Mortgage Design, Repayment Schedules, and Household Borrowing*

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Abstract

How does the design of debt repayment schedules affect household borrowing? We exploit a policy reform in Sweden that eliminated interest-only mortgages for borrowers with loan-to-value ratios above 50%. We document substantial bunching at the threshold, resulting in a 5% reduction in borrowing. The results are not driven by supply-side factors or credit constraints. A life-cycle model with kinks in household preferences generates a realistic LTV distribution with spikes at the 50% threshold, without missing mass. We argue that much of the effect comes from households viewing amortization payments as a cost rather than a form of saving.

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1 Introduction

Signing up for a mortgage contract commits the borrower to a long period of mortgage payments, which in most countries comprise both interest and principal payments. The mandatory principal payments can be substantial: in the United States, for instance, these payments are similar in aggregate magnitude to pension contributions, and thus represent a large share of household savings (Bernstein & Koudijs, 2021). While households traditionally had very little choice over their mortgage repayment schedule, this changed dramatically during the early 2000s. Financial innovation generated a large variety of new mortgage contracts, like the *interest-only* mortgage, that allowed households to avoid amortization. Today, interest-only mortgages are de facto banned in the U.S., yet such contracts remain popular in many other countries as financial regulators continue to grapple with the question of whether to ban such mortgages.

Despite the importance of mortgage amortization, we have little evidence on how this key feature of the mortgage contract affects borrowing behavior and on how borrowers view amortization payments. This paper seeks to fill the gap. First, we exploit a policy reform in Sweden that eliminated interest-only mortgages for borrowers with loan-to-value ratios above 50%. We document substantial bunching below the threshold, as households borrow less in response to the policy. The reduction in leverage is equally large for constrained borrowers and for unconstrained borrowers with substantial additional borrowing capacity. Motivated by the puzzling response by unconstrained borrowers, we develop a theoretical framework that clarifies the different mechanisms that may generate a reduction in leverage from increased amortization payments. While our life-cycle model easily generates bunching for constrained borrowers, it does not replicate the empirical findings for unconstrained borrowers. We discuss various extensions to the baseline model that can generate bunching through household preferences.

Our empirical analysis exploits a macroprudential policy introduced in Sweden in 2016, the amortization requirement, which features two loan-to-value (LTV) thresholds where minimum mandatory mortgage payments exhibit a discontinuous jump. As a result of this policy, mortgage borrowers with LTV ratios above 50% cannot get interest-only mortgages, but have to repay at least 1 percent of their original loan per year. Borrowing more than 70% of the home value requires a repayment of at least 2 percent annually. We estimate the response to the requirement using a bunching analysis, using pre-requirement years to form the counter-factual LTV distribution. We document significant bunching at both LTV thresholds. New borrowers reduce their LTV ratios by 5% in response to a 1 percentage point higher average amortization rate. We find similar degrees of bunching for both homebuyers and refinancers. Roughly 25% of the bunching is driven by credit-constrained households who are forced to avoid amortization due to regulatory payment-to-income (PTI) constraints. That said, even households that could borrow at least 2 million kronor (approximately $250,000, more than double the average loan size in our data) extra before facing binding credit constraints decide to borrow less. Hence, our findings are not driven by credit constraints alone.

Our estimates indicate that borrowers choose lower LTV ratios to avoid amortization, despite the fact that they could borrow more, gradually repay it, and then turn-off amortization the moment they get below the statutory threshold. We verify the validity of our approach and the robustness of our results along several key dimensions. First, we assess the validity of our empirical strategy using various placebo tests, which show that previous years indeed provide a valid counterfactual LTV distribution.[1] Second, we evaluate heterogeneity along various different dimensions. We find similar results for households that purchase a property compared to those who refinance, thus alleviating concerns about housing choices.[2] Finally, we investigate various supply-side factors, such as interest rates, that could potentially affect the budget constraint, but find that none of these supply-side factors are able to explain our results.

Motivated by our empirical results, we develop a theoretical framework that allows us to clarify the different mechanisms that may generate bunching in household borrowing. We develop a life-cycle model of consumption, housing, and mortgages that builds upon the framework developed by Attanasio *et al.* (2012). In the model, households get utility from consumption and housing, face idiosyncratic and uninsurable income risk, may save in liquid assets and illiquid housing, and may borrow using long-term mortgages. Importantly, we model mortgage lending using long-term debt contracts that feature mandatory repayment schedules. Our model features two regimes: In the initial regime, households are only required to pay interest on their mortgage balances, although they can choose to pay more if they desire. In the second regime, households must amortize if their LTV ratio is above the statutory threshold, although they can revert to interest-only payments once they get below the threshold. These two policy regimes (interest-only or amortizing) broadly represent the institutional framework present in Sweden before and after the 2016 reform.

In the baseline model, we find no bunching in the LTV distribution at the statutory threshold. The basic intuition for this result is that unconstrained borrowers have a number of ways to undo higher required amortization payments. Unconstrained households can borrow more at origination (Svensson, 2016), can do (costly) refinancing (Hull, 2017) or reduce savings in liquid assets. Notably, the LTV distribution is smooth even if we turn off the option to refinance, or if we set a high discount rate so that the higher required amortization payments are binding. Without a credit constraint to limit borrowing, higher required savings does not have a first-order impact on borrowing decisions.

If the baseline model does not generate bunching, what potential extensions can help us replicate the observed behavior of households? There exist four potential channels that can generate bunching: notches or kinks in the budget constraint, and notches or kinks in household preferences (Kleven, 2016). We find only a limited role for notches or kinks in the budget constraint in our empirical results. Note that amortization payments are not a cost in the baseline model but instead are a form of savings. As mentioned above, we find that roughly 25% of the excess mass at the threshold can be explained by the previously mentioned PTI constraint. However, we find no evidence for any other supply-side factors that could potentially affect the budget

[1] We repeat the analysis using a polynomial approach to capture the counterfactual (Kleven, 2016) and find even stronger results than our baseline specification.

[2] For refinancers, the home value is set exogenously by the bank based on the bank's assessment of the collateral value. These results support our interpretation that the observed decline in loan-to-value ratios comes from lower loan demand (the numerator in the LTV), and not from changes in housing choices (the denominator).

constraint (e.g. kinks or notches in interest rates, mortgage approval, collateral assessments, and refinancing costs). As a result, we turn our attention towards household preferences and consider various behavioral biases that may generate notches or kinks in preferences.

We introduce two different behavioral wedges into household preferences, where we adopt a reduced-form approach to behavioral modeling following Mullainathan *et al.* (2012). The first wedge introduces a notch in household preferences at the amortization threshold. More specifically, we allow for the possibility that households may experience disutility when going from above to below the statutory threshold. This may capture, for instance, a psychic cost to mortgage renegotiation, which households suffer when they seek to turn off amortization payments.[3] That said, there are other behavioral factors which could also generate a notch, and our approach allows us to remain agnostic about the particular behavioral channel. For instance, if households are uncertain about their ability to turn off amortization, this would also generate a notch. Similarly, if the statutory threshold serves as a target LTV ratio that agents strive to achieve, then reference dependence could also generate a notch in household preferences (Kleven, 2016). The notch induces bunching at the threshold, missing mass just above the threshold, and applies only locally around the threshold.

The second wedge generates a kink in household preferences. More specifically, we introduce a recurring utility cost to amortizing. This cost may occur for various different reasons. For instance, households may view amortization payments as a cost rather than a form of saving (Camanho & Fernandes, 2018).[4] Alternatively, households may perform "monthly payment targeting in the spirit of Argyle *et al.* (2020). In either case, such preferences generate "NPV neglect," where households do not fully consider the net present value of future mortgage payments when choosing between alternative mortgage contracts (see e.g. Shu, 2013). In the model, the kink induces bunching at the threshold but does not induce any missing mass. All borrowers above the threshold are affected by the kink and shift their borrowing downwards, which fills up the missing mass.

The distinction between notches and kinks allows us to disentangle the relative contribution of these two different channels. Specifically, notches generate bunching due to a missing mass directly above the threshold, while kinks generate bunching without a missing mass. In the data, we find that less than 15% of bunching can be explained by the missing mass directly above the threshold. The lack of missing mass is difficult to rationalize with optimizing frictions, since borrowers are themselves choosing a LTV value and since the consequences of choosing a higher LTV is very salient at the time of origination. Moreover, where a notch has a local effect just above the threshold, a kink affects all borrowers above the threshold. In our context, the implication is that a notch in household preferences would have a small effect on

[3]As mentioned previously, Swedish borrowers can turn off amortization once they have paid down enough of the loan to get below the statutory threshold. The higher amortization payments around the threshold induced by the requirement are thus temporary. In most Swedish banks, there is no monetary cost to turn off amortization once you reach the statutory threshold. We know of only one small bank that charges a fee and we find similar results when we exclude that bank from our analysis. The borrower can lower their amortization payments once they hit the threshold with a phone call or online message to the bank advisor.

[4]In survey evidence, 38 percent of Swedish 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).

aggregate borrowing, whereas a kink would have a large effect on aggregate borrowing. These predictions can, in theory, be validated in the data, although identifying an aggregate effect for unconstrained borrowers is challenging. For instance, any evaluation would have to credibly distinguish between the response of constrained and unconstrained borrowers and any other omitted factor that would explain borrowing. Moreover, the response by constrained borrowers could spill over to unconstrained borrowers through general equilibrium effects on house prices, for example (Bäckman & Khorunzhina, 2022). With these caveats in mind, we show that aggregate borrowing slowed down after the amortization requirement came into effect. Supporting the idea of a large response to the amortization requirement, Wilhelmsson (2022) finds that the amortization requirement led to a 7 percent reduction in house prices but did not examine the role of constrained and unconstrained borrowers in driving these price changes. As a result, while both mechanisms play a role, we conclude that our results are driven by a kink in household preferences related to amortization payments. This result is consistent with monthly payment targeting and with viewing amortization payments as a cost.

Taking stock, we make three sets of contributions. First, we provide novel evidence that amortization payments affect household borrowing for both constrained and unconstrained borrowers. An implication of these results is that we need to examine all features of the mortgage contract, including amortization payments, when thinking about credit growth and household borrowing decisions. Unconstrained borrowers act as if amortization payments are costly and voluntarily trade off larger loans for lower payments. To our knowledge, we are the first to document this behavior in mortgage markets. It is notable that similar behavior has been observed in several other settings. In related studies, Argyle *et al.* (2020) find that consumers manage total payment size instead of interest-payments when making car-loan decisions, even in subsamples of unconstrained borrowers. Shu (2013) documents "NPV-neglect", the tendency of borrowers to target total payment size instead of the interest-rate. Similarly, Camanho & Fernandes (2018) find experimental evidence that homebuyers compare the monthly rental payment and the monthly mortgage installment including amortization payments, implicitly using the total mortgage payment instead of the interest cost to decide on whether to buy a house. Bernstein & Koudijs (2021) document that higher mandatory amortization payments lead to a large increase in household savings, even for unconstrained households.

Our paper also contributes to a recent literature that uses bunching to identify kinks or notches in household preferences (see, e.g. Lacetera *et al.*, 2012; Allen *et al.*, 2017; Strulov-Shlain, 2021; Andersen *et al.*, 2022). The use of bunching to estimate behavioral preferences has received attention in Kleven (2016) and DellaVigna (2018). Most of these studies focus on reference dependence or loss aversion, whereas we investigate household behavior in the mortgage market without having a clear prior on the preference that generates our observed empirical result.

The results for constrained borrowers are also of independent interest. We show that amortization payments represent a *de-facto* constraint on savings and borrowing for payment-constrained borrowers. This channel can explain a quarter of our empirical findings. Similar discretionary limits are imposed in the United States (Dodd-Frank's Ability-to-Repay requirement) and elsewhere. While amortization payments have recently been included in several theoretical models that incorporate realistic features of the mortgage contract (Greenwald, 2017; Kaplan *et al.*, 2020; Gorea & Midrigan, 2017), the interaction with credit constraints has generally been under-studied. Moreover, these results suggest that imposing payment-to-income constraints, as many countries have done in recent years (Alam *et al.*, 2019), may cause borrowers to reduce debt repayments. Bernstein & Koudijs (2021) show that amortization payments are crucial for building wealth, implying that imposing payment constraints could impede wealth accumulation if households reduce amortization payments to comply.

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

The paper is organized as follows. Section 2 provides background on the Swedish mortgage market and the amortization requirement. Section 3 presents several arguments for why amortization payments affect household borrowing. Section 4 presents the data and discusses the empirical strategy. Section 5 provides the main results, robustness and threats to identification. Section 6 develops a theoretical framework that allows us to clarify the different mechanisms that may generate bunching. Section 7 concludes.

2 The Amortization Requirement

The Swedish housing and credit markets experienced rapid growth in the early 2010s. House prices increased by 31 percent between 2011 and 2015, and credit growth increased from 5 percent in 2012 to over 8 percent in 2015. Concerned with financial and macroeconomic stability, the Swedish Financial Supervisory Authority (*Finansinspektionen*) announced that they would propose new regulation in November 2014, intending to reduce debt levels over time the amortization requirement. The purpose was to limit macroeconomic risks posed by high household debt levels. The FSA considered households with higher LTV ratios a higher risk; consequently, regulation targeted this group. The requirement came on top of the current recommendation by the Swedish Bankers Association (SBA), which recommended that borrowers amortize if their LTV values exceeded 70%. The amortization requirement was finally proposed in December

2015, and the law went into effect in June 2016. The FSA introduced an additional amortization requirement in March 2018, which mandates that any mortgage where the debt-to-income ratio is above 4.5 has to be amortized by an additional percentage point.

The Swedish amortization requirement mandates that all new mortgages issued after June 1st, 2016, with LTV ratios above 50 percent, must be amortized. New mortgages with LTV ratios below 50 percent are exempt. Borrowers switching banks with no change in contract terms are also exempt. The requirement, along with the previous recommendations from the SBA, is summarized in Figure 1. Before 2016, the SBA recommended that borrowers amortize loans with an LTV ratio above 75 percent (2011-2013, blue dotted line) and 70 percent (2014-2015, blue dashed line), respectively. Compared to the requirement introduced in 2016, the recommended rates were lower and implied an increase in the *marginal* amortization rate. The implemented amortization requirement instead mandates that new borrowers must amortize at least 1 percent per year on any mortgage where the initial LTV ratio exceeds 50 percent and at least 2 percent per year on any mortgage where the LTV ratio exceeds 70 percent. Since continuous re-valuation of property values could have pro-cyclical effects, the law states that the valuation can only be made every five years. Moreover, any re-valuation must be based on changes to the property value due to renovation or rebuilding of the property, not due to house price changes. A borrower can be granted an exception from amortizing after the origination of the loan, due to extenuating circumstances, such as unemployment, illness, or a death in the family.[5]

Once a borrower has amortized down to a threshold, the borrower is legally allowed to reduce the amortization rate. We contacted all banks in our sample to ask for clarification on how reducing amortization payments would work for their customers. All banks state that the borrowers need to contact the bank to ask for a reduction in amortization payments. No bank except one offers a contract where the amortization rate is reduced automatically. While the mortgage contract specifies the amortization rate or repayment plan, no new mortgage contract is required. Instead, a phone call or a request made on the customer's online bank 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 where it has happened, the denial was related to being delinquent or having missed mortgage payments.

The requirement had a large impact on amortization rates for new borrowers. From our microdata, which we discuss in detail in Section 4, Figure 2 plots the share of interest-only mortgages among new mortgages against LTV values for different years. Figure A1 plots the average amortization rates instead for completeness. Panel a) plots results for the lower threshold. In the pre-requirement years between 2013 and 2015, around 60 percent of mortgages

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

around the lower threshold were interest-only. In the post-requirement years between 2016 and 2018, the interest-only share is still around 60 percent to the left of the threshold. To the right of the threshold, the interest-only share is zero, as required by the policy. We also see a spike in interest-only mortgages precisely at the threshold, consistent with borrowers deliberately moving to the threshold to qualify for interest-only mortgages. Panel b) provides similar results for the upper threshold. The blue line tracks the share of borrowers amortizing up to one percent, the level mandated by the requirement. Again the interest-only share in the pre-requirement years was close to 60 percent, and again we see a sharp decline after the amortization requirement was introduced. Table B1 illustrates the corresponding reduction in payments from choosing a mortgage with a lower amortization rate. With a 2 percent mortgage rate, approximately the average mortgage rate for our sample, a borrower can reduce their mortgage payments by 33 percent by moving to the threshold.

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. All Swedish mortgages are subject to a maximum loan-to-value ratio of 85 percent as of 2010, and interest payments are deductible against capital gains and labor income. The banks set mortgage rates. Several Swedish banks use (or have used) a system where the portion of the mortgage with an LTV ratio above 75 percent has a higher interest rate (a so-called "top loan").[6]

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

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

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

3 Previous literature

This section presents several arguments for why amortization payments affect household borrowing. The arguments are mainly derived from standard models in economics and finance and provide rational explanations for why households may prefer lower amortization payments if given a choice. We also discuss how credit constraints imposed by the supply side (banks) would impact household borrowing. We later incorporate several of these channels into the life-cycle model in Section 6.

An amortization requirement can lead to *higher* LTV ratios for unconstrained borrowers (Svensson, 2016). An unconstrained borrower can borrow more than necessary, invest excess borrowing in a savings account, and make amortization payments from the savings account. In this setting, a borrower's net debt (debt minus savings) is the same regardless of the amortization requirement, yet LTV ratios will be higher. In general, in a setting with one-period debt, the borrower can always undo higher amortization payments by changing how much they borrow. Hull (2017) finds that amortization requirements have small effects on household borrowing, as frequent refinancing eliminates the impact. An unconstrained borrower can also reduce other types of savings, implying that the change in borrowing from higher amortization payments would be zero to a first approximation.

The brief discussion above implies that only constrained borrowers should be affected since unconstrained borrowers can undo the effect of required amortization. Why, then, do amortization payments affect household behavior, especially for unconstrained borrowers? Below, we discuss why amortization payments may be costly for borrowers unable or unwilling to undo them by borrowing.

First, required amortization payments may lead to sub-optimal saving rates. In life-cycle consumption models, the optimal savings rate depends on the relationship between current and future income. Since amortization payments are a form of savings, certain borrowers may wish to avoid payments entirely and instead consume. Forced amortization payments induce a cost on households whose optimal savings are below required amortization payments (Piskorski & Tchistyi, 2010). The argument over the suboptimal level of savings intuitively applies to households where current income is lower than permanent income. Examples of such households are young households with rising incomes or retired households who intend to live off their savings. Consistent with this theory, Cocco (2013) finds that young borrowers with rising income profiles are more likely to choose mortgages with smaller repayment, and Bäckman & Lutz (2020a) report that a large fraction of borrowers above the retirement age in Denmark use an interest-only mortgage. In the context of the amortization requirement, borrowers can achieve a lower savings rate and higher consumption by placing themselves at the threshold.

Second, even if households want to save, they do not necessarily wish to repay the mortgage principal (Bernstein & Koudijs, 2021). A borrower may wish to save in risky assets because of the higher expected return or invest in a diversified portfolio to reduce risks. The return on amortization payments is equal to the mortgage rate, and saving by paying down the mortgage concentrates savings in less diversified and more illiquid housing assets. By reducing amortization payments, the borrower may improve portfolio returns, increase diversification and improve liquidity.

Third, households might suffer from temptation and therefore want to save in illiquid assets by paying down their mortgage. Attanasio *et al.* (2020) present a two-asset model with temptation preferences that generate a demand for illiquidity (see also Schlafmann, 2020). Mandatory amortization payments serve as a form of commitment and thus increase household savings. If households could choose their amortization payment, however, they may reasonably disagree with the amount of commitment implied by the amortization requirement. Consequently, some households may reduce their borrowing to attain a lower level of commitment. Households with higher temptation needs can always amortize more than the requirement stipulates.

Fourth, households may consider amortization payments a cost, similar to interest payments. Survey results reported in SBAB (2018) indicate that more than half of Swedish households do not consider amortization payments to be savings: 44 percent stated that amortization payments were savings, 38 percent stated that they were a cost, and 18 percent did not know what amortization payments were (SBAB, 2018). Older Swedes were more likely to see amortization payments as savings (45 percent for 36-55 years old versus 40 percent for 23-35 years old). We report the full results from the survey in Table 1.

Fifth, households may want to maintain a high debt level to receive higher mortgage interest deductions to reduce the tax burden. Finally, in a non-recourse setting, interest-only mortgages benefit borrowers who wish to speculate on rising house prices (Barlevy & Fisher, 2020). A borrower who does not amortize keeps the default option high by maintaining high debt levels. In a Swedish context, this channel is likely limited, as enforced full recourse mortgages remove the option of strategic default. This feature of the Swedish mortgage market also changes the calculation on the mortgage supply side, as banks do not have to estimate the probability of strategic default and loss-given-default in the same manner as they would in the United States.[7] Swedish banks may even prefer an interest-only mortgage, as this maintains high interest income for a longer period while keeping costs for mortgage origination low.

On the supply side, Swedish banks evaluate a borrower's ability to repay based on a discretionary income limit (see Section 2.1). Discretionary income is the disposable income left over after the borrower covers subsistence consumption, borrowing expenses, and housing expenses. Importantly, borrowing expenses comprise both interest and amortization payments. In practice, this calculation functions like a payment-to-income constraint (Grodecka, 2020). Borrowers facing binding constraints may be unable to borrow more because of the discontinuous jump in mortgage payments above the LTV threshold (Bäckman & Lutz, 2020b). As alluded to earlier, the discretionary income limit accounts for around 25% of the bunching we observe (see Section 5).

Finally, several studies examine the effect of the Swedish amortization requirement. Andersson & Aranki (2017) use a difference-in-difference strategy to show that the amortization

[7] Note that this implies that a borrower in the US may value an interest-only mortgage *more*, as some states allow the option to default.

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.

4 Data and Empirical Strategy

4.1 Data

We use data from the Mortgage Survey (Bolåneundersökningen) from 2011 until 2018. The FSA collects this data directly from the eight largest Swedish banks as part of its micro- and macroprudential mandate. The dataset contains information on all new mortgages issued by these banks during certain days between August and October. The FSA varies the exact dates and announces the dates afterward to surprise banks and prevent them from applying different credit standards during these survey dates.[8] The survey includes household-level data on (gross and disposable) incomes, total debt divided into secured and unsecured loans, and certain household characteristics, as well as loan-level data on loan size, interest rates, monthly amortization payments, and value of the collateral. The data also includes the bank's calculation of discretionary income, evaluated at a stressed interest rate. Collateral values are usually based on banks' internal valuation models using previous transaction prices and local hedonic price indices. The transaction price is typically used for new home buyers. We use the total mortgage debt divided by collateral value to calculate LTV ratios. We are unable to link our mortgage data to other register data as households are reported anonymously. Table 2 provides summary statistics for the full sample and for groups based on financial constraints.

4.2 Empirical strategy

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

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

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

pre-and post-reform periods. We note that this is a different assumption than in the empirical bunching literature, where it is more common to assume that the counter-factual distribution is smooth in the absence of the policy change (see, e.g. Kleven & Waseem, 2013). Our approach can account for any spikes in the distribution at the thresholds related to, e.g., round number bunching or supply-side factors that would generate bunching. Our identifying assumption is that such spikes are constant across time. We conduct several robustness checks and rule out several potential mechanisms to ensure that this assumption is plausible in Section 5.5. 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 provides details on the flexible polynomial approach.

We group borrowers into LTV bins with a width of half a percentage point. The goal is to estimate the counter-factual fraction of borrowers in each LTV bin j in the post-requirement period had the amortization requirement not been introduced, denoted $\hat{n}_j$.][9] We measure the amount of bunching $\widehat{B}$ as the difference between the observed and counter-factual bin fractions in the region at and to the left of the threshold located at R:

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

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

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

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

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

Missing mass is equal to the difference between the observed and counter-factual distribution in the region to the right of the threshold. Note that borrowers making up the missing mass could either shift towards the threshold (intensive margin) or exit the market completely (extensive margin). If all borrowers in the region defining the missing mass bunch at the threshold, the intensive margin effect equals the amount of bunching. If some borrowers drop out of the market because of the requirement, this is equivalent to stating that not all borrowers shift toward the threshold. In our setting, there can be intensive margin responses for households located to the right of the notch that do not bunch, making estimating the extensive margin difficult. For

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

example, a household might choose an LTV ratio of 55 percent, whereas it (counterfactually) would have chosen an LTV of 60 percent had there been no amortization requirement. These households fill up the missing mass to the right of the threshold.

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

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

We calculate bootstrapped standard errors for all parameters by drawing 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, described in detail in the next section. This estimate captures the intensive margin response to the amortization requirement – the response of borrowers who still choose to borrow after the requirement was implemented. This margin sufficiently demonstrates our main idea: amortization payments are costly and affect credit demand. Identifying the extensive margin response to the reform convincingly would require strong assumptions over the distribution to the right of the threshold and extrapolation from the threshold up until the maximum borrowing limit of 85 percent. DeFusco *et al.* (2020) estimate a convincing counter-factual distribution above their threshold from the conforming loan market. As the Swedish amortization requirement affected 90% of the new mortgage flow, we lack a counter-factual and instead focus on the intensive margin response.

4.3 The amortization elasticity of mortgage demand

We can translate the bunching estimates into semi-elasticities. The amortization requirement creates a notch 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 notch. Specifically, define the implicit marginal amortization rate α^* for $LTV > \overline{LTV}$ such that:

$$(LTV - \overline{LTV}) \cdot \alpha^* = LTV \cdot (\alpha_0 + \Delta\alpha) - \overline{LTV} \cdot \alpha_0 \quad (4)$$

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

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

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. In our case, the behavioral response at the lower threshold was 2.57, giving us an implicit marginal amortization rate of $\alpha^* = 0 + 0.01 + 0.01 \cdot \frac{50}{(52.57-50)} = 20.4$ percent. The marginal amortization rate at the upper threshold is equal to 27.6 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:

$$e^{\alpha} = \frac{\Delta LTV / \overline{LTV}}{\alpha^*(\overline{LTV} + \Delta LTV) - \alpha_0} \tag{6}$$

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 (5).

5 Main empirical results

This section presents the main results of the analysis. We begin by analyzing the impact of the amortization requirement on borrowing at the lower and upper thresholds, located at LTV ratios of 50 and 70 percent, respectively.

Figure 3 illustrates the identification strategy and main empirical results. Focusing on the lower threshold, panel a) plots the percent of new mortgages in specific LTV bins in pre- and post-requirement years. At this threshold, the minimum amortization rate on new mortgages jumps from zero to one percentage point for mortgages with an LTV ratio above 50 percent. In the post-requirement years, there is a considerable mass at the threshold, indicating that many new borrowers choose lower LTV ratios to avoid mandatory amortization payments. Panel b) provides the results for the upper threshold, where the interpretation is complicated by the presence of a previous amortization recommendation and a higher marginal interest rate, which we discuss shortly.

Since Swedish mortgages feature linear repayment schedules and are not annuity contracts.

The increase in total mortgage payments at the threshold is therefore fully due to higher amortization payments, not interest expenses. Note that affected borrowers include home buyers and existing homeowners who refinance their mortgage and that the requirement does not affect existing mortgages. We later focus on each sample separately.

5.1 Bunching at the lower threshold

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

There are several key results in the figure. First, the counter-factual distribution fits the empirical distribution well up to an LTV ratio of 47.5 percent and again starting from an LTV ratio of 52 percent. The difference between the two distributions comes in the area where we expect that the amortization requirement has an impact, namely around the threshold.

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

Dividing the bunching estimate B by the counter-factual distribution, we find that the marginal buncher reduces its LTV ratio by 2.57 percentage points ($\widehat{\Delta LTV} = 2.57$, standard error 0.16) in response to the requirement. Relative to the threshold, this yields an approximately 5 percent decrease in borrowing.

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% of the value of their home in the post-requirement years compared to the pre-requirement years.

We now calculate the amortization elasticity using equation (6). With the estimated ΔLTV of 2.57, the numerator equals $2.57/50 = 0.0514$. Using the implicit rates from equation (5), the denominator is equal to $\alpha^* = 0 + 0.01 + 0.01 \cdot \frac{50}{(52.57-50)} = 0.204$, and the elasticity is equal to $0.0514/0.204 = 0.25$. A one percentage point increase in the amortization rate decreases LTV ratios by 0.25 percent.

5.2 Bunching at the upper threshold

Next, we turn to 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. This threshold is clearly noticeable in the counter-factual distribution in Figure 5. Figure A2 in Appendix A shows, however, that the interest rate differential between the top and bottom loan only comes into effect at the 75 percent threshold.

The results for the amortization threshold at LTV ratios of 70 percent are presented in Figure 5. Similar to Figure 4, the figure plots the observed distribution using data from the post-requirement years and the counter-factual distribution estimated using pre-requirement data. The estimation procedure uses data from borrowers with LTV ratios between 55 and 80 percent to avoid the lower threshold and the maximum LTV ratio at 85 percent affecting the results. There are two peaks at LTV ratios of 70 and 75 percent in Figure 5. For the black line, the empirical distribution in the post-requirement period, the peak is larger at the upper amortization requirement threshold.

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

We again calculate the amortization semi-elasticity using equation (6). With the estimated ΔLTV of 2.73, the numerator equals $2.73/70 = 0.039$. Using the implicit rates from equation (5), 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.

5.3 Bunching for constrained and unconstrained borrowers

In this section, we examine whether binding payment constraints can explain our results, ultimately concluding that bunching occurs for both constrained and unconstrained borrowers. Recall that banks in Sweden evaluate a borrower's ability to repay based on a discretionary income limit, where the borrower has to have sufficient income to meet expenses. The banks intend to ensure that after-tax household income is sufficient to cover subsistence consumption and borrowing payments, which include interest and amortization payments. Borrowers facing binding constraints may be unable to borrow more because of the discontinuous jump in mortgage payments above the LTV threshold (Bäckman & Lutz, 2020b). In effect, the amortization elasticity of mortgage demand for these borrowers is infinite because of the constraint.

How prevalent are binding payment-to-income (PTI) constraints for borrowers at the threshold? We find a large fraction of unconstrained borrowers at the threshold. Figure 6 shows that 26.3 percent of new borrowers at the threshold would not comply with the payment-to-income constraint set by Swedish banks if they were to amortize more. 73.7 percent of borrowers who bunch are not constrained by the PTI constraint. The figure pools borrowers just below either threshold and plots the distribution of discretionary income with actual amortization payments (orange bars) and with counter-factual amortization payments (blue bars), where we increase the LTV ratio to 1 percentage point above the threshold and consequently increase amortization payments to comply with the requirement.

Are constrained borrowers driving the bunching result above? Table 4 shows that the answer is no. The table provides bunching estimates for three separate groups based on discretionary income. Figure 7 provides the corresponding figures. We calculate the counter-factual discretionary income as the discretionary income given your chosen LTV minus the extra payments if you would have borrowed 1 percentage point more in LTV compared to the closest-by threshold. We group households based on counter-factual discretionary income into a Constrained, an Intermediate and an Unconstrained sample, with a counterfactual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK, and greater than 15,000 SEK, respectively. The Constrained group is close to their debt capacity, as they have nearly maxed out their PTI. Note that this group includes borrowers with positive discretionary income who are close to but not at the constraint. The unconstrained group is far from their debt capacity and could borrow a substantial amount more.[10] The results show that ΔLTV and the elasticity are generally comparable across constrained and unconstrained borrowers. We conclude that payment-to-income constraints cannot fully explain our results. On the contrary: the unconstrained group has larger responses to higher amortization payments.

An important question is whether the unconstrained group is different in some other charac-

[10]For example, a discretionary income of 15,000 SEK implies the household could increase its debt until the additional monthly expenses (interest and amortization) equal 15,000. At a (stressed) interest rate of 7% and amortization rate of 2%, the additional (maximum) loan size equals $12 \times 15,000/(0.07 + 0.02) = 2$ million kronor, which is about the sample average debt level.

teristics that would imply that they face other financial constraints. Table 2 provides summary statistics for borrowers in the three groups, showing that the constrained, intermediate and unconstrained groups appear similar on most observable dimensions. The Unconstrained group has higher income, lower debt-to-income, and lower debt-service-to-income, likely indicating that they are *less* financially constrained. Interestingly, these are also characteristics that correlate with higher financial literacy (Almenberg & Säve-Söderbergh, 2011).

Why do even unconstrained borrowers bunch? A lack of financial literacy could explain the results, if borrowers mistake amortization payments for interest payments and try to minimize total mortgage expenditure. Table 1 show that 38 percent of Swedish households consider amortization payments to be costly (SBAB, 2018). Interestingly, higher income, lower debt-to-income, and lower debt-service-to-income are characteristics that correlate with *higher* financial literacy (Almenberg & Säve-Söderbergh, 2011). In addition, the share believing that amortization payments are a cost is strongly decreasing in income, going from 42 percent in the lowest income group to 22 percent for the highest income group. A second explanation is that borrowers value liquidity. Figure 8 plots the reduction in discretionary income for borrowers at the notch, if they were to increase their leverage by one percentage point. For the constrained group, increasing leverage and starting to amortize entails a large reduction in discretionary income. The average reduction is 80 percent, meaning that even if they were to comply with the requirement, they would have little discretionary income left over. For the intermediate group, the average reduction is 23.5 percent, and for the unconstrained group, the average reduction is 10 percent.

5.4 Endogenous housing demand response

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

For homebuyers, banks almost exclusively use the purchase price to form the collateral assessment. Only in rare cases[11] do bank deviate from using the purchase price for homebuyers. In the case of a refinancing, the bank uses either an external or internal valuation, based in most cases on statistical models of the property value. The external valuation includes using tax-assessed values for houses done by the tax authority as well as assessments by independent appraisers. We discuss the validity of the collateral assessments further in Section 5.7. We find little evidence of discontinuities in house values, either in levels or relative to income, around the thresholds in Figures A3 and A4. We therefore estimate bunching by type of valuation.

[11]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 5 shows that the estimated bunching is similar across valuation methods for the lower threshold. The estimated ΔLTV is 2.44, 2.89 and 2.18 for internal valuation, external valuation and purchase price, respectively. Overall, while there is some differences across the valuation methods in the bunching estimate and the elasticity, the results are consistent for the lower threshold.

For 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 5.3. 53% of these homebuyers are constrained, compared to 33% at the lower threshold.

Importantly, the share of refinancers in the data is large, and we find similar bunching estimates for this group even at the upper threshold. This implies that value effects are not driving our main result, and the decline in loan-to-value ratios stems from lower loan demand.

5.5 Robustness checks

Table 6 shows the robustness of our estimates to the specific choice of bin width and the lower limit of the excluded region. Larger excluded regions typically inflate the estimates; our preferred results are in the center of the tabulated estimates and are robust to these free parameters.

More importantly, we show that our results are robust to using the standard approach of fitting a flexible polynomial to the observed distribution (See Appendix C for details of the estimation procedure). Figure 9 shows the results from the standard approach. While the counter-factual distribution fits the observed distribution well in general, it does not feature any spike around the thresholds due to a preference for round numbers or the SBA's recommendation. As a result, the bunching estimates B and b, as well as the behavioral response, are all larger compared to our earlier results that account for spikes from pre-requirement data. Our preferred results are conservative compared to the polynomial estimates. For a comparison between our preferred estimates using previous years and the polynomial estimates, see Appendix C and Figure C1.

5.6 Placebo tests

We are confident that the counter-factual density presents a good estimate of the fraction of borrowers in each bin. To show this, we create a placebo test to assess whether the counter-factual distribution presents a good estimate of the fraction of borrowers without the requirement (DeFusco *et al.*, 2020). Specifically, each pre-requirement year from 2011 to 2015 is designated a "placebo" year. We then estimate the counter-factual distribution for both requirement thresholds in these years. By estimating the counter-factual distribution as if the requirement had passed in a placebo year, we can assess whether the procedure can yield a good match between the empirical and counter-factual distribution in a year without an amortization requirement. If our assumption is valid, the two distributions should coincide, and the bunching estimate should be zero.

Figure 10 shows that using other years as the counter-factual closely approximates the distribution in years without the requirement. Panels a) and b) plot the empirical and counter-factual distribution in 2014 for the upper and lower amortization requirement, showing a close correspondence between the distributions in both cases. Using other years than 2014 yields similar charts. Importantly, the spikes at 50, 70, and 75 percent LTV ratios are well approximated by this procedure. Panels c) and d) provide histograms of the ratio between the percentage of borrowers in each bin in the empirical and counter-factual distribution for all the pre-requirement years. The mean and median percentage difference in both panels is close to zero, and the interquartile range covers zero. There is little evidence that our approach creates a systematic bias in either direction.

5.7 Threats to identification

In this section, we discuss supply-side factors, other than the payment-to-income constraint, that would cause borrowers to bunch. For example, banks may have an incentive to recommend their clients to place themselves below the threshold or may have an incentive to manipulate the collateral assessments to obtain lower amortization rates on behalf of their customers (Mayordomo *et al.*, 2020). Below we discuss these supply-side factors in the context of the approval process for mortgages, collateral assessments, risk weights, and capital requirements. We argue that supply-side factors are unlikely to explain our results, primarily because of institutional features in Sweden.

Mortgage interest rates around the notches. Figure 11 shows that a plausible explanation for why borrowers place themselves at the thresholds, 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 11 plots the interest rate by LTV ratios around the lower threshold. Although the interest rate level is different each year, reflecting Swedish monetary policy, there are no systematic differences in interest rates over the threshold in any year. Similar results hold for the upper threshold, available in Panel b) of Figure 11. There is little evidence that mortgage banks charged higher mortgage rates to households placing themselves below the threshold. As we discuss below, lower amortization payments in a full-recourse setting do not imply higher credit risk and therefore limit the incentive for banks to charge higher interest rates for borrowers that do not amortize.[12]

[12]Figure 11 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.

Risk weights and capital requirements. A potential concern is that capital requirements may incentivize banks to nudge borrowers towards a lower LTV mortgage if there are thresholds in the capital requirements at set LTV ratios. Even though revenues increase with borrower LTV ratios, expected profits need not when expected losses (due to credit risk) or funding costs increase for banks. Regarding credit risk, it is clear that a loan with a higher LTV ratio should be riskier than a corresponding loan with a lower LTV ratio. However, we expect the marginal increase in credit risk to be negligibly small when moving from a loan with an LTV ratio of 50 percent to a loan with an LTV ratio of 51 percent, given the low LTV levels and full-recourse mortgages. Even in default, the properties' market value is more than sufficient to compensate the lender, and borrowers are liable for any residual debt. We are not aware of any evidence to suggest that risk weights increase discontinuously at the thresholds, and neither is the Swedish Bankers Association nor the individual banks, who we contacted to ask about this issue. Even if level differences exist, our difference-in-bunching strategy will account for any discontinuity that is fixed over time.

All loans with LTV ratios below 75 percent are eligible for covered bond funding. In practice, most Swedish banks use the IRB approach to credit risk, and higher LTV ratios should therefore require more (expensive) capital funding. Importantly, Swedish regulation mandates a minimum risk weight of 25 percent on all loans secured by residential real estate since 2014. Even if the internal models of the bank assumed that the mortgage risk weight exhibited a discrete jump at exactly the LTV threshold, it is very unlikely that the effect from moving just above the threshold would lead to a higher-than-25 percent risk weight.

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

Collateral assessments. A potential concern is that banks are manipulating the value of the collateral to lower the LTV ratio. As described in the previous paragraph, however, collateral assessments are done before the borrowing decision and are done by statistical models without much discretion on behalf of the loan officer. Therefore, it is very unlikely that banks are systematically manipulating the values just around the threshold to create the kind of bunching we observe. Figure A4 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 (Sandstrm *et al.*, 2013).

LTV dynamics. The amortization requirement relates the minimum rate of amortization to the LTV ratio. Yet the LTV ratio decreases over time because of amortization. At some point, the household will cross the threshold. Anecdotal evidence suggests that the amortization rate is not automatically lowered when crossing the threshold, and borrowers would need to actively apply for a lower amortization rate. This suggests that bunching could be in part driven by inertia: a borrower who knows she will likely forget to apply for a lower rate of amortization could decide to bunch just below the threshold.

It also suggests that banks may have an incentive to nudge borrowers just below the threshold. Indeed, if borrowers do not actively apply for lower amortization payments, the bank may get higher interest income when borrowers enter an interest-only loan compared to a loan just above the lower threshold, simply because over the lifetime of the loan (typically 6-7 years), the average debt balance is larger for the non-amortizing loan.[13] The extra interest income from this nudge is likely small and depends on how long the loan stays on the banks' balance sheet and the interest margin. In any case, such a strategy is second-best for the bank: simply informing the borrower when they cross the LTV threshold yields higher revenues.

6 Understanding the determinants of bunching

We develop a theoretical framework that allows us to clarify the different mechanisms that may generate bunching. We use this framework to evaluate each mechanism's various implications and assess which are most important in generating our empirical results. Overall, there are four mechanisms that may generate bunching: kinks or notches in the household budget constraint or kinks or notches in household preferences. The budget constraint could feature notches or kinks at the LTV threshold if interest rates jump at the threshold, if changing the amortization rate upon crossing the threshold induces monetary costs, or if credit constraints bind due to higher payments. Our empirical results show that approximately 25 percent of the bunching is driven by credit-constrained households forced to avoid amortization due to regulatory payment-to-income constraints. We found little evidence for other notches or kinks in the budget constraint in Section 5.7, beyond the mechanical impact of the PTI constraint for constrained borrowers. For instance, we provide evidence for flat interest rates around the requirement threshold. Therefore, we focus on notches and kinks in household preferences in this section.

We generate a notch in household preferences at the amortization threshold by including

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

a utility cost to lowering amortization payments once the borrower hits the threshold. This *refinancing cost* generates a local effect around the threshold. All borrowers to the right of the threshold optimally choose to bunch, which also generates missing mass above the threshold. Borrowers further away from the threshold can discount the fixed cost and consequently do not change their behavior. Alternatively, we generate a kink in household preferences through a disutility to making amortization payments for all borrowers above the notch. Although this is an admittedly ad-hoc behavioral assumption, it captures several different arguments for why amortization payments are viewed as costly that are otherwise difficult to incorporate in the model. For instance, a disutility to amortizing captures the idea that households consider amortization payments a cost, similar to interest payments, and the idea that households want to save in different assets. The kink in preferences generates bunching without missing mass. All borrowers above the threshold are affected and adjust their borrowing downwards, which fills up the whole to the right of the LTV threshold.

6.1 Theoretical framework

Our theoretical framework is based upon the life-cycle model of consumption, housing, and mortgages developed by Attanasio *et al.* (2012). In this model, credit-constrained households face idiosyncratic and uninsurable income risk over the life-cycle. Households get utility from both consumption and housing. Households can save in either liquid deposits or illiquid housing and borrow using long-term mortgages. As the above authors demonstrate, this model does a good job of matching the hump-shaped consumption profile, the gradual accumulation of housing wealth over the life-cycle, and the fact that the vast majority of wealth is held in housing rather than liquid assets.

We build upon the above framework in two main dimensions. First, we extend the model to include a realistic mortgage repayment schedule with two different policy regimes. In the initial regime, households are only required to pay interest on their mortgage balances, although they can choose to pay more than that if they desire. In the second regime, households must amortize if their LTV ratio exceeds a given threshold but can revert to interest-only payments when their LTV ratio gets 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 two types of behavioral wedges that may induce bunching.

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

$$\max_{\{c_t,a_t,h_t,m_t\}} \mathbb{E}_0 \sum_{t=0}^{T} \beta^t u(c_t, h_t, \delta_t) \tag{7}$$

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

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

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

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

$$p_t(h^k) = g(h^k)\bar{p}_t \tag{8}$$

where $0 < g(h^k) \leq 1$, $g'(h^k) > 0$ and $g''(h^k) < 0$. Since house prices grow at a constant rate $1 + r^H$ over time, the initial price index determines all other prices for each time period:

$$\bar{p}_t = (1 + r^H)\bar{p}_{t-1} \quad \forall t \quad \text{given} \quad \bar{p}_1 \tag{9}$$

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

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

$$m_t \leq (1 - \psi)p_t(h_t) \tag{10}$$

where ψ determines the mandatory minimum down-payment. Following Swedish law, we set the minimum down-payment value equal to 15 percent, $\psi = 0.15$. For households that do not choose to extract equity, the law of motion for mortgage balances is given by:

$$m_{t+1} \leq m_t(1 + r^M) - \rho_t \tag{11}$$

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

Alternatively, if households choose to extract equity (by selecting $m_{t+1} > m_t(1 + r^M) - \rho_t$)

then they are required to pay both a proportional (f_2) and fixed (f_3) cost to cash-out refinancing, which show up in the budget constraint. The LTV constraint is only binding at time of purchase or when the household decides to do cash-out refinancing. Negative shocks to income or house prices will not make the borrower shrink their mortgage balance as long as they can continue to make the mortgage payments.

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

$$\rho_t(m_t, p_t) = m_t * r^M \tag{12}$$

and a mandatory amortization policy, where the minimum repayments depend on the loan-to-value ratio of the borrower:

$$\rho_t(m_t, p_t) = m_t * r^M + m_t * \begin{cases} 0 & \text{if } {}^{m_t}/_{p_t} \leq 0.5 \\ 0.01 & \text{if } {}^{m_t}/_{p_t} > 0.5 \end{cases} \tag{13}$$

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

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

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

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

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

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

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

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

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

6.2 Parameter values

To parameterize the model, we follow the existing literature, adapted to reflect the Swedish mortgage market. We calibrate asset returns and interest rates based on Swedish data. Similarly, we set the loan-to-value and amortization requirements based on Swedish law. We then set the remaining parameters based on the existing literature.

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

Mortgages. We set the real mortgage rate to $r^M = 0.0087$ based on the average real rate for a floating rate mortgage in Sweden between 2005 and 2015. We set the maximum loan-to-value ratio $1 - \psi$ at 85% following Swedish mortgage regulation. We take the remaining parameters from the existing literature. We set household preference parameters based on Attanasio *et al.* (2012) and income process parameters based on Kovacs & Moran (2021). The details of our parameterization are contained in Appendix D.

6.3 Baseline model does not generate bunching

How does the Swedish mandatory amortization policy affect household borrowing and the distribution of LTV ratios? We implement a policy where households are required to amortize if the LTV ratio exceeds 50%, based on Sweden's amortization policy implemented in 2016. Figure 12 shows the main results in our baseline model. The first panel shows the distribution of LTV ratios at the time of mortgage origination. We find no bunching at the 50% threshold, despite the presence of mandatory amortization for all loans above the threshold. In short, mandatory amortization does not lead households to bunch in the baseline model. The reason is that mandatory amortization payments do not have a large impact on household welfare in the model. The second panel of Figure 12 shows the expected value function for the baseline model. We see that the expected value in the baseline model with amortization is very close to the value for the interest-only case. Moreover, we see neither a kink nor notch in the expected value function. This is consistent with the fact that there is no bunching at the 50% threshold. Note that households do not face binding credit constraints at the threshold since they are far away from the maximum LTV ratio.

Why is there no change in borrower behavior at the threshold? The basic intuition is that the amortization policy does not generate a kink or notch in the current period budget constraint, nor in household preferences. Amortization affects future period budget constraints, but not the current period choice set. This is especially easy to see if households, in the interest-only regime, were already saving more than what is mandated in the amortization requirement regime. Further, while households may dislike amortization if it pushes them to save more than they would like, there are two ways that households can undo the effects of amortization. First, following the argument by Svensson (2016), households can borrow *more* at origination. Households can use the additional borrowed amount to make the required amortization payments, which allows them to achieve their desired consumption path. The model also generates this result: compared to the interest-only case, households with an LTV ratio above the threshold borrow more in response to the requirement.

The second reason that the amortization requirement does not change the budget constraint is that households can refinance to undo any payments. This result is trivially true in models with short-term debt and no refinancing cost: amortization payments is completely undone by adjusting borrowing every period. Even in models with long-term debt, refinancing limits the impact of higher required amortization payments (Hull, 2017). But even if we turn off refinancing in our model, we still do not observe bunching at the threshold. Finally, we do not see bunching even if we set a high enough discount factor so that households are consuming all their income in every period. Again, without credit constraints households can choose their desired consumption path by adjusting their borrowing, which implies that higher requirement savings has little impact. Overall, the amortization requirement does not generate bunching because higher required payments do not change the budget constraint directly for unconstrained households.

6.4 Kinks and notches in household preferences generate bunching

We augment the model with two additional utility costs to amortizing: a fixed cost to refinancing and a disutility to amortizing. We show that a fixed utility cost to refinancing to an interest-only mortgage once the borrower hits the threshold generates a notch in household preferences. Therefore, the utility cost to refinancing generates bunching at the threshold and missing mass to the right of the threshold. Alternatively, a utility cost to making amortization payments generates a kink in household preferences, which generates bunching but no missing mass. We now motivate and describe these costs in more detail.

Kink in household preferences. The first cost that we model is a utility cost to amortizing. Households may mistake amortization payments for interest payments, or target total mortgage payments instead of just amortization payments. Survey evidence presented in Table 1 shows that 38 percent of Swedish households consider amortization payments costly (SBAB, 2018). Argyle *et al.* (2020) finds evidence that consumers manage total payment size for auto-loans in the United States, a tendency that Shu (2013) calls "NPV-neglect": households do not fully consider the net present value of future mortgage payments when choosing between alternative mortgage contracts. Alternatively, we argued previously that borrowers can undo any required amortization payments by borrowing more or substituting liquid savings for amortization payment. Bsorrowers may be unwilling to do so because of, for example, debt aversion (Meissner, 2016), or they may be unable to undo required amortization payments because of low levels of financial literacy Almenberg & Säve-Söderbergh (2011).[14] Assuming that households are unwilling to borrow more to undo required amortization payments, such payments can be costly for several reasons. Required amortization payments may lead to sub-optimal saving rates (Cocco, 2013), or households may wish to save in risky assets because of the higher expected return or increased diversification. [15]

A kink in household preferences generates bunching at the threshold. Figure 13 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 now has a kink at exactly the amortization threshold. The kink implies that all households above the amortization threshold are affected, and consequently all households adjust their borrowing. The spike at the threshold occurs, as households close enough to the threshold will, in the amortizing regime, choose to avoid bearing the utility cost. But missing mass does not occur, as households with somewhat higher LTV levels now fill up the distribution.

Notch in household preferences. The second cost we model is a cost to refinancing to an interest-only mortgage once the borrower has reduced their LTV ratios to 50 percent. Refinancing costs can represent both monetary and psychic costs to the individual to refinance. Monetary and psychic costs to refinancing have been studied in, e.g., Agarwal *et al.* (2016), Keys *et al.* (2016) and Andersen *et al.* (2020). In our setting, we model these as psychic costs through the utility function since Swedish banks do not charge a monetary cost for reducing amortization payments once a borrower hits the threshold.[16]

We show the result of including this psychic cost in Figure 14 shows that a psychic cost to refinancing affects households close to the threshold and leads to a large area with missing mass just to the right of the threshold. The bunching and missing mass result from a notch in preferences at the threshold, illustrated in panel b). This notch will cause households close to the threshold to bunch, but since households far away from the threshold can discount the cost, it will not affect their borrowing decisions.

6.5 Evaluating the relative importance of the preference channels

We now discuss whether our results are driven by a kink or a notch in household preferences. To start, we first note that refinancing costs are small in Sweden. Swedish banks do not charge a monetary cost for reducing amortization payments once a borrower hits the threshold. Changing to an interest-only loan, if eligible, requires a simple phone call or message to the bank, so the

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

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

[16] One bank charges a small cost to change the mortgage contract, equal to 1200 SEK. This bank represented 3% of total mortgages in 2017.

time cost of reducing amortization payments appears low too. [17] The low refinancing cost would suggest that the results are instead driven by a kink in household preferences generated by a disutility of amortizing. However, there are other reasons why the amortization requirement may create a notch, for example by creating a reference point at the threshold. We therefore turn to other implications of the two behavioral wedges.

The two preference channels have different implications for missing mass and the aggregate effect of changing amortization payments. First, a notch in household preferences generates missing mass above the threshold, whereas a kink does not generate missing mass. Our empirical results show little evidence for a large missing mass: Table 3 finds that missing mass is generally less than 15 percent of the bunching estimate. This result holds across specifications and, in particular, for unconstrained borrowers. The lack of missing mass suggests that most of the effect comes from a kink in household preferences generated by a dislike for amortization payments.

Second, the two channels have different implications for the aggregate response of borrowing. A notch in household preferences generated by a notch has a first-order impact only on borrowers around the threshold. On the other hand, a kink causes a reduction in borrowing for all borrowers above the threshold. This is potentially important, since the vast majority of mortgage originations are above this threshold. In addition, the baseline model predicts an increase in borrowing due to higher amortization payments. These predictions can, in theory, be validated in the data, although identifying an aggregate effect for unconstrained borrowers is challenging. For instance, any evaluation would have to credibly distinguish between the response of constrained and unconstrained borrowers and any other omitted factor that would explain borrowing. Moreover, the response by constrained borrowers could spill over to unconstrained borrowers through general equilibrium effects, for example, when house prices decline (Bäckman & Khorunzhina, 2022). Wilhelmsson (2022) finds that the amortization requirement led to a 7 percent reduction in house prices but did not examine the role of constrained and unconstrained borrowers in driving these price changes.

Figure 15 plots the aggregate credit growth rate for property loans and the interest rate on property loans. The amortization requirements coincided with a sharp reduction in the credit growth rate. These declines are difficult to explain by other fundamentals, such as the interest rate. The blue line shows that the mortgage rate is flat between mid-2015 and 2020. The aggregate-level evidence suggests that the effect we identify is not simply a local effect around the notches but applies throughout the distribution. However, we again note that the effect could come from constrained borrowers being forced to reduce their borrowing. At the same time, we also see a decline in house price growth and an increased supply of housing (Naess-Schmidt *et al.*, 2017), which could be driving the reduction in credit growth. As discussed, we are careful to avoid drawing major conclusions from these aggregate patterns, yet they are

[17] We asked Swedish banks about the procedures related to refinancing to a lower amortization rate once the borrower hits the threshold. In their reply, the banks indicated that there are no associated costs or credit checks, that the borrower does not need a new mortgage contract, and that a simple phone call to the bank advisor is sufficient to start the process. Three of eight banks stated that borrowers are never denied refinancing to a lower amortization rate, and the remaining stated that it is very rare. If it happens, the denial is related to insolvency issues, such as not paying bills.

mostly consistent with a kink in preferences.

7 Conclusion

This paper documents and interprets several empirical facts about mortgage amortization and borrowing. Using bunching in response to a Swedish macroprudential policy, we document that new borrowers reduce their loan-to-value ratios by 4-5 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 homebuyers and refinancers. We argue that existing homeowners adjust the loan value in response to higher amortization payments. We found similar results for constrained and unconstrained borrowers, results inconsistent with a standard life-cycle model of consumption and borrowing. In these models, borrowing is either unaffected by higher amortization rates or is *increased*. We evaluate alternative theories of household behavior and conclude that much of the effect comes from households viewing amortization payments as a cost rather than a form of savings.

The implication of these results is twofold. First, for most borrowers, binding payment financial constraints (payment or leverage related) cannot explain their aversion to amortizing. We observe bunching for borrowers far from the leverage constraints of 85 percent applied in Sweden and the payment-to-income constraint. The results are reminiscent of the monthly payment-targeting documented in Argyle *et al.* (2020) and suggest that even unconstrained household borrowing depends on the total mortgage payments, including amortization, and not simply on the interest rate. These results imply that we need to examine all features of the mortgage contract, including amortization payments, when thinking about credit growth and household borrowing decisions.

Second, amortization payments represent a financial constraint that reduces borrowing for a quarter of the borrowers at the threshold. If given a choice, households reduce amortization payments to comply with payment-to-income constraints. Alam *et al.* (2019) report that payment-to-income constraints (debt-service to income in their terminology) are prevalent in advanced economies as well as in emerging market and developing economies.[18] Policymakers should be aware that households may reduce amortization payments to comply with such constraints, especially as lower amortization payments may lead to lower wealth accumulation over time (Bernstein & Koudijs, 2021).

While the elasticity we estimate is modest, the aggregate effects of changing amortization payments can still be large. A large fraction of borrowers presumably held mortgage debt before the requirement and thus face a potentially large increase in their amortization rate. The correct comparison for a borrower with existing mortgage debt would be more akin to the marginal rate calculation: what is the increase in the amortization rate on the difference between my current and future mortgage debt? As we showed, the marginal rate can be substantial. Conversely,

[18] Table 2 of Alam *et al.* (2019) reports that 15 out of 36 advanced economics in their sample used debt-service-to-income constraints in 2016. Out of 98 emerging markets and developing economies, 20 countries employ such constraints. The definition of debt-service-to-income includes loan-to-income provisions.

the reduction in payments from choosing an interest-only mortgage can also be substantial: at an interest rate of 4 percent, amortization payments are approximately 30 percent of total payments. While the elasticity may be low, the aggregate effect may be largely due to the large change in payments. Looking at the United States in the run-up to the financial crisis, the rapid expansion of mortgages with lower payments likely led to an expansion of credit. Moreover, the disappearance of products with low amortization payments from 2008 (Amromin *et al.*, 2018) implies a rapid credit contraction. The change in cash flow for a borrower who previously had an interest-only mortgage but now has to start amortizing would be considerable: the annual expense for an interest-only mortgage with a 5 percent interest rate would increase by 32 percent (see Table B1). The disappearance of interest-only mortgages in the United States in 2008 likely caused a decline in borrowing.

Finally, we wish to caution that our results do not signify that the amortization requirement necessarily has a positive impact on financial stability. The requirement reduced borrowing and increased the amortization rate, both of which slowed down debt growth. The policy reduced macroeconomic risk if rising debt levels represent a danger to financial stability, as in the debt-overhang hypothesis (Mian *et al.*, 2013, 2017). Higher amortization payments could also lead to higher wealth accumulation and a larger buffer for borrowers. However, households that avoid higher amortization expenses by bunching at the threshold might spend extra liquidity. Moreover, shifting from liquid to illiquid savings because of higher amortization payments could also reduce households' ability to smooth consumption in response to income or interest rate shocks. Accessing illiquid housing wealth in response to a shock requires borrowing in credit markets or selling the underlying property, a difficult proposition in a recession. In the end, whether the amortization requirement improves financial stability is an empirical question not ideally suited to our data and is left for future research.

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8 Figures

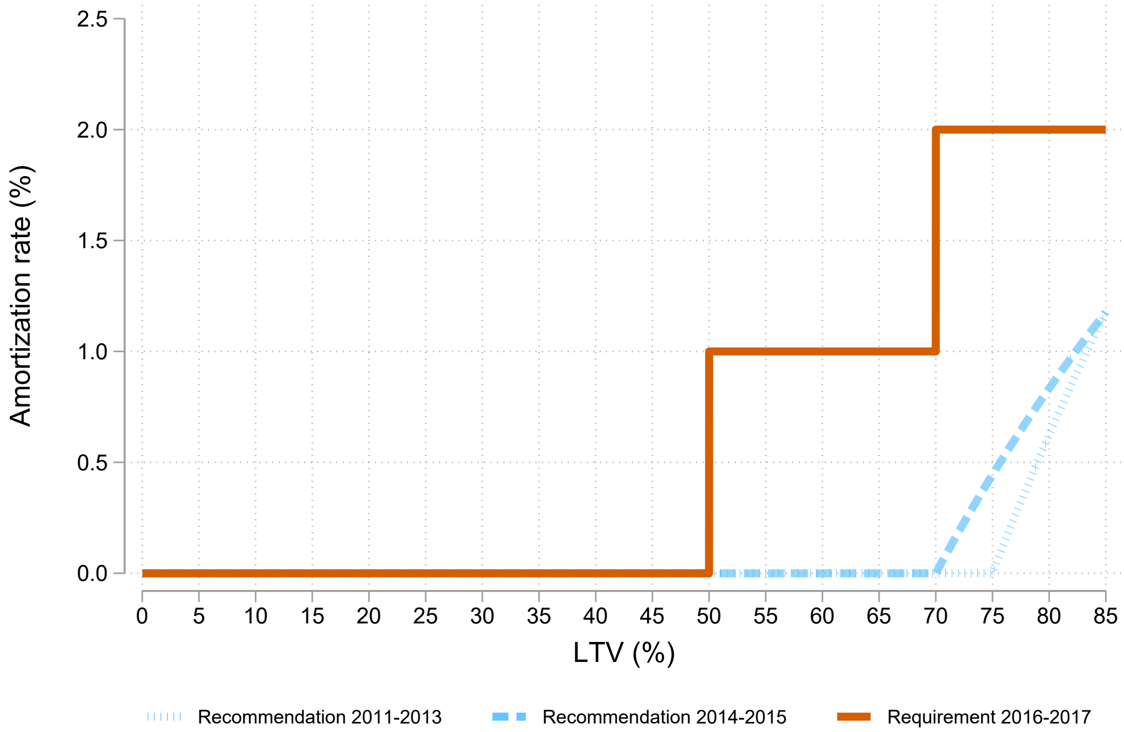
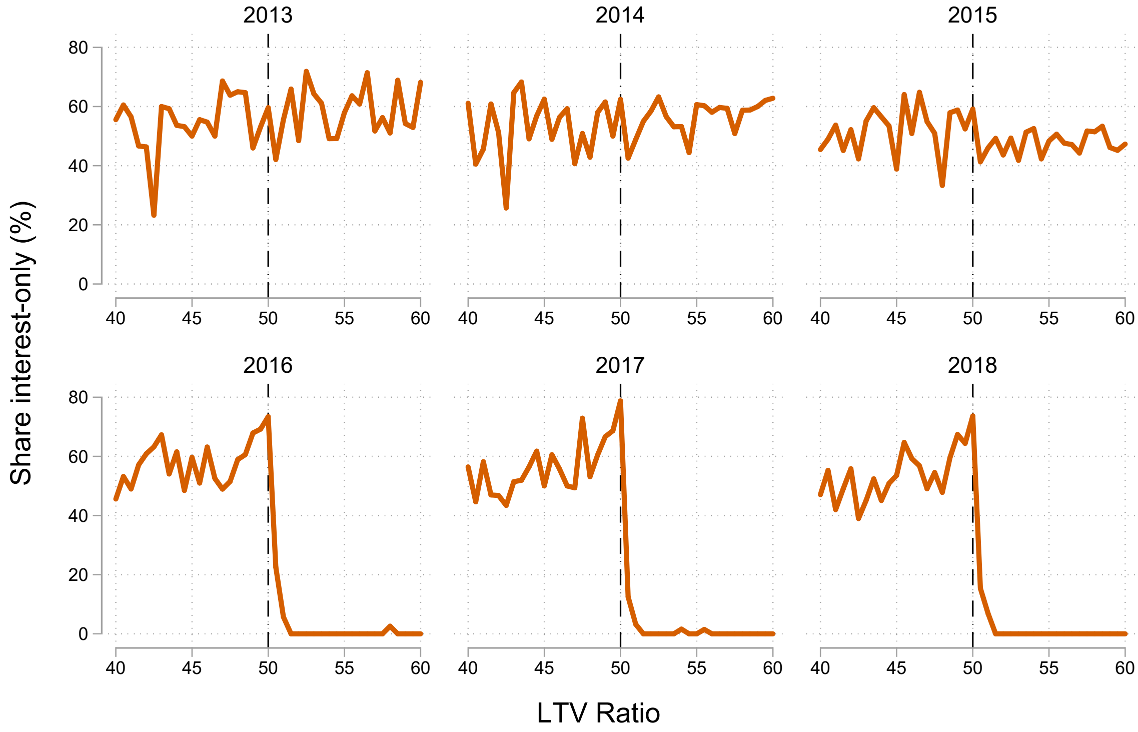
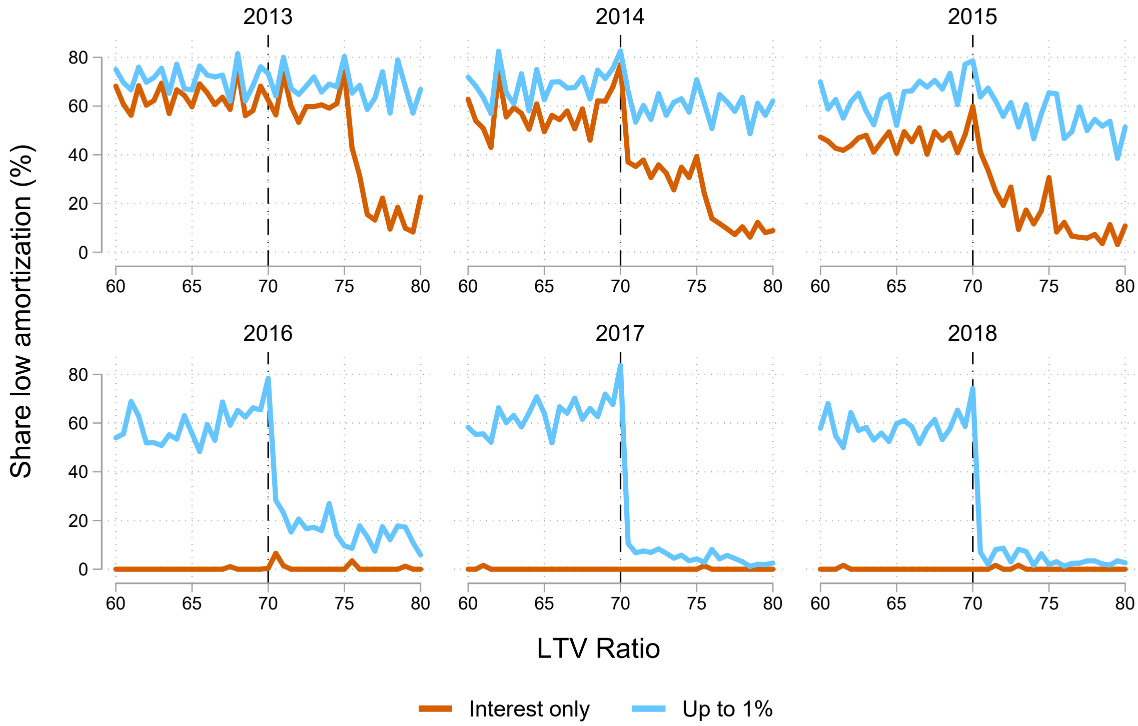


Figure 1. Required Amortization Rates for new mortgages

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



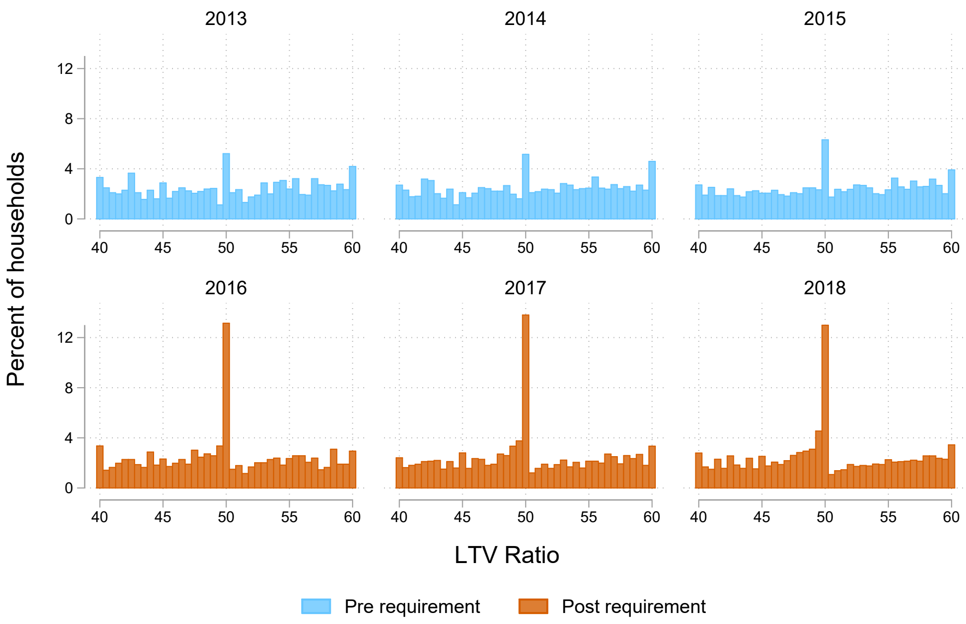
(a) Lower threshold



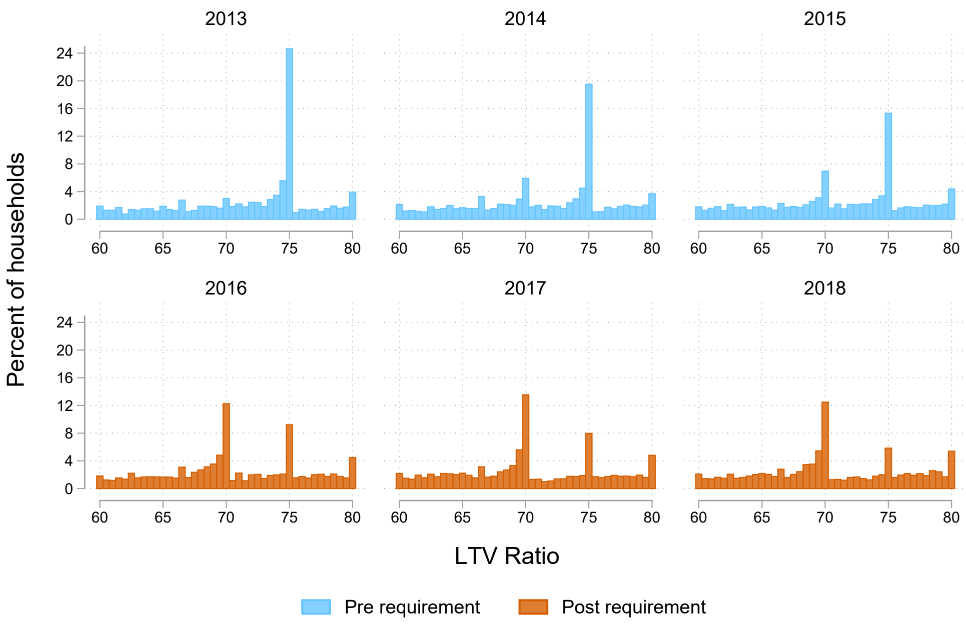
(b) Upper threshold

Figure 2. Share interest-only mortgages by threshold

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



(a) Lower threshold



(b) Upper threshold

Figure 3. LTV distributions around the lower and upper amortization requirement threshold

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

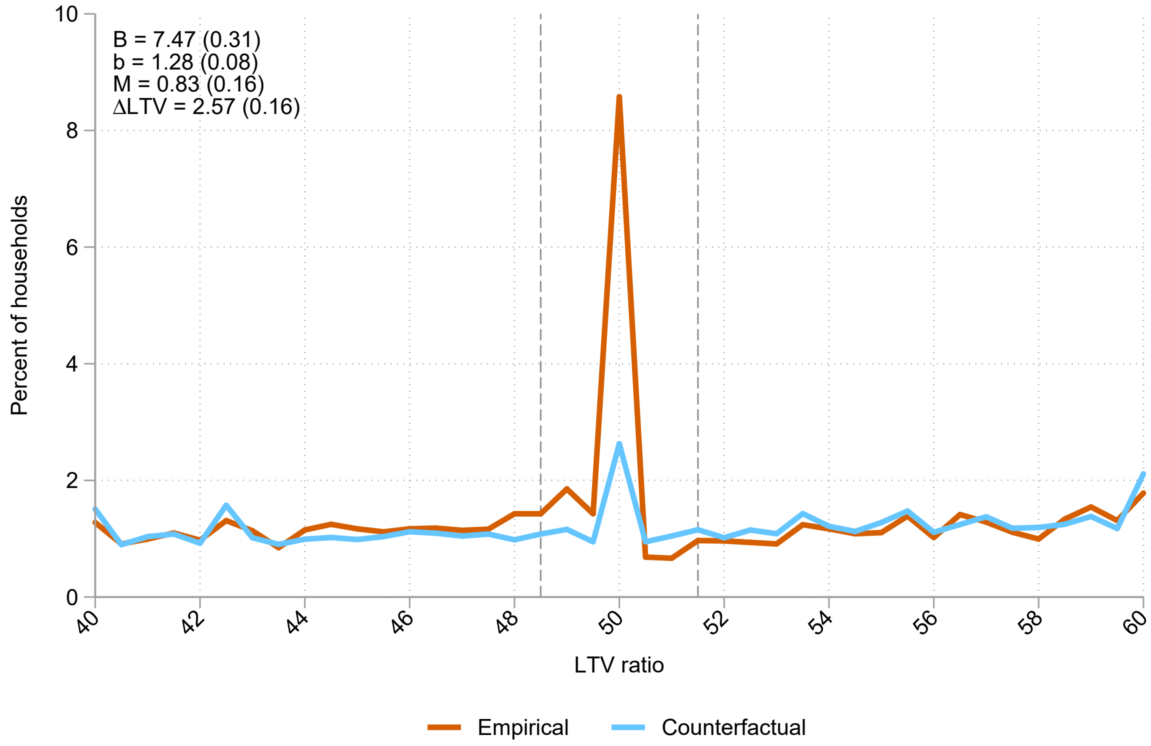


Figure 4. Bunching at LTV=50

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio. The estimation is carried out using all loans with LTV ratios between 20 and 65 percent, but only shows the distribution between 40 and 60. The orange line plots the empirical density, where each dot represents the percent of mortgages within each 0.5 percent LTV bin. The blue line plots the counterfactual density estimated using the procedure described in Section 4. The figure reports the estimated percent of loans that bunch at the threshold (B), the excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 4. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.

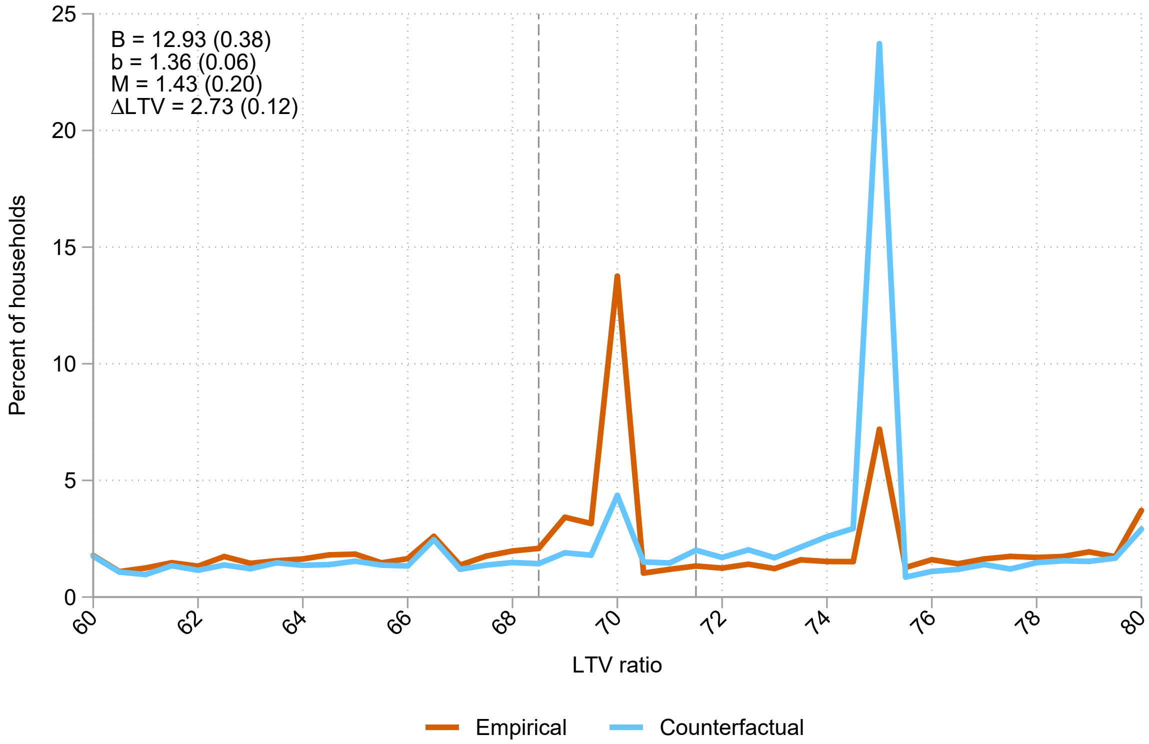


Figure 5. Bunching at LTV=70

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 4. The figure reports the estimated percent of households that bunch at the threshold (B), the excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 4. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.

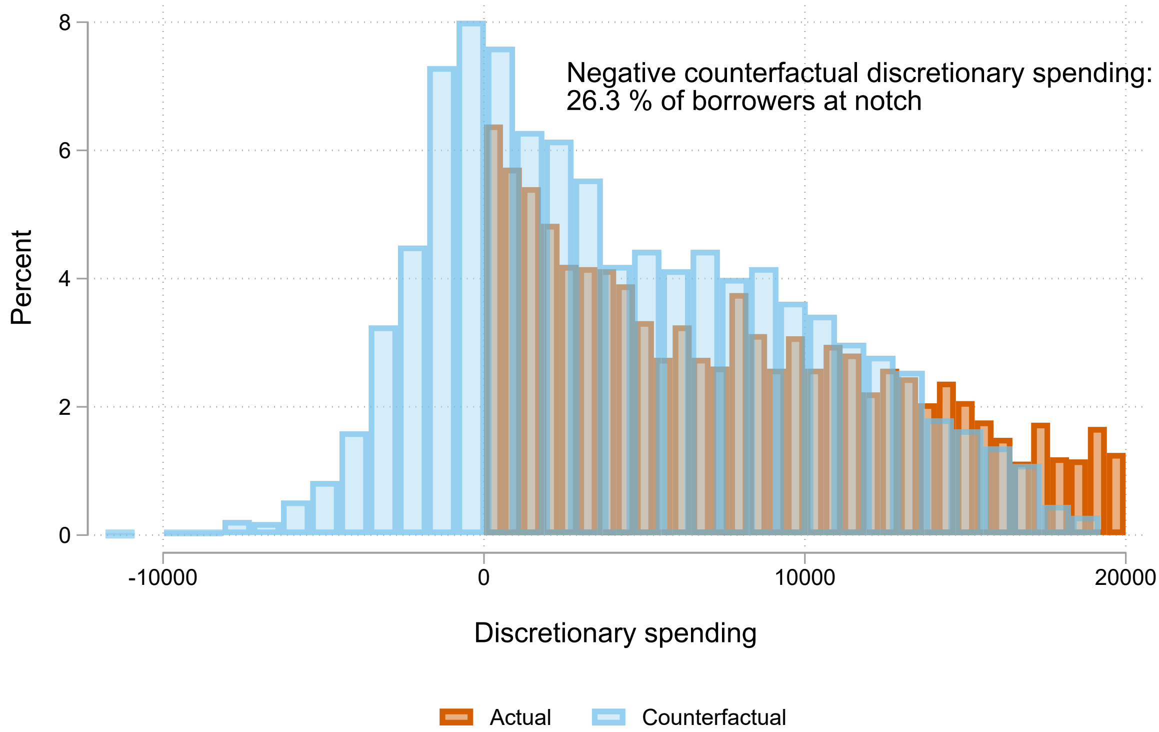
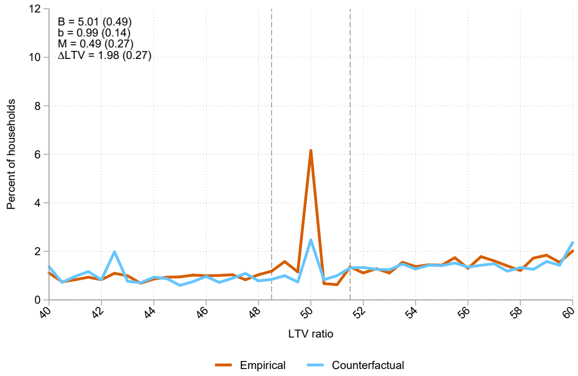
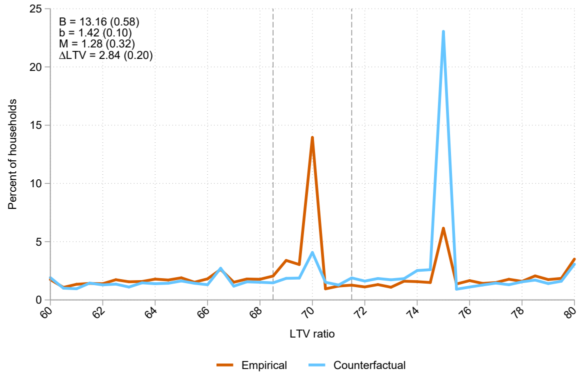


Figure 6. Discretionary income

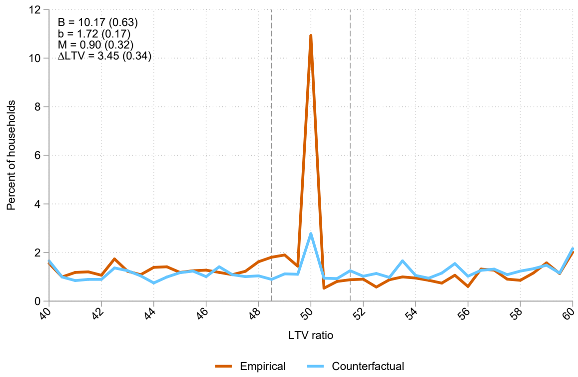
Notes: The figure plots calculations for discretionary spending for borrowers located at the notches. We select borrowers with LTV values between 48.5 and 50, and 68.5 and 70. We update the bank's discretionary income calculation to include higher amortization payments by increasing LTV ratios to one percentage point above the threshold. We use a stressed interest rate of 7 percent for the increase in debt, according to standard practice in Sweden. Panel a) plots the distribution of discretionary spending ("KALP") for borrowers located at the notches. The orange distribution plots the actual KALP distribution, and the blue, transparent, distribution plots the counterfactual KALP where we calculate discretionary spending if households were to amortize their mortgage according to the requirement (1 percent of the mortgage at the lower notch, 2 percent of the mortgage at the upper notch). Panel b) plots the reduction in discretionary spending from higher amortization payments as a share of actual discretionary spending.



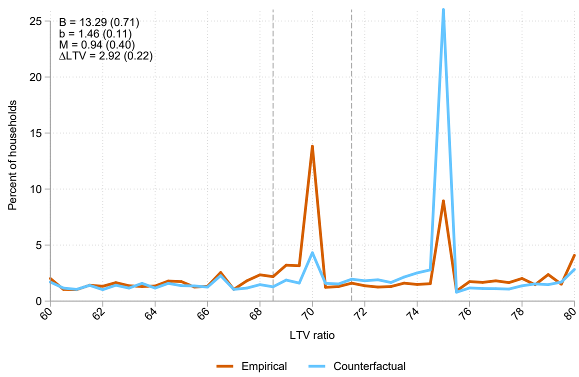
(a) Constrained borrowers, lower threshold



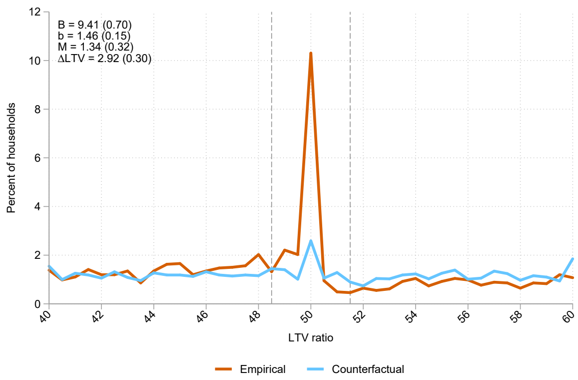
(b) Constrained borrowers, upper threshold



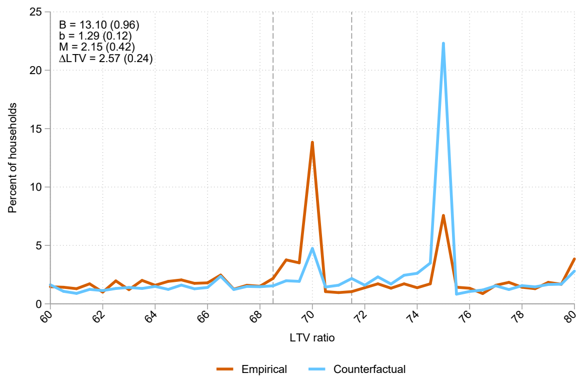
(c) Intermediate, lower threshold



(d) Intermediate, upper threshold



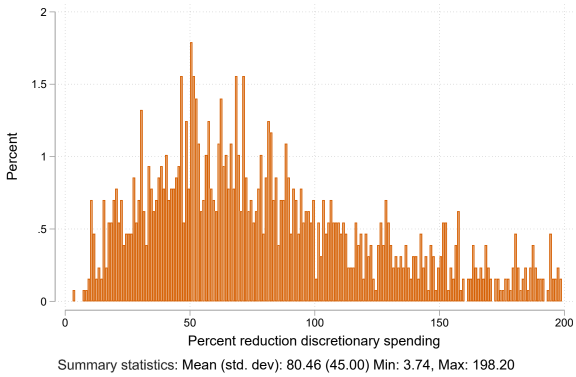
(e) Unconstrained borrowers, lower threshold



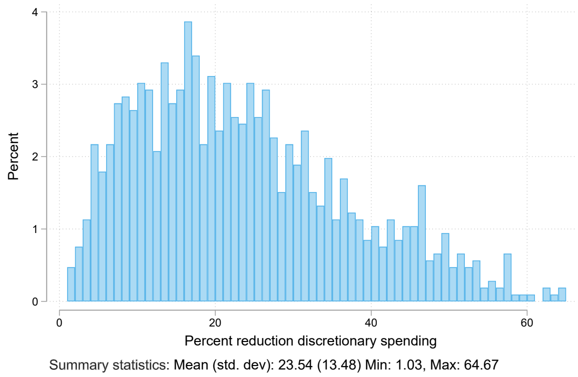
(f) Unconstrained borrowers, upper threshold

Figure 7. Bunching by Payment-to-income at LTV=50 (left) and LTV=70 (right)

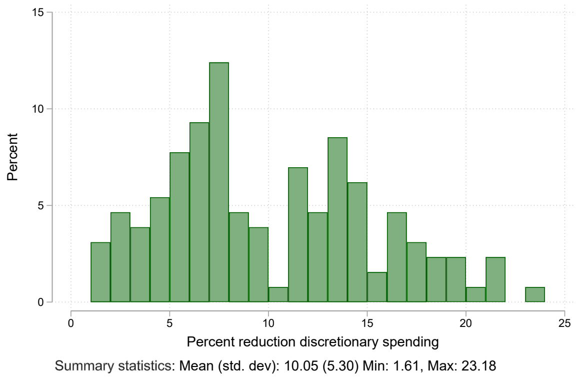
Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio for three different groups based on their counterfactual discretionary income. The estimation for the lower threshold on the left is carried out using all loans with LTV ratios between 20 and 65 percent, but 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 4. The figures reports the estimated percent of households that bunch at the threshold (B), the excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculations are described in Section 4. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.



(a) Constrained borrowers



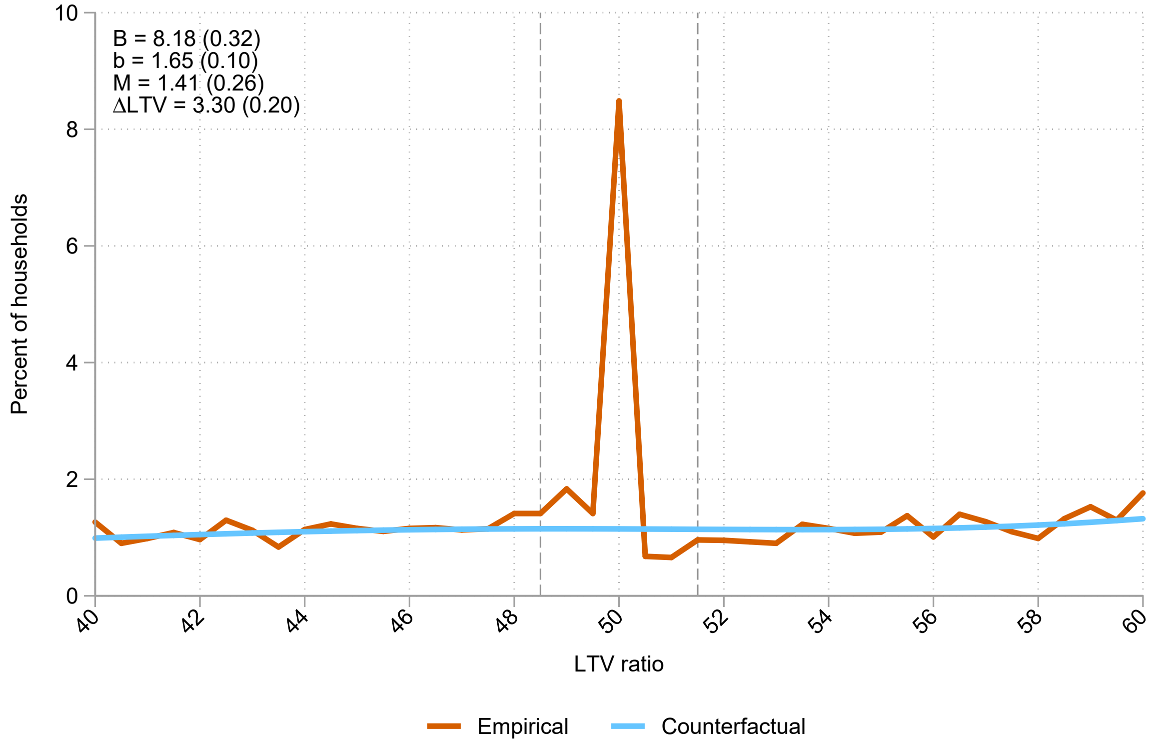
(b) Intermediate



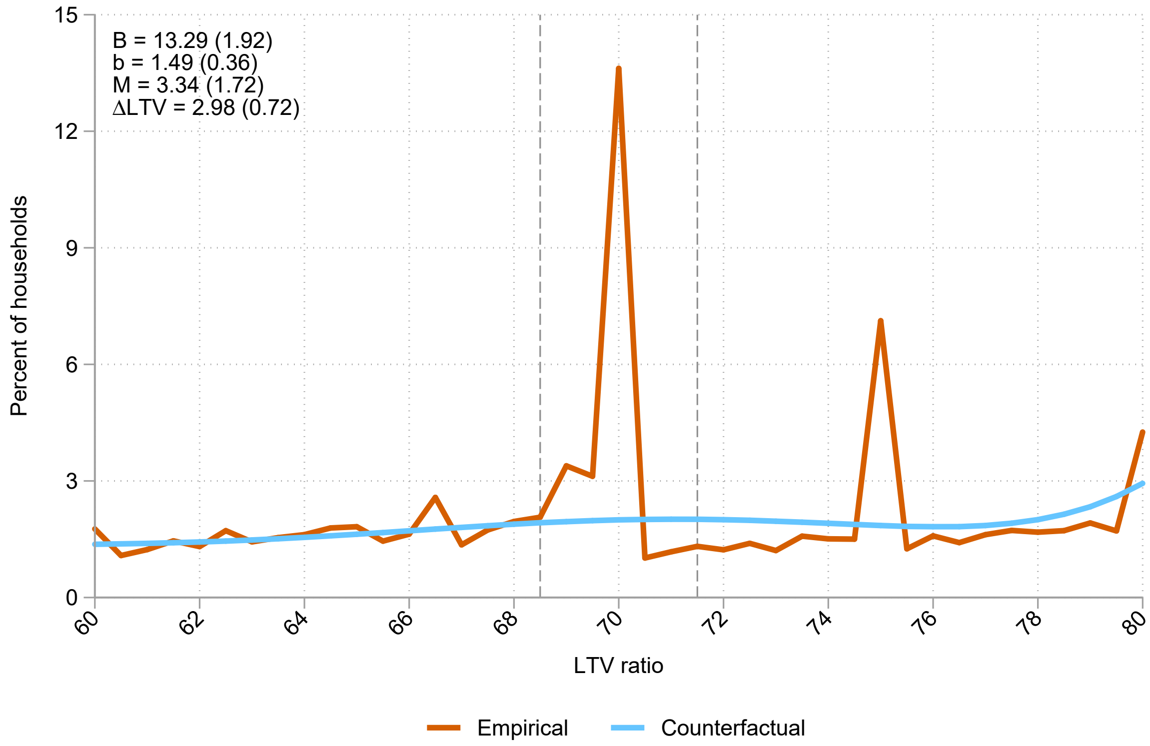
(c) Unconstrained borrowers

Figure 8. Reduction in discretionary income for a one-percentage point increase in leverage

Notes: The figure plots the reduction in discretionary spending for borrowers located at the notches if they a 1 percentage point higher leverage. We group households based on counter-factual discretionary income into a Constrained, an Intermediate and an Unconstrained sample, with a counterfactual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK, and greater than 15,000 SEK, respectively. We select borrowers with LTV values between 48.5 and 50, and 68.5 and 70. We update the bank's discretionary income calculation to include higher amortization payments by increasing LTV ratios to one percentage point above the threshold. We use a stressed interest rate of 7 percent for the increase in debt, according to standard practice in Sweden.



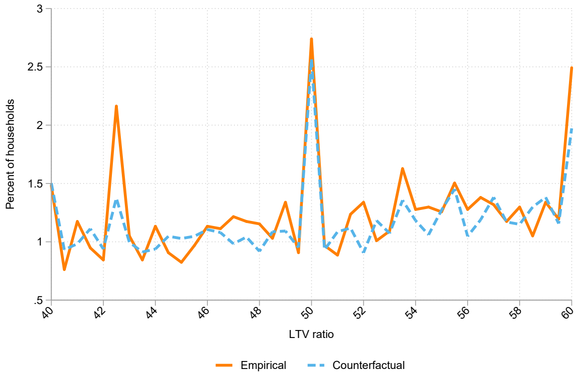
(a)



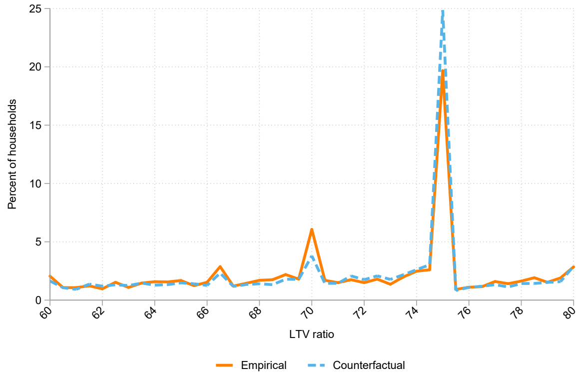
(b)

Figure 9. Bunching estimates from polynomials

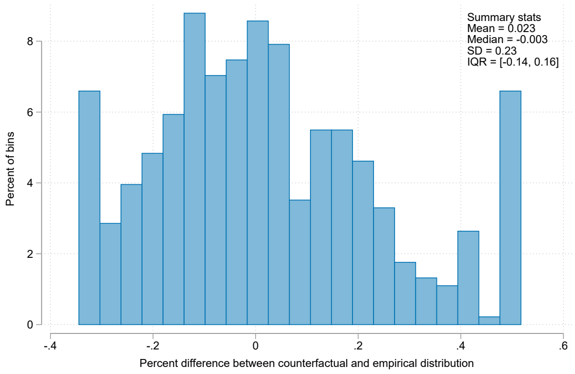
Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio, in the region around the notch at LTV = 50 (Panel a) and the notch at LTV = 70 (Panel b). The orange line is the empirical density, where each dot represents the percent of mortgages within each 0.5 percent LTV bin. The blue line is the counterfactual density, estimated by fitting a flexible polynomial to the observed distribution, excluding the region around the notch. The figure also reports the estimated percent of loans that bunch at the threshold (B), excess mass at the threshold (b), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 4. Standard errors are calculated using a bootstrap procedure and are shown in parentheses.



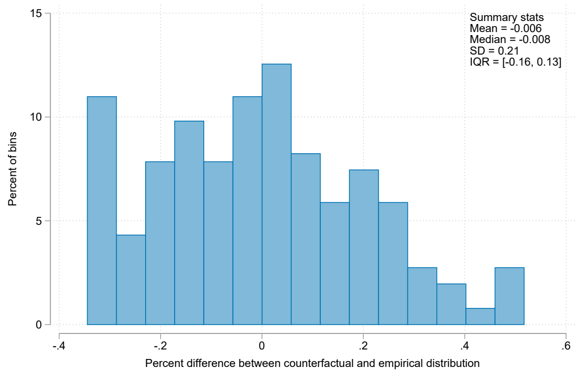
(a) Lower threshold: Placebo reform in 2014



(b) Upper threshold: Placebo reform in 2014



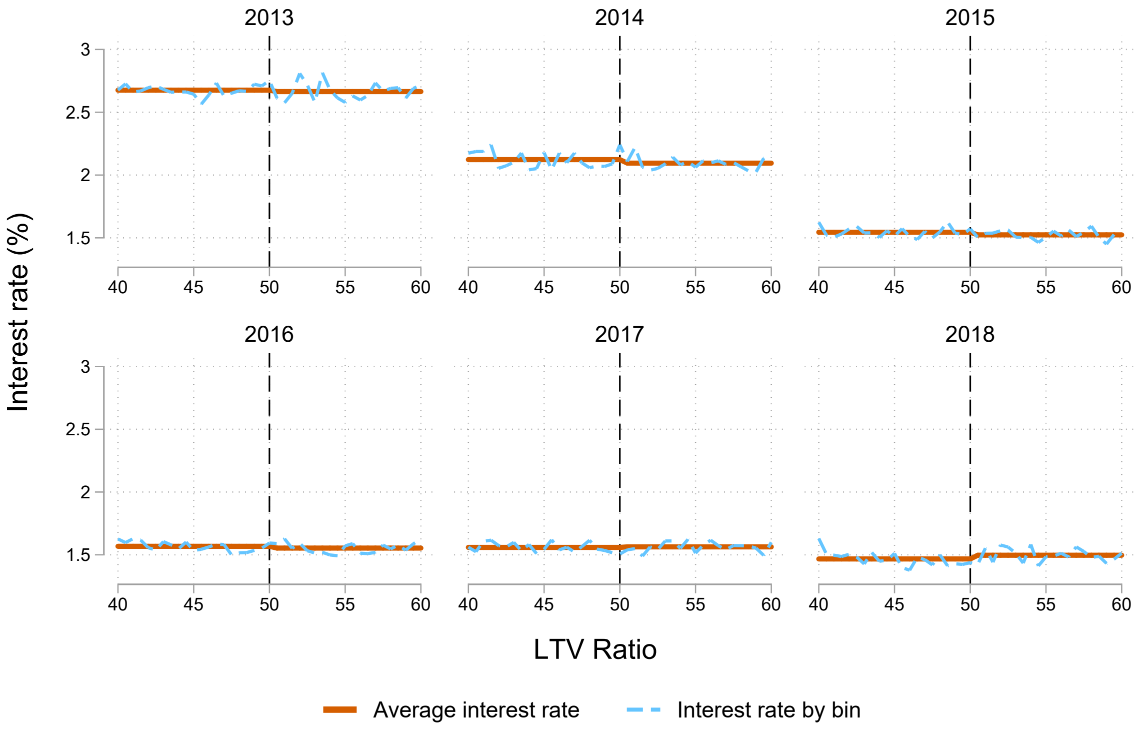
(c) Lower threshold: Ratio, empirical to counterfactual



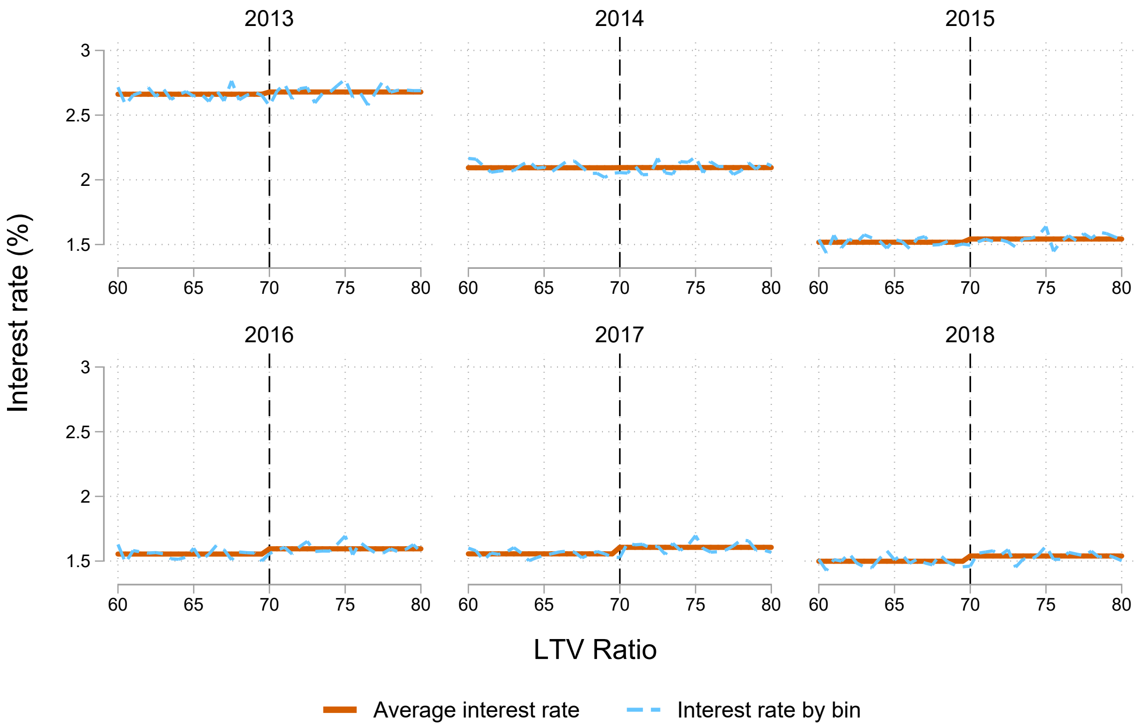
(d) Upper threshold: Ratio, empirical to counterfactual

Figure 10. Counter-factual and empirical distribution in placebo years

Notes: Panels a) and b) plot the empirical (solid orange line) and estimated counter-factual (dashed blue line) distribution of LTV ratios for 2014 for the upper and lower amortization requirement. Plotted LTV ratios are limited to be between 40 and 60 percent (panel a) and between 60 and 80 percent (panel b). The figures designate the placebo treatment to take place in 2014 and uses data from 2011, 2012, 2013, and 2015 to create the counter-factual. Panels c) and d) provide a histogram of the ratio between the empirical and counter-factual distribution, for all bins in all placebo years. For each year we use data from the other pre-requirement years as the counter-factual. LTV ratios are restricted to be between 40 and 60 in panel c) and between 60 and 80 in panel d).



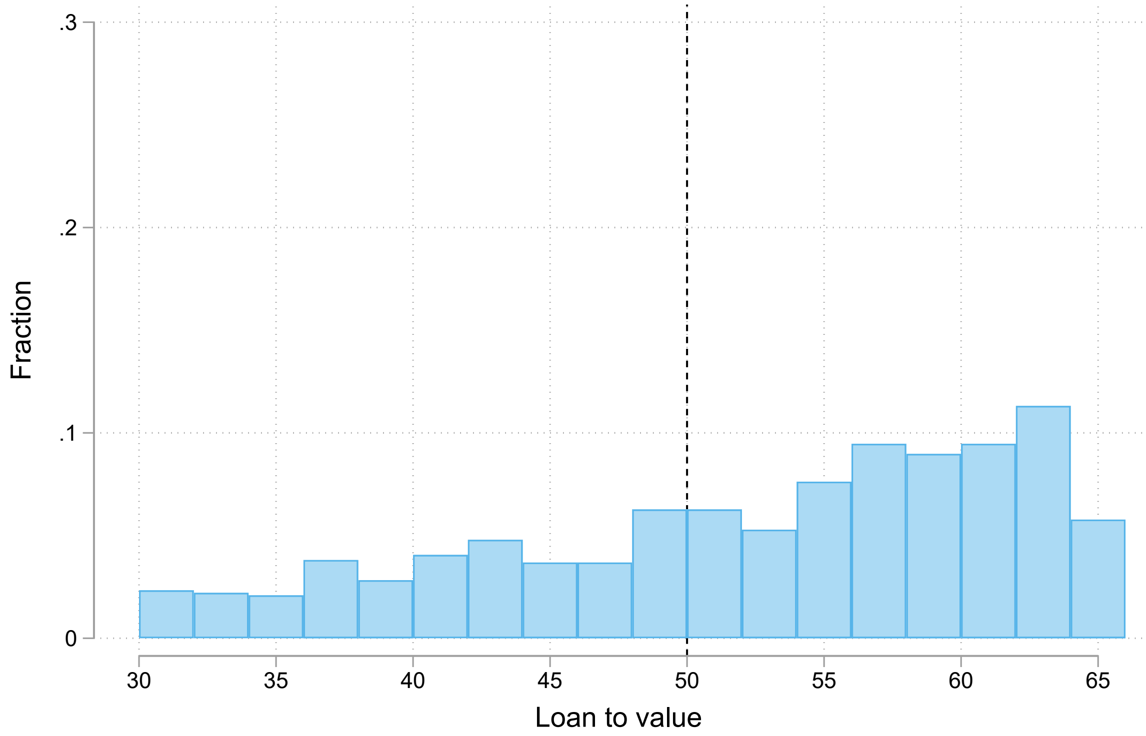
(a) Lower threshold



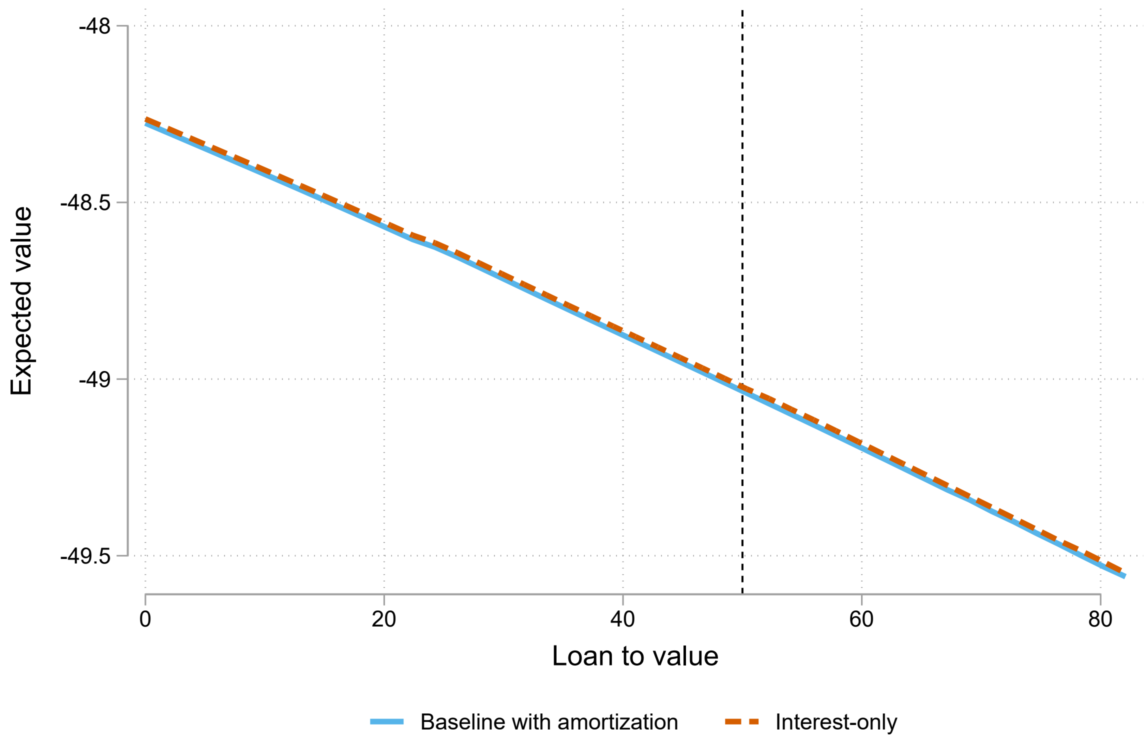
(b) Upper threshold

Figure 11. Interest rates around the lower LTV threshold

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

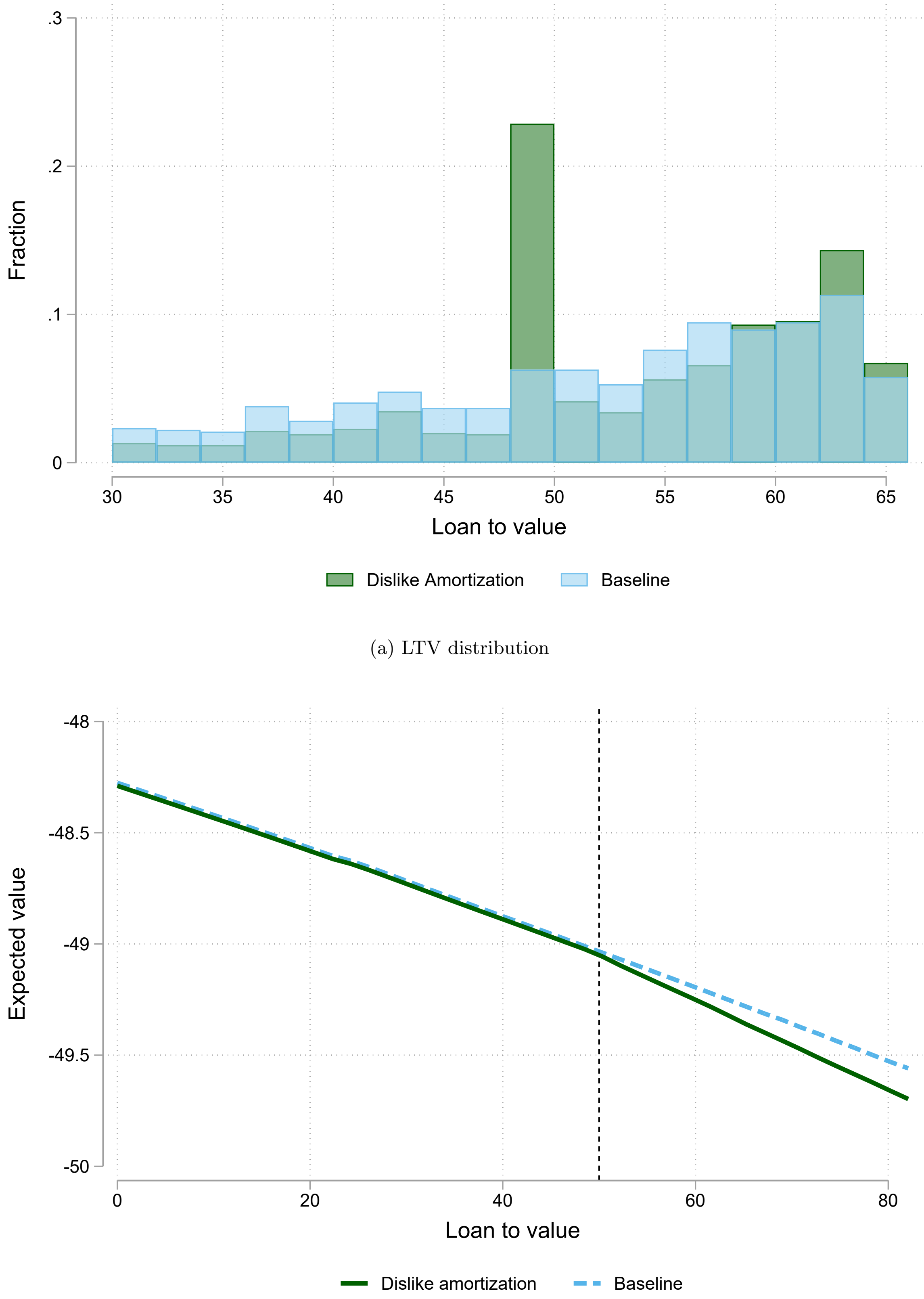


(a) LTV distribution



(b) Value function

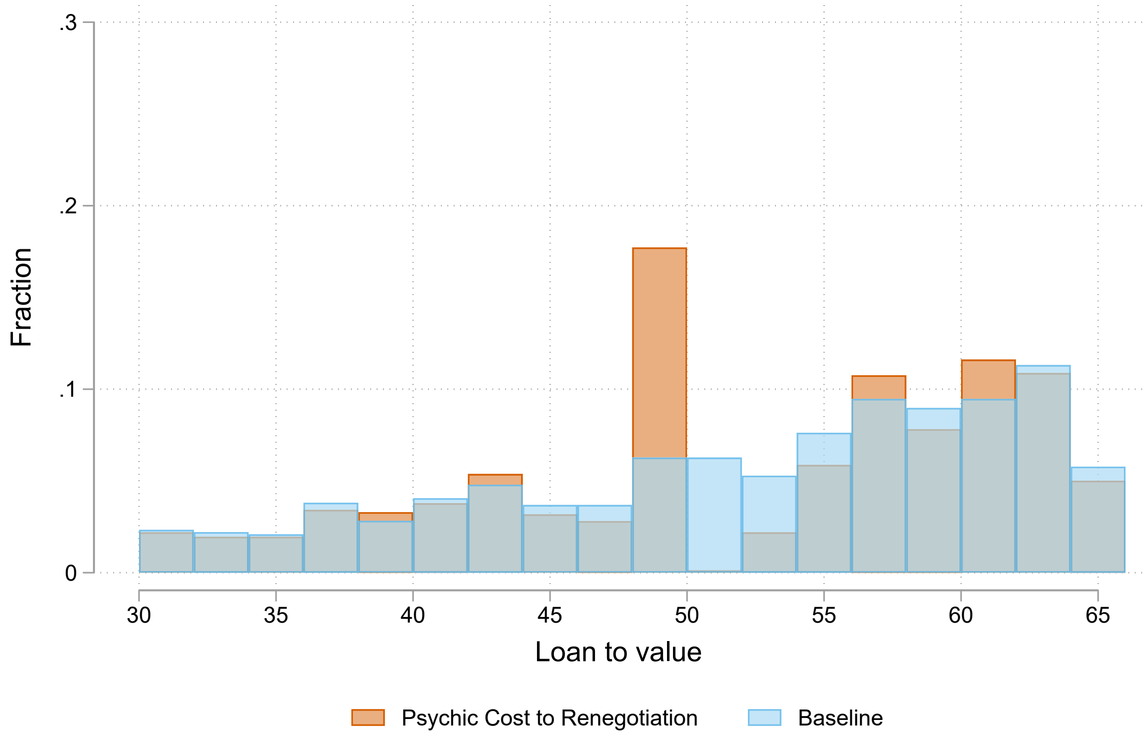
Figure 12. LTV distribution and value function in baseline model



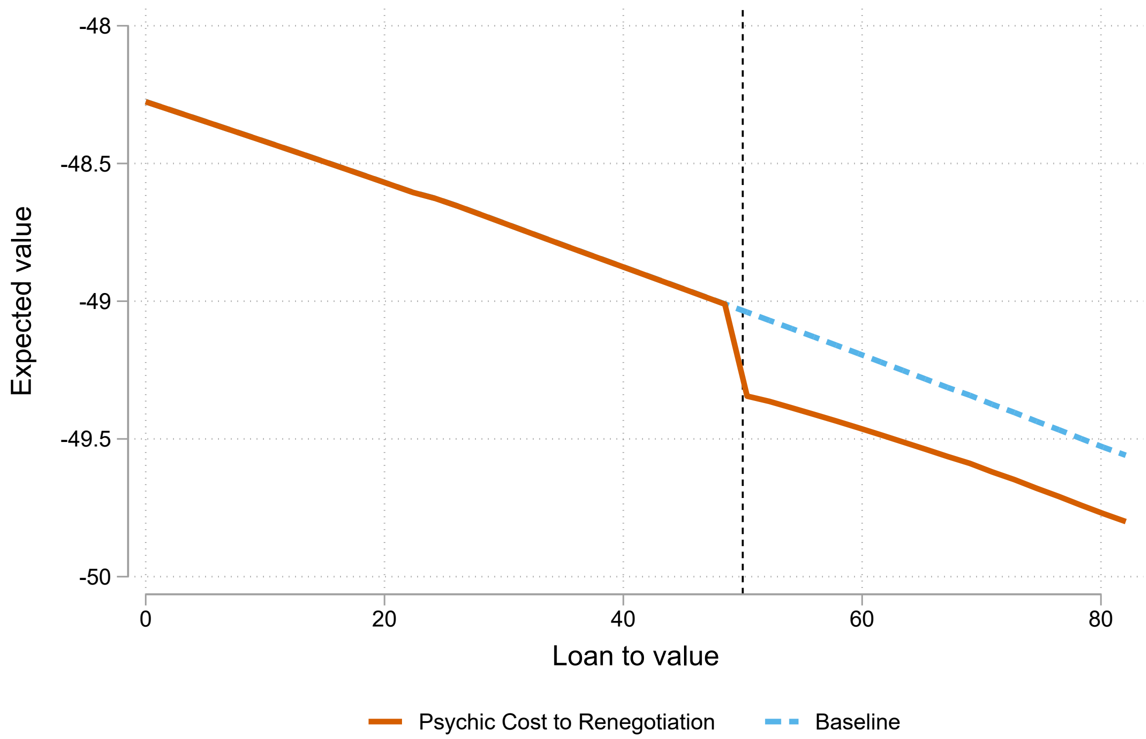
(a) LTV distribution

(b) Value function

Figure 13. LTV distribution and value function with dislike to amortizing



(a) LTV distribution



(b) Value function

Figure 14. LTV distribution and value function with psychic cost to refinancing

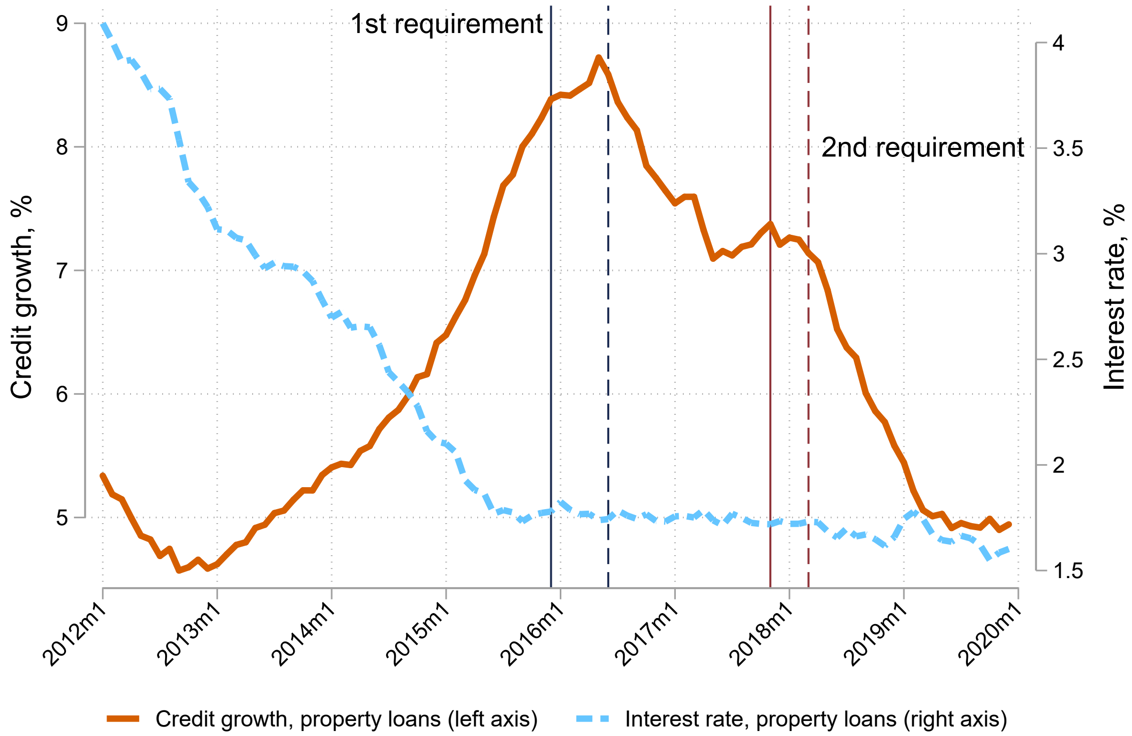


Figure 15. Credit growth for property loans

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

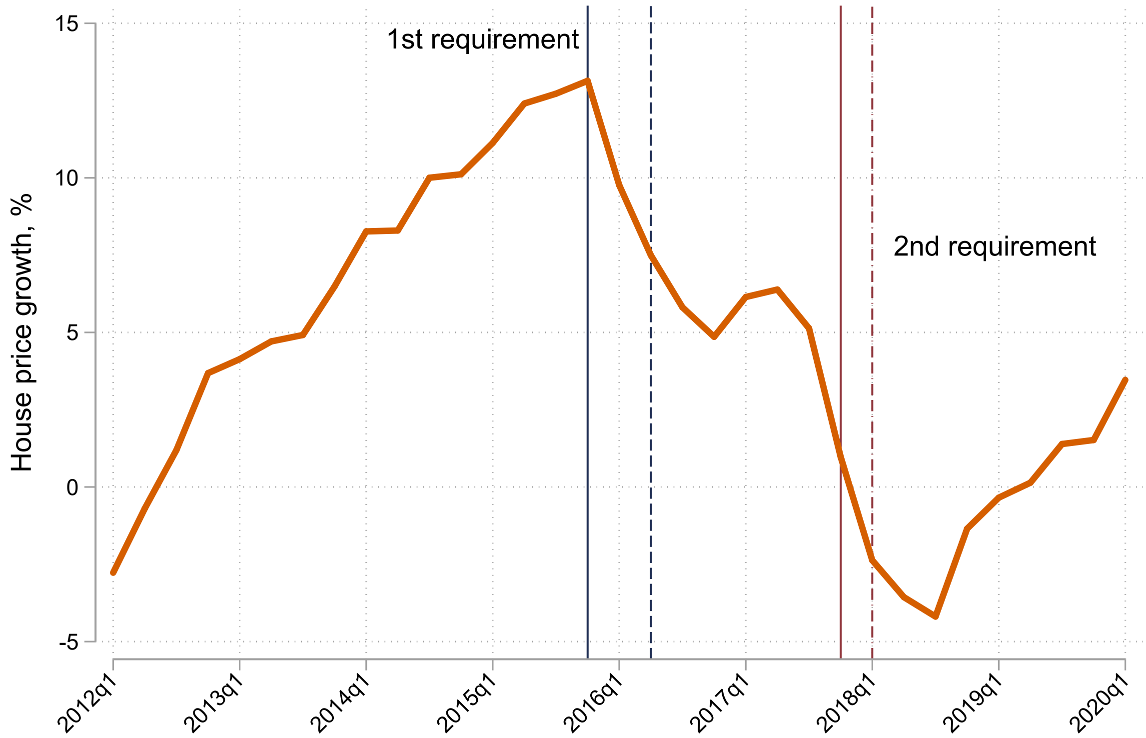


Figure 16. House price growth

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

9 Tables

Table 1. Are amortization payments a cost or a form of savings?

	Cost	Savings	Do not know	Count
All respondents	38%	44%	18%	1004
Gender				
Male	38%	51%	12%	485
Female	38%	38%	24%	519
Age				
18-22	39%	16%	45%	69
23-35	34%	40%	26%	235
36-55	41%	45%	15%	358
56-80	37%	52%	11%	342
Household income before taxes				
Less than 100000 SEK	42%	21%	38%	48
100000 - 300000 SEK	48%	32%	21%	286
300001 - 500000 SEK	39%	51%	10%	263
500001 - 700000 SEK	30%	58%	13%	172
More than 700000 SEK	22%	75%	3%	95
Prefer not to say	34%	28%	38%	140
Education level				
No finished education	50%	50%	0%	2
Primary school	44%	32%	24%	169
High School	40%	41%	19%	518
University	31%	57%	13%	312
Prefer not to say	33%	0%	67%	3

Notes: Translated from Swedish by the authors. Source: SBAB (2018).

Table 2. Summary statistics

	(1) Full Sample	(2) Constrained	(3) Intermediate	(4) Unconstrained
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	13.30	12.77	13.54	13.85
	(15.65)	(15.37)	(15.69)	(15.99)
Adjustable rate mortgage	0.61	0.63	0.60	0.59
	(0.49)	(0.48)	(0.49)	(0.49)
Amortization				
Amortization, KSEK	1.61	1.57	1.58	1.70
	(1.92)	(1.81)	(1.79)	(2.20)
Amortization rate	1.73	1.62	1.81	1.84
	(2.60)	(2.30)	(2.66)	(2.96)
Amortization to income	4.11	4.71	4.07	3.22
	(4.15)	(4.49)	(4.00)	(3.56)
Mortgage Characteristics				
Loan to value	65.43	64.65	67.30	64.45
	(22.97)	(23.41)	(22.05)	(23.20)
Total debt to income	377.95	432.41	359.95	313.28
	(218.47)	(227.32)	(206.73)	(195.36)
Net interest to income	5.55	6.04	5.41	4.95
	(3.76)	(3.78)	(3.72)	(3.66)
Debt service to income	10.87	11.96	10.70	9.35
	(6.80)	(7.05)	(6.57)	(6.33)
N	120,307	50,490	37,823	31,994

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

Table 3. Summary of main estimates

	Lower threshold (Notch at LTV=50)	Upper threshold (Notch at LTV=70)
Bunching	7.47	12.93
	(0.31)	(0.38)
Missing mass	-0.83	-1.43
	(0.16)	(0.20)
Δ LTV	2.57	2.73
	(0.16)	(0.12)

Notes: The table summarizes the main bunching estimates. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). Δ LTV is the estimate of the behavioral response, or the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4.2). 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.

Table 4. Bunching estimates by type of payment constraints

PTI Constraint	Constrained	Intermediate	Unconstrained
Panel A: Notch at LTV=50			
Bunching	5.01	10.17	9.41
	(0.49)	(0.63)	(0.70)
Excess mass	0.99	1.72	1.46
	(0.14)	(0.17)	(0.15)
Missing mass	-0.49	-0.90	-1.34
	(0.27)	(0.32)	(0.32)
Δ LTV	1.98	3.45	2.92
	(0.27)	(0.34)	(0.30)
Elasticity	0.15	0.45	0.32
	(0.04)	(0.09)	(0.06)
Number of households	13350	10471	10182
Panel B: Notch at LTV=70			
Bunching	13.16	13.29	13.10
	(0.58)	(0.71)	(0.96)
Excess mass	1.42	1.46	1.29
	(0.10)	(0.11)	(0.12)
Missing mass	-1.28	-0.94	-2.15
	(0.32)	(0.40)	(0.42)
Δ LTV	2.84	2.92	2.57
	(0.20)	(0.22)	(0.24)
Elasticity	0.16	0.17	0.13
	(0.02)	(0.02)	(0.02)
Number of households	15949	12127	10242

Notes: The table summarizes the main bunching estimates for different samples. We calculate the counter-factual discretionary income as the discretionary income given your chosen LTV, minus the extra payments if you would have borrowed 1%-point more in LTV. The Constrained, Intermediate and unconstrained sample has a counter-factual discretionary income of less than 5,000 SEK, 5,000-15,000 SEK and greater than 15,000 SEK, respectively. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). Δ LTV the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4.2). 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.

Table 5. Bunching estimates by type of valuation

Valuation	Internal	External	Purchase price
Panel A: Notch at LTV=50			
Bunching	7.10	7.38	9.30
	(0.34)	(0.88)	(1.46)
Excess mass	1.22	1.44	1.09
	(0.08)	(0.23)	(0.28)
Missing mass	-0.81	-0.81	-1.25
	(0.19)	(0.48)	(0.76)
Δ LTV	2.44	2.89	2.18
	(0.17)	(0.47)	(0.56)
Elasticity	0.23	0.32	0.18
	(0.03)	(0.10)	(0.09)
Number of households	28588	4948	2211
Panel B: Notch at LTV=70			
Bunching	12.88	6.40	19.13
	(0.43)	(1.05)	(1.01)
Excess mass	1.36	0.58	2.68
	(0.07)	(0.11)	(0.32)
Missing mass	-1.38	-0.53	-1.68
	(0.24)	(0.66)	(0.54)
Δ LTV	2.72	1.17	5.36
	(0.13)	(0.23)	(0.63)
Elasticity	0.15	0.03	0.54
	(0.01)	(0.01)	(0.12)
Number of households	30500	5111	4335

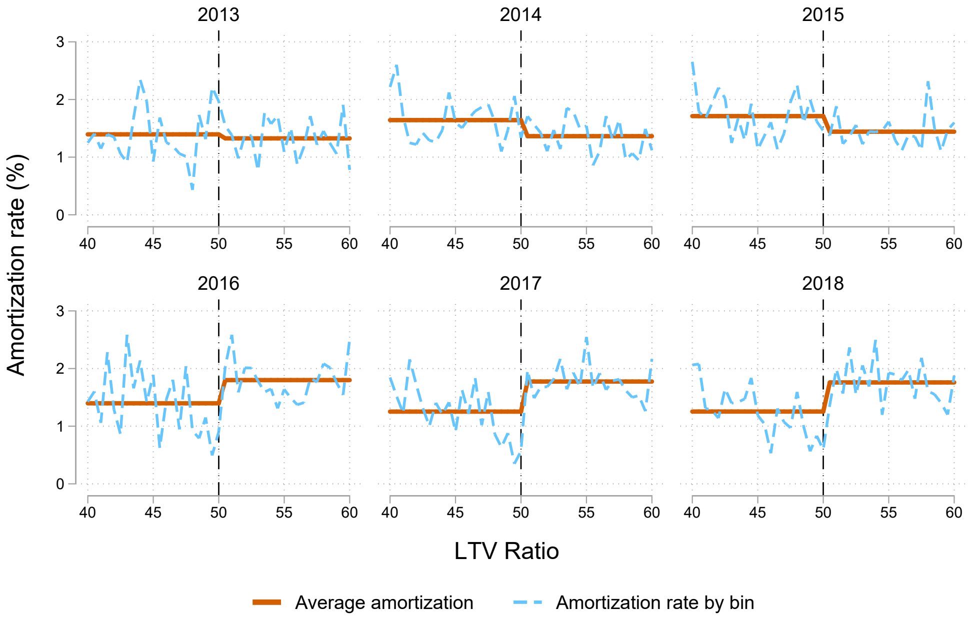
Notes: The table compares the bunching estimates across valuation modes for collateral assessments. For refinancers, banks use either an internal (statistical) valuation model, or an external method, either a tax-assessed value or an independent appraisal. For homebuyers, the purchase price is used. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). *Missing mass* is the percent of households missing at the right of the threshold, calculated using equation (3). Δ LTV is the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4.2). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 6. 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 6. Robustness to choice of bin width and lower limit

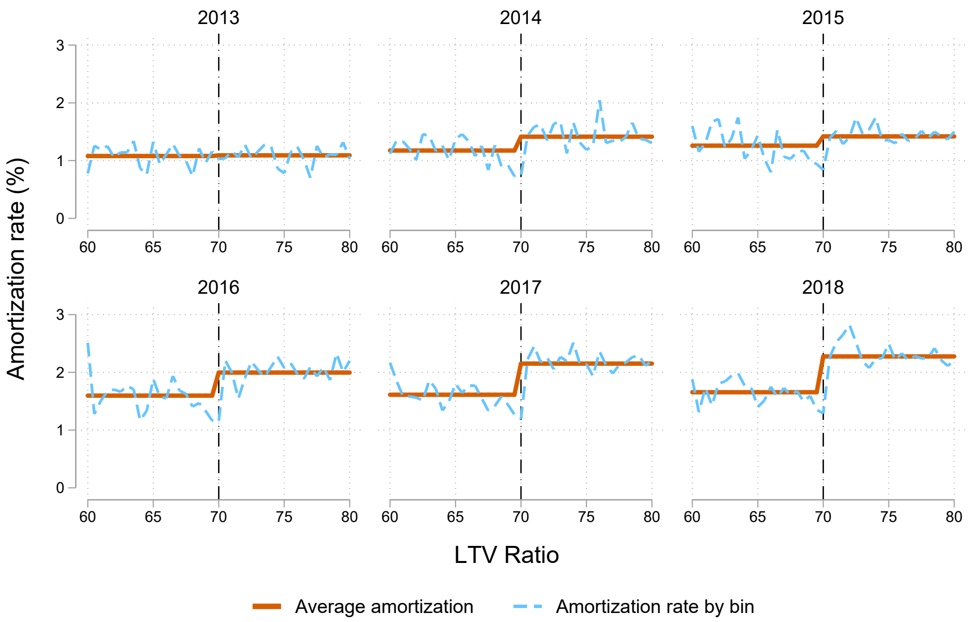
	Notch at LTV = 50							
	Bin width = 0.5					Bin width = 1		
			Preferred					
Lower limit (L)	47.5	48	48.5	49	49.5	47	48	49
Bunching (B)	8.00	7.92	7.47	7.12	6.43	7.98	7.80	7.03
	(0.34)	(0.34)	(0.31)	(0.30)	(0.27)	(0.36)	(0.34)	(0.32)
Excess mass (b)	1.02	1.16	1.28	1.50	1.80	0.80	0.99	1.22
	(0.06)	(0.07)	(0.08)	(0.10)	(0.12)	(0.05)	(0.06)	(0.08)
Δ LTV	3.05	2.91	2.57	2.26	1.80	3.20	2.97	2.43
	(0.18)	(0.18)	(0.16)	(0.15)	(0.12)	(0.19)	(0.18)	(0.16)
Elasticity	0.35	0.32	0.25	0.19	0.12	0.39	0.33	0.23
	(0.04)	(0.04)	(0.03)	(0.03)	(0.02)	(0.04)	(0.04)	(0.03)
	Notch at LTV = 70							
	Bin width = 0.5					Bin width = 1		
			Preferred					
Lower limit (L)	67.5	68	68.5	69	69.5	67	68	69
Bunching (B)	13.82	13.43	12.93	12.28	10.75	13.82	13.39	12.37
	(0.41)	(0.39)	(0.38)	(0.37)	(0.34)	(0.44)	(0.41)	(0.38)
Excess mass (b)	1.12	1.23	1.36	1.53	1.75	0.85	1.07	1.30
	(0.05)	(0.05)	(0.06)	(0.07)	(0.08)	(0.03)	(0.04)	(0.06)
Δ LTV	3.36	3.06	2.73	2.29	1.75	3.42	3.21	2.61
	(0.14)	(0.13)	(0.12)	(0.10)	(0.08)	(0.14)	(0.13)	(0.12)
Elasticity	0.22	0.18	0.15	0.10	0.06	0.23	0.20	0.13
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)

Notes: The table summarizes the robustness of the bunching estimates. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). Δ LTV is the estimate of the behavioral response, or the percentage point change in LTV ratio for the marginal buncher, calculated using equation (4.2). *Elasticity* is the amortization elasticity of mortgage demand, calculated using equation 6. 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.

A Internet Appendix: Figures



(a) Lower Threshold



(b) Upper threshold

Figure A1. 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.

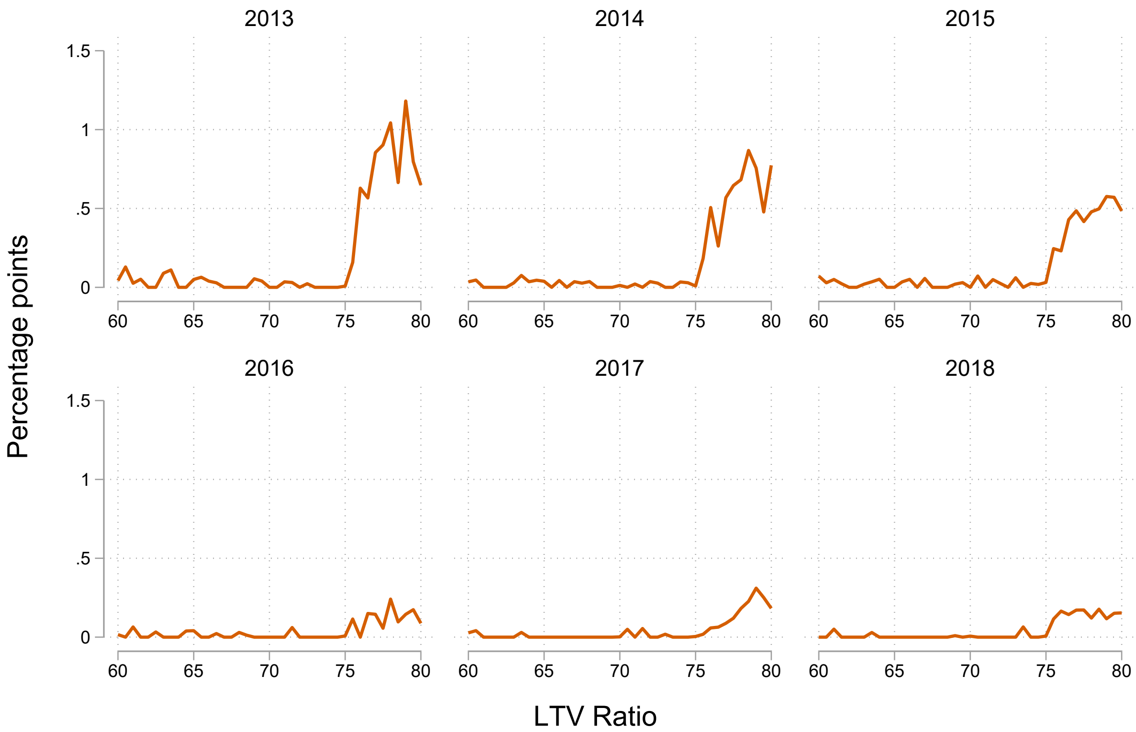
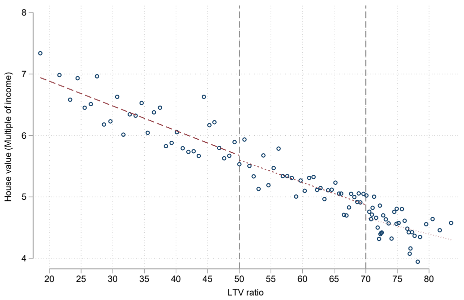
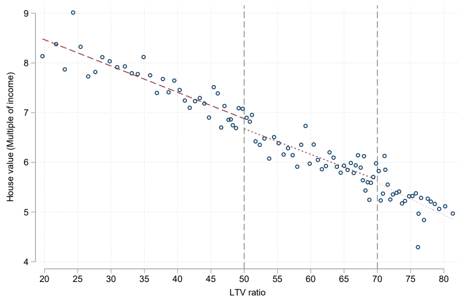


Figure A2. Difference between top and bottom interest rates

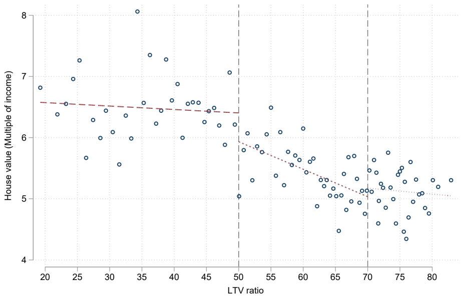
Notes: The figure plots the difference between the average top and bottom interest rate, conditional on the borrower having a top and bottom loan, by LTV bin.



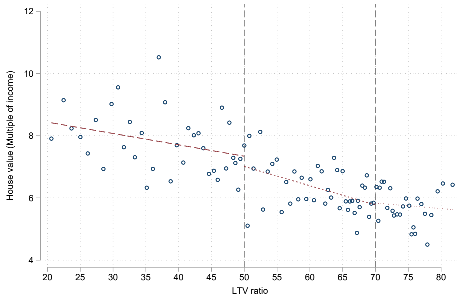
a) Refinancers, internal valuation, 2011-2015



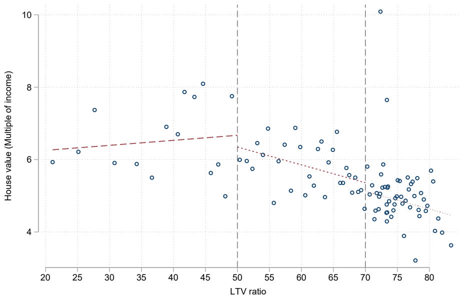
b) Refinancers, internal valuation, 2016-2018



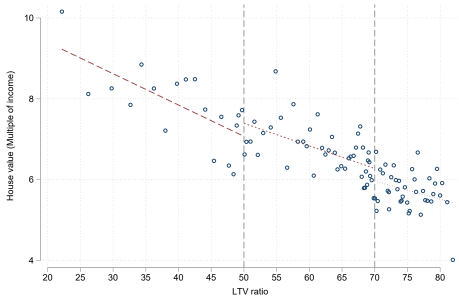
c) Refinancers, external valuation, 2011-2015



d) Refinancers, external valuation, 2016-2018



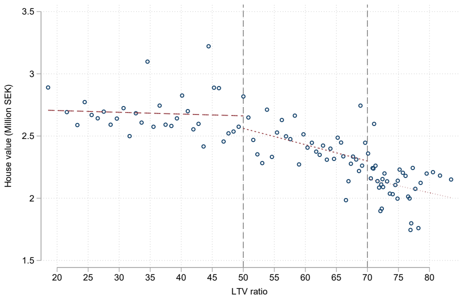
e) Homebuyers, 2011-2015

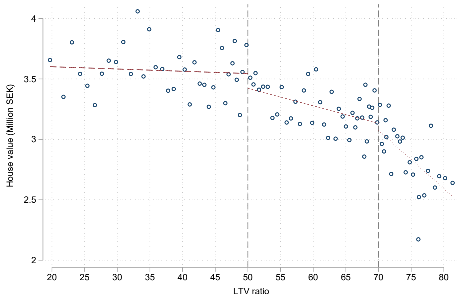


f) Homebuyers, 2016-2018

Figure A3. Housing values by LTV ratio

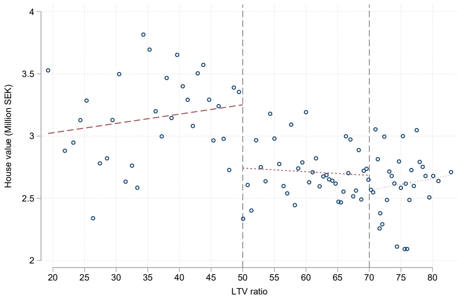
Notes: The figure plots the distribution of house values as a multiple of annual disposable income by LTV ratio. Using data for the pre- and post-requirement periods, each dot displays the average house value as a multiple of annual disposable income per LTV bin, after filtering out region-by-year and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

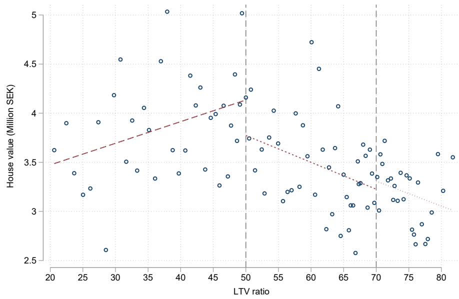




a) Refinancers, internal valuation, 2011-2015

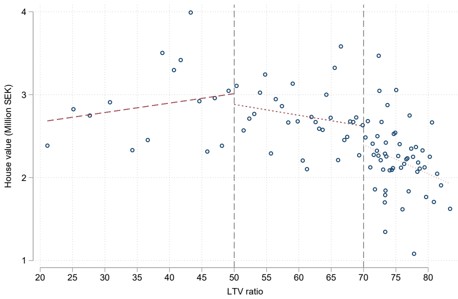
b) Refinancers, internal valuation, 2016-2018

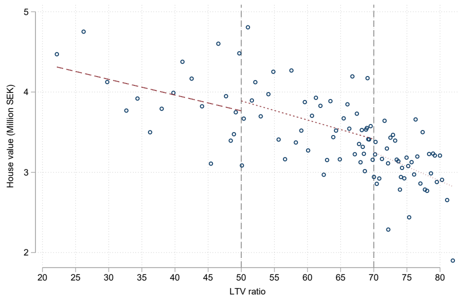




c) Refinancers, external valuation, 2011-2015

d) Refinancers, external valuation, 2016-2018





e) Homebuyers, 2011-2015

f) Homebuyers, 2016-2018

Figure A4. Housing values by LTV ratio

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

B Internet Appendix: Tables

Table B1. Mortgage payments for payment schedules and interest rates

	Interest rate					
	1%	1.5%	2%	3%	5%	10%
Payments under each schedule						
Interest-only mortgage	10,000	15,000	20,000	30,000	50,000	100,000
Annuity schedule	38,597	41,414	44,354	50,592	64,419	105,309
Sweden: Lower threshold	20,000	25,000	30,000	40,000	60,000	110,000
Sweden: Upper threshold	30,000	35,000	40,000	50,000	70,000	120,000
Reduction in payments (%)						
(Annuity - IO) / Annuity	74.09	63.78	54.91	40.70	22.38	5.04
(Lower - IO) / Lower	50.00	40.00	33.33	25.00	16.67	9.09
(Upper - Lower) / Upper	33.33	28.57	25.00	20.00	14.29	8.33

Notes: The table reports mortgage payments in the first year under different interest rates and repayment schedules. We calculate mortgage payments for a 1,000,000 mortgage, using the annual interest rate in the top row. All calculations assume that payments are made monthly. For the annuity schedule the contract term is assumed to be 30 years. *Interest-only mortgage* is calculated as the mortgage amount times the effective annual interest rate. *Annuity schedule* is calculated using an annuity formula where the payments are the same in every period. *Sweden: Lower threshold* and *Sweden: Upper threshold* are calculated as the interest costs from a interest-only mortgage plus an amortization rate of 1% and 2%, respectively. The last three rows under **Reduction in payments (%)** calculate the percent reduction in total mortgage payments from choosing a mortgage with a lower amortization rate. For example, (*Annuity - IO*) compares the total mortgage expense for an interest-only mortgage with the total expense for a mortgage with an annuity schedule: (Annuity schedule - Interest-only mortgage)/Annuity schedule. *Lower - IO* and *Upper - Lower* are calculated similarly.

C Appendix: Bunching Estimates from Polynomials

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

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

$$n_j = \sum_{i=0}^{p} \beta_i (m_j)^i + \sum_{k=L}^{U} \gamma_k \mathbf{1}(m_k = m_j) + \epsilon_j, \tag{14}$$

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

$$\hat{n}_j = \sum_{i=0}^{p} \hat{\beta}_i (m_j)^i \tag{15}$$

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

As in the main analysis, the estimates of bunching and missing mass are calculated by comparing the counter-factual distribution to the empirical distribution in the relevant regions (see equations 1 and 3). We use the procedure in Chetty *et al.* (2011) to calculate standard errors for all estimated parameters. Specifically, we randomly draw from the residuals in equation 14 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 9 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 C1 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-

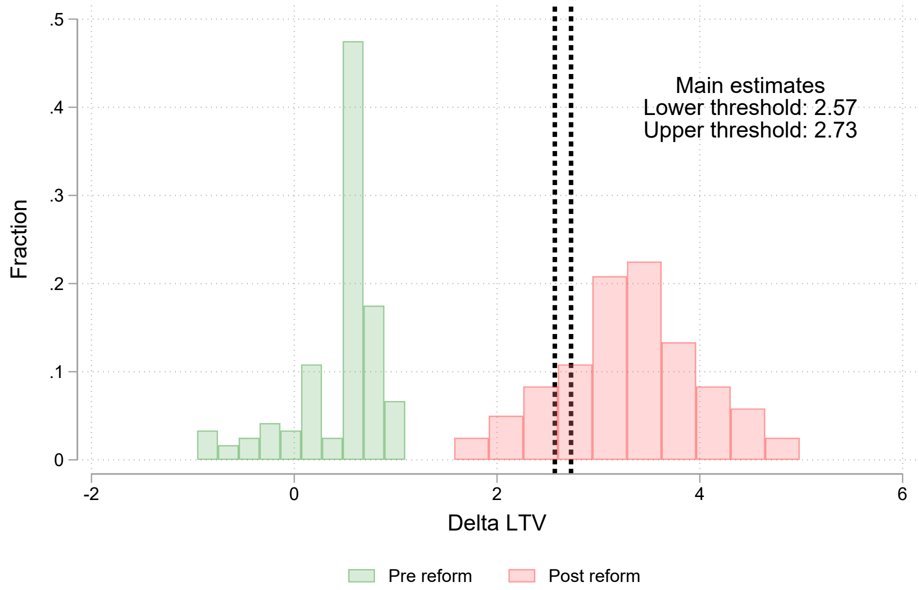


Figure C1. Robustness of estimated behavioral responses

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).

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: Calibration

Table D1 shows the parameters set outside of the model of Section 6. 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)
Household preferences:			
Time preference	β	1.02^{-1}	Attanasio *et al.* (2012)
Risk aversion	γ	1.43	Attanasio *et al.* (2012)
Housing utility (separable)	μ	0.26	Attanasio *et al.* (2012)
Housing utility (non-separable)	θ	0.115	Attanasio *et al.* (2012)
Assets:			
Real return on liquid asset	r	0.0181	Swedish 3 month T-bill
Real return on housing	r^H	0.02953	Statistics Sweden
Mortgage interest rate	r^M	0.0087	Statistics Sweden
Multiplicative cost of refinancing	f_2	5%	Federal Reserve Board (2008)
Additive cost of refinancing	f_3	\$3000	
Downpayment requirement	ψ	0.15	Swedish law
Financial cost to moving homes	F	0.05	OECD (2011)
Rental scale	η	0.035	Leombroni *et al.* (2020)
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)

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

Initial wealth. We assume zero initial housing wealth. We set the initial liquid wealth distribution to match the distribution for 22-25-year old households in the PSID, following Kovacs & Moran (2021). We use that 43.3 percent of households have zero liquid assets at age 22. Conditional on observing positive assets, the mean log liquid asset holdings are estimated to be $\mu_{a_0} = 7.117$, with a conditional standard deviation of $\sigma_{a_0} = 1.972$.

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

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

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

$$r_{t+1} = \frac{p_{t+1} + d_{t+1} - p_t}{p_t} \tag{16}$$

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:

$$r^H_{t+1} = \frac{p_{t+1} + s_{t+1} - c^m_{t+1} - c^i_{t+1} - p_t}{p_t} \tag{17}$$

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 (17) as

$$r^H_{t+1} = \frac{p_{t+1} + (s - c^m - c^i - 1)p_t}{p_t} \tag{18}$$

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

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

$$r^j_{adjusted} = E(r^j) - var(r^j) \tag{19}$$

where superscript j refers to the asset type, i.e. liquid assets based on 3-month Treasury bills or housing.