Mortgage Design, Repayment Schedules, and Household Borrowing*

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Abstract

How does the design of debt repayment schedules affect household borrowing? To answer this question, 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 5% lower borrowing. Wealthy borrowers drive the results, challenging credit constraints as the primary explanation. We develop a model to evaluate the mechanisms driving household behavior and find that much of the effect comes from households experiencing ongoing flow disutility to amortization payments. Our results indicate that mortgage contracts with low initial payments substantially increase household borrowing and lifetime interest costs.

JEL Classification: G51, G21, E21, E6

Keywords: Mortgage design; Amortization payments; Macroprudential policy; Bunching

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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 mortgage repayment represents a large share of aggregate household savings, similar in magnitude to pension contributions (Bernstein & Koudijs, 2024). While historically households had little choice over the repayment schedule, financial innovation during recent decades created a wide variety of alternative mortgage products that allow households to delay mortgage repayment (Cocco, 2013). Perhaps the most famous example is the *interest-only mortgage*, which surged in popularity in the mid-2000s, jumping to roughly 25 percent of mortgage originations in the United States during the run-up of mortgage debt prior to the financial crisis (Amromin *et al.*, 2018). Financial regulators around the world continue to grapple with the question of how to regulate this important feature of the mortgage contract.[1]

Despite the important role of the repayment schedule, we have little evidence on how this feature of the mortgage contract affects household borrowing. There are at least two contrasting views. On one hand, interest-only loans relax credit constraints, helping constrained households borrow out of their future income to better smooth consumption over the life-cycle and adverse shocks (Piskorski & Tchistyi, 2010; Cocco, 2013). On the other hand, many commentators have suggested that behavioral biases or other factors may lead households to increase borrowing when offered loans with delayed repayment. According to one such theory, both constrained and unconstrained consumers may prioritize low monthly payments, which are highly salient, rather than minimize the net present value of future interest expenditure (Argyle *et al.*, 2020). While we already have clear evidence on the role of credit constraints in mortgage lending, we know little about whether these other factors may affect borrowing decisions.

To better understand how the repayment schedule affects household borrowing, we require quasi-experimental variation in repayment schedules that affects households who are far from their credit constraints. To achieve this goal, we exploit a policy reform in Sweden that eliminated interest-only mortgages for borrowers with loan-to-value (LTV) ratios above 50 percent. In response to the reform, we find that many homebuyers make larger down payments, and existing borrowers extract less equity, leading to bunching just below the 50 percent LTV

[1] Countries have taken drastically different approaches. While the US strongly discourages interest-only mortgages, many European countries continue to allow them. In contrast, the UK has recently begun to encourage banks to offer mortgages with longer maturities to counteract high interest rates.

threshold. The reduction in borrowing is driven by relatively wealthy households with substantial additional borrowing capacity, 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, unconstrained households to reduce borrowing to avoid amortization. We find that much of the response is driven not by financial considerations but rather by psychic costs. More specifically, we find that households incur ongoing flow disutility to amortization payments, which leads them to prefer a mortgage with a low monthly payment, even if it comes with higher lifetime interest expenditure. Identification is driven by the fact that most of the bunching is generated without a missing mass, which alternative versions of the model without flow disutility fail to generate. Our results provide evidence that new mortgage products with delayed repayment schedules substantially increase household borrowing, even among relatively wealthy households who are far from other constraints.

In our empirical analysis, we exploit an amortization requirement introduced in Sweden in 2016 with the intent of reducing mortgage debt. Before 2016, interest-only mortgages constituted the majority of mortgage contracts in Sweden. The amortization requirement introduced minimum mandatory mortgage payments based on the borrower's loan-to-value (LTV) ratio. More specifically, for all mortgages issued after June 2016, borrowers with LTV ratios above 50 percent are required to repay at least 1 percent of the original loan each year, while borrowers with LTV ratios above 70 percent are required to repay at least 2 percent. Mortgages with LTV ratios below 50 percent are not required to amortize. Borrowers can reduce amortization payments once they get below the LTV thresholds. We estimate the response to the requirement using a difference-in-bunching estimator, using pre-requirement years to form the counterfactual LTV distribution at origination. 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.

While it would be easy to rationalize bunching by binding credit constraints, most households at the policy threshold have substantial additional borrowing capacity, thus challenging credit constraints as the primary driver of our empirical results. First, borrowers can take out substantially larger mortgages, up to a maximum LTV ratio of 85 percent. Second, while a payment-to-income (PTI) requirement may interact with the amortization requirement, most bunching households still have substantial additional borrowing capacity. More specifically, while roughly 14 percent of borrowers that bunch at the 50 percent LTV threshold are constrained by the PTI requirement, the remaining households could borrow at least an additional $67,000 (44 percent of our sample average) before facing binding payment constraints. Credit constraints are thus unable to explain our empirical results.

We assess the validity of our empirical approach and the robustness of our results along several dimensions. First, we confirm the validity of our empirical strategy using placebo tests, which show that previous years indeed provide a valid counterfactual LTV distribution. Second, estimating the counterfactual distribution using a polynomial approach (Kleven, 2016) yields larger estimates of the impact of the amortization requirement on household borrowing. Third, we find similar results for households that purchase a property compared to those who refinance, alleviating concerns about housing choice.[2] Finally, we investigate various supply-side factors (e.g., mortgage approval, collateral assessments, and refinancing costs) but find that none can explain our results. For instance, the interest rate is flat over the LTV threshold, thus indicating that bunching is not driven by mortgage pricing.

Motivated by the empirical evidence, we develop a theoretical framework to clarify the mechanisms that may lead wealthy households to bunch below the policy threshold to avoid amortization payments. We begin with a traditional life-cycle model of consumption, housing, and mortgage decisions in the spirit of Campbell & Cocco (2003) and Cocco (2004). In the model, credit-constrained households borrow to purchase housing while faced with uninsurable idiosyncratic income risk. Households borrow using long-term mortgage contracts with mandatory minimum payments. We allow for two policy regimes: interest-only (IO) mortgages and mandatory amortization payments for households above the 50 percent LTV threshold. The two policy regimes broadly represent the institutional framework in Sweden before and after the 2016 reform.

While the traditional model described above could easily generate reduced borrowing for poor households facing binding credit constraints, it cannot generate bunching by wealthy borrowers at the 50 percent LTV threshold. We provide intuition for the lack of bunching at this threshold by inspecting how expected discounted utility varies according to the LTV ratio. We find that the amortization requirement reduces expected utility for all households due to reduced

[2] For refinancers, the bank sets the home value exogenously based on their 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 ratio) and not from changes in housing choices (the denominator).

flexibility to smooth consumption in the spirit of Cocco (2013). That said, the amortization requirement does not create a discontinuous change at the policy threshold, and therefore does not generate bunching. The lack of bunching by wealthy households is robust to a wide variety of alternative assumptions related to preferences, returns, and refinancing costs.

If the traditional 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. We therefore turn our attention towards household preferences, extending the model with two broad classes of behavioral mechanisms that may generate either a notch or kink in preferences. We adopt a reduced-form approach to behavioral modeling, remaining agnostic about the specific behavioral biases that may create the wedge in household preferences, following Mullainathan *et al.* (2012).

The first broad mechanism is that households may experience a one-off disutility cost 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 percent LTV threshold is discontinuously worse than taking out a mortgage just below the threshold. This one-off disutility may occur if households experience a cost to mortgage renegotiation when calling the bank to turn off amortization payments once eligible. We model this as a utility cost, as monetary refinancing costs are low in Sweden. That said, various behavioral factors could generate a similar one-off cost, and our approach nests these possibilities. For example, if households are uncertain about their ability to turn off amortization, this would create a one-off cost. Similarly, if the policy 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 broad mechanism is that households may incur ongoing flow disutility from amortization payments. This mechanism generates a kink in preferences, as the effect is stronger for households further from the 50 percent LTV threshold, since these households must make amortization payments for more periods. There are various mechanisms that may generate ongoing flow disutility from amortization payments. For instance, households may perform "monthly payment targeting," where they focus on minimizing the monthly mortgage payment rather than minimizing the lifetime cost of the loan, in the spirit of Argyle *et al.* (2020). Alternatively, households may prefer 'set and forget' investment strategies, due to real or psychic portfolio adjustment costs. Or households may view amortization payments as a cost rather than a form of saving, in the spirit of Camanho & Fernandes (2018).[3] As a result of any of the above explanations, households may choose mortgage contracts with lower initial payments and higher lifetime interest costs, even when they could afford to do otherwise.

To disentangle the relative contribution of these two broad mechanisms, we exploit the fact that the one-off disutility cost generates a notch in household preferences while ongoing flow disutility generates a kink. This distinction is useful for identification, as notches generate bunching due to a dominated region with missing mass directly above the threshold, while in contrast, kinks alter the incentives for all households above the threshold, thus generating bunching without a 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 since the consequences of choosing a higher LTV are highly salient. We conclude that while both mechanisms play a role, most of the response is driven by households facing ongoing flow disutility to amortization.

Our results have important implications for understanding the link between financial innovation and household borrowing. In a world where households incur flow disutility to amortization, new mortgage products with low initial payments (e.g. mortgages with interest-only payments or longer maturities) greatly increase aggregate household borrowing. Moreover, such products substantially increase lifetime interest expenses. To demonstrate, we use our model to study one of the key aspects of financial innovation in US mortgage markets during the late 1990s and early 2000s: the transition from traditional 30-year mortgages to alternative mortgage products with less stringent repayment schedules. We begin with an economy where households only have access to 30-year amortizing mortgages, then suddenly allow households to borrow using IO mortgages. The introduction of IO mortgages increases mortgage debt by about 33 percent in our calibrated model. Using our model, we decompose the different channels driving increased borrowing, and find that roughly two-thirds of the increase comes from flow disutility, while the remaining one-third comes from relaxed credit constraints (in the spirit of Cocco, 2013). The policy change has a similar effect on interest expenditures, which also increase by 33

[3] 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 do not know (SBAB, 2018).

percent over the life-cycle. In short, we find that flow disutility amplifies the effects of financial innovation on household borrowing. The degree of amplification is heightened by the fact that we find a kink rather than notch in household preferences. Had households' observed behavior been driven by a notch, there would have been only a local effect on borrowing and thus less amplification relative to the traditional model.

Finally, we evaluate the relationship between mortgage amortization and household wealth accumulation in our calibrated model. Reassuringly, we find that our baseline model with flow disutility has good out-of-sample fit of the empirical evidence from Bernstein & Koudijs (2024), who show that every dollar of additional mortgage amortization leads to roughly a dollar of additional wealth accumulation, as homeowners do not meaningfully reduce their liquid savings in response to greater required mortgage repayment. We then use our model to decompose the different channels driving this relationship. We find that much of the effect comes from the presence of wealthy hand-to-mouth households, in the spirit of Kaplan & Violante (2014), with a small additional contribution coming from flow disutility to amortization. In short, flow disutility raises the shadow value of mortgage repayment, thus incentivizing homeowners to repay debt and build wealth more quickly in the form of home equity.

Taking stock, our findings have important implications for understanding household borrowing decisions. Our findings indicate that borrowers are highly sensitive to initial monthly mortgage payments, beyond what would be suggested by credit constraints alone. As a result, changes in mortgage repayment schedules have large effects on aggregate borrowing. Further, while we focus on the mortgage market, many of our results extend to other forms of consumer credit, where there is similar debate about how households respond to new financial products with longer maturities or lower initial payments. Better understanding such behavior is crucial for both consumer protection agencies thinking about the implications of new financial products, as well as macroprudential regulators concerned about aggregate debt levels.

We believe that there is substantial scope for further research, since the sensitivity of borrowing to monthly mortgage payments is consistent with multiple explanations. Overall, we conclude that observed borrowing behavior is being driven by a kink in household preferences, and can exclude many mechanisms related to credit constraints or one-off costs as unable to explain the majority of our results. That said, it is beyond the scope of the present paper to fully discern between the various potential mechanisms that may generate a kink in preferences.

We find this to be a promising avenue for future research. Moreover, while the present paper seeks to better understand household borrowing decisions when faced with alternative repayment schedules, we do not attempt to evaluate the welfare effects of mandatory amortization, and believe more research will be needed to evaluate the various costs and benefits of mortgage amortization on household well-being.[4]

Related Literature. We see three main contributions of this paper. First, we provide novel evidence that repayment schedules affect borrowing decisions, even for unconstrained borrowers, which helps improve our understanding of household preferences for debt repayment. We view our results as complementary to Argyle *et al.* (2020), who find that consumers perform "monthly payment targeting" when choosing between auto loans, even in subsamples of unconstrained borrowers. In a similar spirit, Shu (2013) provides survey evidence of "NPV neglect," the tendency of borrowers to focus on the initial monthly payment, rather than minimize the net present value of future interest costs. Survey evidence by Camanho & Fernandes (2018) shows that many individuals decide whether to purchase housing based on the difference between monthly rental payments and monthly mortgage payments, even when the latter includes amortization payments. Overall, all of the above theories suggest that borrowing decisions should be more sensitive to monthly payments than future interest expenditures, even for unconstrained borrowers. Relative to the existing literature, we are the first to exploit quasi-experimental variation in required payments to study the effects of repayment schedules on household borrowing.

Second, we contribute to the growing literature on mortgage design, which has recently shown increasing interest in mortgage repayment schedules.[5] Bernstein & Koudijs (2024) show that amortization payments contribute substantially to household wealth accumulation. Campbell *et al.* (2021) study a model where an option to lower amortization payments in a recession helps to stabilize consumption. Guren *et al.* (2021) study an equilibrium model where countercyclical payment reductions reduce default and stimulate housing demand. Attanasio *et al.* (2021) evaluate the role of amortization payments as a savings commitment device. Ganong & Noel (2020) find that extending mortgage maturity has a large impact on default rates.

[4] On one hand, households value greater flexibility to smooth consumption over the life-cycle, therefore lower required mortgage payments will be beneficial for the reasons discussed in Cocco (2013). On the other hand, if housing acts as a commitment device, then greater flexibility may weaken commitment (Attanasio *et al.*, 2024).

[5] See also seminal contributions from Cocco (2013) and Piskorski & Tchistyi (2010). Recent papers on the topic also include Vihriälä (2023) and Ferrari & Loseto (2023).

Amromin *et al.* (2018) show that interest-only mortgages were used by prime borrowers in the US housing boom. Garmaise (2013) shows that increased flexibility in mortgage contracts led to higher borrowing. We also note that amortization payments represent a *de-facto* constraint on savings and borrowing for payment-constrained borrowers. Amortization payments have recently been included in several theoretical models that incorporate realistic features of the mortgage contract (Greenwald, 2017; Kaplan *et al.*, 2020; Boar *et al.*, 2022), but the interaction with credit constraints has received less attention. Within this literature, we are the first to consider the possibility that households may suffer from behavioral biases when choosing between mortgage contracts with alternative repayment schedules.

Third, our results are relevant for understanding the role of financial innovation in contributing to the accumulation of mortgage debt prior to the 2008 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, 2021; Justiniano *et al.*, 2021). Similar occurred in other countries: Australia, Denmark, Finland, Greece, Korea, and Portugal all introduced interest-only mortgages between 1995 and 2005 (Scanlon *et al.*, 2008). Our results suggest that the increased availability and subsequent disappearance of non-traditional mortgages with lower amortization payments can explain large movements in household debt in the United States. Looking forward, policymakers should be aware that debt repayment schedules could have large consequences for credit growth. Our results, therefore, also contribute to the growing literature on the effect of macroprudential policies (e.g. Cerutti *et al.*, 2017; Laufer & Tzur-Ilan, 2021; Peydró *et al.*, 2024; DeFusco *et al.*, 2020).

Methodologically, the present paper builds upon a growing literature that uses bunching to understand preferences. The use of bunching to identify preferences has received attention in review articles by Kleven (2016) and DellaVigna (2018). Prominent examples in household finance include Andersen *et al.* (2022) who study reference dependence in housing markets, Choukhmane (2021) who studies opt-out costs in retirement decisions, Collier *et al.* (2021) who study collateral aversion in lending markets, and Best *et al.* (2020) who estimate the intertemporal elasticity of substitution using mortgage decisions. Other prominent examples include Lacetera *et al.* (2012) and Strulov-Shlain (2023) who study left-digit bias in pricing. To the best of our knowledge, we are the first to use bunching to study how alternative repayment schedules affect borrowing. Subsequent research by Ng (2024) also finds a large sensitivity of borrowing to monthly payments, beyond that explained by traditional budget-constraint based explanations. We believe that his results provide comforting external validity to our analysis, as the author reaches similar conclusions in the US using very different policy variation.

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.

The paper is organized as follows. Section 2 describes 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 households' response to the amortization requirement. Section 6 discusses the implications of the model for aggregate borrowing and wealth accumulation. Section 7 summarizes and discusses potential extensions.

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*, or FSA) announced that they would propose new regulation in November 2014 – the amortization requirement – intending to reduce debt levels over time. 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 was enacted in June 2016. The FSA introduced an

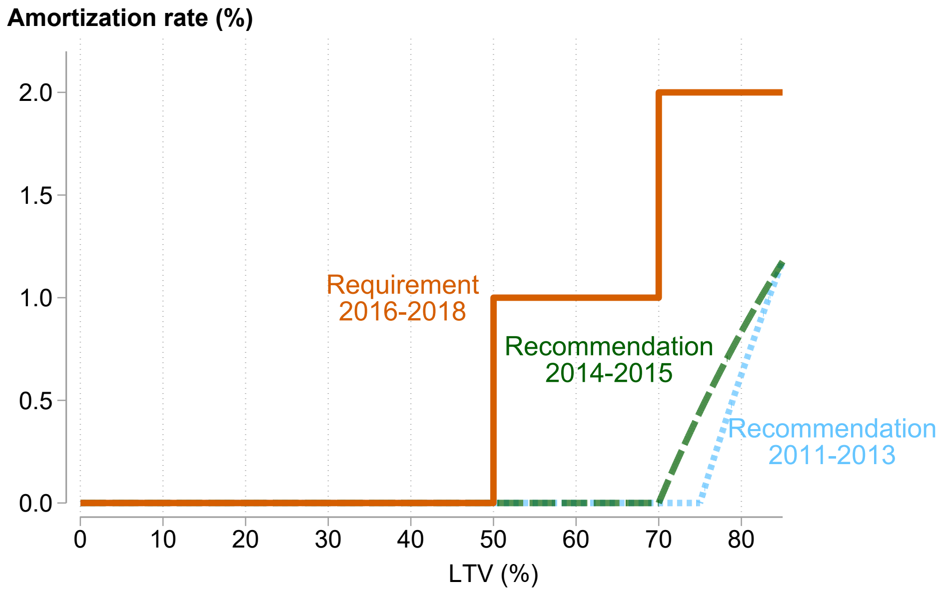


Figure 1. Required Amortization Rates for new mortgages

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

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-evaluation of property values could have pro-cyclical effects, the law states that the valuation can only be made every five years. Moreover, any re-evaluation must be based on changes to the property value due to renovation or rebuilding, not due to aggregate house price changes. At any point, a borrower can be granted an exemption from amortization due

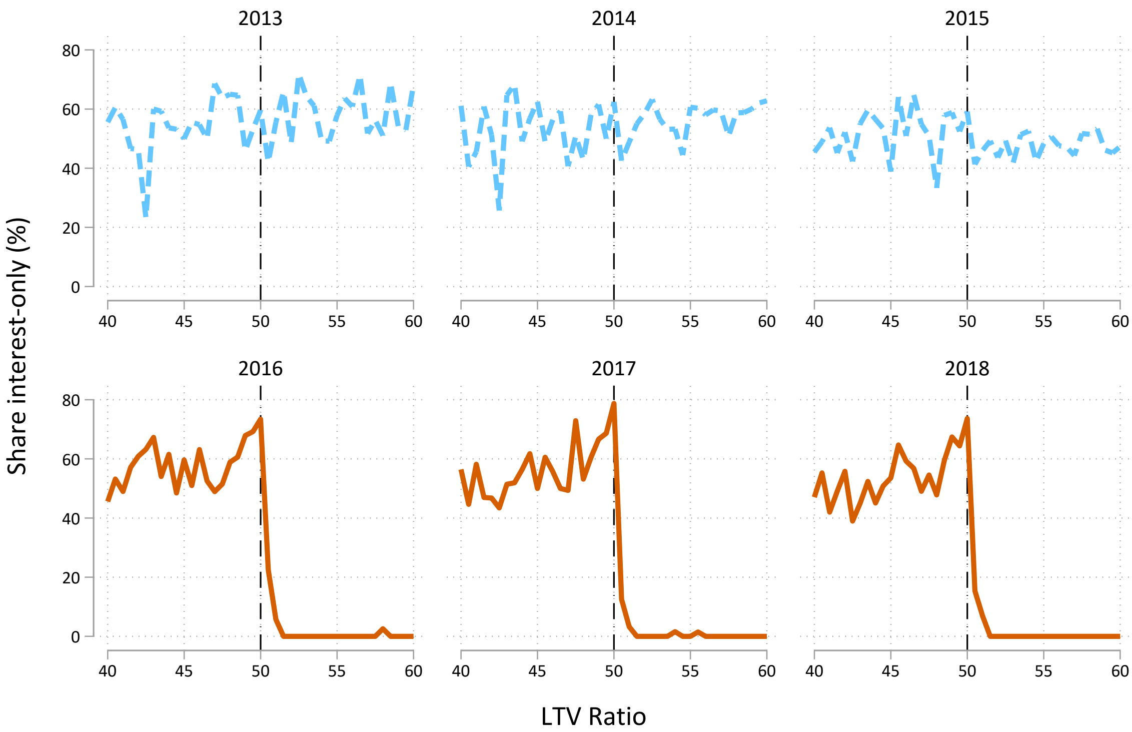


Figure 2. Share interest-only mortgages at the 50 percent LTV threshold

Notes: The figure plots the share of interest-only mortgages by LTV bin and year. The top three panels with dashed blue lines plot the interest-only share for the three years before the amortization requirement, and the bottom three panels with solid orange lines plot the interest-only share for the three years after the requirement.

to extenuating circumstances, such as unemployment, illness, or a death in the family.[6]

Once a borrower has amortized down to a threshold, the borrower is allowed to reduce the amortization rate. We contacted all banks in our sample to ask for clarification on how customers can reduce amortization rates. All banks state that borrowers must contact the bank to request a reduction in amortization. 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 contract is required. Instead, a phone call or a request 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 occur, the denials were related to delinquencies or missed mortgage payments.

[6]In addition, the amortization requirement was temporarily paused during the covid pandemic to give households greater flexibility during the crisis (Andersson & Aranki, 2021).

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.[7] In the pre-requirement years between 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 IO share is still around 60 percent to the left of the threshold. To the right of the threshold, the IO share is essentially zero, as the policy requires. We also see a spike in IO mortgages precisely at the threshold, consistent with borrowers deliberately moving to the threshold to qualify for interest-only repayment.

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, 2021). 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").[8]

Importantly, Swedish mortgages are *not* annuity contracts. Instead, total mortgage payments consist of the sum of interest payments and amortization payments. Interest payments equal the interest rate on the mortgage times the outstanding mortgage debt. Amortization payments equal 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 amortization requirement's threshold is then fully due to higher amortization payments. An implication of this empirical setup is that the mortgage interest payments are falling over time.[9]

Swedish banks are required to assess the borrower's financial status. Banks assess financial

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

[8]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.

[9]Effectively, the difference in *interest payments* on Swedish-style mortgages and US-style annuity contracts are small over the initial years of the mortgage duration.

status through a *discretionary income limit*, which requires the household to have enough disposable income to afford basic consumption and housing (including amortization). This limit, functionally equivalent to a payment-to-income constraint (Grodecka, 2020), is calculated using a high "stressed" interest rate to ensure that borrowers' finances are resilient to higher rates.[10] When applying for a mortgage, Swedish borrowers first seek a "borrowing pledge" from their preferred bank. In the pledge, the bank states the maximum amount they are willing to lend to the borrower, given e.g. household income and household size. Importantly, banks give this pledge *before* home purchase, making manipulation of the LTV ratio of the bank unlikely.

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 them afterward to surprise banks and prevent them from applying different credit standards during these survey dates.[11] 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 collateral value. 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 cannot link our mortgage data to other register data as households are reported anonymously. Table B1 provides summary statistics for the full sample and groups based on financial constraints.

[10] While mortgage rates were typically below 2 percent during the end of our sample, stressed rates were on the order of 6-7 percent, thus ensuring households can manage much higher interest rates.

[11] 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.

3.2 Empirical strategy

We now describe our approach to estimating the counterfactual distribution and the amount of bunching induced by the amortization requirement. Our empirical strategy hinges on estimating the counterfactual LTV distribution that would have occurred without the amortization requirement. We exploit the availability of repeated cross-sections to estimate the counterfactual distribution. In other words, we compute a *difference-in-bunching* estimate, where the distribution observed before the requirement serves as the counterfactual 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 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 counterfactual 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 this assumption is plausible in Appendix C. 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.4 details the flexible polynomial approach.

We group borrowers into LTV bins with a width of half a percentage point. The goal is to estimate the counterfactual fraction of borrowers in each LTV bin j post-requirement period if the amortization requirement is not introduced, denoted $\hat{n}_j$.[12] We measure the amount of bunching $\widehat{B}$ as the difference between the observed and counterfactual bin fractions in the region at and to the left of the threshold located at R:

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

[12] 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 data is collected, the count is uninformative. As we are using the previous years to form the counterfactual 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 amount of bunching equals the fraction of additional borrowers who place themselves at the threshold beyond what the counterfactual distribution based on previous years would predict. Similarly, but to the right of the threshold, the amount of missing mass is equal to:

$$\widehat{M} = \sum_{j>R}^{U} (n_j - \hat{n}_j) \tag{2}$$

Missing mass equals the difference between the observed and counterfactual distribution in the region to the right of the threshold. Note that borrowers making up the missing mass could shift towards the threshold (intensive margin) or exit the market altogether (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, following 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 $\widehat{g_{linear}}(\overline{LTV})$:

$$\widehat{\Delta LTV} = \frac{\widehat{B}}{\widehat{g_{linear}}(\overline{LTV})} \tag{3}$$

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 debt with respect to the amortization rate is:

$$e^{\alpha} = \frac{\Delta LTV/\overline{LTV}}{\alpha^*(\overline{LTV} + \Delta LTV) - \alpha_0} \tag{4}$$

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.

Our estimates capture the intensive margin response to the amortization requirement – the response of borrowers who still borrow after the requirement was implemented. This margin sufficiently demonstrates our primary goal: to identify the effect of higher amortization payments on LTV ratios. Identifying the extensive margin response convincingly would require strong assumptions about 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 counterfactual 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 thresholds, 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 counterfactual distribution in Figure C2. We provide results for the upper threshold in Appendix C.3, and 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, a considerable mass at the threshold indicates that many new borrowers choose lower LTV ratios to avoid mandatory amortization payments. 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,

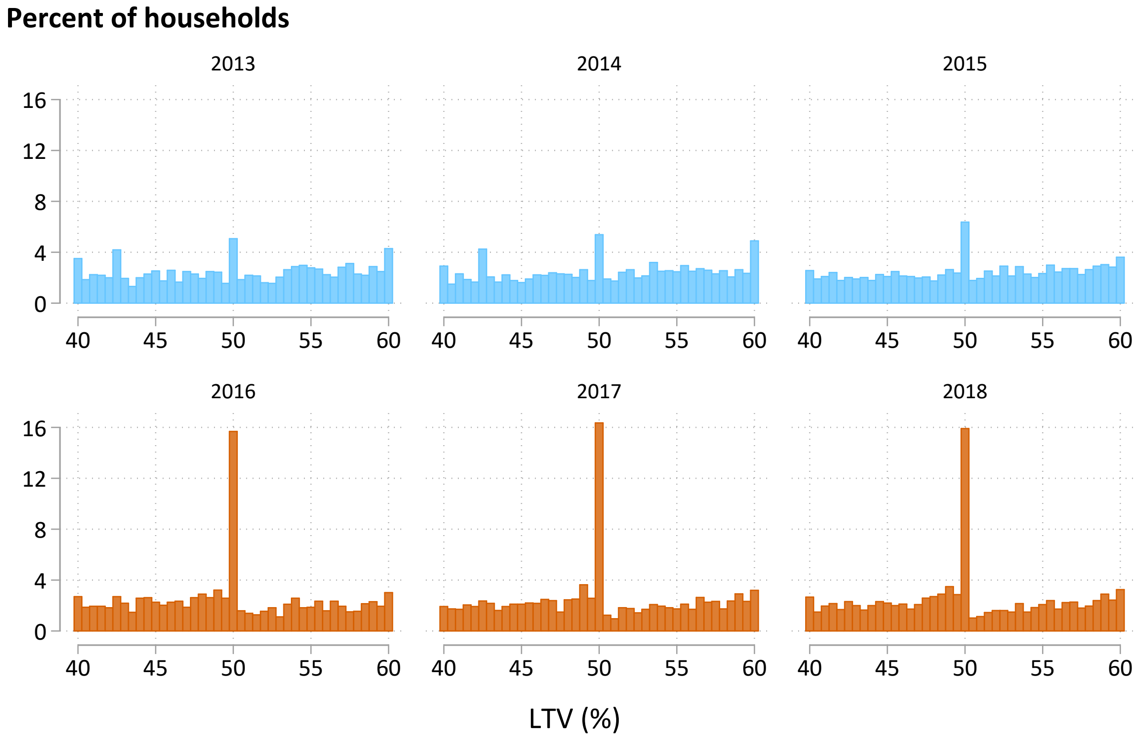


Figure 3. LTV distributions around the requirement threshold

Note: The figure plots the percent of borrowers per loan-to-value bin for each year. Pre-requirement years are marked with blue in the top row, and post-requirement years featuring a minimum 1 percent amortization rate for LTV above 50 are marked with orange in the bottom row.

the increase in total mortgage payments at the threshold is entirely due to higher amortization payments, not interest expenses. Note that affected borrowers include home buyers and 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 50 percent LTV 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 counterfactual distribution estimated from the bunching procedure around the threshold at an LTV ratio of 50. The solid orange line plots the empirical distribution, i.e., the distribution in 2016-2018, and the solid blue line plots the counterfactual distribution. 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 (2)). Our estimates of ΔLTV, B, and M are robust to changing these limits of the excluded area in either direction (see Table B3). Using a placebo

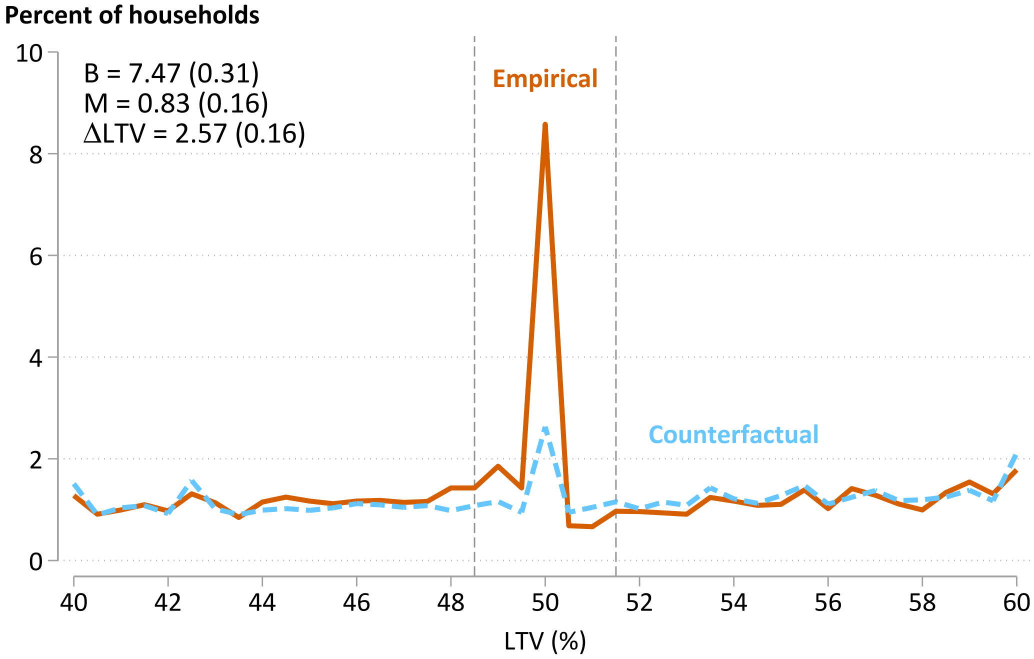


Figure 4. Bunching at LTV=50

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio. The estimation uses all loans with LTV ratios between 20 and 65 percent but only shows the distribution between 40 and 60. The solid orange line plots the empirical density, i.e., the percent of mortgages within each 0.5 percent LTV bin. The dashed 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 missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 3. Standard errors are calculated by bootstrapping and are shown in parentheses.

test, Appendix C.2 further shows that the counterfactual density obtained from pre-requirement data presents a good estimate of the fraction of borrowers in each bin, a key identifying assumption in our approach. We also show that the results are more conservative compared to the standard approach of fitting a flexible polynomial to the distribution and excluding an area around the threshold in Appendix C.4.

The figure contains several key results. First, the counterfactual distribution fits the empirical distribution well up to an LTV ratio of 47.5 percent and again from an LTV 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 at the threshold contains approximately 9 percent of borrowers, compared to around 3 percent in the same bin in the counterfactual 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. 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 Sweden's discretionary income limit, which we will evaluate shortly. In response to the requirement, the marginal buncher reduces its LTV ratio by 2.57 percentage points ($\widehat{\Delta LTV} = 2.57$, standard error 0.16). Relative to the threshold, this yields an approximately 5 percent decrease in LTV ratios. We use this elasticity to calculate an amortization elasticity using equation (4). With the estimated ΔLTV of 2.57, the marginal reduction in borrowing in the numerator equals $2.57/50 = 0.0514$. The marginal amortization rate in the denominator equals 0.204, and the elasticity equals $0.0514/0.204 = 0.25$. A one percentage point increase in the amortization rate decreases LTV ratios by 0.25 percent.

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. This finding will be important to identify between alternative explanations of why households bunch (see Section 5.5.)

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. At the time of borrowing, 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, 2024). Note that the credit check is only in effect at the time of borrowing and that there are no new credit checks if the borrower wishes to reduce amortization payments at a later stage.

How prevalent are binding payment-to-income (PTI) constraints for borrowers at the lower threshold? To answer this question, we calculate the counterfactual discretionary income as the discretionary income given your chosen LTV minus the extra payments if you would have borrowed one percentage point more in LTV compared to the closest-by threshold. We find a small fraction of constrained borrowers at the threshold: 13.6 percent would not comply with the payment-to-income constraint set by Swedish banks if they were to amortize more. The

Table 1. Bunching estimates by distance from payment constraints

PTI Constraint	Near constraint	Intermediate	Far from constraint
Bunching ($\hat{B}$)	5.01	10.17	9.41
	(0.49)	(0.63)	(0.70)
Missing mass ($\hat{M}$)	-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	13,350	10,471	10,182

Notes: The table compares the main bunching estimates across groups based on payment-to-income constraints. We calculate the counterfactual discretionary income as the discretionary income given your chosen LTV minus the extra payments if you would have borrowed one percentage point more in LTV. The near-constraint, Intermediate, and Far-from-constraint samples have a counterfactual 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). Δ LTV the percentage point change in LTV ratio for the marginal buncher, calculated using equation (3). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 4. 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.

remaining 86.4 percent of borrowers who bunch are not constrained by the PTI constraint. On average, therefore, payment constraints are not driving our results.

We then group households based on counterfactual discretionary income into a Near-constraint, an Intermediate, and a Far-from-constraint sample, with a counterfactual monthly discretionary income of less than 5,000 SEK, 5,000-15,000 SEK, and greater than 15,000 SEK, respectively.[13] The Near-constraint group is close to their debt limit, as they have nearly maxed out their PTI. 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 limit and could borrow substantially more.[14] For the Far-from-constraint group, increasing leverage (and starting to amortize) reduces discretionary income by 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

[13] Recall that discretionary income is income after taxes, housing expenses such as maintenance, car payments, basic consumption needs, and a stressed interest rate of 7 percent.

[14] For example, a discretionary income of 15,000 SEK implies the household could increase its debt until the additional monthly expenses equal 15,000 SEK. At a (stressed) interest rate of 7 percent and amortization rate of 2 percent, the 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.

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 other characteristics that imply 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 characteristics 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 value of home purchase (V). To isolate borrowing from value effects, we focus on borrowers who refinance. For these borrowers, the bank sets the value exogenously 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 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 do banks deviate from using the purchase price for homebuyers.[15] In the case of 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 and assessments by independent appraisers. We discuss the validity of the collateral assessments further in Section 4.4. We find little evidence of discontinuities in house values, either in levels or relative to income, around the thresholds in Figure A5. We therefore estimate bunching by type of valuation. Table 2 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. While there are some differences in the bunching estimate across the valuation methods and the elasticity, the results are generally aligned of a similar magnitude as the baseline results. The share of

[15] 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 ($\hat{B}$)	7.10	7.38	9.30
	(0.34)	(0.88)	(1.46)
Missing mass ($\hat{M}$)	-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	28,588	4,948	2,211

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). *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (2). Δ LTV is the percentage point change in LTV ratio for the marginal buncher, calculated using equation (3). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 4. 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.

refinancers in the data is large, and we find identical bunching estimates for this group even at the upper threshold in Appendix C.3. This implies that value effects are not driving our main result, and the decline in LTV ratios stems from lower loan demand, not house prices.

4.4 Validating the results

In this section, we discuss various other supply-side factors that could cause borrowers to bunch. For example, banks may have an incentive to recommend their clients 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.*, 2024). Below, we discuss these supply-side factors in the context of the approval process for mortgages, collateral assessments, risk weights, and capital requirements. Overall, we find that these supply-side factors cannot explain the bunching that we observe.

Mortgage rates. Figure 5 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 5 plots the interest rate by LTV ratios around the lower threshold. As interest rates vary over time, reflecting Swedish monetary policy, we normalize them to have the same average as in 2017. Importantly, there are no systematic differences in interest rates: average rates are nearly identical below or

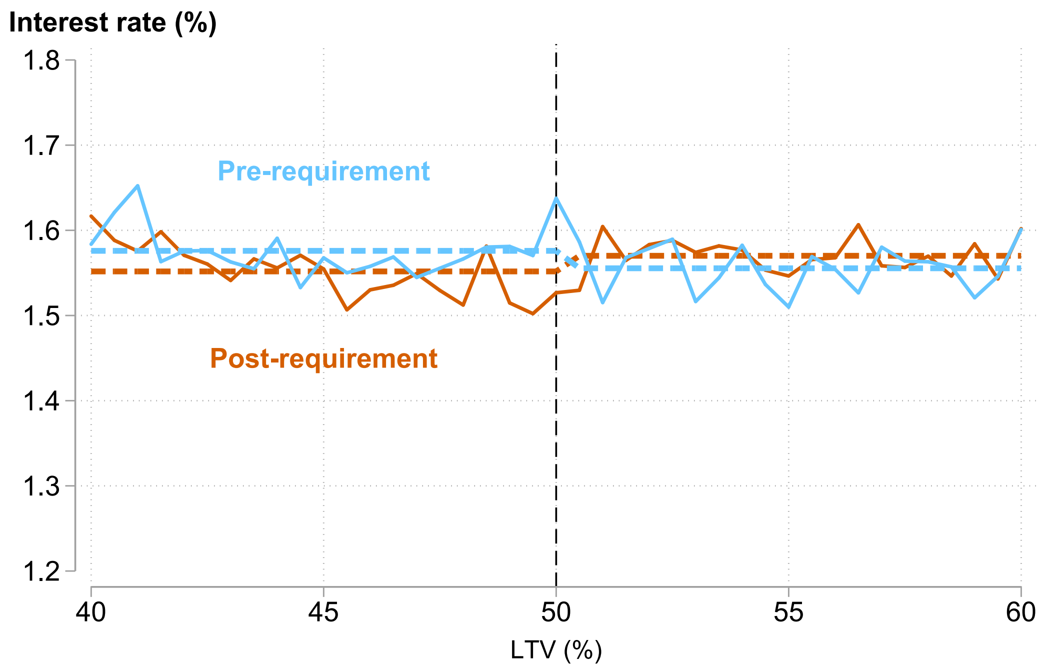


Figure 5. Interest rates around the lower LTV threshold

Notes: The figure plots the average mortgage rate by LTV bin. The blue lines use data from the pre-requirement years (2012-2015), and the orange lines use data from the post-requirement years (2016-2018). The solid lines represent the average mortgage rate by bin, and the dashed lines are the average mortgage rates above (LTV between 40 and 50) or below (LTV between 50 and 60) the threshold. The threshold is marked with a dashed black line.

above the thresholds. Similar results hold for the upper threshold, available in Panel b) of Figure 5. 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.[16]

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. This is because, over the life of the loan (typically 6-7 years), the average debt balance is larger for the interest-only loan. The extra interest income from this nudge is likely small and depends on how long the loan stays on the bank's 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.

[16]Figure 5 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.

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 negligible 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 weight increases discontinuously at the thresholds. [17] Even if level differences exist, our difference-in-bunching strategy will account for any discontinuity that is fixed over time.

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).

[17] Further, 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 exceed the floor.

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 A5 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 develop a theoretical framework that allows us to clarify the different mechanisms that may cause households to borrow less to avoid amortization payments. We begin with a traditional life-cycle model of consumption, housing, and mortgage decisions in the spirit of Campbell & Cocco (2003).While such a model can easily explain why poor households want to avoid amortization payments, we demonstrate that this model cannot replicate the observed behavior of relatively wealthy households who reduce their initial principal balance to get just below the threshold and lower their monthly principal payments.

How should we understand wealthy households' desire to make larger downpayments to avoid amortization? Kleven (2016) explains that there are four mechanisms that can generate bunching: kinks or notches in the budget constraint or kinks or notches in household preferences. As mentioned previously, we found no evidence of kinks or notches in the budget constraint, with the one exception of the PTI constraint that accounted for only 14 percent of bunching households (Section 4.4). As a result, we rule out the budget constraint as the primary driver of observed behavior and instead turn our attention toward potential mechanisms operating through household preferences.

We consider two broad classes of preferences that may generate bunching: a one-off disutility cost to amortizing mortgages and an ongoing flow disutility to amortization payments. As there are various motivations for each class of preferences, we adopt a reduced-form approach to behavioral modeling in the spirit of Mullainathan *et al.* (2012). Briefly, the one-off disutility captures that Swedish borrowers must contact the bank to turn off amortization and that this refinancing may be costly to the borrower. The ongoing flow disutility captures the idea that households consider amortization payments a cost akin to interest payments. We later discuss additional motivations for each psychic cost.

We demonstrate that the one-off disutility cost generates a notch in household preferences while the ongoing disutility cost generates a kink. While both mechanisms generate bunching at the policy threshold, they do so in different ways, which forms the basis for identification. More specifically, the notch in preferences generates bunching through a dominated region directly above the policy threshold, while the kink generates bunching without a missing mass. Based on this distinction, we disentangle the relative importance of the two potential mechanisms, assess the sensitivity of our results to possible threats to identification, such as optimization frictions, and then evaluate the implications of our findings for the aggregate economy.

5.1 Theoretical framework

We develop a life-cycle model of consumption, housing, and mortgage decisions in the spirit of Campbell & Cocco (2003) and Cocco (2004). In the model, credit-constrained households face idiosyncratic and uninsurable income risk over the life cycle. Households are heterogeneous with respect to initial assets and income, as well as realized income shocks. Households get utility from both consumption and housing, can save in either liquid deposits or illiquid housing, and can borrow using long-term mortgages. As shown by previous authors, such a model performs well at matching the hump-shaped profile of nondurable spending, 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 (see, e.g. Attanasio *et al.*, 2011, 2024).

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 extend household preferences to include either a one-off disutility to amortizing mortgages or an ongoing flow disutility from amortization payments. That said, we begin with the baseline model without either disutility costs.

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 lifetime utility:

$$\max_{\{c_t, a_t, h_t, m_t\}} \mathbb{E}_0 \sum_{t=0}^{T} \beta^t u(c_t, h_t, \delta_t) \tag{5}$$

subject to the household budget constraint, the law-of-motion for mortgages, and an exogenous income process. We require that 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 and a behavioral wedge (δ_t), which we set to zero in the initial analysis but later extend to capture potential psychic costs to amortization.

Demographics – Households live for T years, receiving exogenous labor income during their working life, then social security income after retirement at age W. Household income gradually rises during working life.

Heterogeneity – In the model, households are ex-ante heterogeneous with respect to initial assets, initial income, and realized income shocks. This leads to ex-post heterogeneity in liquid assets, housing, and mortgage balances. This heterogeneity leads to a wide distribution of loan-to-value ratios, which is our main object of interest.

Assets – Households have access to two different saving vehicles: a fully liquid asset a_t and a partially illiquid housing asset h_t. The liquid asset yields a certain return r. We impose the assumption that $a_t \geq \underline{a}$ to capture the presence of credit constraints. For simplicity, we abstract away from return risk, although this assumption is not critical to our results. The presence of both a liquid asset and relatively illiquid housing allows us to capture hand-to-mouth behavior in the spirit of Kaplan & Violante (2014).

Housing – Housing exists on a discrete grid with k different sizes: $h^k \in \{h^1, h^2, \ldots, h^k\}$. The price of each house $p_t(h^k) = h^k * \bar{p}_t$ depends on both house size h^k and the price index $\bar{p}_t$. House prices grow at a constant rate over time, $\bar{p}_t = (1 + r^H)\bar{p}_{t-1}$.

All households are born as renters but can purchase housing. Buying or selling a home incurs a transaction cost f_1 that is a fraction of the house price p_t. Households are allowed to own or rent any unit. If households choose to rent, they must pay rent in proportion to the house price, with $\text{rent}_t = \eta p_t$.

Mortgages − Homeowners can borrow using long-term mortgages m_t with interest rate r^M. We allow for both borrowing to finance housing purchases and cash-out refinancing. Mortgage balances are constrained by a maximum loan-to-value (LTV) constraint:

$$m_t \leq (1 - \psi)p_t(h_t) \tag{6}$$

where ψ determines the mandatory minimum downpayment. For households that do not choose to extract equity, their next-period mortgage balance is constrained by:

$$m_{t+1} \leq m_t(1 + r^M) - \rho_t(m_t, p_t) \tag{7}$$

where $\rho_t(m_t, p_t)$ represents the mandatory minimum mortgage payment.

Households that choose to extract equity are required to pay a proportional (f_2) and fixed (f_3) cash-out refinancing cost. Households extract equity when they select $m_{t+1} > m_t(1 + r^M) - \rho_t(m_t, p_t)$. The LTV constraint binds at both the time of purchase and in any periods of cash-out refinancing.

Mortgage Repayment − The mandatory minimum mortgage payment (ρ_t) represents our main policy instrument. We model two different policy regimes. First is an interest-only policy where the borrower only needs to make interest payments, similar to Sweden pre-2016:

$$\rho_t(m_t, p_t) = m_t * r^M \tag{8}$$

Second is a mandatory amortization policy, where the minimum payment depends on the LTV ratio of the borrower, similar to the amortization requirement in Sweden after 2016:

$$\rho_t(m_t, p_t) = m_t * r^M + m_t * \begin{cases} 0 & \text{if } {}^{m_t}/_{p_t} \leq 0.5 \\ 0.01 & \text{if } {}^{m_t}/_{p_t} > 0.5 \end{cases} \tag{9}$$

Note that the mortgage repayment schedule only defines the minimum payment each period, as the household is always allowed to repay more than the minimum requirement. In our policy experiment, we switch between the interest-only policy and the amortization requirement.[18]

Income – Households face exogenous and idiosyncratic income risk. We model income using a household 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 its last working period's income.

Functional form – We assume that households obtain utility from both consumption and housing based on the following utility function:

$$u(c_t, h_t, \delta_t) = \frac{\left(c_t^{1-\theta}\phi(h_t)^\theta\right)^{1-\gamma}}{1-\gamma} - \delta_t \tag{10}$$

where γ is the coefficient of relative risk aversion, and θ is the preference for housing relative to consumption. Our utility function closely follows Cocco (2004) with two modifications. First, we allow for owning or renting, where $\phi(h_t)$ captures the utility of the tenure decision:

$$\phi(h_t) = \begin{cases} h_t & \text{if owner} \\ \zeta h_t & \text{if renter} \end{cases} \tag{11}$$

and where ζ is the disutility of renting. Second, we allow for a psychic cost to amortization, denoted by δ_t. In the baseline model, we set $\delta_t = 0$. We find that this model is unable to generate bunching at the amortization threshold. This motivates us to extend the model by allowing δ_t to depend on mortgage amortization in Section 5.4.

5.2 Parameter values

We set the model parameters based on the existing literature and institutional details from the Swedish mortgage market. We calibrate asset returns and interest rates based on Swedish data and set the loan-to-value and amortization requirements based on Swedish law. We set the main household preference parameters following Cocco (2004) and set the income process parameters following Kovacs & Moran (2021). The details are contained in Appendix D.

[18]For simplicity, we only model the 50 percent threshold of the amortization requirement, although our results would generalize to multiple thresholds.

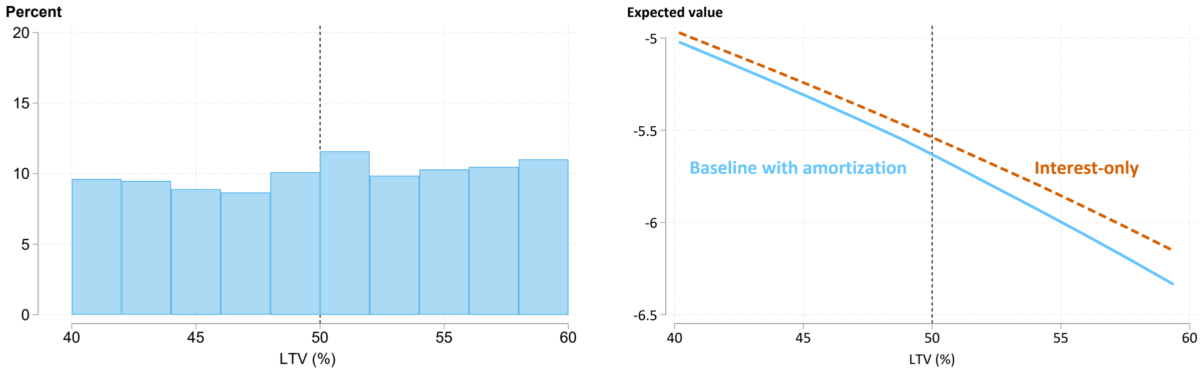
We set $r = 0.018$ based on the real risk-adjusted return of the Swedish 3-month T-Bill. We set $r^H = 0.029$ based on the real risk-adjusted return to housing, which we calculate using the house price index from Statistics Sweden augmented with housing service flows, maintenance costs, and home insurance. 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 $r^M = 0.043$ based on the average real rate for a floating-rate mortgage in Sweden between 1985 and 2015. Following Swedish mortgage regulation, we set the maximum loan-to-value ratio of $1 - \psi$ to 85 percent.

5.3 The baseline model does not generate bunching by wealthy households

How does mandatory principal repayment affect household borrowing in the traditional model? We implement a policy where households are required to make amortization payments if the LTV ratio exceeds 50 percent, similar to Sweden. While such a policy could easily generate bunching for low-wealth households at the credit constraint, we find that the traditional model does not generate bunching for wealthy households purchasing a home with 50 percent down.

Figure 6 shows the results from our baseline model. The left panel shows the distribution of LTV ratios around the policy threshold at the time of mortgage origination in a world with mandatory amortization. The model generates substantial variation in LTV ratios due to exogenous variation in household resources (coming from age, initial resources, and realized income shocks). However, we find no bunching at the 50 percent LTV threshold despite mandatory amortization for all loans above the threshold.

The value function in the right panel provides intuition for the lack of bunching around the policy threshold. The figure plots the expected discounted utility (the value function) as a function of the LTV ratio, with all other state variables held constant. The solid blue line shows the expected value in the baseline model with the Swedish mandatory amortization policy. The dashed orange line shows the expected value in the alternative model with interest-only mortgages, similar to Sweden prior to 2016. Mandatory amortization reduces expected discounted utility for all households, as households would prefer to live in the world with interest-only mortgages due to the benefits of improved consumption smoothing (Cocco, 2013). That said, mandatory amortization reduces expected discounted utility in a smooth manner, without generating a notch or kink around the policy threshold. As a result, mandatory amortization



(a) LTV distribution

(b) Value function

Figure 6. 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 percent to 1 percent per year when the LTV ratio exceeds 50 percent. 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.

does not generate bunching at the threshold. Intuitively, while the amortization requirement forces households to save, this does not induce households to choose larger downpayments to avoid amortization. In addition, households can undo amortization, either by borrowing more at origination and making payments from the borrowed amount (Svensson, 2016) or through cash-out refinancing (Hull, 2017). Further, the lack of bunching holds despite realistic credit constraints in the model. While credit constraints are binding for households purchasing a home with the maximum 85 percent LTV ratio, households near the 50 percent LTV threshold are far from the credit constraint and have substantial additional borrowing capacity.

The lack of bunching in the baseline model is invariant to key model parameters. More specifically, we do not find bunching in the baseline model even when a) households are highly impatient, b) income grows more steeply over the life-cycle, thus exacerbating the role of credit constraints, c) households are not allowed to perform home equity withdrawal, d) the liquid asset gives negative real returns, or e) households have access to a high return liquid asset.[19] While the above model parameters affect the curvature of the expected value function and may increase households' desire to be in a world with interest-only mortgages, none of the above parameters introduce a kink or notch into the expected value function and thus are unable to generate bunching at the 50 percent threshold.

[19]When we include a high return liquid asset, most borrowers increase debt to the maximum LTV ratio of 85%, obtaining higher returns while gradually paying back the mortgage. While our model assumes that such portfolio adjustments are costless, in reality, there may be psychic costs to selling some of the investment each period and using those funds to repay the mortgage, which we view as complementary to flow disutility (see Section 5.6).

5.4 Extending household preferences to generate bunching

We augment household preferences to capture the possibility that households may dislike mandatory amortization due to behavioral biases or other psychological reasons. We consider two broad classes of psychic costs: a one-off disutility to amortization and an ongoing flow disutility to amortization payments. We adopt a reduced-form approach to behavioral modeling, using psychic costs that may capture various behavioral biases in the spirit of Mullainathan *et al.* (2012). We now motivate and describe these costs in more detail.

One-off disutility cost to amortization – The first psychic cost we consider is a one-off disutility cost that applies to all mortgage contracts with amortization. While there are various ways we could model this cost, we choose to do so by assuming that households suffer a psychic cost to turning off amortization payments once they cross below the mandatory amortization threshold.[20] More specifically, we model the one-off cost as:

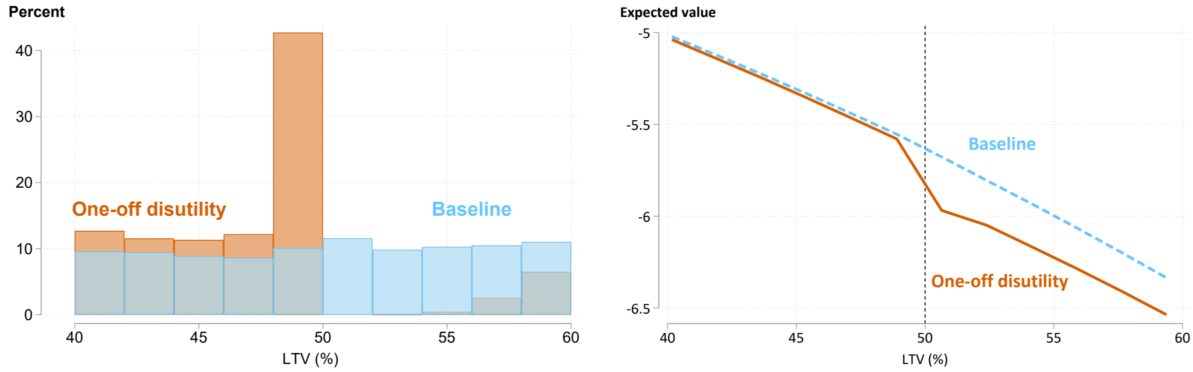
$$\delta_t = -\Delta_n \times \mathbb{1}_{\text{amort}_t=0,\ \text{amort}_{t-1}>0} \tag{12}$$

where for simplicity we define $\text{amort}_t = \rho_t(m_t, p_t) - m_t * r^M$ as the required principal payment. In our model, households suffer a one-off disutility (Δ_n) when they start with an LTV ratio above 50 percent, gradually pay down their mortgage, and eventually cross below the policy threshold and turn off amortization. This disutility cost captures the fact that Swedish borrowers must contact the bank to turn off amortization. Refinancing costs can represent both monetary and psychic costs to the individual to refinance. In our setting, we model these as psychic costs through the utility function since 97 percent of mortgages in our sample are issued by Swedish banks that allow eligible households to turn off amortization payments without a fee.[21]

We show the result of including a one-off disutility cost in Figure 7. The histogram shows that a one-off disutility cost affects households close to the threshold and leads to a dominated region directly above the threshold. As a result, the bunching at the threshold is generated by missing mass directly above the threshold. The bunching and missing mass result from a notch in preferences at the threshold, illustrated in panel b), where expected utility shifts down exactly at the 50 percent LTV threshold. The notch causes households who otherwise would

[20] That said, this psychic cost is isomorphic to a one-off cost at the time of mortgage origination.

[21] Monetary and psychic costs to refinancing have been studied in Agarwal *et al.* (2016), Keys *et al.* (2016) and Andersen *et al.* (2020). In the Swedish setting, just one bank charges a small fee (of slightly less than $200) to turn off amortization payments. This bank represented 3 percent of total mortgages in 2017.



(a) LTV distribution

(b) Value function

Figure 7. 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.

have chosen an LTV ratio just above the 50 percent threshold to choose lower LTV ratios to avoid the one-off utility cost to amortization. Since households far away from the threshold can discount the cost, it will not affect their borrowing decisions.

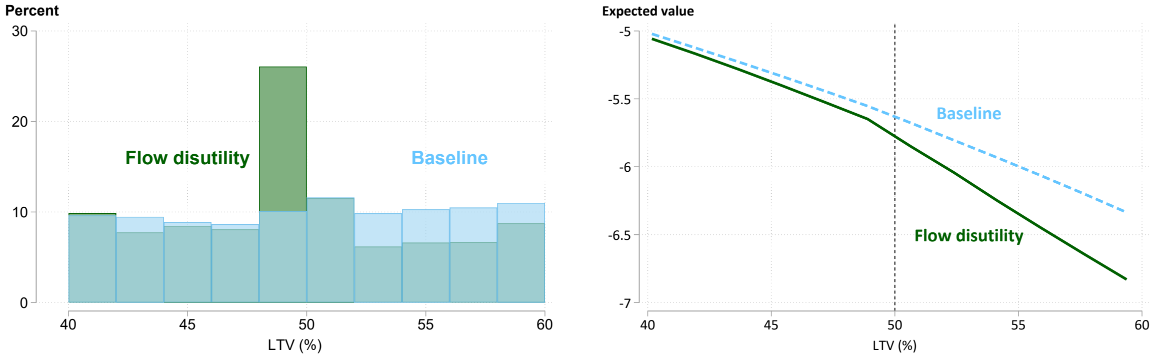
Flow disutility to amortization payments – The second psychic cost we consider is flow disutility to amortization payments. We model the psychic cost as follows:

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

Borrowers incur a disutility cost (Δ_k) in every period where they are required to make principal payments. This disutility flow may occur if borrowers mistakenly view principal repayment as a cost rather than a form of saving, if borrowers incur psychic costs to portfolio adjustment, or if borrowers try to target a specific monthly payment when choosing how much to borrow.

We choose to model flow disutility as a behavioral wedge, as it allows us to remain agnostic about the specific factors driving such preferences. Indeed, there are various ways to motivate flow disutility based on recent literature. For instance, Argyle *et al.* (2020) argue that consumers perform "monthly payment targeting" when choosing between auto loans with different terms, paying more attention to the initial monthly payment than the lifetime cost of the loan.[22] Camanho & Fernandes (2018) propose that households suffer from the "mortgage illusion,"

[22] This is consistent with the theory of "NPV neglect", where households do not fully consider the net present value of future interest costs when choosing between contracts with alternative repayment schedules (Shu, 2013).



(a) LTV distribution

(b) Value function

Figure 8. LTV distribution and value function with flow disutility to 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.

where housing decisions are driven by heuristics, such as how the monthly mortgage payment compares to rental payments, which may occur if households do not internalize the fact that amortization payments represent a form of saving. Indeed, one recent survey in Sweden found that 38 percent of Swedish households view amortization payments as a cost rather than a form of savings (SBAB, 2018). Alternatively, households may face real or psychic costs to portfolio adjustment, leading them to prefer "set and forget" investment strategies.[23] As a result of any of these explanations, households may choose mortgage contracts with lower initial payments and higher lifetime interest costs, even when they could afford to do otherwise.

We find that flow disutility to amortization generates bunching at the threshold without a missing mass. Figure 8 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 above the threshold reduce 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 flow disutility completely. These households now fill up the distribution to the right of the threshold.

[23]For instance, a household may want to borrow to invest in the stock market. Even if there are no monetary adjustment costs, there may be psychic costs to selling some of the investment each month and using those funds to make amortization payments on one's mortgage.

5.5 Identification: Flow disutility obtains a better fit of the data

How do we evaluate the relative importance of the two different mechanisms described above? Fortunately, the two mechanisms have drastically different implications for what drives bunching. More specifically, the notch in household preferences generates bunching at the threshold based on a dominated region just about the threshold with missing mass. In contrast, the kink generates bunching at the threshold by altering the incentives for all households above the threshold, thus generating bunching without a corresponding missing mass. This difference in implications allows us to determine the relative importance of the two opposing channels.

Our empirical results show little evidence for a large missing mass. The summary of our main estimates in Table B2 shows 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 flow disutility to amortization payments.

5.6 Evaluating robustness to alternative mechanisms

Here we assess the robustness of our results to various alternative mechanisms. We find that our empirical results cannot be explained by policy uncertainty, endorsement effects, or optimization frictions. That said, outside investment opportunities may provide a complementary explanation for flow disutility, assuming that households incur real or psychic costs to portfolio adjustment that lead them to prefer "set and forget" investment strategies.

Policy uncertainty. One potential concern is that households may not fully understand the policy. For instance, households might not know that they can turn off amortization payments once they pay down their mortgage and get below the 50 percent LTV threshold, or they may feel some uncertainty about whether they will be allowed to do so. In practice, turning off amortization payments once a borrower has passed below the policy threshold is relatively straightforward in Sweden, which we verified by email correspondence with the eight main banks. For example, there is no new credit check or discretionary income calculation when the borrower decides to turn off amortization payments.[24] Further, we do not believe that such policy uncertainty can explain our main results. Policy uncertainty would create a notch, as it

[24] In their replies, the banks stated that there are no associated costs, the borrower does not need a new mortgage contract or price appraisal, and a simple phone call to the bank advisor is sufficient to turn off amortization. Three of the eight banks stated that borrowers are never denied the ability to turn off amortization. The remaining banks stated that denial is very rare and only related to insolvency issues, such as not paying bills.

would imply that taking out a mortgage just above the 50 percent threshold is discontinuously worse than taking out a mortgage just below. As mentioned above, this notch would generate bunching at the threshold based on missing mass above the threshold, something which we find is small in the data. Thus, while policy uncertainty could explain some of our results, we believe it could explain no more than 15 percent of the bunching.

Better investment opportunities. Another concern is that households may have other investment opportunities that give a higher return than the interest rate on mortgage debt. For instance, households may prefer to invest in the stock market rather than pay down their mortgage, similar to Andersen *et al.* (2023). To assess the ability of this mechanism to explain our empirical results, we simulated our model with an alternative calibration where the liquid asset gives a high return, $r = 0.06$, greater than the interest rate on mortgage debt. We find that the alternative calibration increases the welfare costs of mandatory amortization, but does not generate either a kink or notch at the 50 percent LTV threshold, and thus does not induce bunching at the 50 percent threshold. The intuition for this result is that the presence of a high-return liquid asset compels households to increase borrowing, but not to avoid amortization. Households would rather borrow up to the maximum LTV limit of 85 percent, then gradually pay down their principal balance, rather than reduce leverage to avoid amortization.

One caveat, however, is that our model assumes that the high-return liquid asset can be adjusted costlessly. While this is a common modeling assumption, it may breakdown if (i) the high-return investment opportunity is long-term and illiquid, or (ii) there are sufficiently large psychic costs to portfolio adjustment. In such cases, the household may prefer a "set and forget" investment strategy, rather than borrowing up to the maximum LTV ratio and then gradually paying down their mortgage balance. While we do not incorporate this into our model, we think that this could generate an additional and complementary reason why households may dislike amortization. We therefore take a broad view of what may generate flow disutility to amortization. We believe that better understanding the exact mechanisms for why households dislike amortization is an important avenue for future research.

Endorsement of a recommended down payment or amortizing. By choosing a specific threshold at which policies change, governments may inadvertently create focal points that individuals strive to achieve. In this case, if the 50 percent LTV threshold becomes a goal that agents try to meet when taking out a mortgage, such reference dependent preferences could also generate bunching at the policy threshold. That said, while there are various forms of reference dependence that may generate either notches or kinks, Kleven (2016) states that the notch-based theory is "arguably more natural in settings in which reference points represent goals that agents strive to meet." As a result, such a theory would imply a substantially larger missing mass, contrary to what we see in the data.[25] In addition, if individuals strive to achieve 50 percent or seek to increase their amortization payments because of the requirement, we would expect to see a response *below and above* the threshold in either borrowing or amortization payments. Figure 4 shows that the number of borrowers with LTV ratios below 47 is essentially unchanged, and Figure 2 shows that the share of interest-only mortgages at lower LTV values is similarly unchanged when comparing pre-and post-requirement years.

Optimization frictions. Finally, one remaining concern is that optimization frictions may prevent borrowers from fully reacting to incentives around the policy threshold (Best *et al.*, 2020; Anagol *et al.*, 2022). As a result, we might think that the lack of missing mass is not indicative of a kink, but rather a notch combined with optimization frictions. In our setting, optimization frictions are potentially related to inattention, misperception, or real adjustment costs.[26] That said, there are various reasons why we think the issue of optimization frictions should be relatively minor in our setting. First, the consequences of choosing a higher LTV are highly salient for the borrower at the time of mortgage origination. All Swedish banks provide online tools that show the borrower how different LTV ratios affect total mortgage payments (see Figure A6 for an example). The calculator typically allows the borrower to enter a property value and a down payment and calculate 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. Further, loan officers at banks generally advise their clients about the consequences of choosing different LTV ratios. We believe that the institutional setup related to mortgage choice in Sweden strongly limits the relevance of inattention or misperception.

Second, 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, for households who own just under 50 percent of the equity in their homes, the amounts required to comply with the requirement do not appear to

[25]In contrast, loss aversion would generate a kink in household preferences (Andersen *et al.*, 2022), although we see little reason why households would feel loss aversion as a result of this policy.

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

be prohibitive. Complying with the requirement requires lowering the borrowed amount by 1 percent for borrowers just above the threshold. This percentage represents about 16,000 SEK (approximately 1,600 USD), or 3 percent of annual disposable income. Further, if the household really needs immediate liquidity, they could always borrow more and then gradually pay down the mortgage balance (Svensson, 2016). Overall, given the salience of the mortgage decision and other institutional details, we believe that the lack of missing mass above the policy threshold is not due to optimization frictions.

6 Aggregate implications of mortgage payment sensitivity

The above results show that households experience excess sensitivity to monthly mortgage payments, beyond what would be suggested by traditional theories of household behavior. How does this matter for our understanding of the aggregate economy? Here we consider two important implications of mortgage payment sensitivity: (1) the effects of financial innovation on household borrowing and (2) the effects of mortgage amortization on wealth accumulation.

6.1 The aggregate effects of financial innovation on household debt

Our model helps us better understand the effects of financial innovation on household borrowing. Financial innovation in the 1990s and early 2000s generated a wide variety of new mortgage products with alternative repayment schedules in the US and other countries. During the same period, household debt increased substantially. Some commentators have suggested that new mortgage products, such as interest-only mortgages, contributed substantially to this increase in mortgage borrowing. Of course, it is impossible to isolate the effect of IO mortgages on overall debt by looking at aggregate time series alone.

We use our model to shed new light on the link between financial innovation and aggregate borrowing. Our model allows us to isolate the effect of financial innovation on household behavior, something that would not be possible without a model. Overall, we find that interest-only mortgages substantially increase household borrowing. Further, the psychic cost amplifies the effect of financial innovation on aggregate debt and lifetime interest expenditure.

To demonstrate, we use our model to study the transition from traditional mortgages with fully amortizing repayment schedules to alternative mortgage products with interest-only (IO) repayment schedules, similar to the US experience during the late 1990s and early 2000s. We begin with a model economy where households only have access to fully amortizing mortgages with constant-level repayment plans, then suddenly allow households to borrow using IO mortgages. We model fully amortizing mortgages following Attanasio *et al.* (2024), who assume that households must make equal mortgage payments every year that they own the house until retirement, based on the following formula:[27]

$$\rho_t(m_t, p_t) = \frac{(1 + r^M)^s}{\sum_{j=1}^{W-t}(1 + r^M)^j} * m_t \tag{14}$$

We compare the steady state distribution of mortgage balances in a model economy with fully amortizing mortgages to the steady state distribution of mortgage balances with interest-only mortgages, given by equation (8). For simplicity, we assume that only the repayment schedule changes and that no other model parameters are affected. We assume households incur ongoing flow disutility to amortization payments, given by equation (13). We later turn off this mechanism to evaluate the relative importance of flow disutility.

We find that the introduction of interest-only mortgages increases mortgage debt by 33.4 percent relative to the world with traditional amortizing mortgages, according to our calibrated model. Debt service payments also increase by 33.4 percent over the life, in line with the increase in mortgage borrowing. There are two reasons why households are willing to increase borrowing when they have access to IO mortgages. First, they no longer incur flow disutility due to amortization payments. Second, they have greater flexibility to smooth consumption over the life-cycle, in the spirit of Cocco (2013). Using our model, we decompose the relative importance of these two channels. We find that over two-thirds of the increase in mortgage debt can be explained by flow disutility, while just under one-third comes from improved flexibility. In contrast, when we simulate the introduction of IO mortgages in the model without psychic costs ($\Delta_k = 0$), mortgage balances increase by only 9.1 percent. Overall, our results indicate that flow disutility amplifies the effects of financial innovation on household borrowing.

The degree of amplification is heightened by the fact that we find a kink rather than a notch in preferences. Had household behavior been driven by a notch, there would have been only a local effect on borrowing and thus less amplification relative to the traditional model. This is because a notch reduces borrowing for households who otherwise would have located directly above the

[27] We calculate the repayment schedule based on time to retirement so that we do not need to keep track of the maturity of each mortgage, which allows us to save a state variable in the household decision problem.

threshold, while a kink reduces borrowing for all households above the threshold.

6.2 The effects of mortgage amortization on wealth accumulation

Recent quasi-experimental evidence shows that mortgage amortization plays an important role in household wealth accumulation. In an influential paper, Bernstein & Koudijs (2024) (BK) evaluate the effects of mortgage amortization on wealth accumulation, exploiting a Dutch policy reform of mandatory amortization to obtain the first causal estimates of the degree of marginal wealth building from amortization (MWA). The authors find that the MWA is close to one, meaning that every dollar of additional mortgage amortization leads to nearly a dollar of additional wealth accumulation. More specifically, mandatory amortization leads households to increase net housing wealth without reducing their liquid wealth. That said, the mechanisms behind this empirical result are not yet fully understood. Here we consider the effects of mandatory amortization on wealth accumulation through the lens of our calibrated model.

More specifically, we evaluate whether our model can replicate the high MWA observed in the data, then examine how different model mechanisms affect the relationship between amortization and wealth accumulation. To do so, we simulate two versions of our model, one with interest-only mortgages and one with partial amortization, as in Section 5. We then estimate the same regressions as BK, using the change in policy as an instrument for mortgage repayment. Despite some differences in the institutional details, the policy reform in our model generates a remarkably similar increase in mandatory mortgage repayment as the Dutch reform studied by BK. In our model, the share of mortgage principal that must be repaid each year increases by 1.5 percentage points following the introduction of mandatory amortization — identical to the 1.5 percentage point increase observed following the Dutch reform.[28]

Following BK, we estimate the MWA using an intent-to-treat design, focusing on the wealth accumulation of first-time home-buyers and exploiting the change in policy regime as an instrument for mortgage repayment. In particular, using simulated data from the model with and without mandatory amortization, we estimate the following first stage regression:

$$\Delta M_{t+2,i} = \lambda + \delta \, 1_{\text{MA, i}} + \eta_i \tag{15}$$

[28] The main institutional differences are that (1) Dutch borrowers can obtain mortgages with an LTV>100% and (2) the Dutch reform converted mortgages from partially amortizing to fully amortizing. We view these details as largely irrelevant given that the two policies simply serve as an instrument for mortgage repayment in equation (15) and generate a similar increase in amortization in both our model and the Dutch data.

where ΔM is mortgage repayment, λ is a constant term, and $1_{\text{MA, i}}$ is a dummy variable equal to 1 if household i purchased their house in the policy regime with mandatory amortization. This equation is almost identical to BK, modified to exploit the fact that we can observe the same household across both policy regimes and simplify from regional heterogeneity not present in our model. If the reform increases mortgage repayment, δ will be positive. The second stage estimates the effect of predicted mortgage repayment from equation (15) on total savings:

$$\Delta W_{t+2,i} = \lambda + \gamma \widehat{\Delta M}_{t+2,i} + u_i \tag{16}$$

where ΔW is the change in net wealth, λ is a constant term, and γ represents marginal wealth building from amortization (MWA). We focus on mortgage repayment and wealth accumulation two years after home purchase to align with the empirical setting in BK. We also follow the same sample selection as BK, restricting our sample to first-time home buyers who do not have large fluctuations in mortgage balances of €100,000 or more. Finally, to evaluate the reduced-form effects of mandatory amortization on different types of wealth accumulation, we re-estimate equation (15) using the change in liquid wealth and net wealth as the dependent variable.

Table 3 shows the results of estimating equations (15) and (16) on simulated data generated by the model under four alternative calibrations. The introduction of mandatory amortization leads to a large increase in mortgage repayment (column 1) in all settings. Focusing on the baseline calibration, we see that mandatory amortization leads to greater wealth accumulation (column 2), as additional mortgage repayment is financed by reduced consumption and offset only partially by reduced liquid wealth (column 3). Taken together, our 2SLS estimates reveal an MWA of 0.85 in the baseline model without psychic costs and 0.98 in the baseline model with flow disutility (column 4). This means that every additional dollar of mortgage amortization leads to an additional 85 to 98 cents of wealth accumulation in our model. For comparison, BK obtain a baseline estimate of 99.7 cents, very close to our baseline model with flow disutility.

The baseline model generates an MWA close to one regardless of whether the model includes flow disutility to amortization. The economic intuition for this result is that the model features many wealthy hand-to-mouth (WHTM) households in the spirit of Kaplan & Violante (2014). This is especially true of first time home buyers, who hold little liquid wealth just after home during that period. As such, mandatory amortization forces young, credit-constrained households to reduce spending to repay their debt more quickly than they would otherwise like to do.

Table 3. The Effects of Mortgage Amortization on Wealth Accumulation

	(1) Mortgage Repaid	(2) ΔNet Wealth	(3) ΔLiquid Wealth	(4) MWA	(5) MWA
Empirical Results:					
Bernstein Koudijs	2,045.0***	2,038.2***	—	0.997***	1.008***
Baseline Model Calibration:					
No Psychic Cost	1292.57	1106.99	-185.79	0.856	0.522
Flow Disutility	2855.29	2800.10	-55.19	0.981	0.914
Alternative Model Calibration: High r					
No Psychic Cost	4074.23	574.20	-3500.04	0.141	0.081
Flow Disutility	4343.68	1969.15	-2374.52	0.453	0.435
Sample:	Full	Full	Full	Full	$a > 10,000$

Notes: The table compares the empirical estimates in Bernstein & Koudijs (2024, Tables II and V) to estimates using simulated data from the model in Section 5. In Columns 1-3, BK results are in Euros and model results are in USD. Columns 1-3 are reduced form estimates from equation (15) and columns 4-5 are 2SLS estimate from equation (16). The sample consists of first-time buyers who do not adjust their mortgage balance by more than €100,000 in the two years after home purchase, implying that they do not sell their home shortly after purchase.

Further, the presence of flow disutility to amortization boosts the MWA because it increases households' desire to repay debt and build wealth in the form of home equity, raising the shadow value of mortgage repayment relative to saving in liquid assets.[29]

Similar to Kaplan & Violante (2014), our baseline model generates WHTM households by assuming that the return on liquid assets is strictly dominated by the return on illiquid assets. To illustrate the importance of WHTM households, we repeat the above experiment using an alternative model calibration where households have access to a (unrealistically) high return liquid asset ($r = 0.06$) that greatly reduces the share of WHTM households. When mandatory amortization is introduced in this setting, we see that much of the increase in mortgage repayment (column 1) is financed by reduced liquid wealth (column 3). Mandatory amortization leads households to substitute away from liquid assets and towards mortgage repayment, with relatively little effect on net wealth accumulation (column 2). As a result, we estimate an MWA of only 14 cents on the dollar when we omit the psychic cost and 45 cents on the dollar when we include the psychic cost, both well below the empirical estimate.

It's important to note that WHTM behavior cannot entirely explain the high MWA, as BK find that the MWA is close to one even for households with considerable liquidity. In column 5,

[29]This is reminiscent of Becker & Shabani (2010), who note that debt repayment is optimal if the interest rate on debt is higher than the expected return on outside investments. In our model, flow disutility to amortization raises the expected return on mortgage repayment.

we replicate their analysis by re-estimating equation (16) on the sub-sample of households with $a >$ €10,000 at the time of first home purchase. In the baseline calibration, we find that the MWA is relatively low in the model without flow disutility, while remaining above 90 cents to the dollar when households incur flow disutility. In the alternative calibration with a high return liquid asset, the MWA is even lower in both cases. Taken together, these results highlight the importance of having an additional mechanism beyond WHTM behavior to explain the observed effects of mortgage amortization on wealth accumulation.

While flow disutility to amortization increases the MWA, it is still an open question what exactly flow disutility represents. The presence of WHTM households helps to raise the MWA, yet this mechanism is not sufficient to explain the large MWA for households with substantial liquid assets. Another possibility is that housing may act as a savings commitment device. Attanasio *et al.* (2021) show that mandatory amortization increases overall wealth accumulation, as greater mortgage repayment does not crowd out liquid saving one-to-one in a model where housing acts as a savings commitment device. Further, Attanasio *et al.* (2024) argue that mortgages may act as commitment devices when they come with repayment schedules that force wealth accumulation in the form of home equity. We believe that better understanding the mechanisms behind the one-for-one increase in wealth accumulation due to mortgage amortization is an important open question for future research.

7 Conclusion

This paper provides evidence that amortization payments directly affect household borrowing decisions. We find that borrowers reduce their loan-to-value ratios by five percent at origination in response to a one percentage point higher amortization rate. Our results are not driven by supply-side factors, such as interest rates, credit assessments, or fees, and apply to both home buyers and refinancers. Instead, the results are driven mainly by wealthy, unconstrained borrowers, indicating that credit constraints are not the primary driver of our results.

Based on the empirical evidence, we develop a model to help us better understand why wealthy borrowers bunch to avoid amortization payments. While a traditional model with housing and mortgages can easily account for bunching by low-wealth, credit-constrained households, it cannot account for bunching by wealthy, unconstrained households. We amend the traditional model with two potential mechanisms – a one-off disutility to amortization and flow disutility to amortization payments – that generate either a notch or a kink in the households' expected discounted utility. We disentangle the two mechanisms by showing that a one-off disutility cost generates missing mass above the threshold, which is in contrast to our empirical results. The evidence is thus consistent with many households incurring some form of ongoing flow disutility to amortization. While fully identifying the exact mechanisms generating flow disutility is beyond the scope of the present analysis, one possibility is that households may perform monthly payment targeting (in the spirit of Argyle *et al.*, 2020) or may not recognize amortization as a form of savings. If this is the case, consumers may suffer from "NPV neglect" when making borrowing decisions, and thus may substantially increase borrowing and lifetime interest expenditure when offered mortgage products with delayed repayment schedules.

While our analysis demonstrates that changes in debt repayment schedules affect borrowing behavior, an important open question is how changes in repayment schedules affect household well-being. We caution the reader against interpreting our results in a normative manner. Our findings suggest that amortization payments are viewed as costly by households, but do not offer a full picture as to why these payments are perceived as costly. Amortization payments could be costly due to behavioral factors that may motivate regulatory intervention, but also because of investment choices that would not motivate regulatory intervention. As our data do not allow us to answer such questions, we leave the normative implications for future research.

There are several ways that one could extend our analysis. First, it would be possible to extend our analysis using the empirical moments to estimate the preference parameters of the model. Indeed, we have already calibrated the amount of flow disutility to match the amount of bunching observed at the policy threshold (see Appendix D) and could use other moments to discipline the other preference parameters in the model. Second, while we have focused on how flow disutility to amortization affects household borrowing, it may be worthwhile to study how such preferences affect the types of contracts affected by banks. For instance, if banks understand that households target low monthly payments, there may be an incentive for banks to increase lending by offering longer loan maturities or interest-only repayment schedules. Third, our data allow us to evaluate how households respond to the amortization requirement at origination. Investigating borrowing and saving choices in subsequent periods is interesting and relevant from a financial stability perspective, and for understanding the normative implications of our results.

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A Internet Appendix: Figures

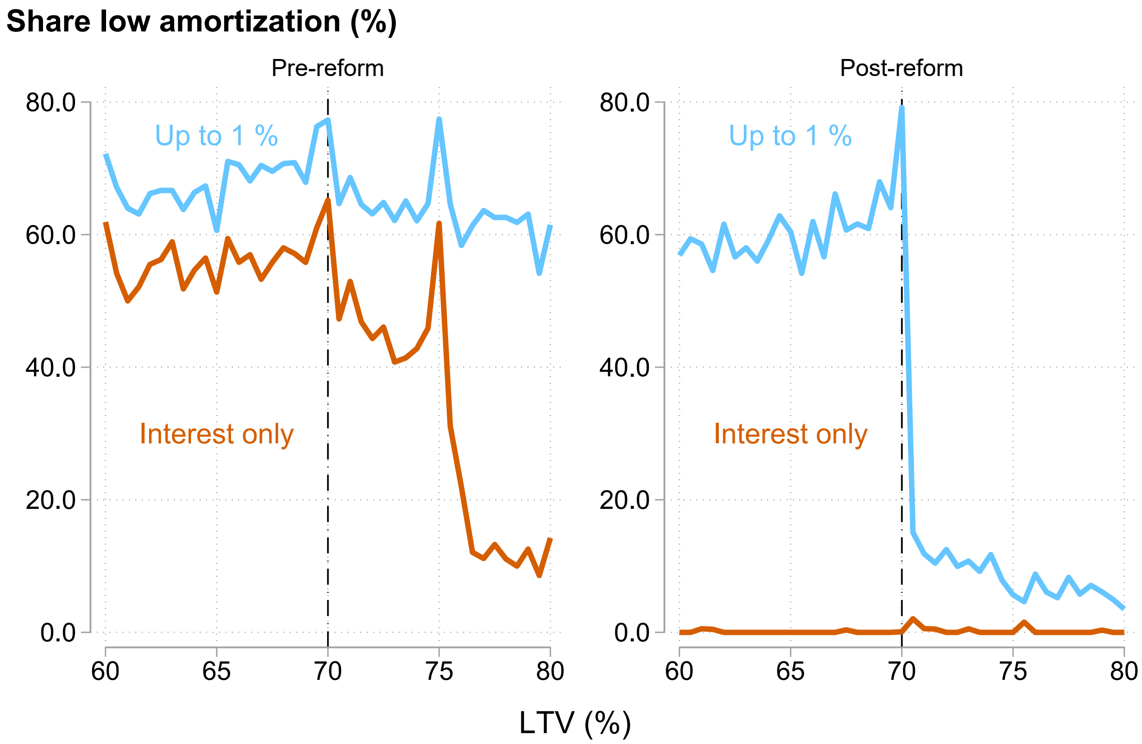
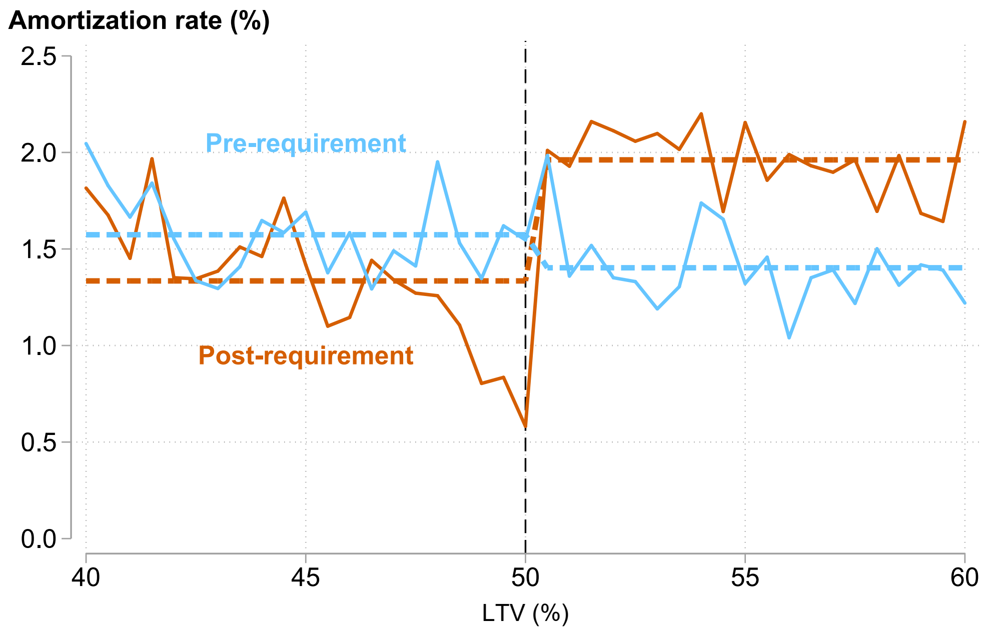
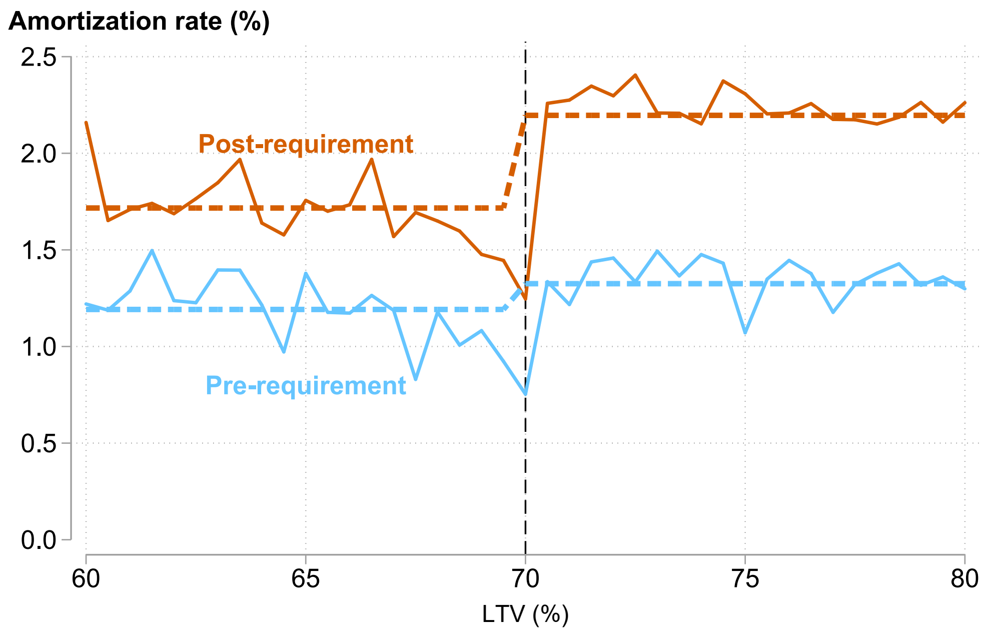


Figure A1. Share interest-only mortgages at the upper threshold

Notes: The orange line plots the share of interest-only loans by LTV in the years before the amortization requirement (left panel) and in the years after the requirement (right panel). The blue line plots the share of loans with amortization rates up to 1% of the loan amount.



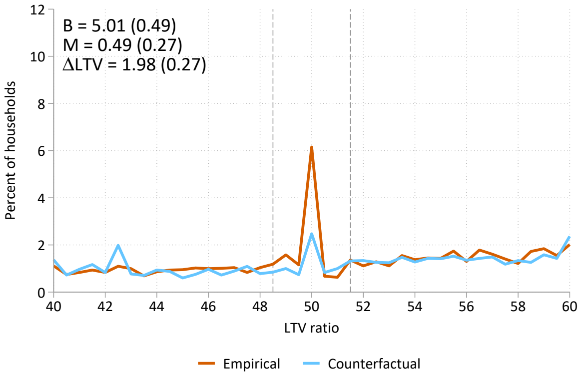
(a) Lower Threshold



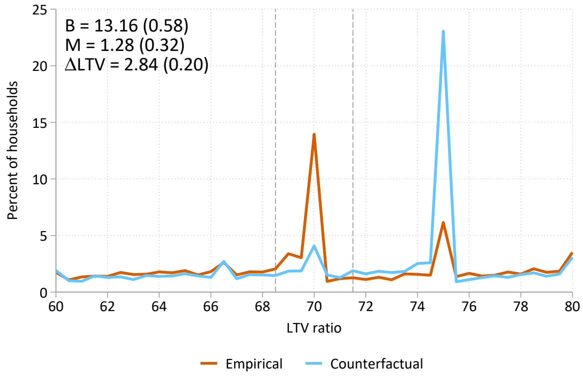
(b) Upper threshold

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

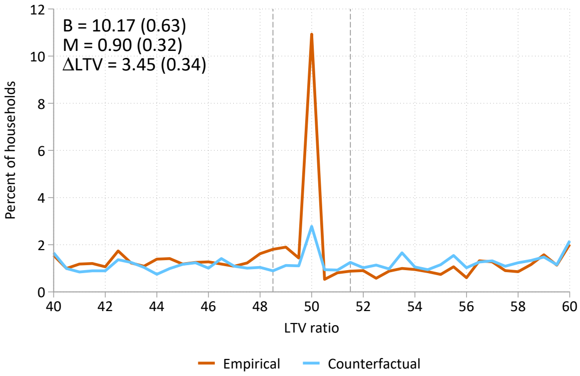
Notes: The figure plots the average amortization rate by LTV bin (blue dashed line) and the average amortization rate (orange solid line) above or below the LTV threshold marked by the black dashed line. Panel a) plots these around the lower threshold, and panel b) around the upper threshold.



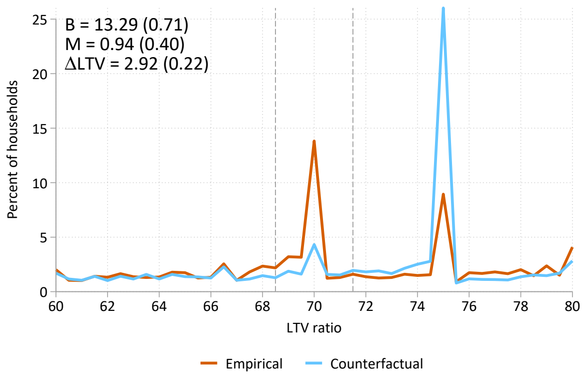
(a) Constrained borrowers, lower threshold



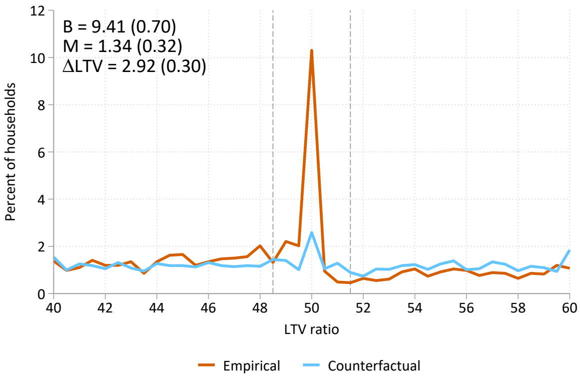
(b) Constrained borrowers, upper threshold



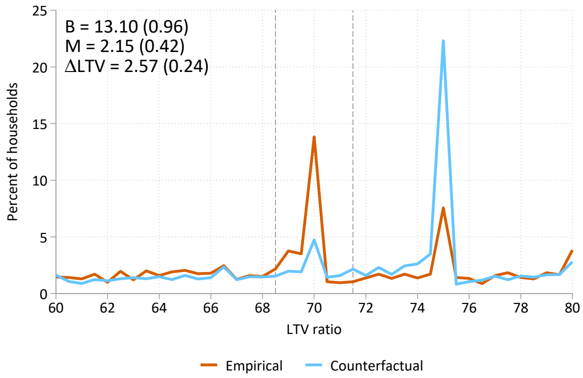
(c) Intermediate, lower threshold



(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 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.

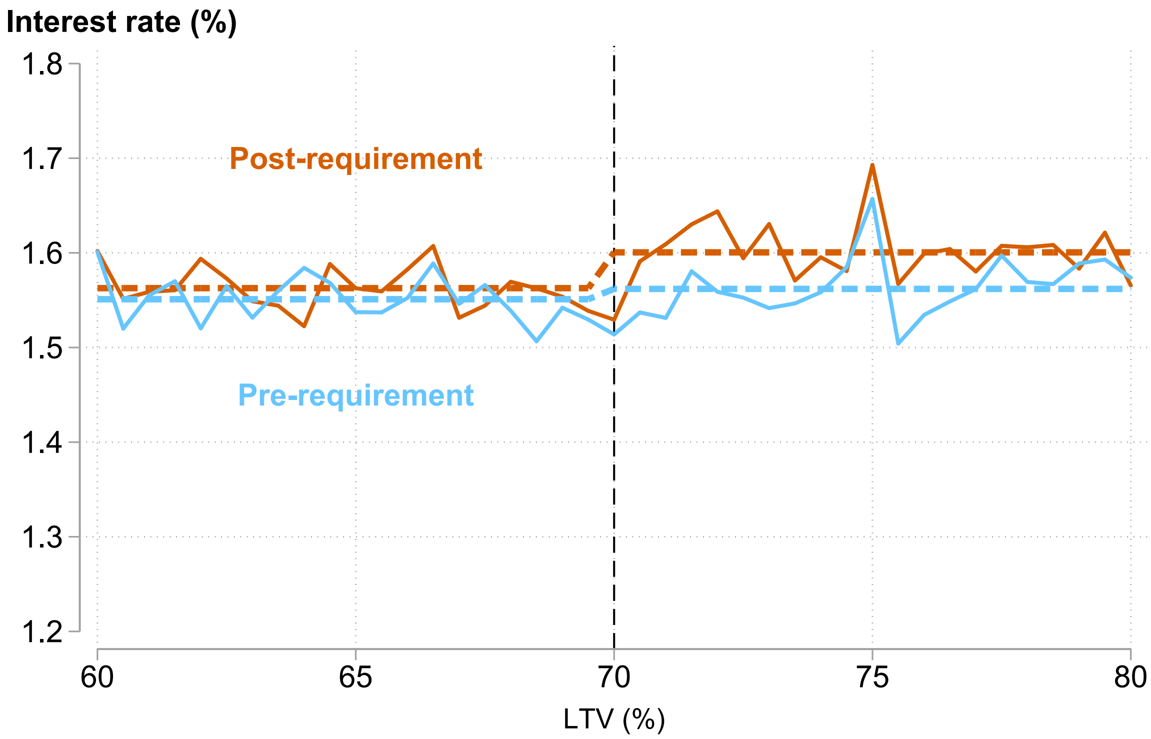
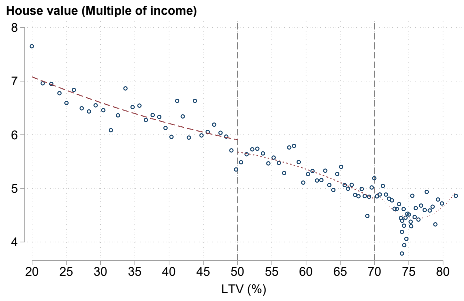
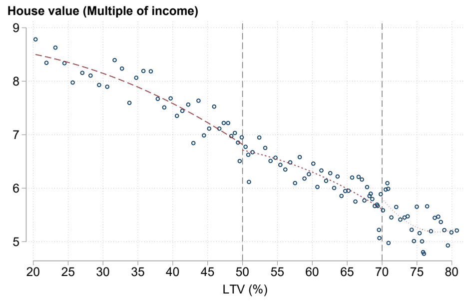


Figure A4. Interest rates around the upper LTV threshold

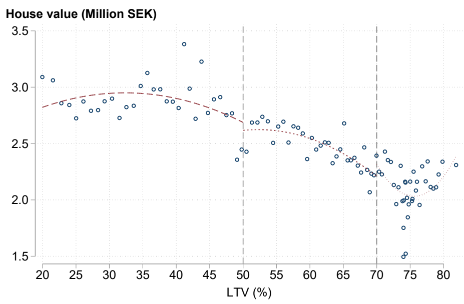
Notes: The figure plots the average mortgage rate by LTV bin for the upper threshold. The blue lines use data from the pre-requirement years (2012-2015) and the orange lines use data from the post-requirement years (2016-2018). The solid lines represent the average mortgage rate by bin, and the dashed lines are the average mortgage rates above (LTV between 60 and 70) or below (LTV between 70 and 80) the threshold. The threshold is marked with a dashed black line.



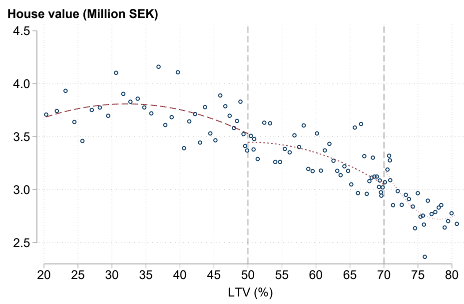
a) Ratio, pre-requirement



b) Ratio, post-requirement



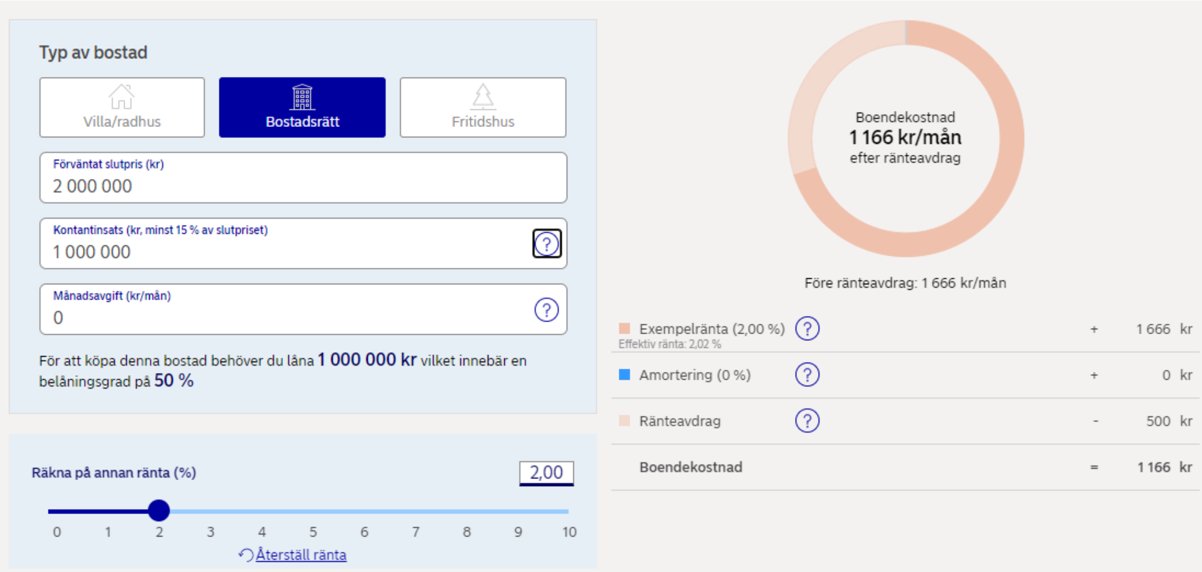
c) Level, pre-requirement



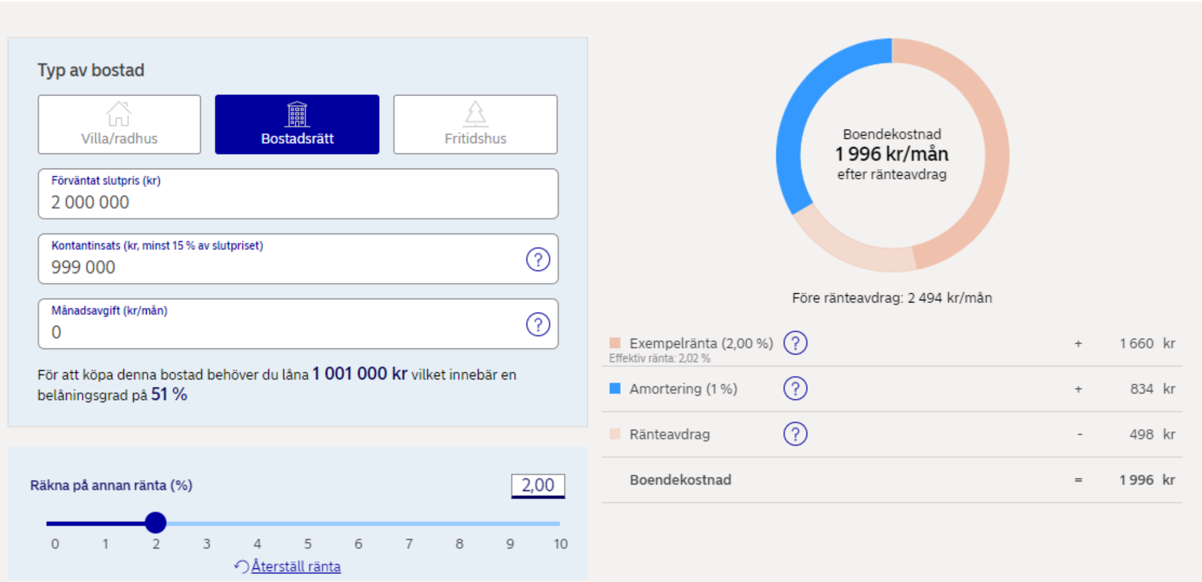
d) Level, post-requirement

Figure A5. 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 house values as a ratio to annual disposable income. Panels c) and d) plot the distributions for house values in millions of Swedish krona. 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 A6. 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' counterfactual discretionary income (see Section 4.2. We calculate the counterfactual 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 have counterfactual discretionary incomes 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. *Amortization, KSEK* is the monthly amortization payment in thousands of SEK. *Amortization rate* is calculated as mortgage amortization divided by mortgage debt. *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 ($\hat{B}$)	7.47	12.93
	(0.31)	(0.38)
Missing mass ($\hat{M}$)	-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	35,747	39,946

Notes: The table summarizes the main bunching estimates. *Bunching* is the percent of households bunching, calculated using equation (1). *Missing mass* is the percent of households missing, 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 (3). *Elasticity* is the estimated percentage change in LTV for a one percentage point higher amortization rate, calculated using equation (4). 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($\hat{B}$)	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)
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 ($\hat{M}$)	-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	35,747							

	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 ($\hat{B}$)	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)
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($\hat{M}$) (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	39,946							

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). Δ LTV is the estimate of the behavioral response, or the percentage point change in LTV ratio for the marginal buncher, calculated using equation (3). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 4. *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (2). 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 we measure the amortization elasticity of mortgage demand. Section C.2 provides placebo tests to verify our identification approach. Section C.3 provides the results for the upper threshold. Section C.4 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:

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

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

$$\alpha^* = \alpha_0 + \Delta\alpha + \Delta\alpha \cdot \frac{\overline{LTV}}{(LTV - \overline{LTV})} \tag{18}$$

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:

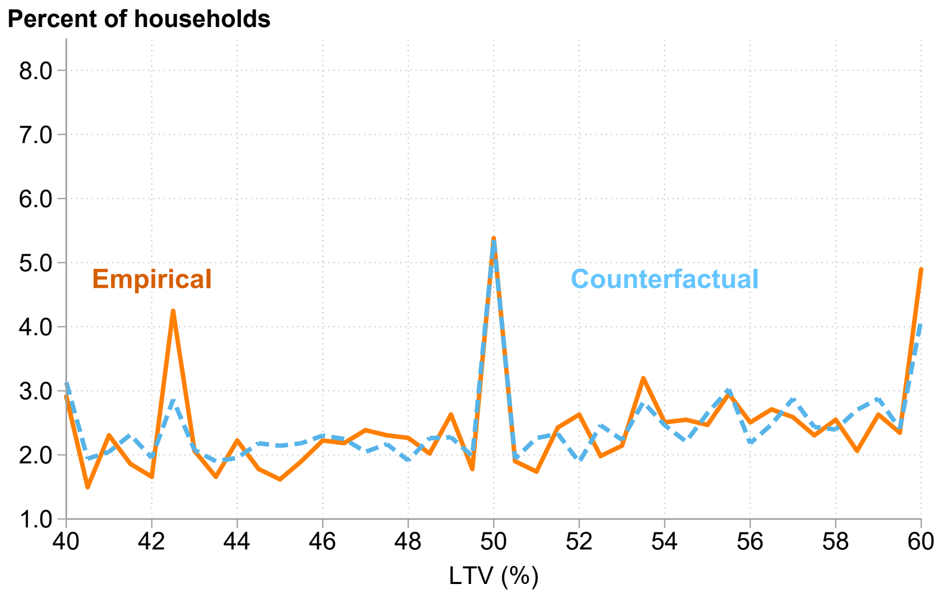
$$e^{\alpha} = \frac{\Delta LTV/\overline{LTV}}{\alpha^*(\overline{LTV} + \Delta LTV) - \alpha_0} \tag{19}$$

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 (18).

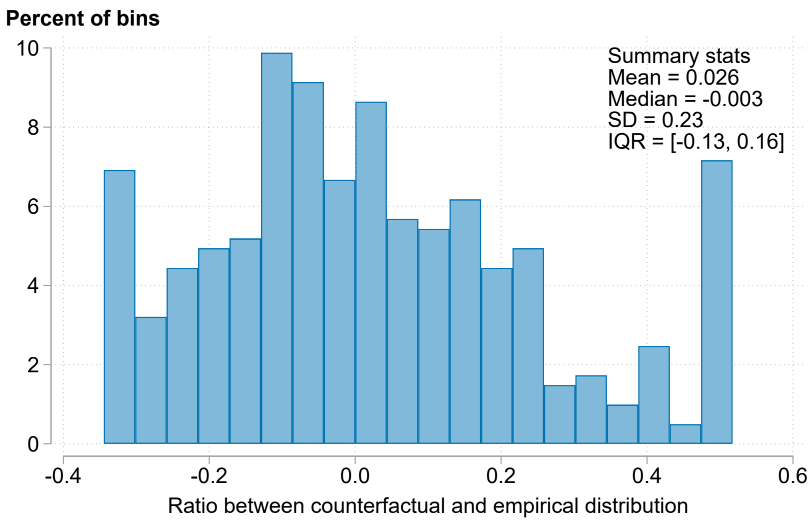
C.2 Placebo tests

We now study whether the counterfactual density obtained from pre-requirement data presents a good estimate of the fraction of borrowers in each bin, a key identifying assumption in our approach. We create a placebo test to assess whether the counterfactual distribution presents a good estimate of the fraction of borrowers without the requirement (DeFusco *et al.*, 2020). Specifically, each pre-requirement year from 2011 to 2015 is designated a "placebo" year. We then estimate the counterfactual distribution for both requirement thresholds in these years. By estimating the counterfactual 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 counterfactual distribution in a year without an amortization requirement. If our assumption is valid, the two distributions should coincide.

Figure C1 shows that our preferred approach passes this placebo test. Panels a) and b) plot the empirical and counterfactual 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 counterfactual



(a) Lower threshold: Placebo reform in 2014



(b) Lower threshold: Ratio, empirical to counterfactual

Figure C1. Counterfactual and empirical distribution in placebo years

Notes: Panels a) plots the empirical (solid orange line) and estimated counterfactual (dashed blue line) distribution of LTV ratios for 2014 for the lower threshold. 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 counterfactual. Panels b) provides a histogram of the ratio between the empirical and counterfactual distribution, for all bins in all placebo years. For each year we use data from the other pre-requirement years as the counterfactual. LTV ratios are restricted to be between 40 and 60. The summary statistics (mean, median, standard deviation and interquartile range) in the top right of panel b) are based on the same data.

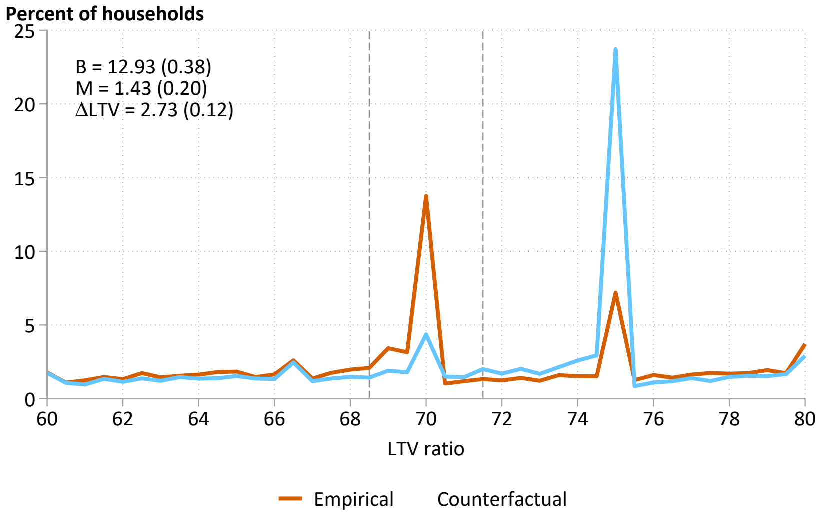


Figure C2. Bunching at LTV=70

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 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.

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.

C.3 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

C2. Similar to Figure 4, the figure plots the observed distribution using data from the post-requirement years and the counterfactual 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 C2.

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 counterfactual 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 (4). With the estimated ΔLTV of 2.73, the numerator equals $2.73/70 = 0.039$. Using the implicit rates from equation (18), 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.

C.3.1 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

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)
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	15,949	12,127	10,242

Notes: The table compares the main bunching estimates across groups based on payment-to-income constraints. We calculate the counterfactual 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. The Near constraint, Intermediate and Far from constraint sample has a counterfactual 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). Δ LTV the percentage point change in LTV ratio for the marginal buncher, calculated using equation (3). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 4. 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 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.

C.3.2 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.4 Bunching Estimates from Polynomials

This section provides additional results where we estimate the counterfactual distribution using the standard approach in the literature of fitting a flexible polynomial to the distribution and

Table C2. Bunching estimates by type of valuation

Valuation	Internal	External	Purchase price
Bunching ($\hat{B}$)	12.88	6.40	19.13
	(0.43)	(1.05)	(1.01)
Missing mass ($\hat{M}$)	-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	30,500	5,111	4,335

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). *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (2). Δ LTV is the percentage point change in LTV ratio for the marginal buncher, calculated using equation (3). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 4. 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.

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:

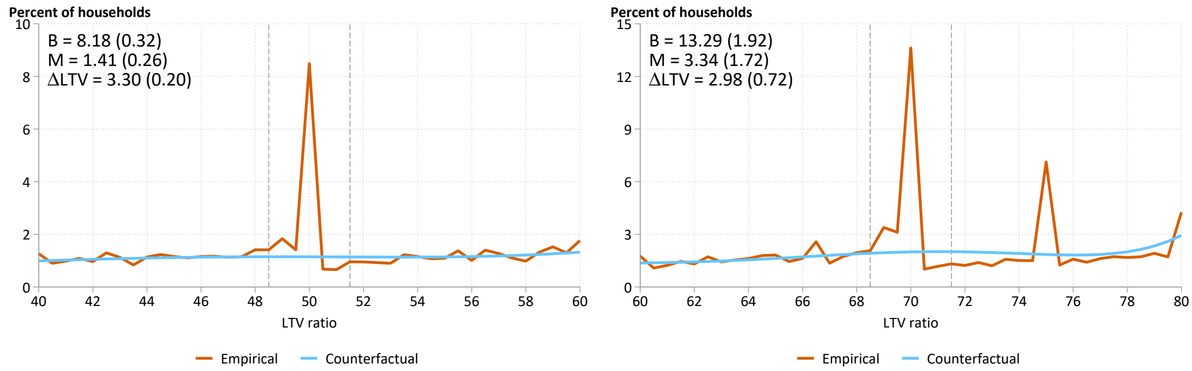
$$n_j = \sum_{i=0}^{p} \beta_i (m_j)^i + \sum_{k=L}^{U} \gamma_k \mathbf{1}(m_k = m_j) + \epsilon_j, \tag{20}$$

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 counterfactual distribution are given by the predicted values from the above regression while omitting the effect of the dummies in the excluded region:

$$\hat{n}_j = \sum_{i=0}^{p} \hat{\beta}_i (m_j)^i \tag{21}$$

The identifying assumption to estimate the causal effect of the amortization requirement is that the counterfactual 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 counterfactual distribution to the empirical distribution in the relevant regions (see equations 1 and 2). We use the procedure in Chetty *et al.* (2011) to calculate standard errors



(a) Lower threshold (b) Upper threshold

Figure C3. 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), 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.

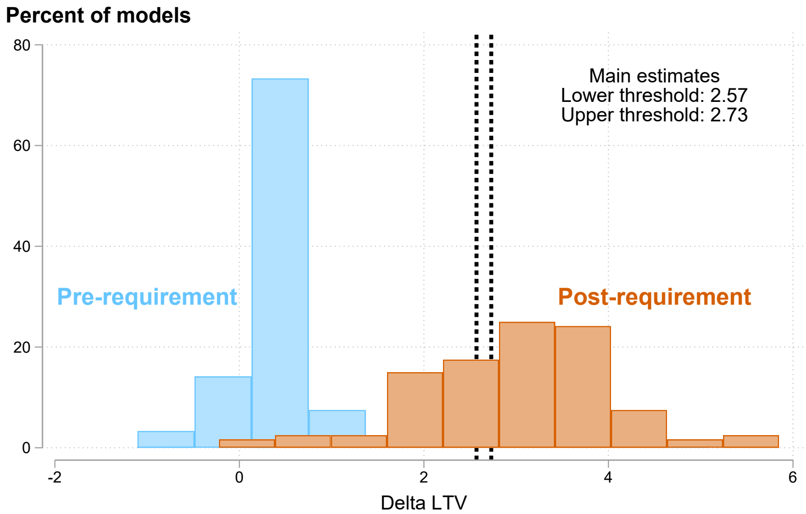


Figure C4. Robustness of estimated behavioral responses

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).

for all estimated parameters. Specifically, we randomly draw from the residuals in equation 20 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 C3 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 C4 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-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.

D Internet Appendix: Model Calibration

Table D1 shows the parameters set outside of the model of Section 5. Here we describe how we calculate the parameters in more detail.

Table D1. 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)
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)
Preferences:			
Time preference	β	0.96	Cocco (2004)
Risk aversion	γ	5.0	Cocco (2004)
Housing utility share	θ	0.1	Cocco (2004)
Disutility of renting	ζ	0.03	Leombroni *et al.* (2020)
Flow Disutility of Amortization	Δ_k	0.08	Author's calibration
One-Off Disutility of Amortization	Δ_n	0.35	Author's calibration
Assets:			
Real return on liquid asset	r	0.018	Swedish 3 month T-bill
Real return on housing	r^H	0.029	Statistics Sweden
Mortgage interest rate	r^M	0.043	Statistics Sweden
Multiplicative cost of refinancing	f_2	5.0%	Federal Reserve Board (2008)
Additive cost of refinancing	f_3	$3000	Federal Reserve Board (2008)
Liquid borrowing constraint	$\underline{a}$	0.0	Cocco (2004)
Maximum Loan-to-Value Ratio	$1-\psi$	0.85	Swedish law
Financial cost to moving homes	f_1	0.05	OECD (2011)
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

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).

Initial conditions. 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 $\sigma_{a_0} = 1.972$.

Household preferences. We set the main preference parameters following Cocco (2004). That said, we have explored alternative calibrations and found little impact on our main results. For instance, in an earlier version of the paper, we calibrated household preferences following Attanasio *et al.* (2012), assuming a higher β and substantially lower γ. In this alternative calibration, we still found that the traditional model could not generate bunching for wealthy households, and found similar results regarding the importance of notches or kinks in household preferences. We set the disutility of renting following Leombroni *et al.* (2020). For the notch and kink in household preferences, denoted by Δ_n and Δ_k, we calibrate these parameters in an attempt to roughly match the size of the excess mass at the policy threshold (see Figure D1). That said, given the identification strategy discussed in the paper, it would be straightforward to extend our analysis to estimate these parameters using the method of simulated moments.

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:

$$r_{t+1} = \frac{p_{t+1} + d_{t+1} - p_t}{p_t} \tag{22}$$

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:

$$r^H_{t+1} = \frac{p_{t+1} + s_{t+1} - c^m_{t+1} - c^i_{t+1} - p_t}{p_t} \tag{23}$$

where s_{t+1} and c_{t+1} are housing service flow and the costs related to homeownership (maintenance cost c^m_{t+1} and insurance costs c^i_{t+1}). We follow Kaplan & Violante (2014) and assume that housing service flows and costs are proportional to house prices, allowing us to rewrite Equation (23) as

$$r^H_{t+1} = \frac{p_{t+1} + (s - c^m - c^i - 1)p_t}{p_t} \tag{24}$$

Following Kovacs & Moran (2021), we assume that net housing service flows is 8 percent 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 percent and the insurance cost to 0.35 percent 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):

$$r^j_{adjusted} = E(r^j) - var(r^j) \tag{25}$$

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

Housing transaction costs. We assume that moving homes requires households to pay a transaction cost F equal to 5 percent 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).

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

Disutility costs. We calibrate the flow disutility of amortization (Δ_k) to match the excess mass at the policy threshold observed in the data ($\widehat{B} = 7.47$). Based on this approach, we choose to set $\Delta_k = 0.08$ which gives a model-implied excess mass of $B(\Delta_k) = 7.53$, only a touch larger than our baseline estimate from the data.

Figure D1 shows excess mass as a function of flow disutility, $B(\Delta_k)$, based on simulated data from our model. Excess mass is monotonically increasing in flow disutility. The dashed horizontal line indicates our baseline empirical estimate of excess mass $\widehat{B} = 7.47$, which we target. The dashed vertical line indicates our baseline calibration of flow disutility $\Delta_k = 0.08$.

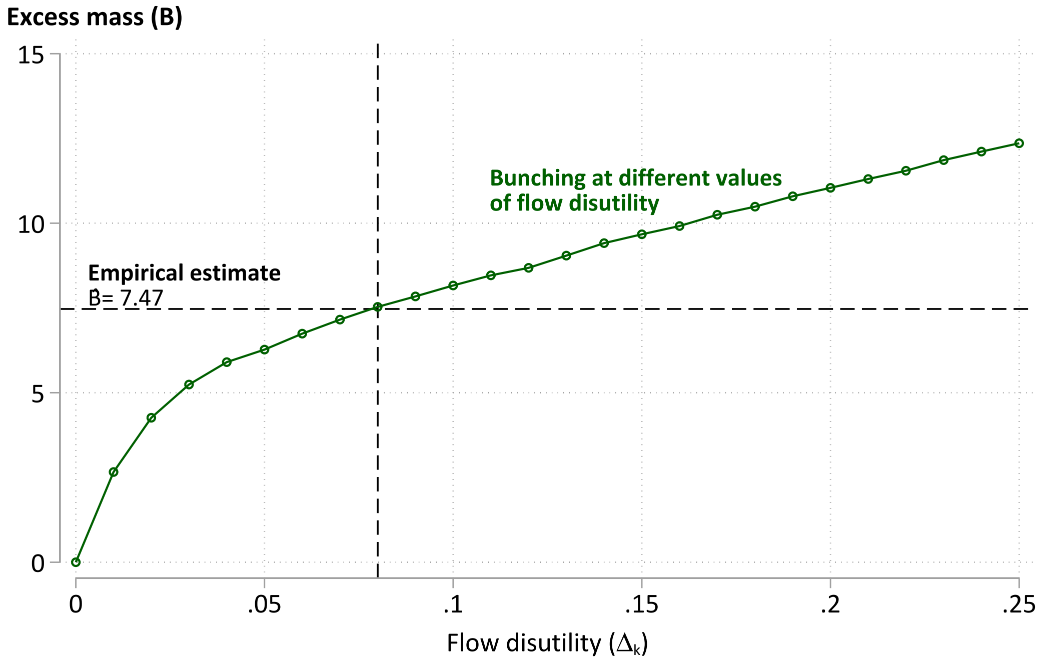


Figure D1. Relationship between flow disutility and excess mass

Note: This figure plots the model-implied excess mass $B(\Delta_k)$ as a function of the flow disutility of amortization based on simulations of the model with different values of Δ_k while all other structural parameters are kept constant.