over time as banks abolished the top-loan system but did provide an incentive to bunch at a nearby threshold in the years before the requirement. The marginal interest rate changes above LTV ratios of 75 percent, and a borrower may want to reduce their borrowing to avoid this higher interest rate. This threshold is clearly noticeable in the counter-factual distribution in Figure C1. We provide all results for the upper threshold in Appendix C.2, and the interested reader can compare the bunching estimates for the lower and upper threshold in Table B2.

Figure 3 illustrates the identification strategy and main empirical results. The figure plots the percent of new mortgages in specific LTV bins in pre- and post-requirement years. At this threshold, the minimum amortization rate on new mortgages jumps from zero to one percentage point for mortgages with an LTV ratio above 50 percent. In the post-requirement years, there is a considerable mass at the threshold, indicating that many new borrowers choose lower LTV ratios to avoid mandatory amortization payments. Importantly, the amount of bunching is consistent across the post-requirement years, implying that the effect that we uncover is not short-lived.

Since Swedish mortgages feature linear repayment schedules and are not annuity contracts. The increase in total mortgage payments at the threshold is therefore fully due to higher amortization payments, not interest expenses. Note that affected borrowers include home buyers and

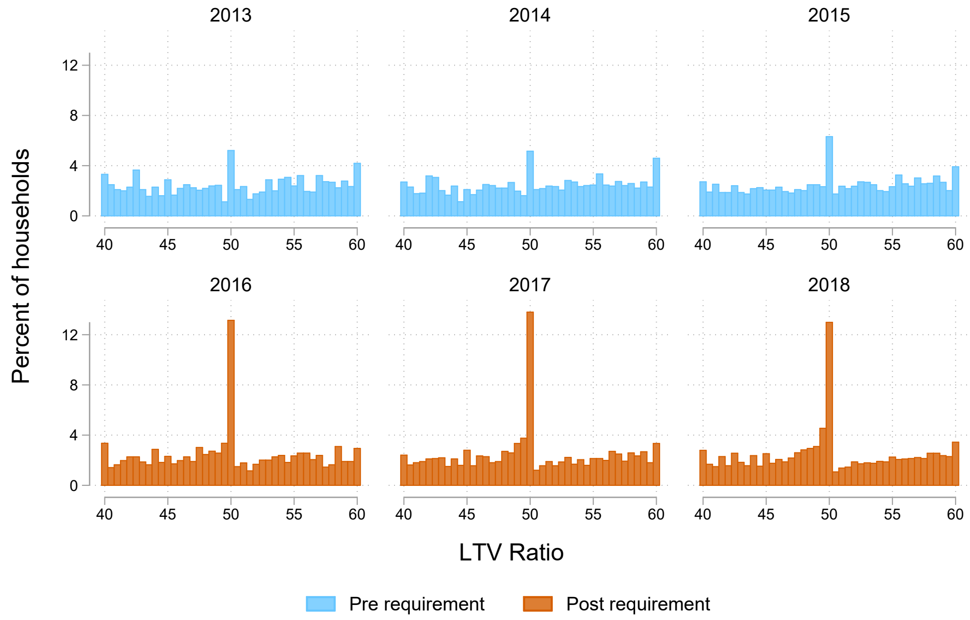


Figure 3. LTV distributions around the lower amortization requirement threshold

Note: The figure plots the percent of borrowers per loan-to-value bin for each year. We use data from the Mortgage Survey by the Swedish Financial Supervisory Authority. The dataset contains information about all new mortgage loans issued during a two week window in the fall for each year. Loan-to-value ratios are calculated using consolidated household mortgage debt levels divided by the value of the collateral. Collateral values are supplied by the banks, and are based on either the transaction price or the banks' internal valuation models. Pre requirement years are in the top row, and post requirement years featuring a 1% higher amortization rate for LTV above 50 are in the bottom row of each panel.

existing homeowners who refinance their mortgage and that the requirement does not affect existing mortgages. We later focus on each sample separately.

4.1 Bunching at the lower threshold

The main result for the lower threshold is presented in Figure 4. The figure plots the observed distribution of loans by LTV ratio and the counter-factual distribution estimated from the bunching procedure around the threshold at an LTV ratio of 50. The estimation procedure uses LTV ratios up to 65 percent to avoid the upper threshold affecting the results. The vertical axis shows the percent of loans in each bin, where each bin is 0.5 percentage points wide. We choose $L = 48.5$ and $U = 51.5$ as our main specification (see equations (1) and (3)). Our estimates of ΔLTV, B, and M are robust to changing these limits of the excluded area in either direction (see Section 4.4). The solid orange line plots the empirical distribution, i.e., the distribution in 2016-2018, and the solid blue line plots the counter-factual distribution.

There are several key results in the figure. First, the counter-factual distribution fits the empirical distribution well up to an LTV ratio of 47.5 percent and again starting from an LTV

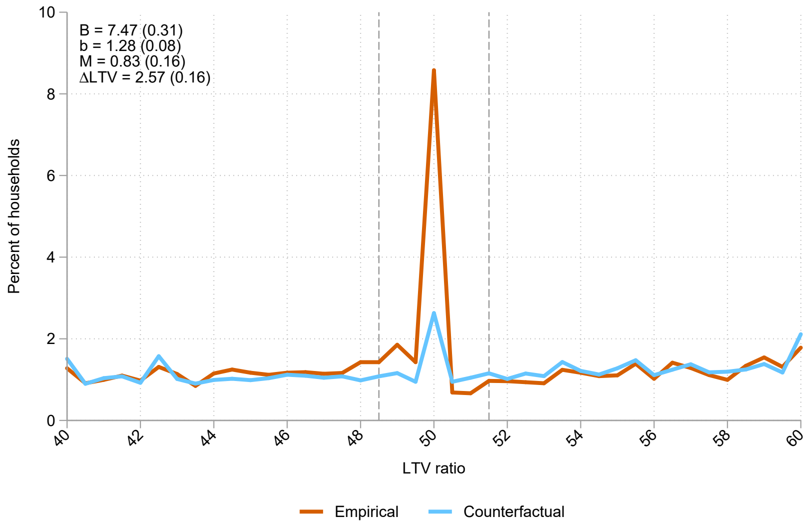


Figure 4. Bunching at LTV=50

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio. The estimation is carried out using all loans with LTV ratios between 20 and 65 percent, but only shows the distribution between 40 and 60. The orange line plots the empirical density, where each dot represents the percent of mortgages within each 0.5 percent LTV bin. The blue line plots the counterfactual density estimated using the procedure described in Section 3. The figure reports the estimated percent of loans that bunch at the threshold (B), the excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 3. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.

ratio of 52 percent. The difference between the two distributions comes in the area where we expect that the amortization requirement has an impact, namely around the threshold.

Second, there is a considerable amount of bunching at the threshold. The bin precisely at the threshold contains approximately 9 percent of borrowers, compared to around 3 percent in the same bin in the counter-factual density. We find 7.47 percent ($\widehat{B} = 7.47$, standard error 0.31) more borrowers with LTV ratios between 48.5 and 50 percent in the post-requirement years compared to the pre-requirement years, an increase by a factor of 1.28 ($\widehat{b} = 1.28$, standard error 0.08). Interestingly, there is considerable bunching even at relatively low LTV ratios. These borrowers have access to considerable amounts of home equity, making it difficult to argue that they face collateral constraints related to their LTV ratio. However, they can still face credit constraints related to payments due to the discretionary income limit applied in Sweden. We will evaluate this shortly. Dividing the bunching estimate B by the counter-factual distribution, we find that the marginal buncher reduces its LTV ratio by 2.57 percentage points ($\widehat{\Delta LTV} = 2.57$, standard error 0.16) in response to the requirement. Relative to the threshold, this yields an approximately 5 percent decrease in LTV ratios.

Third, missing mass is small. We find 0.83 percent ($\widehat{M} = 0.83$, standard error 0.16) fewer households borrowing slightly more than 50 percent of the value of their home in the post-requirement years compared to the pre-requirement years. Finally, we calculate the amortization elasticity using equation (5). With the estimated ΔLTV of 2.57, the numerator equals $2.57/50 = 0.0514$. Using the implicit rates from equation (16), the denominator is equal to $\alpha^* = 0+0.01+0.01 \cdot \frac{50}{(52.57-50)} = 0.204$, and the elasticity is equal to $0.0514/0.204 = 0.25$. A one percentage point increase in the amortization rate decreases LTV ratios by 0.25 percent.

4.2 Bunching for constrained and unconstrained borrowers

In this section, we examine whether binding payment constraints can explain our results, ultimately concluding that bunching occurs for both constrained and unconstrained borrowers. Recall that banks in Sweden evaluate a borrower's ability to repay based on a discretionary income limit, where the borrower has to have sufficient income to meet expenses. The banks intend to ensure that after-tax household income is sufficient to cover subsistence consumption and borrowing payments, which include interest and amortization payments. Borrowers facing binding constraints may be unable to borrow more because of the discontinuous jump in mortgage payments above the LTV threshold (Bäckman & Khorunzhina, 2022). In effect, the amortization elasticity of mortgage demand for these borrowers is infinite.

How prevalent are binding payment-to-income (PTI) constraints for borrowers at the lower threshold? To answer this question, we calculate the counter-factual discretionary income as the discretionary income given your chosen LTV minus the extra payments if you would have borrowed 1 percentage point more in LTV compared to the closest-by threshold. We find a small fraction of unconstrained borrowers at the threshold: 13.6 percent of new borrowers at the threshold would not comply with the payment-to-income constraint set by Swedish banks if they were to amortize more. The remaining 86.4 percent of borrowers who bunch are not constrained by the PTI constraint. We then group households based on counter-factual discretionary income into Near constraint, an Intermediate and a Far from constraint sample, with a counterfactual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK, and greater than 15,000 SEK, respectively. The Near constraint group is close to their debt capacity, as they have nearly maxed out their PTI. Note that this group includes borrowers with positive discretionary income who are close to but not at the constraint. The Far from constraint group is far from their debt capacity and could borrow a substantial amount more. For example, a discretionary income of 15,000 SEK implies the household could increase its debt until the additional monthly expenses equal 15,000. At a (stressed) interest rate of 7 percent and amortization rate of 2 percent, the

Table 1. Bunching estimates by type of payment constraints

PTI Constraint	Near constraint	Intermediate	Far from constraint
Bunching	5.01	10.17	9.41
	(0.49)	(0.63)	(0.70)
Excess mass	0.99	1.72	1.46
	(0.14)	(0.17)	(0.15)
Missing mass	-0.49	-0.90	-1.34
	(0.27)	(0.32)	(0.32)
Δ LTV	1.98	3.45	2.92
	(0.27)	(0.34)	(0.30)
Elasticity	0.15	0.45	0.32
	(0.04)	(0.09)	(0.06)
Number of households	13350	10471	10182

Notes: The table compares the main bunching estimates across groups based on payment-to-income constraints. We calculate the counter-factual discretionary income as the discretionary income given your chosen LTV, minus the extra payments if you would have borrowed 1%-point more in LTV. The Near constraint, Intermediate and Far from constraint sample has a counter-factual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK and greater than 15,000 SEK, respectively. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). Δ LTV the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 5. Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

additional loan size equals $12 \times 15,000/(0.07 + 0.02) = 2$ million kronor, which is more than the average debt level in our sample. For the Far from constraint group, increasing leverage and starting to amortize entails a reduction in discretionary income of 8 percent, on average. Naturally, this decrease is much larger for more constrained households: The average reduction for the Near constraint group is 62 percent and for the intermediate group, the average reduction is 16 percent.

Are constrained borrowers driving the bunching result above? Table 1 shows that the answer is no. The table provides bunching estimates for the three separate groups based on discretionary income. Figure A3 provides the corresponding figures. The results show that ΔLTV and the elasticity are generally comparable across constrained and unconstrained borrowers. We conclude that payment-to-income constraints cannot explain our results.

An important question is whether the unconstrained group is different in some other characteristics that would imply that they face other financial constraints. Table B1 provides summary statistics for borrowers in the three groups, showing that the constrained, intermediate and unconstrained groups appear similar on most observable dimensions. The Unconstrained group has higher income, lower debt-to-income, and lower debt-service-to-income, likely indicating that they are *less* financially constrained. Interestingly, these are also characteristics that correlate with higher financial literacy (Almenberg & Säve-Söderbergh, 2011).

4.3 Endogenous housing demand response

The leverage ratio is a function of mortgage debt and property value. Homebuyers can adjust to the requirement by taking out a smaller loan (L) or adjusting the type of home they purchase (V). To isolate borrowing from value effects, we focus on borrowers who refinance to a new mortgage. For these borrowers, the value is set exogenously by the bank based on the bank's assessment of the collateral value. Because of institutional design and the incentives faced by banks (see Section 2), we argue that banks do not have an opportunity to manipulate property valuation. The reduction in LTV then has to come from a change in the loan size, L, derived from borrower preferences.

For homebuyers, banks almost exclusively use the purchase price to form the collateral assessment. Only in rare cases[9] do bank deviate from using the purchase price for homebuyers. In the case of a refinancing, the bank uses either an external or internal valuation, based in most cases on statistical models of the property value. The external valuation includes using tax-assessed values for houses done by the tax authority as well as assessments by independent appraisers. We discuss the validity of the collateral assessments further in Section 4.6. We find little evidence of discontinuities in house values, either in levels or relative to income, around the thresholds in Figures A5 and A6. We therefore estimate bunching by type of valuation. Table C2 shows that the estimated bunching is similar across valuation methods. The estimated ΔLTV is 2.44, 2.89 and 2.18 for internal valuation, external valuation and purchase price, respectively. Overall, while there is some differences across the valuation methods in the bunching estimate and the elasticity, the results are consistent for the lower threshold. The share of refinancers in the data is large, and we find similar bunching estimates for this group even at the upper threshold. This implies that value effects are not driving our main result, and the decline in loan-to-value ratios stems from lower loan demand for a large share of our sample.

4.4 Robustness checks

Table B3 shows the robustness of our estimates to the specific choice of bin width and the limits of the excluded region. Larger excluded regions typically inflate the estimates; our preferred

[9]Apartments in the main cities, the most common type of dwelling, are always assessed using purchase prices. For homes in rural areas, mortgage banks might use external appraisers when transaction prices are high.

Table 2. Bunching estimates by type of valuation

Valuation	Internal	External	Purchase price
Bunching	7.10	7.38	9.30
	(0.34)	(0.88)	(1.46)
Excess mass	1.22	1.44	1.09
	(0.08)	(0.23)	(0.28)
Missing mass	-0.81	-0.81	-1.25
	(0.19)	(0.48)	(0.76)
Δ LTV	2.44	2.89	2.18
	(0.17)	(0.47)	(0.56)
Elasticity	0.23	0.32	0.18
	(0.03)	(0.10)	(0.09)
Number of households	28588	4948	2211

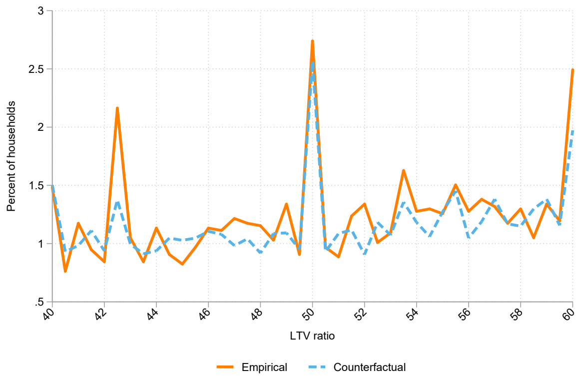
Notes: The table compares the bunching estimates across valuation modes for collateral assessments. For refinancers, banks use either an internal (statistical) valuation model, or an external method, either a tax-assessed value or an independent appraisal. For homebuyers, the purchase price is used. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (3). Δ LTV is the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 5. Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

results are in the center of the tabulated estimates and are robust to these free parameters.

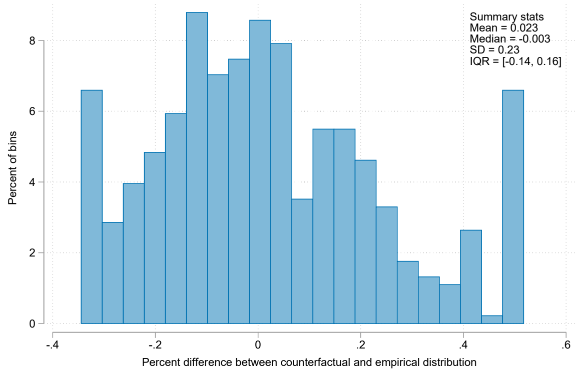
More importantly, we show that our results are robust to using the standard approach of fitting a flexible polynomial to the observed distribution (See Appendix C.3 for details of the estimation procedure). Figure C2 shows the results from the standard approach. While the counter-factual distribution fits the observed distribution well in general, it does not feature any spike around the thresholds due to a preference for round numbers or the SBA's recommendation. As a result, the bunching estimates B and b, as well as the behavioral response, are all larger compared to our earlier results that account for spikes from pre-requirement data. Our preferred results are conservative compared to the polynomial estimates. For a comparison between our preferred estimates using previous years and the polynomial estimates, see Appendix C.3 and Figure C3.

4.5 Placebo tests

We now study whether the counter-factual density obtained from pre-requirement data presents a good estimate of the fraction of borrowers in each bin, a key identifying assumption our approach. We create a placebo test to assess whether the counter-factual distribution presents a good estimate of the fraction of borrowers without the requirement (DeFusco *et al.* , 2020).



(a) Lower threshold: Placebo reform in 2014



(b) Lower threshold: Ratio, empirical to counterfactual

Figure 5. Counter-factual and empirical distribution in placebo years

Notes: Panels a) plots the empirical (solid orange line) and estimated counter-factual (dashed blue line) distribution of LTV ratios for 2014 for the lower amortization requirement. Plotted LTV ratios are limited to be between 40 and 60 percent. The figures designate the placebo treatment to take place in 2014 and uses data from 2011, 2012, 2013, and 2015 to create the counter-factual. Panels b) provides a histogram of the ratio between the empirical and counter-factual distribution, for all bins in all placebo years. For each year we use data from the other pre-requirement years as the counter-factual. LTV ratios are restricted to be between 40 and 60.

Specifically, each pre-requirement year from 2011 to 2015 is designated a "placebo" year. We then estimate the counter-factual distribution for both requirement thresholds in these years. By estimating the counter-factual distribution as if the requirement had passed in a placebo year, we can assess whether the procedure can yield a good match between the empirical and counter-factual distribution in a year without an amortization requirement. If our assumption is valid, the two distributions should coincide.

Figure 5 shows that our preferred approach passes this placebo test. Panels a) and b) plot the empirical and counter-factual distribution in 2014 for the upper and lower amortization requirement, showing a close correspondence between the distributions in both cases. Using other years than 2014 yields similar charts. Importantly, the spikes at 50, 70, and 75 percent LTV ratios are well captured by this procedure. Panels c) and d) provide histograms of the ratio between the percentage of borrowers in each bin in the empirical and counter-factual distribution for all the pre-requirement years. The mean and median percentage differences are close to zero, and the interquartile range covers zero. There is little evidence that our approach creates a systematic bias in either direction.

4.6 Validating the results

In this section, we discuss supply-side factors, other than the payment-to-income constraint, that would cause borrowers to bunch. For example, banks may have an incentive to recommend

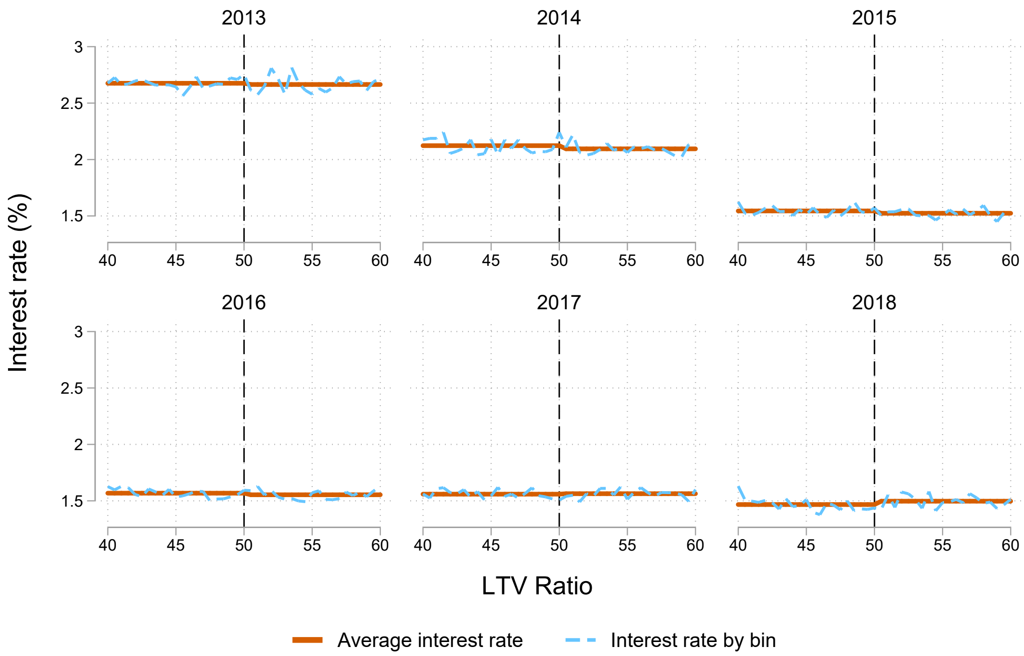


Figure 6. Interest rates around the lower LTV threshold

Notes: The figure plots the average mortgage rate by LTV bin (blue dashed line) and the average mortgage rate (orange solid line) above or below the lower (panel a)) and upper (panel b) thresholds. The thresholds are marked with dashed black line.

their clients to place themselves below the threshold or may have an incentive to manipulate the collateral assessments to obtain lower amortization rates on behalf of their customers (Mayordomo *et al.* , 2020). Below we discuss these supply-side factors in the context of the approval process for mortgages, collateral assessments, risk weights, and capital requirements. We confirm that our empirical results are valid, primarily because of institutional features in Sweden.

Mortgage interest rates around the notches. Figure 6 shows that the mortgage interest rate does not vary around the threshold. While banks may charge different interest rates for borrowers around the threshold in response to higher credit risk for borrowers who do not amortize (Garmaise, 2013; Elul *et al.* , 2010), we do not find any evidence of this in our setting. Panel a) of Figure 6 plots the interest rate by LTV ratios around the lower threshold. Although the interest rate level is different each year, reflecting Swedish monetary policy, there are no systematic differences in interest rates over the threshold in any year. Similar results hold for the upper threshold, available in Panel b) of Figure 6. There is little evidence that mortgage banks charged higher mortgage rates to households placing themselves at the threshold, which Best *et al.* (2020) show is a key factor explaining LTV choices in the UK. As we discuss below, lower amortization payments in a full-recourse setting like Sweden do not imply higher credit risk and therefore limit the incentive for banks to charge higher interest rates for borrowers that do not amortize.[10]

Even if interest rates are constant, the bank may get higher interest income when borrowers enter an interest-only loan compared to a loan just above the 50 percent LTV threshold which keeps amortizing at a 1 percent rate, simply because over the lifetime of the loan (typically 6-7 years), the average debt balance is larger for the non-amortizing loan.[11] The extra interest income from this nudge is likely small and depends on how long the loan stays on the banks' balance sheet and the interest margin. In any case, such a strategy is second-best for the bank: simply informing the borrower when they cross the LTV threshold yields higher revenues.

Risk weights and capital requirements. A potential concern is that capital requirements may incentivize banks to nudge borrowers towards a lower LTV mortgage if there are thresholds in the capital requirements at set LTV ratios. Even though revenues increase with borrower LTV ratios, expected profits need not when expected losses (due to credit risk) or funding costs increase for banks. Regarding credit risk, it is clear that a loan with a higher LTV ratio should be riskier than a corresponding loan with a lower LTV ratio. However, we expect the marginal increase in credit risk to be negligibly small when moving from a loan with an LTV ratio of 50 percent to a loan with an LTV ratio of 51 percent, given the low LTV levels and full-recourse mortgages. Even in default, the properties' market value is more than sufficient to compensate the lender, and borrowers are liable for any residual debt. Correspondence with the Swedish Bankers Association and the individual banks did not reveal any evidence to suggest that risk weights increase discontinuously at the thresholds. Even if level differences exist, our difference-in-bunching strategy will account for any discontinuity that is fixed over time.

Most Swedish banks use the IRB approach to credit risk, using (unobserved) internal models for PDs, LGDs and ultimately risk weights. Importantly, Swedish regulation mandates a minimum risk weight of 25 percent on all loans secured by residential real estate since 2014. Even if the (unobserved) internal models of mortgage banks assumed that the risk weight exhibited a discrete jump at exactly the LTV threshold, it is very unlikely that the risk weight would

[10] Figure 6 also implicitly shows that the fixation period was similar across the threshold, as borrowers are charged a premium for longer fixation periods. A shorter fixation period would lead to lower interest rates, but this is not apparent in the figure. We verified that fixation periods are indeed stable around the thresholds.

[11] A similar argument holds for the upper LTV threshold, assuming loans above this threshold keep amortizing at a rate of 2 percent even after crossing the 70 percent threshold.

exceed the floor.

Mortgage approval. Mortgage approval in Sweden depends highly on i) discretionary income (what we call "PTI"), ii) a down payment requirement of 15 percent, and iii) credit scores based on, for example, arrears or payment remarks registered at a credit bureau, UC (there is no system of continuous credit scoring in Sweden). In Sweden, borrowers apply for a pledge from the bank before making the purchase decision. This pledge states the maximum amount the bank is willing to lend, which depends on the household's income and composition as well as the value of the collateral. The household purchases a home based on this maximum loan promise and available net worth. The household's borrowing decision comes after the assessment, provided the requested amount does not exceed the promised amount. In other words, the bank assesses the value of the collateral and approves the loan *before* the borrower makes their purchase decisions. In the case of a home equity loan, valuations are done by appraisers or statistical models employed by the bank. If the household purchases a new home, appraisal values come from transaction prices, which the bank cannot manipulate. The amortization requirement does not seem likely to impact the mortgage approval process, except when the PTI constraint is violated (which we have investigated above).

Collateral assessments. A potential concern is that banks are manipulating the value of the collateral to lower the LTV ratio. As described in the previous paragraph, however, collateral assessments are done before the borrowing decision and are done by statistical models without much discretion on behalf of the loan officer. Therefore, it is very unlikely that banks are systematically manipulating the values just around the threshold to create the kind of bunching we observe. Figure A6 plots the distribution of house value by LTV ratio. There is little evidence in the figure that the house values from the assessments are manipulated around either threshold.

Moreover, since Swedish banks are reliant on covered bonds and other wholesale funding to a large extent, manipulation could have large repercussions for the banks' reputation and funding costs. Nearly 50 percent of total funding comes from wholesale funding, half of which is covered bonds (Sandström *et al.* , 2013).

5 Understanding the determinants of bunching

We now develop a theoretical framework that allows us to clarify the different mechanisms that make households choose larger downpayments to avoid or lower amortization payments. We first show that a standard life-cycle model of consumption, housing, mortgage decisions in the spirit of Campbell & Cocco (2003) does not replicate the observed bunching behavior, even though households prefer to live in a world with interest-only mortgages. We therefore augment the model with two mechanisms related to household preferences: a one-off disutility that applies when borrowers turn off amortization payments and an ongoing flow disutility to amortization payments. Kleven (2016) explains that four mechanisms can generate bunching: kinks or notches in the household budget constraint, or kinks or notches in household preferences. We found little evidence for other notches or kinks in the budget constraint in Section 4.6, beyond the mechanical impact of the PTI constraint for constrained borrowers. Therefore, we focus on notches and kinks in household preferences. We show that a one-off disutility generates a notch in household preferences, and that an ongoing flow disutility to amortization payments generates a kink in preferences. We discuss the motivation for each preference channel, study their effect on individual and aggregate borrowing, and at the end examine the relative importance of each mechanism.

5.1 Theoretical framework

Our theoretical framework is based upon the life-cycle model of consumption, housing, and mortgages in the spirit of Campbell & Cocco (2003) and Cocco (2005). In this model, credit-constrained households face idiosyncratic and uninsurable income risk over the life-cycle. Households get utility from both consumption and housing. Households can save in either liquid deposits or illiquid housing, and borrow using long-term mortgages. The model does a good job of matching the hump-shaped consumption profile, the gradual accumulation of housing wealth over the life-cycle, and the fact that the vast majority of wealth is held in housing rather than liquid assets.

We build upon the above framework in two main dimensions. First, we extend the model to include a realistic mortgage repayment schedule with two different policy regimes. In the initial regime, households are only required to pay interest on their mortgage balances, although they can choose to pay more than that if they desire. In the second regime, households must amortize if their LTV ratio exceeds a given threshold, but can revert to interest-only payments when their LTV ratio falls below that threshold. These two policy regimes broadly represent the institutional framework present in Sweden before and after the 2016 reform. Second, we later extend household preferences to include either a one-off disutility that applies when borrowers turn off amortization payments or an ongoing flow disutility from amortization payments.

Baseline Model – Households choose consumption (c_t), liquid assets (a_t), housing (h_t), and mortgages (m_t) each period to maximize their expected discounted life-time utility:

$$\max_{\{c_t, a_t, h_t, m_t\}} \mathbb{E}_0 \sum_{t=0}^{T} \beta^t u(c_t, h_t, \delta_t) \tag{6}$$

The above optimization problem is subject to the household budget constraint, the law-of-motion for mortgages, and the exogenous income process. In addition, liquid assets must always be positive ($a \geq 0$) and mortgage borrowing ($m > 0$) is only allowed when a household owns a home. Households derive utility from both consumption and housing, as well as a behavioral wedge (δ_t), which we set to zero in the initial analysis, but later incorporate in two different forms.

Demographics and Heterogeneity – Households live for T years, receiving exogenous labor income during their working life, then social security style retirement income after their mandatory retirement at age W. Households are heterogeneous with respect to initial assets and income shocks. All households are born as renters but have the possibility to purchase housing later in life. Household income gradually rises during working life.

Assets – Households can transfer resources across periods using either the fully liquid asset a_t or less-liquid housing asset h_t. The liquid asset yields a certain return r in each period, and we do not allow households to borrow using a_t. The presence of both a safe asset and less-liquid housing allows us to capture hand-to-mouth behavior (Kaplan & Violante, 2014). We follow convention in the literature and abstract away from return risk in our model.

Housing exists on a discrete grid with k different sizes: $h^k \in \{h^1, h^2, \ldots, h^k\}$. Households are allowed to own or rent any unit. The price of each house $p_t(h^k)$ depends on its size and is determined by a price index $\bar{p}_t$:

$$p_t(h^k) = g(h^k)\bar{p}_t \tag{7}$$

where $0 < g(h^k) \leq 1$, $g'(h^k) > 0$ and $g''(h^k) < 0$. Since house prices grow at a constant rate

$1 + r^H$ over time, the initial price index determines all other prices for each time period:

$$\bar{p}_t = (1 + r^H)\bar{p}_{t-1} \quad \forall t \quad \text{given} \quad \bar{p}_1 \tag{8}$$

Buying or selling a home incurs a transaction cost f_1 that is a fraction of the house price p_t. If households choose to rent, they must pay rent each period, which is proportional to the house price, thus $\text{rent}_t = \eta p_t$.

Mortgage Borrowing – Homeowners can borrow using long-term mortgages m_t with a fixed interest rate r^M. We allow for both borrowing to finance housing purchases and cash-out refinancing. A maximum loan-to-value-constraint constrains the mortgage balance at origination:

$$m_t \leq (1 - \psi)p_t(h_t) \tag{9}$$

where ψ determines the mandatory minimum down-payment. For households that do not choose to extract equity, the law of motion for mortgage balances is given by:

$$m_{t+1} \leq m_t(1 + r^M) - \rho_t \tag{10}$$

Where ρ_t represents the mandatory minimum mortgage payment (interest plus amortization) at time t. The less than or equal sign indicates that households can always choose to pay more than the minimum payment.

Alternatively, if households choose to extract equity (by selecting $m_{t+1} > m_t(1 + r^M) - \rho_t$) then they are required to pay both a proportional (f_2) and fixed (f_3) cost to cash-out refinancing, which show up in the budget constraint. The LTV constraint is only binding at time of purchase or when the household decides to do cash-out refinancing. Negative shocks to income or house prices will not make the borrower shrink their mortgage balance as long as they can continue to make the mortgage payments.

Mortgage repayment – The mandatory minimum mortgage payment (ρ_t) represents our main policy instrument. We model two different repayment policies: an interest-only policy where the borrower is simply asked to make interest payments,

$$\rho_t(m_t, p_t) = m_t * r^M \tag{11}$$

and a mandatory amortization policy, where the minimum repayment depends on the loan-to-value ratio of the borrower,

$$\rho_t(m_t, p_t) = m_t * r^M + m_t * \begin{cases} 0 & \text{if } {}^{m_t}/_{p_t} \leq 0.5 \\ 0.01 & \text{if } {}^{m_t}/_{p_t} > 0.5 \end{cases} \tag{12}$$

The amortization schedule in the model closely mimics the amortization requirement implemented in Sweden. For simplicity, we only model the lower threshold, although our results would generalize to multiple thresholds. In our key policy experiments, we will switch between the interest-only policy and the amortization requirement.

Income – Households face exogenous and idiosyncratic income risk. We model the earnings process using a household-specific fixed effect α_i, a deterministic life-cycle profile that follows a third-order polynomial in age, and an idiosyncratic component $z_{i,t}$ that follows an AR(1) Markov process:

$$\ln y_{i,t} = \alpha_i + g_t + z_{i,t}, \quad \text{where } z_{i,t} = \rho z_{i,t-1} + \varepsilon_{i,t}, \quad \varepsilon_{i,t} \sim N(0, \sigma_\varepsilon^2)$$

After retirement, the household earns a fraction ω of last working period's income.

Functional form – We adopt the utility function from Attanasio *et al.* (2012). The utility function is a CRRA function of consumption, augmented with an additive and multiplicative benefit of housing:

$$u(c_t, h_t, \delta_t) = \frac{c_t^{1-\gamma}}{1-\gamma} e^{\theta\phi(h_t)} + \mu\phi(h_t) - \delta_t$$

where γ is the coefficient of relative risk aversion, θ and μ are housing preference parameters that determine the utility premium derived from homeownership, and δ_t represents the behavioral wedge, which we define later (we set $\delta = 0$ in the baseline analysis). The non-separable term for the value of ownership represents a proportional scaling of the utility from homeownership. When $h = 0$, the household is a renter that only derives utility from non-durable consumption: the multiplicative term is equal to one and the additive term is zero. The additive term implies that housing and consumption are non-homothetic, and that housing is either a luxury good ($\mu > 0$) or a necessary good ($\mu < 0$).

The relative utility of house choice h_t is determined by ϕ, where ζ is the disutility of renting:

$$\phi(h_t) = \begin{cases} \log(h_t) & \text{if owner} \\ \log(\zeta h_t) & \text{if renter} \end{cases}$$

5.2 Parameter values

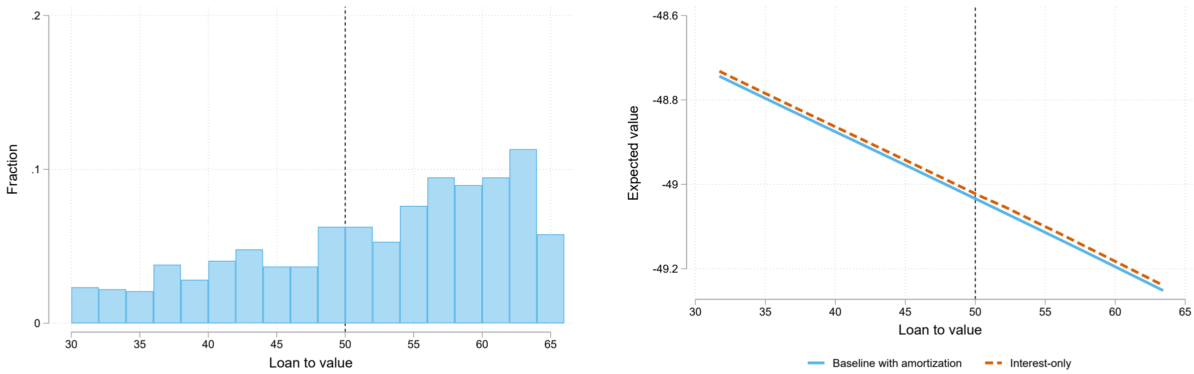
To parameterize the model, we follow the existing literature, adapted to reflect the Swedish mortgage market. We calibrate asset returns and interest rates based on Swedish data. Similarly, we set the loan-to-value and amortization requirements based on Swedish law. We then set the remaining parameters based on the existing literature. The details of our parametrization are contained in Appendix D.

We set $r = 0.0181$ based on the real risk-adjusted return of the Swedish 3-month T-Bill. We set $r^H = 0.02953$ based on the real risk-adjusted return to housing, which we calculate using the house price index from Statistics Sweden augmented with housing service flows, maintenance costs, and home insurance. We explicitly account for imputed rents in housing returns using the balance-sheet approach (Piazzesi *et al.* , 2007; Kaplan & Violante, 2014).

We set the real mortgage rate to $r^M = 0.0087$ based on the average real rate for a floating rate mortgage in Sweden between 2005 and 2015. We set the maximum loan-to-value ratio $1-\psi$ at 85 percent following Swedish mortgage regulation. We set household preference parameters based on Attanasio *et al.* (2012) and income process parameters based on Kovacs & Moran (2021).

5.3 Baseline model does not generate bunching

How does the Swedish mandatory amortization policy affect household borrowing and the distribution of LTV ratios? We implement a policy where households are required to amortize if the LTV ratio exceeds 50 percent. Figure 7 shows the main results in our baseline model. The first panel shows the distribution of LTV ratios at the time of mortgage origination. We find no bunching at the 50 percent threshold, despite the presence of mandatory amortization for all loans above the threshold. The reason is that mandatory amortization payments do not have a large impact on household welfare in the model. The second panel of Figure 7 shows the expected value function for the baseline model. Households naturally prefer to live in an interest-only world, since they are free to amortize any amount. However, we see that



(a) LTV distribution

(b) Value function

Figure 7. LTV distribution and value function in baseline model

Notes: The figure plots results from the model in Section 5. Panel a) plots the LTV distribution at origination in the baseline model with amortization requirement, where the minimum amortization rate increases from 0% to 1% per year when the LTV ratio exceeds 50%. Panel b) plots the expected value function from the model, separately for the baseline model with (blue solid line) and without (orange dashed line) the amortization requirement.

the expected value in the baseline model with amortization is very close to the value for the interest-only case. Moreover, we see neither a kink nor notch in the expected value function. This is consistent with the fact that there is no bunching at the 50 percent threshold. Note that households do not face binding credit constraints at the threshold since they are far away from the maximum LTV ratio.

Why is there no change in borrower behavior at the threshold? The basic intuition is that amortization affects future period budget constraints, but not the current period choice set. This is especially easy to see if households in the interest-only regime were already saving more than what is mandated in the amortization requirement regime. Further, while households may dislike amortization if it pushes them to save more than they would like, there are two ways that households can undo the effects of amortization. First, following the argument by Svensson (2016), households can borrow *more* at origination. Households can use the additional borrowed amount to make the required amortization payments, which allows them to achieve their desired consumption path. The model also generates this result: compared to the interest-only case, households with an LTV ratio above the threshold borrow more in response to the requirement.

The second reason that the amortization requirement does not change the budget constraint is that households can refinance to undo any payments. This result is trivially true in models with short-term debt and no refinancing cost: amortization payments are completely undone by adjusting borrowing every period. Even in models with long-term debt, refinancing limits the impact of higher required amortization payments (Hull, 2017). But even if we turn off the refinancing option in our model, we still do not observe bunching at the threshold. Again, without credit constraints households can choose their desired consumption path by adjusting their borrowing, which implies that higher saving requirements have little impact.

The lack of bunching in the baseline model is invariant to key model parameters. More specifically, we do not see bunching in the baseline model even when a) households are highly impatient, b) income grows steeply over the life-cycle, thus exacerbating the role of credit constraints, c) households are not allowed to perform home equity withdrawal, d) households have access to a high return liquid assets, or e) households do not have access to a high return liquid asset.

5.4 Kinks and notches in household preferences generate bunching

We augment the model with two additional utility costs to amortizing: a one-off disutility that applies when borrowers turn off amortization payments and an ongoing flow disutility to amortization payments. We now motivate and describe these costs in more detail.

A one-off disutility – The first behavioral wedge we include in our model is a one-off disutility that applies when borrowers turn off amortization payments and resume interest-only payments:

$$\delta_t = -\Delta_n \times \mathbb{1}_{\text{amort}_t=0,\ \text{amort}_{t-1}>0} \tag{13}$$

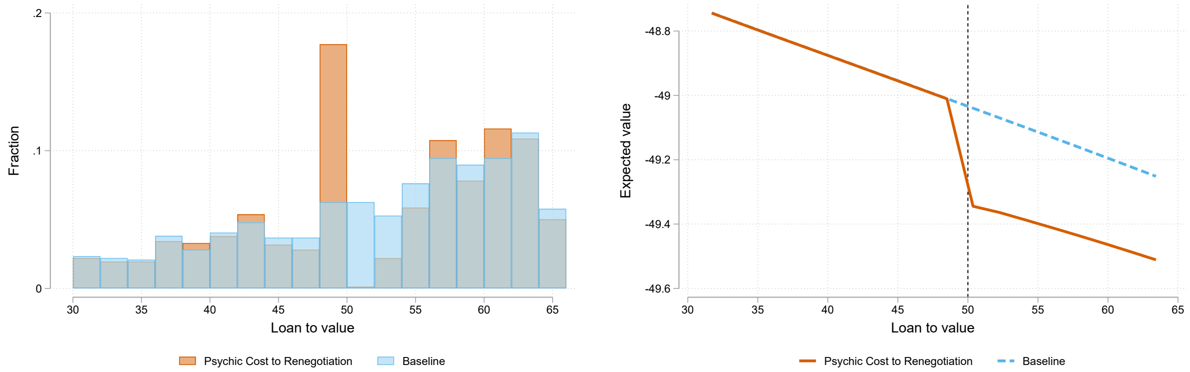
where $\text{amort}_t = \rho_t(m_t, p_t) - m_t * r^M$ is the required amortization payment.

In our model, households suffer the one-off disutility when they start with a LTV ratio above 50 percent, gradually pay down their mortgage, and then eventually cross below the policy threshold and turn off amortization. This disutility captures the fact that Swedish borrowers have to take action to turn off amortization. Refinancing costs can represent both monetary and psychic costs to the individual to refinance.[12] In our setting, we model these as psychic costs through the utility function since almost all Swedish banks offer reducing amortization payments for free.[13] [14]

[12] Monetary and psychic costs to refinancing have been studied in, e.g., Agarwal *et al.* (2016), Keys *et al.* (2016) and Andersen *et al.* (2020).

[13] One bank charges a small amount to change the mortgage contract, equal to 1500 SEK. This bank represented 3 percent of total mortgages in 2017.

[14] We asked Swedish banks about the procedures related to refinancing to a lower amortization rate once the borrower hits the threshold. In their reply, the banks indicated that there are no associated costs or credit checks, that the borrower does not need a new mortgage contract or reassessment of collateral values, and that a simple



(a) LTV distribution

(b) Value function

Figure 8. LTV distribution and value function with one-off disutility to amortization payments

Notes: The figure plots results from the model in Section 5. Panel a) plots the LTV distribution at origination in the model with a one-off disutility to amortization payments (orange), relative to the baseline model (blue). Panel b) plots the expected value functions from both specifications of the model.

The one-off disutility can also represent other factors related to the decision to turn off amortization payments once the statutory threshold is reached. For example, since this was a new policy with uncertain implementation, households could be uncertain about their ability to turn off amortization. This behavior would also generate a notch. Similarly, if the statutory threshold serves as a target LTV ratio that agents strive to achieve, then reference dependence could also generate a notch in household preferences (Kleven, 2016). The disutility at refinancing is equivalent to a one-time disutility at origination, discounted appropriately, for signing up for a mortgage with a high LTV ratio requiring amortization payments.

We show the result of including a one-off disutility in Figure 8. The figure shows that a one-off disutility to amortization payments affects households close to the threshold and leads to a large area with missing mass just to the right of the threshold. The bunching and missing mass result from a notch in preferences at the threshold, illustrated in panel b). This notch will cause households with baseline LTV above the 50% threshold to choose larger downpayments to avoid suffering the utility cost. Since households far away from the threshold can discount the cost, it will not affect their borrowing decisions.

Flow disutility to amortization – The second behavioral wedge we include in our model is a flow disutility to amortization. We model the wedge in household preferences as

phone call to the bank advisor is sufficient to turn off amortization. Three of eight banks stated that borrowers are never denied the ability to turn off amortization, and the remaining stated that it is very rare. If it happens, the denial is related to insolvency issues, such as not paying bills.

follows:[15]

$$\delta_t = -\Delta_k \times \mathbb{1}_{\text{amort}_t > 0} \tag{14}$$

This disutility may occur if households mistake amortization payments as a cost, rather than a form of savings, or alternatively, if households focus on the monthly mortgage payment when choosing how much to borrow. Argyle *et al.* (2020) find evidence that consumers perform "monthly payment targeting" when choosing between auto loans with different terms. In addition, Camanho & Fernandes (2018) provide survey evidence showing that households focus on the monthly payment, rather than the actual cost, when deciding whether to purchase a home. In the Swedish context, survey evidence shows that 38 percent of Swedish households consider amortization payments as a cost, rather than a form of savings (SBAB, 2018). All of the above explanations are consistent with the concept of "NPV-neglect", in which households do not fully consider the net present value of future costs when choosing between alternative debt contracts (Shu, 2013).

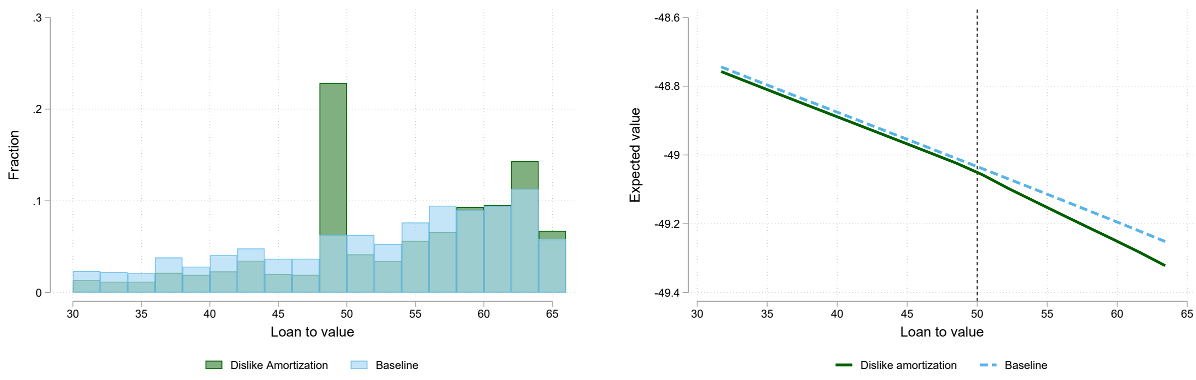
From the baseline model and Svensson (2016), we have that borrowers can undo required amortization payments by borrowing more or substituting liquid savings for amortization payment. Borrowers may be unwilling or unaware that they can do so, however.[16] Assuming that households do not borrow more to undo required amortization payments, such payments can be costly for several reasons. Required amortization payments may lead to sub-optimal saving rates (Piskorski & Tchistyi, 2010; Cocco, 2013; Bäckman & Khorunzhina, 2022), or households may wish to save in risky assets because of the higher expected return or increased diversification.[17]

The flow disutility to amortization payments generates bunching at the threshold but no missing mass. Figure 9 provides the results, where panel a) shows that household now bunch in response to higher amortization payments. We see the intuition behind this result in panel b): the value function has a kink at exactly the amortization threshold. The kink implies that all households above the amortization threshold are affected, and consequently all households

[15] While we assume a flow disutility to amortization, it would be equivalent to include a flow cost to monthly mortgage payments, as this would also generate a kink at the policy threshold.

[16] Almenberg & Säve-Söderbergh (2011) find that many Swedish adults have low levels of financial literacy. Furthermore, Almenberg *et al.* (2021) report that 84 percent of surveyed individuals in Sweden consider it appropriate to pay down the principal. They may then be unwilling to borrow more to undo principal repayments.

[17] Calvet *et al.* (2007) report that 62 percent of Swedish household saved in stocks or risky mutual funds in 2002, using a random sample of 100,000 households based on register data. The register data was discontinued in 2007. More recent numbers are available in Almenberg & Dreber (2015), who report data from a survey in 2010. The authors find that 49 percent of women and 59 percent of men are stock market participants.



(a) LTV distribution

(b) Value function

Figure 9. LTV distribution and value function with dislike of amortization

Notes: The figure plots results from the model in Section 5. Panel a) plots the LTV distribution at origination in the model with a flow disutility to amortization (green), relative to the baseline model (blue). Panel b) plots the expected value functions from both specifications of the model.

adjust their borrowing. The spike at the threshold occurs because households close enough to the threshold will, in the amortizing regime, choose to avoid bearing the utility cost via larger downpayments. But missing mass does not occur, as households with somewhat higher LTV levels also put in more cash, though not enough to avoid paying the cost at origination. These households now fill up the distribution to the right of the threshold.[18]

5.5 Evaluating the relative importance of the preference channels

The two mechanisms have different implications for missing mass and the aggregate effect of changing amortization payments. First, a notch in household preferences generates missing mass above the threshold, whereas a kink does not generate missing mass. Our empirical results show little evidence for a large missing mass: Table B2 finds that missing mass is generally less than 15 percent of the bunching estimate. This result holds across specifications and, in particular, for unconstrained borrowers. The lack of missing mass suggests that most of the effect comes from a kink in household preferences generated by a dislike for amortization payments. We also note that refinancing costs are low in Sweden. Swedish banks do not charge a monetary cost for reducing amortization payments once a borrower hits the threshold. If eligible, changing to an interest-only loan requires a simple phone call or message to the bank, so the time cost of reducing amortization payments appears low too. The low refinancing cost would suggest that our results are instead driven by a kink in household preferences generated by a disutility of

[18] An interesting extension would be to allow households to be heterogeneous in their dislike of mortgage payments. Indeed, as Figures 2 and A2 show, some households below the 50 percent threshold do amortize. We leave this to future research, as our model intends to highlight the mechanism and not give quantitative estimates.

amortizing.

In practice, optimization frictions may prevent some borrowers from understanding the incentives created by the notch (Best *et al.* , 2020; Anagol *et al.* , 2022), which prevents some borrowers from bunching. Instead of a kink, we could rationalize the lack of missing mass with a notch combined with optimization friction. In our setting, optimization frictions are potentially related to inattention, misperception, or real adjustment costs.[19] We therefore consider the empirical relevance of different optimization frictions in our context. First, we note that the consequences of choosing a higher LTV are very salient for the borrower at the time of origination. All Swedish banks provide online tools that allow the borrower to examine how different LTV ratios affect total mortgage payments (see Figure A7 for an example). The calculator typically allows the borrower to select a property value and a down payment and calculates the monthly cost. The amortization payment is highly salient in these calculators, and it is easy to see how different LTV values translate into different payments. In addition, bank advisors will certainly advise their clients about the consequences of choosing a certain LTV ratio. We believe that the institutional setup in Sweden strongly limits the relevance of optimization frictions related to inattention or misperception.

Optimization frictions could also arise due to real adjustment costs, such as the cost of liquidating other assets or adjusting large purchase decisions like a home renovation to comply with the requirement. However, we note that the amounts required to comply with the requirement are not prohibitive. Complying with the requirement requires lowering the borrowed amount by 1 percent for borrowers just above the threshold. With the average mortgage amount from Table B1 of 1.6 million SEK, the average borrower would need to liquidate liquid assets equal to 16.000 SEK. Using the fee for stock trading in Sweden at time of writing, the cost of such a trade ranges from $16.000 * 0.0005 = 8$ to $16.000 * 0.0025 = 40$ SEK.[20] The average monthly income in our sample is 40.680 SEK, meaning that the added liquidity represents $16/40.68 * 12 = 3\%$ of annual disposable income.

Overall, we do not believe that optimization frictions can explain the lack of missing mass. The lack of refinancing costs, the saliency of the decision, and the small amounts involved in complying with the requirement lead us to believe that amortization payment instead represents a flow-disutility, consistent with a kink in the value function. However, it is difficult to rule

[19] See Søgaard (2019) and Anagol *et al.* (2022) for an overview of different optimization frictions.

[20] We have taken the fees from a Compriser, , a fee comparison website, accessed on the 6th of July, 2023.

(a) Credit growth (b) House price growth

Figure 10. Credit growth for property loans and house price growth

Notes: The figure plots the time series of annual credit growth and the interest rate for property loans in panel a) and the time series of house price growth in panel b). The first solid line in December 2015 indicates the date when the first amortization requirement was proposed by the FSA. The second dashed line in June 2016 indicates when the first amortization requirement went into effect. This is the policy that we study. The second solid line in November 2017 indicates when the second requirement was proposed by the FSA. The second dashed line in March 2018 indicates when the second amortization requirement went into effect. The second requirement added an additional 1 percent in amortization payments for new mortgages with a debt-to-income ratio above 4.5. We do not examine this requirement. Source: Statistics Sweden and authors' calculations.

out optimization frictions completely and conclusively argue for flow-disutility to amortization payments with our empirical design. As a result, we now instead turn toward another implication of the two cases from the model: the aggregate effect of limiting interest-only mortgages.

5.6 Implications for the aggregate economy

The notch and the kink from the model have different implications for the aggregate response of borrowing. A notch in household preferences generated by a notch has a first-order impact only on borrowers around the threshold. In contrast, a kink causes a reduction in borrowing for all borrowers above the threshold. This is potentially important, since the vast majority of mortgage origination is above this threshold.

These predictions can, in theory, be validated in the data, although identifying an aggregate effect for unconstrained borrowers is challenging. For instance, any evaluation would have to credibly distinguish between the response of constrained and unconstrained borrowers and any other omitted factor that would explain borrowing. Moreover, the response by constrained borrowers could spill over to unconstrained borrowers through general equilibrium effects, for example, when house prices decline (Bäckman & Khorunzhina, 2022). Wilhelmsson (2022) finds that the amortization requirement led to a 7 percent reduction in house prices but did not examine the role of constrained and unconstrained borrowers in driving these price changes.

With these caveats in mind, Figure 10 plots the aggregate credit growth rate for property loans and the interest rate on property loans. The amortization requirements coincided with a sharp reduction in the credit growth rate. These declines are difficult to explain by other fundamentals, such as the interest rate. The blue line shows that the mortgage rate is flat between mid-2015 and 2020. The aggregate-level evidence suggests that the effect we identify is not simply a local effect around the thresholds (i.e. a notch) but applies throughout the distribution (i.e. a kink). However, we again note that the effect could come from constrained borrowers being forced to reduce their borrowing. At the same time, we also see a decline in house price growth (panel b) and an increased supply of housing (Naess-Schmidt *et al.* , 2017), which could be driving the reduction in credit growth. As discussed, we are careful to avoid drawing major conclusions from these aggregate patterns, yet they are mostly consistent with a kink in preferences.

6 Conclusion

This paper argues that amortization payments can directly affect household borrowing decisions. We document that new borrowers reduce their loan-to-value ratios by five percent at origination in response to a one percentage point higher amortization rate. We show this by combining administrative data with a reform that mandates mortgage repayment for households borrowing more than 50% of the value of their home. The LTV distribution features a spike at the 50% threshold after the reform, as wealthy households make larger downpayments or extract less equity to avoid having to amortize. Our results are not driven by supply-side factors, such as interest rates, credit assessments, or fees, and apply to homebuyers and refinancers. We find that the results are driven mainly by wealthy, unconstrained borrowers, suggesting that credit constraints cannot explain the results. A standard life-cycle model with housing and mortgages cannot account for the empirical results that we document. We amend the model with a one-time disutility to amortizing and a flow disutility to amortizing, two mechanisms that generate either a notch or a kink in the discounted utility of households in the model. We disentangle these two mechanisms by showing that a one-time disutility to amortizing generates missing mass in our model, which is in contrast to our empirical results. The evidence is thus more consistent with a ongoing flow disutility to amortization. This suggests that households either target monthly payments, or do not recognize amortization as a form of savings. Either way, our findings caution that interest-only loans may increase household borrowing and the lifetime cost of debt.

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A Internet Appendix: Figures

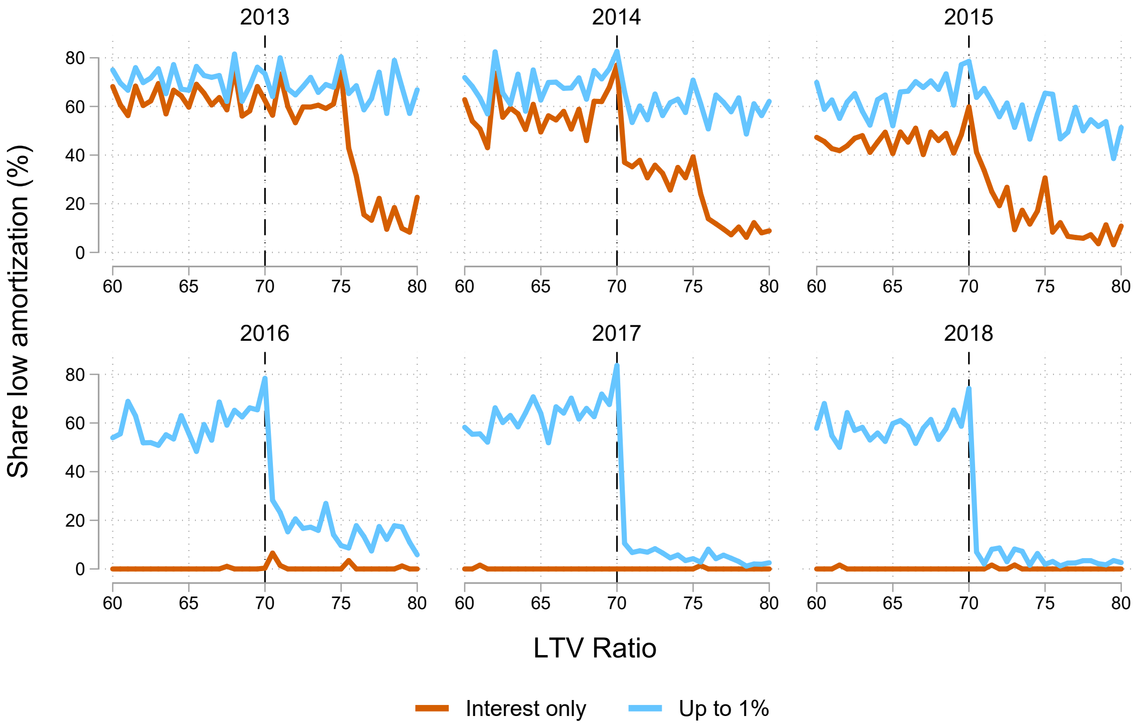
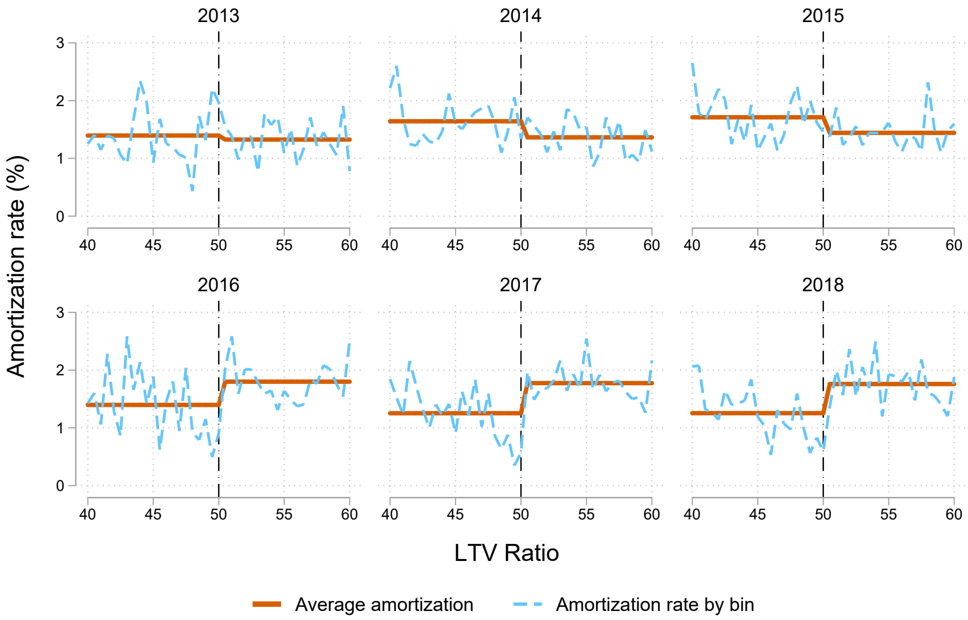
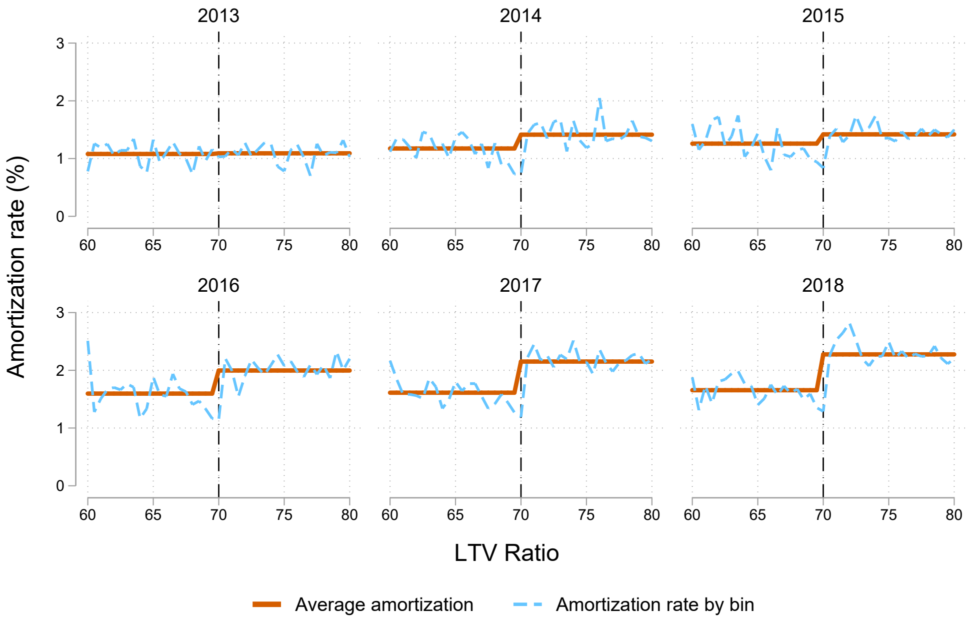


Figure A1. Share interest-only mortgages at the upper threshold

Notes: The orange line plots the share of interest-only loans in orange and the share of borrowers who amortize up to 1 percent in blue by LTV for the upper threshold.



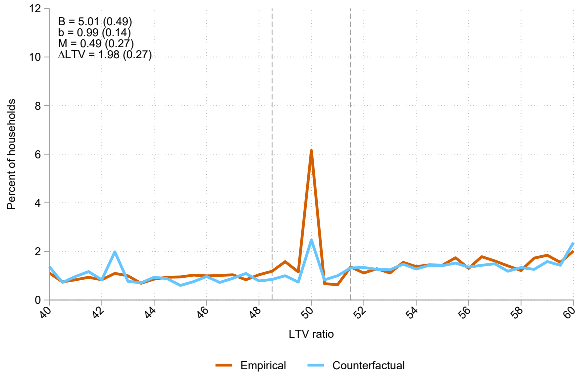
(a) Lower Threshold



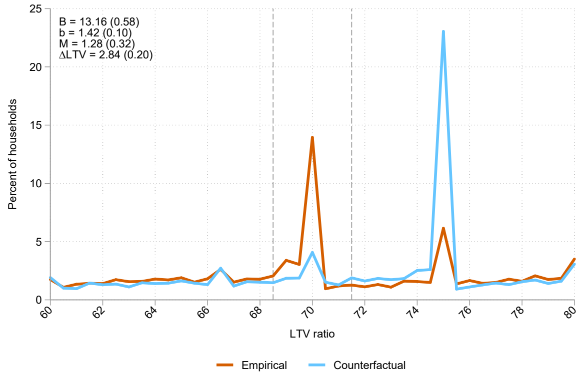
(b) Upper threshold

Figure A2. Amortization rate by year and LTV ratio for both thresholds

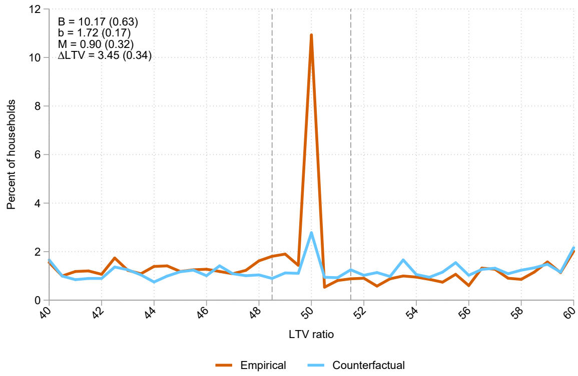
Notes: The figure plots the average amortization rate by LTV bin (blue dashed line) and the average amortization rate (orange solid line) above or below the LTV threshold marked by the black dashed line. Panel a) plots these around the lower threshold, and panel b) around the upper threshold.



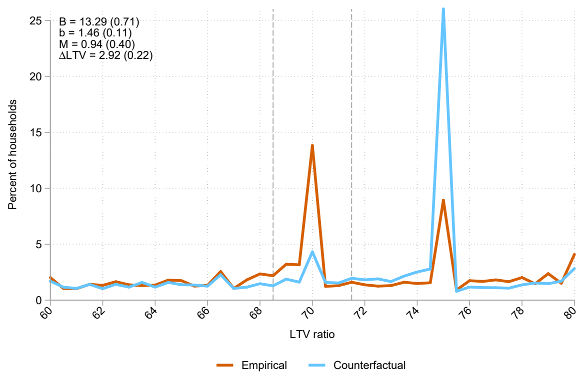
(a) Constrained borrowers, lower threshold



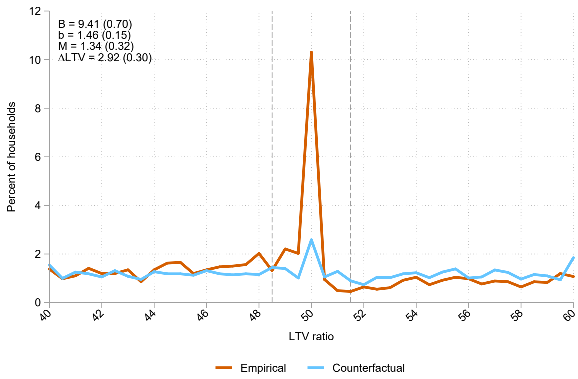
(b) Constrained borrowers, upper threshold



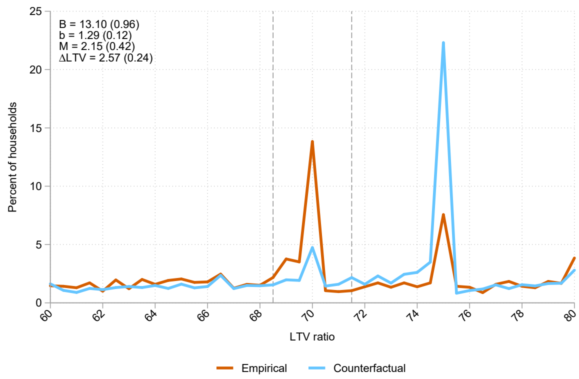
(c) Intermediate, lower threshold



(d) Intermediate, upper threshold



(e) Unconstrained borrowers, lower threshold



(f) Unconstrained borrowers, upper threshold

Figure A3. Bunching by Payment-to-income at LTV=50 (left) and LTV=70 (right)

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio for three different groups based on their counterfactual discretionary income. The estimation for the lower threshold on the left is carried out using all loans with LTV ratios between 20 and 65 percent, but only shows the distribution between 40 and 60. The estimation for the upper threshold on the right is carried out using all loans with LTV ratios between 55 and 80 percent, but only shows the distribution between 60 and 80. The orange lines plots the empirical density, where each dot represents the percent of mortgages within each 0.5 percent LTV bin. The blue lines plots the counterfactual density estimated using the procedure described in Section 3. The figures reports the estimated percent of households that bunch at the threshold (B), the excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculations are described in Section 3. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.

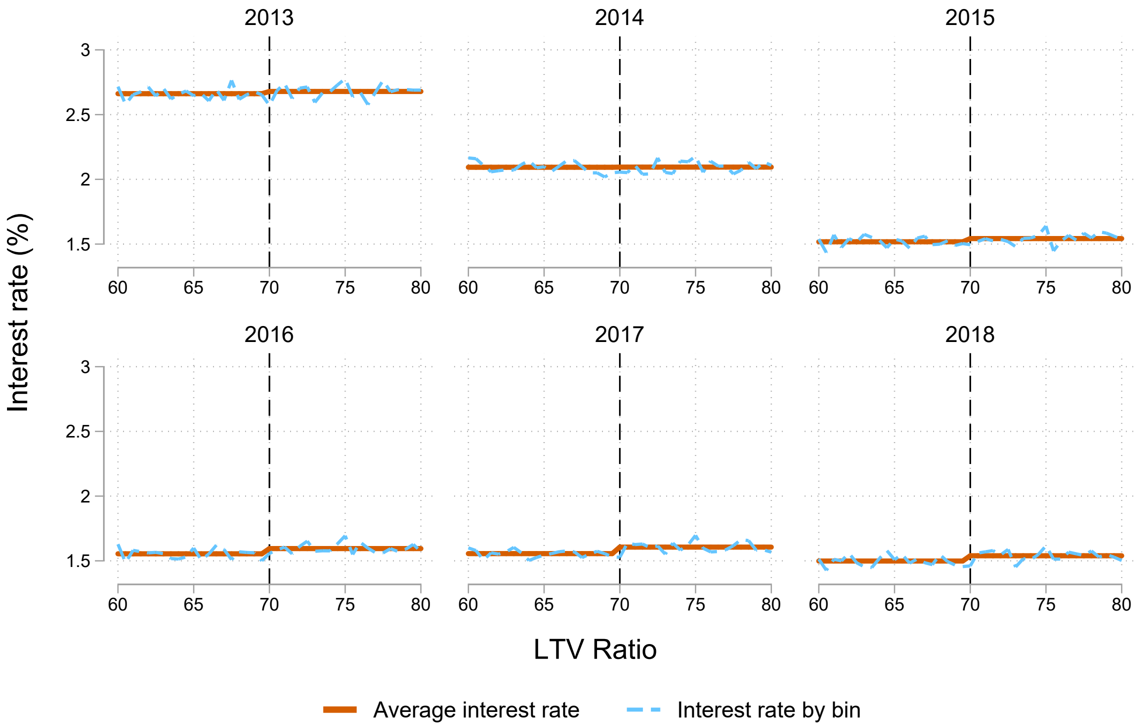
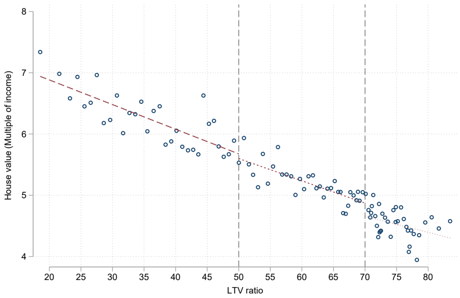
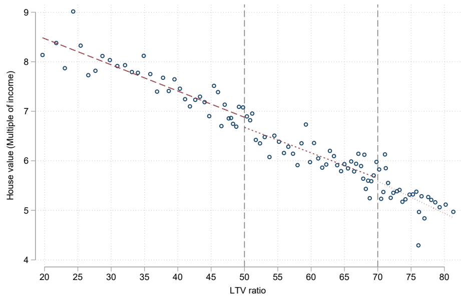


Figure A4. Interest rates around the upper LTV threshold

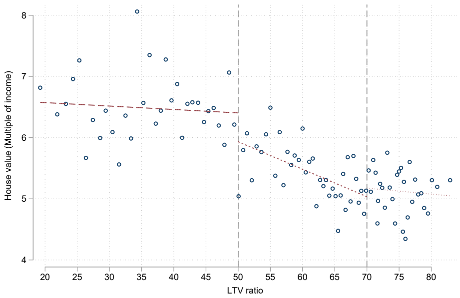
Notes: The figure plots the average mortgage rate by LTV bin (blue dashed line) and the average mortgage rate (orange solid line) above or below the upper threshold at an LTV of 70 percent marked by the black dashed line.



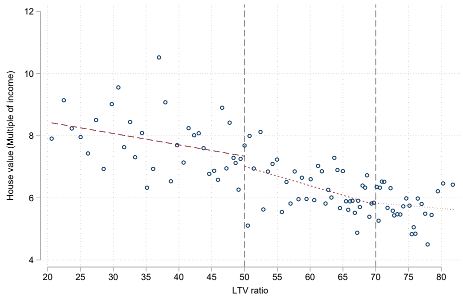
a) Refinancers, internal valuation, 2011-2015



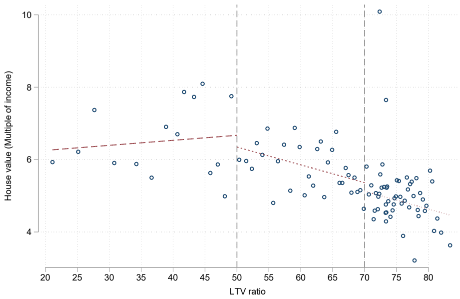
b) Refinancers, internal valuation, 2016-2018



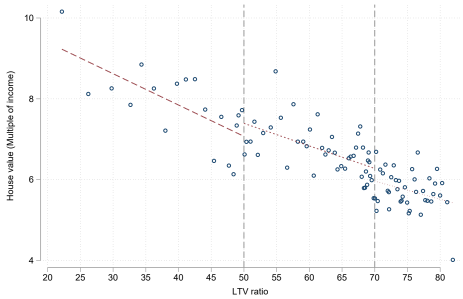
c) Refinancers, external valuation, 2011-2015



d) Refinancers, external valuation, 2016-2018



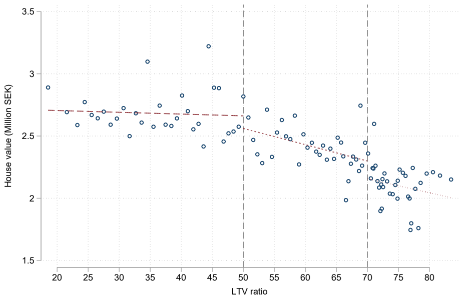
e) Homebuyers, 2011-2015



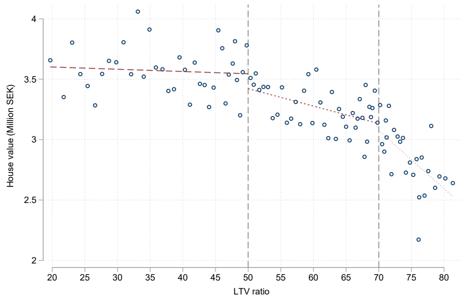
f) Homebuyers, 2016-2018

Figure A5. Housing values relative to income by LTV ratio

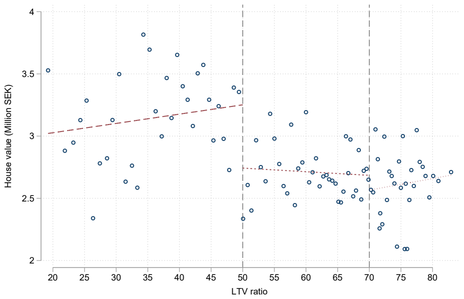
Notes: The figure plots the distribution of house values as a multiple of annual disposable income by LTV ratio. Using data for the pre- and post-requirement periods, each dot displays the average house value as a multiple of annual disposable income per LTV bin, after filtering out region-by-year and dwelling type fixed effects. The linear fitted curves are estimated separately for the LTV intervals ranging from 20-50, 50-70 and 70-80, respectively. Panels a) and b) plot the distributions for refinancers with a valuation done by the bank. Panels c) and d) plot the distributions for refinancers using an external valuation. Panels e) and f) plot the distributions for homebuyers. The dashed vertical lines display the amortization requirement's LTV thresholds at 50 and 70 percent.



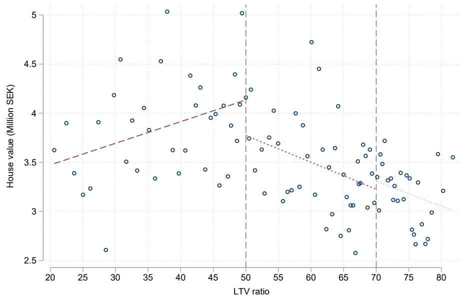
a) Refinancers, internal valuation, 2011-2015



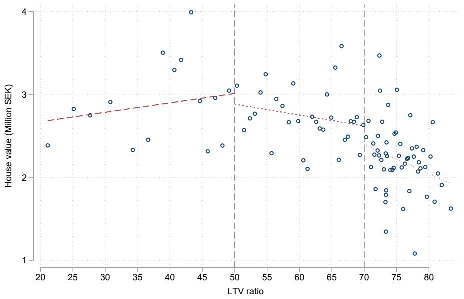
b) Refinancers, internal valuation, 2016-2018



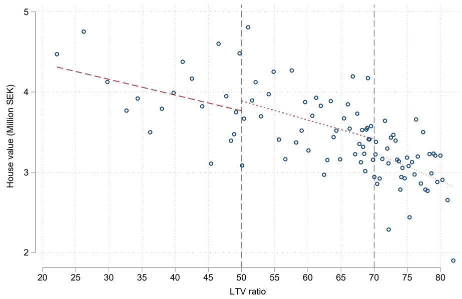
c) Refinancers, external valuation, 2011-2015



d) Refinancers, external valuation, 2016-2018



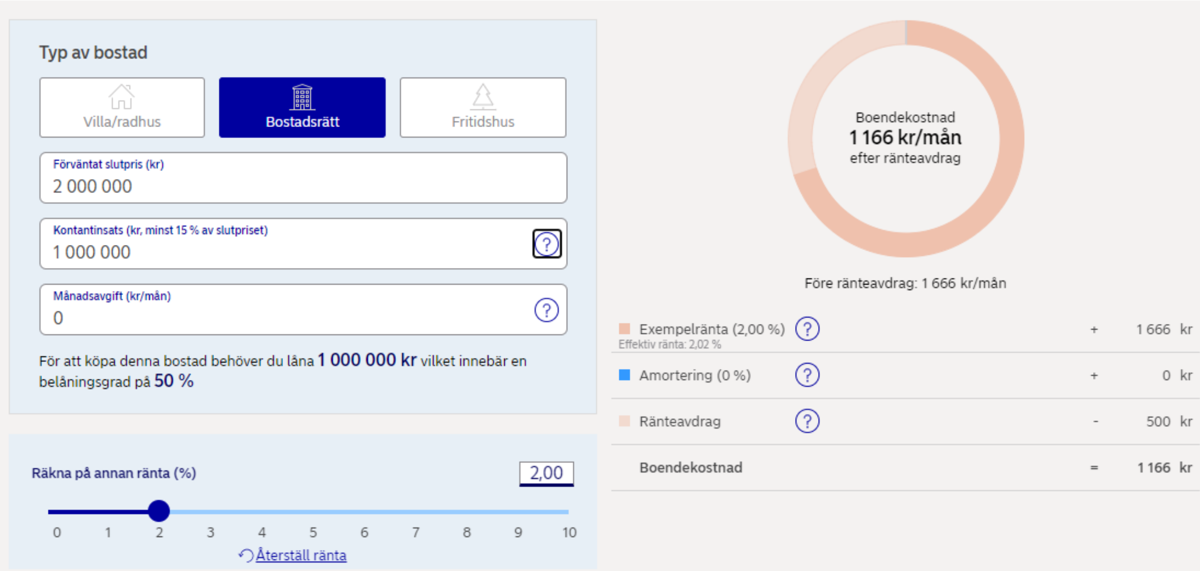
e) Homebuyers, 2011-2015



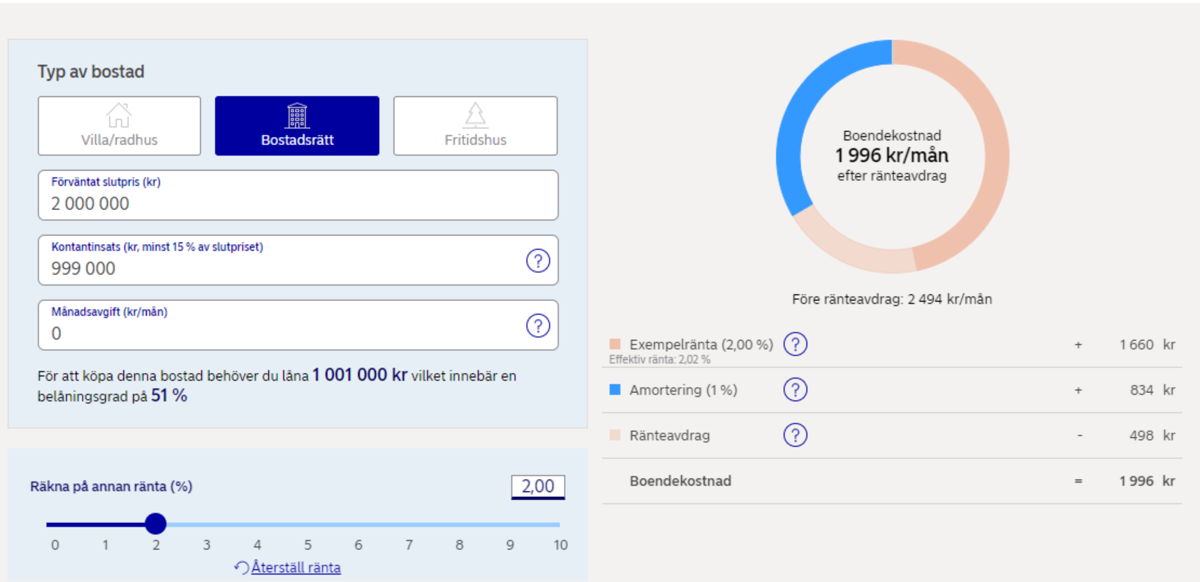
f) Homebuyers, 2016-2018

Figure A6. Housing values by LTV ratio

Notes: The figure plots the distribution of house values by LTV ratio. Using data for the pre- and post-requirement periods, each dot displays the average house value per LTV bin, after filtering out region-by-year and dwelling type fixed effects. The linear fitted curves are estimated separately for the LTV intervals ranging from 20-50, 50-70 and 70-80, respectively. Panels a) and b) plot the distributions for refinancers with a valuation done by the bank. Panels c) and d) plot the distributions for refinancers using an external valuation. Panels e) and f) plot the distributions for homebuyers. The dashed vertical lines display the amortization requirement's LTV thresholds at 50 and 70 percent.



(a) No amortization (LTV = 50%)



(b) With amortization (LTV = 51%)

Figure A7. Online tool for calculating mortgage payments

Notes: The figure provides an example of a mortgage calculator provided by a large Swedish bank. To generate the figure, we have selected an apartment (bostadsrätt) with an expected price of 2 million SEK (Förväntat slutpris") and an interest rate (exempelränta) of 2 percent, close to the average of 2.19 from Table B1. The top panel uses a downpayment value (kontantinsats) of 1 million SEK, which corresponds to a loan-to-value (belåningsgrad) of 50%. The corresponding amortization payment (amortering) is 0%, as seen on the right of the figure. The total cost for the mortgage (boendekostnad) is then 1,166 SEK. The bottom panel uses a downpayment value of 999,000 SEK, which corresponds to a loan-to-value) of 51%. The corresponding amortization payment is 1% or 834 SEK, as seen on the right of the figure. The total cost for the mortgage is then 1,996 SEK.

B Internet Appendix: Tables

Table B1. Summary statistics

	(1) Full Sample	(2) Near constraint	(3) Intermediate	(4) Far from constraint
Demographics				
Main borrowers age	44.63	44.01	43.91	46.47
	(14.89)	(15.83)	(14.79)	(13.25)
Household size	2.18	1.98	2.07	2.62
	(1.14)	(1.15)	(1.09)	(1.07)
Large city	0.45	0.46	0.43	0.45
	(0.50)	(0.50)	(0.49)	(0.50)
Disposable income, KSEK	40.68	32.58	39.15	55.26
	(83.31)	(14.97)	(139.20)	(50.22)
Loan sizes (MSEK)				
Total debt	1.86	1.80	1.73	2.12
	(1.63)	(1.53)	(1.44)	(1.93)
Mortgage debt	1.49	1.48	1.39	1.61
	(1.24)	(1.23)	(1.14)	(1.34)
House price	2.45	2.50	2.20	2.68
	(2.15)	(2.26)	(1.82)	(2.28)
Interest Rates				
Mortgage rate	2.19	2.07	2.21	2.34
	(0.83)	(0.75)	(0.84)	(0.92)
Mortgage fixation period (months)	13.30	12.77	13.54	13.85
	(15.65)	(15.37)	(15.69)	(15.99)
Adjustable rate mortgage	0.61	0.63	0.60	0.59
	(0.49)	(0.48)	(0.49)	(0.49)
Amortization				
Amortization, KSEK	1.61	1.57	1.58	1.70
	(1.92)	(1.81)	(1.79)	(2.20)
Amortization rate	1.73	1.62	1.81	1.84
	(2.60)	(2.30)	(2.66)	(2.96)
Amortization to income	4.11	4.71	4.07	3.22
	(4.15)	(4.49)	(4.00)	(3.56)
Mortgage Characteristics				
Loan to value	65.43	64.65	67.30	64.45
	(22.97)	(23.41)	(22.05)	(23.20)
Total debt to income	377.95	432.41	359.95	313.28
	(218.47)	(227.32)	(206.73)	(195.36)
Net interest to income	5.55	6.04	5.41	4.95
	(3.76)	(3.78)	(3.72)	(3.66)
Debt service to income	10.87	11.96	10.70	9.35
	(6.80)	(7.05)	(6.57)	(6.33)
N	120,307	50,490	37,823	31,994

Notes: The table reports means and standard deviations (in parentheses). Column 1 provides results for the full sample. Columns 2-4 divides by sample according to the borrowers' counter-factual discretionary income. We calculate the counter-factual discretionary income as the discretionary income given your chosen LTV, minus the extra payments if you would have borrowed 1%-point more in LTV. The Near constraint, Intermediate and unconstrained sample has a counter-factual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK and greater than 15,000 SEK, respectively. KSEK is thousands of Swedish krona, and MSEK is millions of Swedish krona. Demographic variables include the main borrower age and household size. *Large city* is a dummy variable equal to one if the borrower lives in one of the three largest cities (Stockholm, Malmö or Gothenburg). *Disposable income, KSEK* is disposable income adjusted for inflation in thousands of Swedish krona per month. *Total debt* is defined as mortgage debt plus unsecured credit. *House price* is the collateral value in millions of SEK, which in most cases is based on bank's internal valuations of properties, or transaction prices otherwise. These internal valuations use previous transaction prices and local hedonic price indices. *Mortgage fixation period* is the number of months for which the mortgage has a fixed interest rate. *Adjustable rate mortgage* is a dummy equal to one if the fixation period 3 months or less, i.e. if the mortgage has a variable interest rate. *Mortgage amortization, KSEK* is the monthly amortization payment in thousands of SEK. *Mortgage amortization rate* is calculated as mortgage amortization divided by mortgage debt. *Mortgage amortization to income* is calculated as mortgage amortization divided by disposable income. *Loan to value* is calculated as mortgage debt divided by house price. *Total debt to income* is calculated as total debt divided by annual disposable income. *Net interest to income* is calculated as interest payments divided by disposable income. *Debt service to income* is calculated as the sum of interest payments and amortization payments, divided by disposable income.

Table B2. Summary of main estimates

	Lower threshold (Notch at LTV=50)	Upper threshold (Notch at LTV=70)
Bunching	7.47	12.93
	(0.31)	(0.38)
Excess mass	1.28	1.36
	(0.08)	(0.06)
Missing mass	-0.83	-1.43
	(0.16)	(0.20)
Δ LTV	2.57	2.73
	(0.16)	(0.12)
Elasticity	0.25	0.15
	(0.03)	(0.01)
Number of households	35747	39946

Notes: The table summarizes the main bunching estimates. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). *Missing mass* is the percent of households missing, calculated using equation (3). Δ LTV is the estimate of the behavioral response, or the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4). *Elasticity* is the estimated percentage change in LTV for a one percentage point higher amortization rate, calculated using equation (5). Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

Table B3. Robustness of empirical results

	Notch at LTV = 50							
	Bin width = 0.5					Bin width = 1		
			Preferred					
Lower limit (L)	47.5	48	48.5	49	49.5	47	48	49
Bunching (B)	8.00	7.92	7.47	7.12	6.43	7.98	7.80	7.03
	(0.34)	(0.34)	(0.31)	(0.30)	(0.27)	(0.36)	(0.34)	(0.32)
Excess mass (b)	1.02	1.16	1.28	1.50	1.80	0.80	0.99	1.22
	(0.06)	(0.07)	(0.08)	(0.10)	(0.12)	(0.05)	(0.06)	(0.08)
Δ LTV	3.05	2.91	2.57	2.26	1.80	3.20	2.97	2.43
	(0.18)	(0.18)	(0.16)	(0.15)	(0.12)	(0.19)	(0.18)	(0.16)
Elasticity	0.35	0.32	0.25	0.19	0.12	0.39	0.33	0.23
	(0.04)	(0.04)	(0.03)	(0.03)	(0.02)	(0.04)	(0.04)	(0.03)
Upper limit (U)	50.5	51	51.5	52	52.5	51	52	53
Missing mass (M)	-0.26	-0.64	-0.83	-0.88	-1.10	-0.58	-0.83	-1.22
	(0.09)	(0.14)	(0.16)	(0.20)	(0.23)	(0.14)	(0.20)	(0.26)
Number of households	35747							

	Notch at LTV = 70							
	Bin width = 0.5					Bin width = 1		
			Preferred					
Lower limit (L)	67.5	68	68.5	69	69.5	67	68	69
Bunching (B)	13.82	13.43	12.93	12.28	10.75	13.82	13.39	12.37
	(0.41)	(0.39)	(0.38)	(0.37)	(0.34)	(0.44)	(0.41)	(0.38)
Excess mass (b)	1.12	1.23	1.36	1.53	1.75	0.85	1.07	1.30
	(0.05)	(0.05)	(0.06)	(0.07)	(0.08)	(0.03)	(0.04)	(0.06)
Δ LTV	3.36	3.06	2.73	2.29	1.75	3.42	3.21	2.61
	(0.14)	(0.13)	(0.12)	(0.10)	(0.08)	(0.14)	(0.13)	(0.12)
Elasticity	0.22	0.18	0.15	0.10	0.06	0.23	0.20	0.13
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
Upper limit (U)	70.5	71	71.5	72	72.5	71	72	73
Missing mass (M)	-0.48	-0.75	-1.43	-1.88	-2.50	-0.93	-1.89	-2.92
	(0.11)	(0.16)	(0.20)	(0.23)	(0.26)	(0.17)	(0.24)	(0.30)
Number of households	39946							

Notes: The table summarizes the robustness of the bunching estimates when varying the width of LTV bins and the upper and lower limits of the excluded region around the notch. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). Δ LTV is the estimate of the behavioral response, or the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 5. *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (3). Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

C Internet Appendix: Additional bunching estimates

This section provides additional bunching estimates. Section C.1 describes how the measure the amortization elasticity of mortgage demand. Section C.2 provides the results for the upper threshold. Section C.3 describes how we estimate bunching using a flexible polynomial approach, and provides the results.

C.1 Calculating the amortization elasticity of mortgage demand

The amortization requirement creates a jump in mortgage payments for borrowers because the rate above the threshold applies to the entire mortgage instead of the excess amount above the threshold. In other words, the requirement creates a discontinuous change in the *average* amortization payment instead of a discontinuous change in the *marginal* rate. Since elasticities relate marginal changes in costs to marginal changes in quantities, we cannot use the jump in payments created by the requirement to calculate the elasticity. We instead follow DeFusco & Paciorek (2017) and Kleven & Waseem (2013) and calculate an implicit marginal amortization rate on the mortgage. The idea behind the approach is to relate the reduction in LTV ratios to the change in the implicit marginal amortization rate created by the requirement. Specifically, define the implicit marginal amortization rate α^* for $LTV > \overline{LTV}$ such that:

$$(LTV - \overline{LTV}) \cdot \alpha^* = LTV \cdot (\alpha_0 + \Delta\alpha) - \overline{LTV} \cdot \alpha_0 \tag{15}$$

The above equation states that the implicit marginal amortization rate α^* on the mortgage above the requirement threshold $(LTV - \overline{LTV})$ is equal to the amortization rate above the threshold $(\alpha_0 + \Delta\alpha)$, minus the amortization rate at the LTV threshold (α_0). Solving this equation for α^*, we have

$$\alpha^* = \alpha_0 + \Delta\alpha + \Delta\alpha \cdot \frac{\overline{LTV}}{(LTV - \overline{LTV})} \tag{16}$$

The equation shows that α^* is equal to the amortization rate below the threshold plus the change in the amortization rate above the threshold, plus the change times a term that is decreasing in the distance between the LTV ratio and the threshold. Placing yourself just above the threshold gives a small increase in the LTV but a large increase in amortization payments, as the jump in the rate applies to the whole mortgage. Loans just above the limit imply a very large marginal amortization rate: for example, the marginal amortization rate for a mortgage with an LTV of 51 percent on the last 1 percent of the LTV is then equal to $\alpha^* = 0 + 0.01 + 0.01 \cdot \frac{50}{(51-50)} = 51$ percent.

We can relate these marginal amortization rates to the percent reduction in LTVs. The semi-elasticity of borrowing with respect to the amortization rate is equal to the following:

$$e^{\alpha} = \frac{\Delta LTV/\overline{LTV}}{\alpha^*(\overline{LTV} + \Delta LTV) - \alpha_0} \tag{17}$$

where we relate the percent change in the LTV ratio (calculated as the behavioral response, ΔLTV, divided by the LTV at the threshold, $\overline{LTV}$), to the implicit change in the level of the marginal amortization rate for the marginal buncher from equation (16).

C.2 Bunching at the upper threshold

This section presents the results for the upper threshold. Recall that there are several potential confounding effects relevant to this threshold. First, some new borrowers may already choose an LTV ratio of 70 percent in the pre-requirement years because of a previous recommendation that households amortize on the portion of the mortgage in excess of a 70 percent LTV ratio. The previous recommendation represents a potential downward bias in our estimates, as borrowers may bunch even in the pre-requirement period. Second, several banks offer mortgages with a higher marginal interest rate on the part of the mortgage with an LTV above 75 percent (a so-called "top loan"). This incentive was phased out over time as banks abolished the top-loan system but did provide an incentive to bunch at a nearby threshold in the years before the requirement. The marginal interest rate changes above LTV ratios of 75 percent, and a borrower may want to reduce their borrowing to avoid this higher interest rate.

The results for the amortization threshold at LTV ratios of 70 percent are presented in Figure C1. Similar to Figure 4, the figure plots the observed distribution using data from the post-requirement years and the counter-factual distribution estimated using pre-requirement data. The estimation procedure uses data from borrowers with LTV ratios between 55 and 80 percent to avoid the lower threshold and the maximum LTV ratio at 85 percent affecting the results. There are two spikes at LTV ratios of 70 and 75 percent in Figure C1.

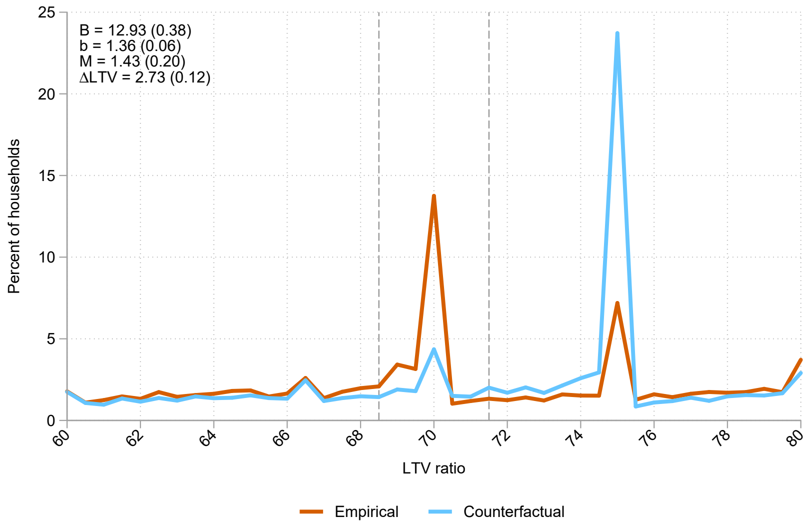


Figure C1. Bunching at LTV=70

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio. The estimation is carried out using all loans with LTV ratios between 55 and 80 percent, but only shows the distribution between 60 and 80. The orange line plots the empirical density, where each dot represents the percent of mortgages within each 0.5 percent LTV bin. The blue line plots the counterfactual density estimated using the procedure described in Section 3. The figure reports the estimated percent of households that bunch at the threshold (B), the excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 3. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.

For the pre-requirement period, the peak at LTV ratios of 75 percent is considerably larger than the peak at LTV ratios of 70 percent. For lower LTV ratios, the empirical and counterfactual densities are almost identical, showing that the procedure is well able to approximate the distribution. The bunching statistic $\widehat{B}$ shows that 12.93 percent of borrowers decide to bunch (standard error 0.38), an increase by a factor $\widehat{b} = 1.36$. Dividing the bunching statistic by the counter-factual distribution at the threshold, we find that the marginal buncher reduces its LTV ratio by 2.73 percentage points (standard error 0.12) due to the amortization requirement. The effect is marginally higher than the reduction in LTV ratios of 2.57 percent at the lower threshold. Finally, we find 1.43 percent ($\widehat{M} = 1.43$, standard error 0.2) fewer borrowers to the right of the threshold in the post-requirement years compared to the pre-requirement years.

We again calculate the amortization semi-elasticity using equation (5). With the estimated ΔLTV of 2.73, the numerator equals $2.73/70 = 0.039$. Using the implicit rates from equation (16), the denominator is equal to $\alpha^* = 0.01 + 0.01 + 0.01 \cdot \frac{70}{(72{,}73-70)} = 0.276$, and the semi-elasticity is equal to $0.039/0.276 = 0.14$. A one percentage point increase in the amortization rate decreases LTV ratios by 0.14 percent.

Table C1. Bunching estimates by type of payment constraints

PTI Constraint	Near constraint	Intermediate	Far from constraint
Bunching	13.16	13.29	13.10
	(0.58)	(0.71)	(0.96)
Excess mass	1.42	1.46	1.29
	(0.10)	(0.11)	(0.12)
Missing mass	-1.28	-0.94	-2.15
	(0.32)	(0.40)	(0.42)
Δ LTV	2.84	2.92	2.57
	(0.20)	(0.22)	(0.24)
Elasticity	0.16	0.17	0.13
	(0.02)	(0.02)	(0.02)
Number of households	15949	12127	10242

Notes: The table compares the main bunching estimates across groups based on payment-to-income constraints. We calculate the counter-factual discretionary income as the discretionary income given your chosen LTV, minus the extra payments if you would have borrowed 1%-point more in LTV. The Near constraint, Intermediate and Far from constraint sample has a counter-factual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK and greater than 15,000 SEK, respectively. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). Δ LTV the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 5. Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

C.2.1 Payment constraints at the upper threshold

We found limited evidence that credit constraints were an important determinant of bunching for the lower threshold. We now present similar evidence for the upper threshold. We begin by noting that the share of bunchers facing binding credit constraints at this threshold is somewhat larger than at the lower threshold: 32.6 percent at the upper threshold compared to 13.6 percent at the lower threshold. We define three groups of borrower based on counterfactual discretionary income, and estimate bunching separately for each group. For the near constraint group, increasing leverage by one percentage point implies a reduction in discretionary income by 88 percent.

The results are presented in Table C1. Overall, the results are consistent with the previous results for the lower threshold. There is little variation in bunching across the three groups, with similar levels of bunching for the Near contraint group and the Far from constraint group. The estimated ΔLTV is 2.84 for the Near contraint group and 2.57 for the Far from constraint group.

Table C2. Bunching estimates by type of valuation

Valuation	Internal	External	Purchase price
Bunching	12.88	6.40	19.13
	(0.43)	(1.05)	(1.01)
Excess mass	1.36	0.58	2.68
	(0.07)	(0.11)	(0.32)
Missing mass	-1.38	-0.53	-1.68
	(0.24)	(0.66)	(0.54)
Δ LTV	2.72	1.17	5.36
	(0.13)	(0.23)	(0.63)
Elasticity	0.15	0.03	0.54
	(0.01)	(0.01)	(0.12)
Number of households	30500	5111	4335

Notes: The table compares the bunching estimates across valuation modes for collateral assessments. For refinancers, banks use either an internal (statistical) valuation model, or an external method, either a tax-assessed value or an independent appraisal. For homebuyers, the purchase price is used. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (3). Δ LTV is the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 5. Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

C.2.2 Endogenous housing demand responses at the upper threshold

We move on to estimates of the response by refinancers and homebuyers at the upper threshold. We find interesting heterogeneity across refinancers and homebuyers. Bunching and ΔLTV is considerably higher for homebuyers, with 19.13 percent of households bunching with a corresponding reduction in LTV ratios of 5.36 percentage points, or $5.36/70 = 7.6\%$. A natural explanation is that homebuyers are more credit constrained than refinancers, which forces them to adjust their LTV ratios by either adjusting the loan size or housing demand. Indeed, we find that homebuyers at the upper threshold are more likely credit constrained, according to the definition in section 4.2. 53 percentof these homebuyers are constrained, compared to 33 percent at the lower threshold.

C.3 Bunching Estimates from Polynomials

This section provides additional results where we estimate the counter-factual distribution using the standard approach in the literature of fitting a flexible polynomial to the distribution and excluding an area around the threshold (see Kleven, 2016, for an overview).

We begin by grouping households into bins based on their Loan-to-Value ratio and calculate the fraction of households in each bin. We then fit the following regression:

$$n_j = \sum_{i=0}^{p} \beta_i (m_j)^i + \sum_{k=L}^{U} \gamma_k \mathbf{1}(m_k = m_j) + \epsilon_j, \tag{18}$$

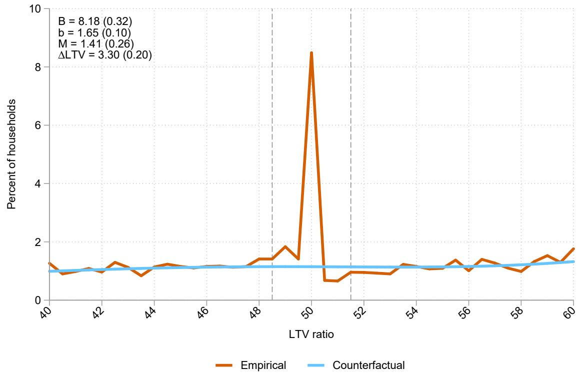
where n_j is the fraction of households in bin j and m_j is loan-to-value ratio of the loan. The first term is a p-th degree polynomial in LTV ratios, and the second term is a set of dummy variables for each bin in the excluded region $[L, U]$. The estimates of the counter-factual distribution are given by the predicted values from the above regression while omitting the effect of the dummies in the excluded region:

$$\hat{n}_j = \sum_{i=0}^{p} \hat{\beta}_i (m_j)^i \tag{19}$$

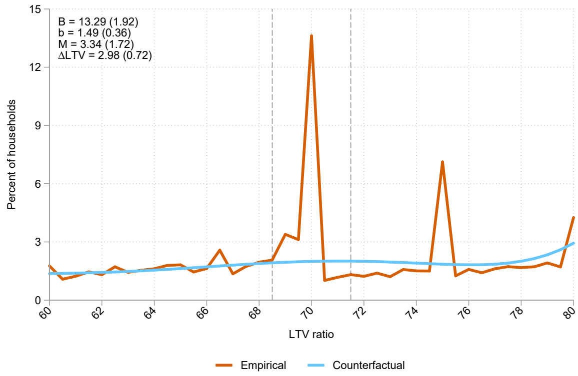
The identifying assumption to estimate the causal effect of the amortization requirement is that the counter-factual LTV distribution is smooth. This precludes spikes in the distribution at the thresholds that are unrelated to the amortization requirement.

As in the main analysis, the estimates of bunching and missing mass are calculated by comparing the counter-factual distribution to the empirical distribution in the relevant regions (see equations 1 and 3). We use the procedure in Chetty *et al.* (2011) to calculate standard errors for all estimated parameters. Specifically, we randomly draw from the residuals in equation 18 with replacement to generate new bootstrapped bin fractions. We then re-estimate the bunching parameters. Standard errors are calculated as the standard deviation of the bootstrap estimates.

Figure C2 plots the empirical and counterfactual density of mortgage loans by LTV ratio, in the region around the notches in the amortization requirement. The figure is generated using the same bin width and width of the excluded region (L and U) as for the difference-in-bunching approach, while the order of the polynomial (p) was determined to minimize the difference between bunching and missing mass. To demonstrate robustness, we follow Kleven & Waseem (2013) and DeFusco & Paciorek (2017) and estimate many specifications that vary in the order of the polynomial (p), the bin width and the width of the excluded region to the left of the notch (L), while the width of the excluded region to the right of the notch (U) is determined by an iterative procedure that aims to equate the degree of bunching with the missing mass. Figure C3 provides a histogram of the estimated behavioral response ΔLTV across all these specifications. Our main estimates are in the conservative region of the outcomes using post-



(a) Lower threshold



(b) Upper threshold

Figure C2. Bunching estimates from polynomials

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio, in the region around the notch at LTV = 50 (Panel a) and the notch at LTV = 70 (Panel b). The orange line is the empirical density, where each dot represents the percent of mortgages within each 0.5 percent LTV bin. The blue line is the counterfactual density, estimated by fitting a flexible polynomial to the observed distribution, excluding the region around the notch. The figure also reports the estimated percent of loans that bunch at the threshold (B), excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 3. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.

reform data; the figure shows that a 2 percentage points decline in LTV is roughly the lower bound. Interestingly, using pre-reform data, some specifications still result in significant, albeit lower, estimated behavioral responses, while there shouldn't be any response. Most likely, this comes from the presence of rounding and/or the SBA's prior recommendation to amortize loans with LTV above 70. This strengthens our choice to use pre-requirement years as the counterfactual, which controls for such factors directly and does not rely on the identifying assumption of smooth counterfactual distributions.

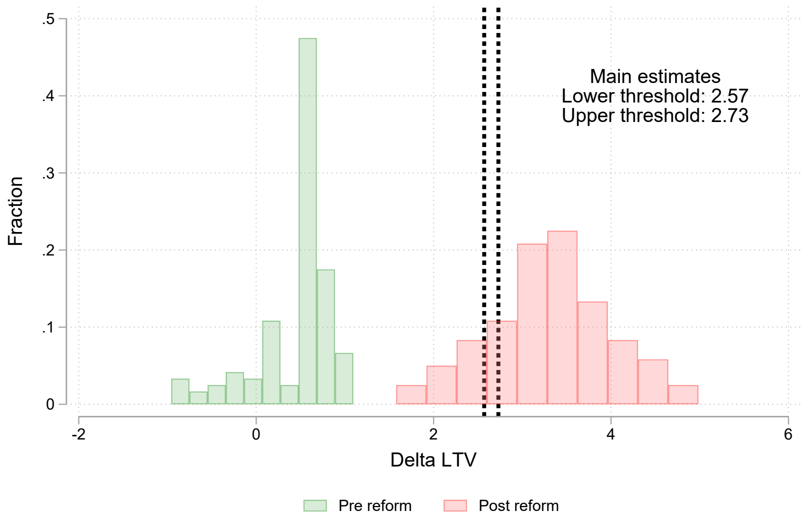


Figure C3. Robustness of estimated behavioral responses

Notes: The figure plots the distribution of estimated behavioral responses (ΔLTV) using the flexible polynomial approach. The red bars use post-requirement data only (years 2016-2018) while the green bars use pre-requirement data (years 2011-2015). The vertical black dashed lines depict our main estimates of the behavioral response using the difference-in-bunching approach. The specifications differ in their bin width (0.5 or 1 percent bins), the order of the polynomial ($p \in [3, 5, 7, 9, 11, 13]$) and the initial width of the excluded region to the left of the notch ($L \in [0.5, 1, 1.5]$ for a bin width of 0.5, and $L \in [1, 2]$ using a bin width of 1).

D Internet Appendix: Calibration

Table E1 shows the parameters set outside of the model of Section 5. Here we describe how we calculate the parameters in more detail.

Table E1. Model parameter values

Parameter	Symbol	Value	Source
Income process:			
Income persistence	ρ	0.97	Kovacs & Moran (2021)
Std dev income shocks	σ_ϵ	0.180	Kovacs & Moran (2021)
Income constant	d_0	8.2007	Kovacs & Moran (2021)
Income *Age* effect	d_1	0.1378	Kovacs & Moran (2021)
Income Age^2 effect	d_2	-0.0019	Kovacs & Moran (2021)
Income Age^3 effect	d_3	0.000007	Kovacs & Moran (2021)
Household preferences:			
Time preference	β	1.02^{-1}	Attanasio *et al.* (2012)
Risk aversion	γ	1.43	Attanasio *et al.* (2012)
Housing utility (separable)	μ	0.26	Attanasio *et al.* (2012)
Housing utility (non-separable)	θ	0.115	Attanasio *et al.* (2012)
Disutility of renting	ζ	0.03	Leombroni *et al.* (2020)
Disutility of amortization	Δ_k	0.05	Author's calibration
Disutility of renegotiation	Δ_n	1.2	Author's calibration
Assets:			
Real return on liquid asset	r	0.0181	Swedish 3 month T-bill
Real return on housing	r^H	0.02953	Statistics Sweden
Mortgage interest rate	r^M	0.0087	Statistics Sweden
Multiplicative cost of refinancing	f_2	5%	Federal Reserve Board (2008)
Additive cost of refinancing	f_3	\$3000	Federal Reserve Board (2008)
Downpayment requirement	ψ	0.15	Swedish law
Financial cost to moving homes	F	0.05	OECD (2011)
Initial conditions:			
Std Dev Initial Income	σ_0	0.410	Kovacs & Moran (2021)
Share with zero initial assets	a_0^{zero}	0.433	Kovacs & Moran (2021)
Cond. mean initial assets	μ_{a_0}	7.117	Kovacs & Moran (2021)
Cond. std dev initial assets	σ_{a_0}	1.972	Kovacs & Moran (2021)
Demographics:			
Age at labor market entry	$t=0$	22	Attanasio *et al.* (2012)
Age of retirement	W	65	Attanasio *et al.* (2012)
Age of certain death	T	120	Statistical life tables

Housing transaction costs. We assume that moving homes requires households to pay a transaction cost F equal to 5 % of the value of the house. F represents costs to real estate agents, lawyers, surveyors, and moving companies. The high value of F is consistent with empirical evidence from OECD (2011). We set the rental scale equal to $\eta = 0.035$ to match the lower bound of the rent-price ratio time series in Leombroni *et al.* (2020).

Initial wealth. We assume zero initial housing wealth. We set the initial liquid wealth distribution to match the distribution for 22-25-year old households in the PSID, following

Kovacs & Moran (2021). We use that 43.3 percent of households have zero liquid assets at age 22. Conditional on observing positive assets, the mean log liquid asset holdings are estimated to be $\mu_{a_0} = 7.117$, with a conditional standard deviation of $\sigma_{a_0} = 1.972$.

Income. We set the values of the earning process following Kovacs & Moran (2021), who estimate the earnings process using the two-step minimum distance approach by Guvenen (2009) and Low *et al.* (2010). These authors estimate the parameters of the deterministic component of income (g_t) by approximating it with a third-order polynomial in age. They identify the stochastic income component as $z_{it} = \ln y_{it} - g_t$. In the second step, they estimate the persistence of income risk (ρ), the variance of income innovations (σ_ϵ^2), and the variance of initial income (σ_0^2). These authors find very persistent income innovations, with a coefficient of $\rho = 0.97$. The parameter estimates for the income process are generally in line with the rest of the literature. More details about the estimation strategy and results are available in Appendix C.2.2 in Kovacs & Moran (2021).

Refinancing costs. We assume that the multiplicative cost to refinancing f_2 is 5% and that the additive cost to refinancing f_3 is \$3000. The cost of refinancing reflects a range of fees related to mortgage refinancing.

Asset returns. We calibrate the model using real risk-adjusted returns. Starting with a consumption-based pricing equation, we can write the asset return in terms of prices and dividends:

$$r_{t+1} = \frac{p_{t+1} + d_{t+1} - p_t}{p_t} \tag{20}$$

where r_{t+1} is the net return on the asset between periods t and $t+1$, p_t is the price of the asset in period t, and d_{t+1} is the dividend in period $t+1$.

For liquid assets, we measure the real return on 3-month Swedish Treasury bills between 1982 and 2022. To calculate the return on housing, we assume that households who invest in housing enjoy housing service flows between periods t and $t+1$, but also have to pay maintenance and insurance costs related to homeownership. This allows us to write the return to housing as:

$$r_{t+1}^H = \frac{p_{t+1} + s_{t+1} - c_{t+1}^m - c_{t+1}^i - p_t}{p_t} \tag{21}$$

where s_{t+1} and c_{t+1} are housing service flow and the costs related to homeownership (maintenance cost c_{t+1}^m and insurance costs c_{t+1}^i). We follow Kaplan & Violante (2014) and assume that housing service flows and costs are proportional to house prices, allowing us to rewrite Equation (21) as

$$r^H_{t+1} = \frac{p_{t+1} + (s - c^m - c^i - 1)p_t}{p_t} \tag{22}$$

Following Kovacs & Moran (2021), we assume that net housing service flows is 8% a year. This value is calculated by dividing the average housing gross value added at current dollars from the Bureau of Economic Analysis (BEA) by the residential fixed assets at current dollars. The average is calculated between 1950 and 2016. Following Kaplan & Violante (2014), we set maintenance cost to 1% and the insurance cost to 0.35% of the value of housing.

We calculate risk-adjusted returns by subtracting the variance of the return from the expected return, following Kaplan & Violante (2014):

$$r^j_{adjusted} = E(r^j) - var(r^j) \tag{23}$$

where superscript j refers to the asset type, i.e. liquid assets or housing.