

The Amortization Elasticity of Mortgage Demand*

Claes Bäckman[†]

Patrick Moran[‡]

Peter van Santen[§]

November 8, 2022

[\[For the latest version, please click here\]](#)

Abstract

We study the causal impact of amortization payments on household borrowing. Exploiting notches in the Swedish amortization requirement, we find that new borrowers reduce their loan-to-value ratios by 5 percent in response to a 1 percentage point higher amortization rate. Even unconstrained households reduce their borrowing, contrary to predictions from standard life-cycle theory. The results are not driven by supply-side factors and apply to both homebuyers and refinancers. 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. Our results are relevant for understanding household mortgage choice and savings behavior.

JEL Classification: G51, G21, E21, E6

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

*We thank Rob Alessie, Johan Almenberg, Olga Balakina, Vimal Balasubramaniam, Tobin Hanspal, Ragnar Juelsrud, Kaveh Majlesi, Lars E.O. Svensson, Nikodem Szumilo, Taha Choukhmane and seminar participants at Sveriges Riksbank, University of Groningen, Lund University, Nordic Junior Macro Seminar, EFA 2020, Central Bank of Ireland workshop on Borrower finances, financial stability assessment and macroprudential policies, the NFN Young Scholars Finance Webinar series, IAAE 2022, and EEA-ESEM 2022 for helpful comments. Support from the Danish Finance Institute (DFI) is gratefully acknowledged. Claes Bäckman would like to thank Jan Wallanders och Tom Hedelius stiftelse for generous financial support. The empirical analysis in this paper was done when van Santen worked at the Financial Stability Department of Sveriges Riksbank. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Executive Board of Sveriges Riksbank. The findings and conclusions expressed are solely those of the authors and do not represent the views of the Federal Reserve System.

[†]Corresponding author. Aarhus University (claes.backman@econ.au.dk)

[‡]Federal Reserve Board, CEBI, and IFS (patrick.e.donnellymoran@frb.gov)

[§]Faculty of Economics and Business, University of Groningen (p.c.van.santen@gmail.com)

1 Introduction

Signing up for a mortgage loan commits the borrower to a long period of mortgage payments, which in most countries comprise both interest and principal repayments. Borrowers often have limited choice over the minimum amounts they have to repay, which can be a substantial portion of total mortgage payments and represent large aggregate savings flows. Amortization payments are 55 percent of mortgage payments in the first year for a 30-year annuity loan with an interest rate of two percent and are of similar aggregate magnitudes as pension contributions in the United States (Bernstein & Koudijs, 2021). In standard theoretical life-cycle models, unconstrained households can undo these minimum payments by borrowing more at origination (Svensson, 2016), by frequent refinancing (Hull, 2017) or by changing other types of savings (Bernstein & Koudijs, 2021). We have limited empirical evidence, however, on how higher required amortization payments affect borrowing, which we call the amortization elasticity of mortgage demand. This paper seeks to fill this gap.

To shed light on this topic, we exploit a macroprudential policy introduced in Sweden in 2016, the amortization requirement, which features two notches where minimum mandatory mortgage payments exhibit a discontinuous jump at specified loan-to-value (LTV) thresholds. We formally estimate the response to the requirement using a bunching analysis performed on administrative data, and document significant bunching at the LTV thresholds. Approximately 25 percent of the bunching is driven by credit-constrained households who are forced to avoid amortization due to regulatory payment-to-income constraints. However, we also find that even borrowers far from payment-to-income and leverage constraints reduce their borrowing in response to higher amortization payments, contrary to the theoretical predictions above. We find similar degrees of bunching for existing homeowners, who can only adjust the loan amounts. We investigate various supply-side factors that could potentially cause bunching (e.g. interest rate discontinuities, risk weights, mortgage approval, collateral assessments, and refinancing costs), but find that none of these supply-side factors are able to explain our results. This suggests a crucial role for household preferences.

Figure 1 illustrates the identification strategy and main empirical results. Focusing on the lower threshold, the figure plots the percent of new mortgages in specific LTV bins in pre- and post-requirement years. At this threshold, the minimum amortization rate on new mortgages jumps from zero to one percentage point for mortgages with an LTV ratio above 50 percent.

The increase in total mortgage payments at the threshold is 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. 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.

We formally estimate the amount of bunching using pre-requirement years to form the counterfactual distribution. The method was first developed in public finance (Saez, 2010; Chetty *et al.*, 2011; Kleven & Waseem, 2013; Kleven, 2016), and has recently been used in the context of mortgage markets by DeFusco & Paciorek (2017) and Best *et al.* (2020). Our preferred specification indicates that 7.5 percent of borrowers place themselves at the lower 50 percent LTV threshold because of the higher amortization payments. Borrowers reduce their LTV ratios by 5 percent in response to the requirement. The corresponding number for the upper LTV threshold at 70 percent is 12.9 percent of borrowers and a 4 percent reduction in LTV. We use placebo tests to verify that previous years provide a valid counter-factual LTV distribution as in DeFusco *et al.* (2020), and we show that our results are robust to the standard approach of fitting a flexible polynomial to the observed distribution (Chetty *et al.*, 2011; Kleven & Waseem, 2013). The bunching estimates translate into a reduction in LTV of 0.15 to 0.25 percent for a one percentage point higher marginal amortization rate. For comparison, note the average amortization rate on a 30-year fixed-rate mortgage is 3.33 percent. Assuming that the borrower adjusts the loan amount, refinancing from an interest-only mortgage would reduce their leverage ratio by 0.5 to 0.83 percent. Using similar methods, DeFusco & Paciorek (2017) finds that a one percentage point increase in the interest rate on a 30-year fixed-rate mortgage reduces mortgage demand by 1.5 to 2 percent.

These estimates suggest that many borrowers choose lower LTV ratios to avoid higher payments. However, several key confounds interfere with a simple interpretation of the results. The first issue is that credit constraints may cause some borrowers to shift down to the notch after the amortization requirement is introduced. For these borrowers, the elasticity of borrowing with respect to amortization payments is effectively infinite. Credit constraints related to amortization payments are a key empirical confound, as Swedish banks use a discretionary income threshold that can be interpreted as a *payment-to-income constraint* (Grodecka, 2020). Impor-

tantly, Swedish banks include amortization payments when assessing repayment ability based on discretionary income. To cleanly separate credit constraints from household preferences, we select borrowers based on the distance to the banks' *discretionary income* cutoffs and construct groups of constrained and unconstrained borrowers. Since both amortization thresholds are far from the maximum loan-to-value threshold of 85 percent, unconstrained borrowers do not have any credit constraint that would limit their borrowing. We have verified in our data and in conversations with banks that other dimensions of the mortgage contract, such as the interest rate or credit assessments, do not vary across the amortization thresholds. Approximately 75 percent of borrowers at the threshold would comply with payment-to-income constraints even with the higher amortization payments above the notch.

We find considerable bunching even for households away from the discretionary income constraint. At the lower threshold, 9.4 percent of unconstrained borrowers bunch, reducing their LTV ratios by 2.29 percentage points, or $2.92/50 = 5.84$ percent. The corresponding elasticity is 0.32. At the upper threshold, 13 percent of borrowers bunch, reducing their LTV by 2.57 percentage points, or $2.57/70 = 3.6$ percent. The corresponding elasticity is 0.13. In contrast, a modified version of the [Svensson \(2016\)](#) model with a notch in the amortization schedule predicts the opposite result for unconstrained borrowers: no bunching, but instead a hole in the distribution just above the notch.

A second issue arises because we are estimating the behavioral response in LTV, not borrowing. Homebuyers can adjust to the requirement by taking out a smaller loan (L) or adjusting the type of home they purchase (V). To deal with this issue, 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, 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. The amount of bunching and the estimated elasticities are similar across borrowers who borrow to purchase a property and those who refinance.

An important consideration is that borrowers can turn off amortization payments again once they have paid down enough of the loan to hit the LTV cutoff. The higher amortization payments around the threshold induced by the requirement are thus temporary. Bunching by unconstrained borrowers reveals that they consider it more costly to start at an LTV above

the threshold and then amortize down to the threshold, compared to starting directly at the threshold by reducing the LTV value at mortgage origination. One potential confound that can generate this pattern is refinancing costs. Suppose, for example, that there is a high cost to lowering the amortization rate once the borrower hits the threshold or that there is uncertainty around being able to reduce amortization payments once you hit the threshold. In that case, some borrowers would be willing to lower their LTV to the threshold to avoid any cost or uncertainty. Empirically, however, it is unlikely that there will be high refinancing costs once you hit the threshold in Sweden. Only one bank, with a market share of 5 percent in 2017, charges a (small) monetary cost to lowering the amortization rate once the borrower hits the threshold. Lowering the rate is free for all other banks and does not require a new mortgage contract. Moreover, in communication with Swedish banks, they state i) that they do not conduct a new credit check once the borrower hits the threshold, ii) that a phone call or online message to the bank advisor is usually enough to submit a request to reduce the amortization rate, and iii) that the request to lower the amortization rate is rarely denied.

What accounts for the positive amortization elasticity of mortgage demand for unconstrained borrowers? Our data suggest that unconstrained borrowers are unwilling to undo higher amortization payments by borrowing more. Instead, they choose lower LTV ratios in the face of higher amortization payments. On a fundamental level, our findings suggest that borrowers consider amortization payments costly. Backing up the assertion that amortization payments are costly, 38 percent of respondents to survey of Swedish households 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](#)).

A potential mechanism is that borrowers mistake amortization payments for interest payments (see [Almenberg & Säve-Söderbergh, 2011](#), for evidence on financial literacy in Sweden). However, unconstrained borrowers tend to have higher income and lower debt-to-income ratios, characteristics that would typically correlate with *higher* financial literacy. Another plausible mechanism is that borrowers value liquidity. Examining borrowers who place themselves just at the notch, we find that 60 percent would experience a drop in their discretionary income by at least 30 percent if they were to amortize. Unconstrained borrowers at the notch would experience an average decrease in discretionary income of 10 percent if they were to amortize more. These numbers suggest new borrowers deliberately choose a lower LTV ratio to free up

monthly cash flow.

In conclusion, our main contribution is to provide credible and novel evidence that amortization payments affect household borrowing for both constrained and unconstrained borrowers. 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. 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 \(2013\)](#) similarly documents “NPV-neglect”, the tendency of borrowers to target total payment size instead of the interest-rate. 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.

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](#)), their role in relaxing credit constraints have 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 and house prices. 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 Bakkum *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, and discusses our data. Section 3 presents several arguments for why amortization payments affect household borrowing. We discuss the empirical strategy in Section 4. Section 5 provides the main results and Section 6 discusses robustness and threats to identification. Finally, Section 7 discusses how housing markets reacted to the policy, and Section 8 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 2. 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.¹

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 micro-data, which we discuss in detail in Section 4, Figure 3 plots the share of interest-only mortgages among new mortgages against LTV values for different years. Panel a) plots results for the lower

¹Due 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).

threshold. In the pre-requirement years between 2013 and 2015, around 60 percent of mortgages around the lower threshold were interest-only. In the post-requirement years between 2016 and 2018, the 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 sorting to the threshold to attain an interest-only mortgage. 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. We discuss the aggregate housing and mortgage market implications of the reform in Section 7.

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”).²

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, including their ability to pay borrowing expenses. Banks assess financial status through a *discretionary income limit*, which requires the household to have enough disposable income to afford consumption and

²Top 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.

housing expenses (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.

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.

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. We shall return to this below, showing that the implied theoretical distribution of LTV ratios in that model will differ from the empirical distribution we observe in the data. 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 undoes the effect. 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, can amortization payments affect household behavior? Below, we discuss why amortization payments may be costly for borrowers unable or unwilling to undo them by borrowing. First, forced 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 & Tchisty, 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 not realize that amortization payments are savings and may consider them 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 6. Selecting an LTV ratio to minimize amortization payments is a rational response, even though it comes from a misunderstanding of amortization payments.

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.³ Swedish banks may even prefer an interest-only mortgage, as this maintains high debt levels and thus 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, checking whether the borrower has sufficient income to meet expenses. Discretionary income is the disposable income left over after the borrower covers subsistence consumption, borrowing expenses, and housing expenses. Importantly, borrowing payments 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 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

³Note that this implies that a borrower in the US may value an interest-only mortgage *more*, as some states allow the option to default.

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.⁴ 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 1 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 re-

⁴The 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.

quirement 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 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 6.2. 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^{post} . 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.

We measure the amount of bunching \hat{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 :

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

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:

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

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

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

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 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 notch. These households fill up the missing mass to the right of the notch.

We use the bunching estimate \widehat{B} to calculate the behavioral response to the requirement, ΔLTV , using equation (4.2). 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 counter-factual density around the notch:

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

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, [DeFusco *et al.* \(see 2020\)](#), 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 now 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

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

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:

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

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 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. We then compute elasticities and examine who seeks to avoid amortization payments. The bunching estimates and associated standard errors for the lower and upper threshold are summarized in Table 2.

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 notch at LTV ratios 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 notch, this yields an approximately 5 percent decrease in borrowing. Third, there is little missing mass to the right of the requirement. We find 0.83 percent ($\widehat{M} = 0.83$, standard error 0.16) fewer borrowers to the right of the notch 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 \hat{B} shows that 12.93 percent of borrowers decide to bunch (standard error 0.38), an increase by a factor $\hat{b} = 1.36$. 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 ($\hat{M} = 1.43$, standard error 0.2) fewer borrowers to the right of the notch 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 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%-point more in LTV. 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.⁵ 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 characteristics that would imply that they face other financial constraints. Table 1 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. Survey evidence presented in Table 6 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.

⁵For 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.

5.4 Endogenous housing demand response

The leverage ratio is a function of mortgage debt and property value. Any change in the loan-to-value ratio of the borrower because of the amortization requirement can come from either the amount borrowed or the value of the property. In this section, we examine bunching for existing homeowners and new purchases to understand the margin that borrowers adjust.

Existing homeowners would be unable to adjust their collateral value as the bank sets this. Instead, their margin of adjustment would be the amount borrowed. On the other hand, homebuyers could adjust both the amount they borrow and the value of the property by paying less. For buyers, the elasticity then includes an adjustment of both the value of the property and the loan value. In contrast, for existing homeowners, the adjustment is fully due to changing loan amounts.

Table 5 shows that the estimated elasticity at the lower threshold is 0.23 for existing homeowners and 0.18 for buyers. The elasticity at the upper threshold is 0.15 for existing homeowners and 0.54 for buyers. Overall, while there are some differences across the valuation methods in the bunching estimate and the elasticity, the results are consistent.

6 Robustness and threats to identification

This section first summarizes the robustness of the results to different choices when estimating bunching. We then discuss several threats to identification, starting with the counter-factual LTV distribution in the post-requirement years. We discuss interest rates around the threshold, bank incentives, collateral assessments by banks, and salience. Note that our difference-in-bunching strategy eliminates many possible confounders that might affect LTV distributions, as they will be differenced out. Only factors that systematically impact borrowers at one side of the amortization requirement thresholds, which change exactly when introducing the requirement, potentially threaten the identification of causal effects. We conclude that none of these factors can explain the observed bunching.

6.1 Robustness

Table 3 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 polynomial⁶ 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.

6.1.1 Placebo tests

We start with evidence that the counter-factual density presents a good estimate of the fraction of borrowers in each bin. To do 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.⁷ Importantly, the spikes at 50, 70, and 75 percent LTV ratios are well approximated by this procedure. Panels c) and d) provide

⁶The degree of the polynomial is chosen such that the difference between bunching (B) and missing mass (M) is smallest across specifications (Kleven, 2016).

⁷Using other years than 2014 yields similar charts.

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.

6.1.2 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.⁸

6.1.3 Salience

The amortization requirement may have increased the salience of the thresholds. In this case, however, there is no reason to expect that the salience would only increase for borrowers above the threshold. Indeed, if threshold saliency increased, we should observe bunching from above and below, which we do not.

6.2 Supply side factors that would cause bunching

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 (May-

⁸Figure 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.

ordomo *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.

6.2.1 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 Banker Association nor the individual banks, who we contacted to ask about this issue. We also do not see any evidence for higher mortgage rates around the thresholds. Even if such thresholds exist, our difference-in-bunching strategy will account for any threshold 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.

6.2.2 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).

6.2.3 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 A3 plots the distribution of house value by LTV ratio using data from 2016 to 2018. There is little evidence in the figure that the house values from the assessments are manipulated around either threshold.

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

7 Housing and credit market impact of the requirement

Our main empirical exercise identifies a local average treatment effect around the notches. This section briefly discusses two potential aggregate effects of the requirement: credit and housing market impacts. We note that the below discussion and figures are speculative. For instance,

the decline in house prices around the reform could also be related to the increased housing supply around this time or due to other omitted factors. While we believe that the aggregate results for house price and credit growth are informative, we caution against a strong causal interpretation without a more detailed study. See, e.g., [Wilhelmsson \(2022\)](#), who finds that the amortization requirement led to a 7 percent reduction in house prices.

The orange line in Figure 12 plots the credit growth rate for property loans, showing that 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 thus suggests that the effect we identify is not simply a local effect around the notches but applies throughout the distribution. Interestingly, and consistent with our results that borrowers want to avoid higher amortization payments, we see a short-lived acceleration in credit growth just before the requirement was implemented in June 2016, suggesting households were eager to take out loans before mandatory amortization was required.

The introduction of the amortization requirement also coincided with a sharp reduction in the house price growth rate, as seen in Figure 13. The figure plots year-over-year house price growth, showing a clear break in the trend in the quarter when the FSA formally proposed the requirement. Again, this pattern is not consistent with a local effect around the threshold but instead consistent with a global effect of the requirement. However, we again caution against a over-interpreting these aggregate trends.

8 Conclusion

This paper documents and interprets several empirical facts about mortgage amortization and borrowing. We show that higher required amortization rates directly impacted household loan-to-value ratios at mortgage origination. Using bunching in response to a macroprudential policy, we document that new borrowers reduce their loan-to-value ratios by 4-5 percent in response to a one percentage point higher amortization rate. These estimates translate into an amortization elasticity of mortgage demand between 0.15 and 0.25. 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*. Both these results are contrary to what we find. We also find similar results for

existing homeowners who cannot easily adjust the collateral values. These results suggest that existing homeowners adjust the loan value in response to higher amortization payments.

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.⁹ 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, 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

⁹Table 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.

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.

References

- Alam, Zohair, Alter, Mr Adrian, Eiseman, Jesse, Gelos, Mr RG, Kang, Mr Heedon, Narita, Mr Machiko, Nier, Erlend, & Wang, Naixi. 2019. *Digging deeper—Evidence on the effects of macroprudential policies from a new database*. International Monetary Fund. [5](#), [27](#)
- Almenberg, Johan, & Säve-Söderbergh, Jenny. 2011. Financial literacy and retirement planning in Sweden. *Journal of Pension Economics & Finance*, **10**(4), 585–598. [4](#), [20](#)
- Amromin, Gene, Huang, Jennifer, Sialm, Clemens, & Zhong, Edward. 2018. Complex mortgages. *Review of Finance*, **22**(6), 1975–2007. [5](#), [28](#)
- Andersson, Michael K, & Aranki, Ted. 2017. Amortisation requirement reduced household debt. *FI Analysis*. [11](#)
- Andersson, Michael K, & Aranki, Ted. 2019. Fewer vulnerable households after stricter amortization requirement. *FI Analysis*. [11](#)
- Andersson, Michael K, & Aranki, Ted. 2021. Temporary amortisation exemption led to new mortgagors borrowing more. *FI Analysis*. [7](#)
- Argyle, Bronson S, Nadauld, Taylor D, & Palmer, Christopher J. 2020. Monthly payment targeting and the demand for maturity. *The Review of Financial Studies*, **33**(11), 5416–5462. [5](#), [27](#)
- Attanasio, Orazio, Kovacs, Agnes, & Moran, Patrick. 2020. Temptation and Commitment: Understanding Hand-to-Mouth Behavior. *National Bureau of Economic Research Working Paper No. 27944*. [10](#)
- Bäckman, Claes, & Lutz, Chandler. 2020a. The impact of interest-only loans on affordability. *Regional Science and Urban Economics*, **80**. [10](#)
- Bäckman, Claes, & Lutz, Chandler. 2020b. Mortgage Innovations and House Price Booms. [11](#), [19](#)
- Barlevy, Gadi, & Fisher, Jonas DM. 2020. Why Were Interest-Only Mortgages So Popular During the U.S. Housing Boom? [5](#), [11](#)
- Bernstein, Asaf, & Koudijs, Peter. 2021. The Mortgage Piggy Bank: Wealth Building through Amortization. *Available at SSRN 3569252*. [1](#), [5](#), [6](#), [10](#), [27](#)

- Best, Michael Carlos, Cloyne, James S, Ilzetzi, Ethan, & Kleven, Henrik J. 2020. Estimating the elasticity of intertemporal substitution using mortgage notches. *The Review of Economic Studies*, **87**(2), 656–690. [2](#)
- Cerutti, Eugenio, Claessens, Stijn, & Laeven, Luc. 2017. The use and effectiveness of macro-prudential policies: New evidence. *Journal of Financial Stability*, **28**, 203–224. [6](#)
- Chetty, Raj, Friedman, John N, Olsen, Tore, & Pistaferri, Luigi. 2011. Adjustment costs, firm responses, and micro vs. macro labor supply elasticities: Evidence from Danish tax records. *The Quarterly Journal of Economics*, **126**(2), 749–804. [2](#), [58](#)
- Cocco, Joao F. 2013. Evidence on the benefits of alternative mortgage products. *The Journal of Finance*, **68**(4), 1663–1690. [10](#)
- DeFusco, Anthony A, & Paciorek, Andrew. 2017. The interest rate elasticity of mortgage demand: Evidence from bunching at the conforming loan limit. *American Economic Journal: Economic Policy*, **9**(1), 210–40. [2](#), [15](#), [59](#)
- DeFusco, Anthony A, Johnson, Stephanie, & Mondragon, John. 2020. Regulating household leverage. *The Review of Economic Studies*, **87**(2), 914–958. [2](#), [15](#), [22](#)
- Elul, Ronel, Souleles, Nicholas S, Chomsisengphet, Souphala, Glennon, Dennis, & Hunt, Robert. 2010. What” triggers” mortgage default? *American Economic Review*, **100**(2), 490–94. [23](#)
- Garmaise, Mark J. 2013. The attractions and perils of flexible mortgage lending. *Review of Financial Studies*, **26**(10), 2548–2582. [23](#)
- Gorea, Denis, & Midrigan, Virgiliu. 2017. *Liquidity constraints in the us housing market*. Tech. rept. National Bureau of Economic Research. [5](#)
- Greenwald, Daniel L. 2017. *The Mortgage Credit Channel of Macroeconomic Transmission*. Working Paper, MIT Sloan. [5](#)
- Grodecka, Anna. 2020. On the Effectiveness of Loan-to-Value Regulation in a Multiconstraint Framework. *Journal of Money, Credit and Banking*, **52**(5), 1231–1270. [2](#), [11](#)
- Hull, Isaiah. 2017. Amortization requirements and household indebtedness: An application to Swedish-style mortgages. *European Economic Review*, **91**, 72–88. [1](#), [9](#)

- Justiniano, Alejandro, Primiceri, Giorgio E, & Tambalotti, Andrea. 2021. The mortgage rate conundrum. *Journal of Political Economy*, forthcoming. 5
- Kaplan, Greg, Mitman, Kurt, & Violante, Giovanni L. 2020. The Housing Boom and Bust: Model Meets Evidence. *Journal of Political Economy*, **128**(9), 3285–3345. 5
- Kleven, Henrik J, & Waseem, Mazhar. 2013. Using notches to uncover optimization frictions and structural elasticities: Theory and evidence from Pakistan. *The Quarterly Journal of Economics*, **128**(2), 669–723. 2, 13, 15, 59
- Kleven, Henrik Jacobsen. 2016. Bunching. *Annual Review of Economics*, **8**, 435–464. 2, 22, 58
- Laufer, Steven, & Tzur-Ilan, Nitzan. 2019. The Effect of LTV-Based Risk Weights on House Prices: Evidence from an Israeli Macroprudential Policy. *SSRN Working Paper series*. 6
- Mayordomo, Sergio, Rachedi, Omar, & Moreno, Maria Rodriguez. 2020. Bank Regulatory Capital Arbitrage: Evidence from Housing Overappraisals. 23
- Mian, A., Rao, K., & Sufi, A. 2013. Household Balance Sheets, Consumption, and the Economic Slump. *The Quarterly Journal of Economics*, **128**(4), 1687–1726. 28
- Mian, Atif, Sufi, Amir, & Verner, Emil. 2017. Household debt and business cycles worldwide. *The Quarterly Journal of Economics*, **132**(4), 1755–1817. 28
- Peydró, José-Luis, Rodriguez Tous, Francesc, Tripathy, Jagdish, & Uluc, Arzu. 2020. Macroprudential policy, mortgage cycles and distributional effects: Evidence from the UK. 6
- Piskorski, Tomasz, & Tchistyi, Alexei. 2010. Optimal mortgage design. *Review of Financial Studies*, **23**(8), 3098–3140. 10
- Riksbank. 2014. From A to Z: the Swedish mortgage market and its role in the financial system. 8
- Saez, Emmanuel. 2010. Do taxpayers bunch at kink points? *American Economic Journal: Economic Policy*, **2**(3), 180–212. 2
- Sandström, Maria, Forsman, David, von Rosen, Johanna Stenkula, & Wettergren, Johanna Fager. 2013. The Swedish covered bond market and links to financial stability. 2, 22–49. 25
- SBAB. 2018. Mer än var tredje svensk ser amorteringen som en kostnad. <https://www.sbab.se>

se/1/om_sbab/press/arkiv_publicering/pressmeddelande/2018-03-27_mer_an_var_tredje_svensk_ser_amorteringen_som_en_kostnad_.html. [Online: Accessed 2019-08-19]. 4, 10, 11, 20, 51

Scanlon, Kathleen, Lunde, Jens, & Whitehead, Christine. 2008. Mortgage product innovation in advanced economies: more choice, more risk. *European journal of housing policy*, 8(2), 109–131. 5

Schlafmann, Kathrin. 2020. Housing, Mortgages, and Self-control. *Review of Financial Studies*. 10

Shu, Suzanne B. 2013. *Npv neglect in consumer behavior for multi-period borrowing decisions*. Tech. rept. UCLA Working Paper. 5

Svensson, Lars EO. 2016. Amortization requirements may increase household debt: a simple example. *IMF Working Paper No. 16/83*. 1, 3, 9, 60, 61

Van Bakkum, Sjoerd, Gabarro, Marc, Irani, Rustom M, & Peydró, José-Luis. 2019. Take It to the limit? The effects of household leverage caps. 6

Wilhelmsson, Mats. 2022. What is the impact of macroprudential regulations on the Swedish housing market? *Journal of Housing Economics*, 57, 101840. 12, 26

9 Figures

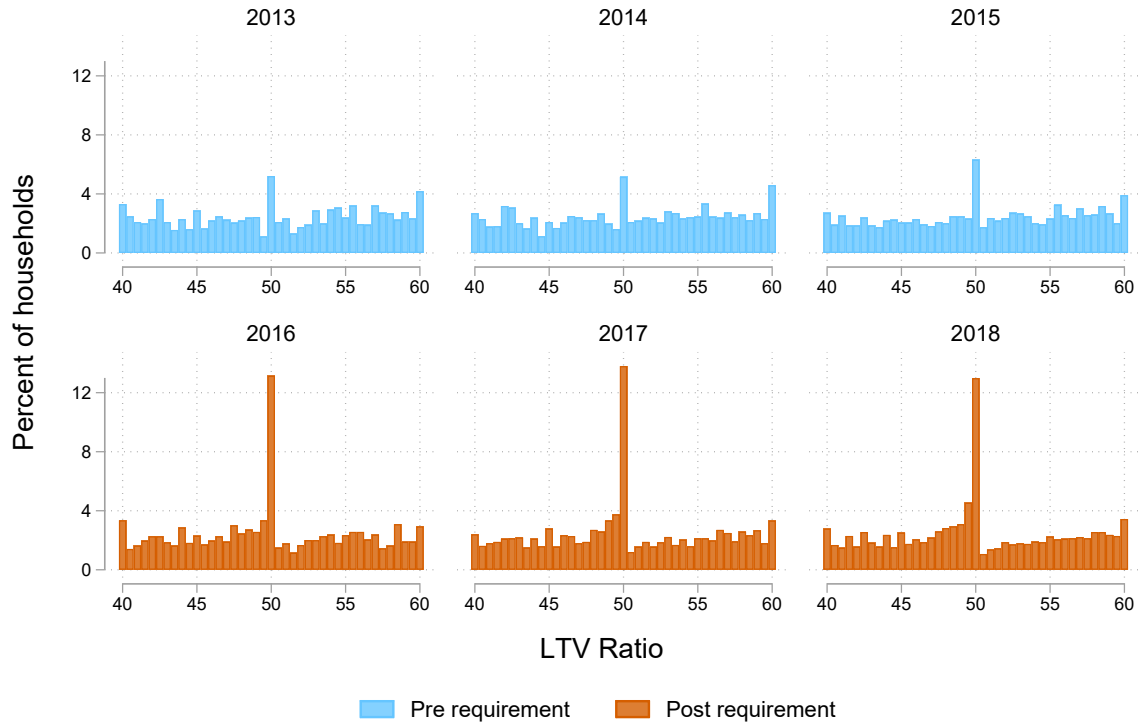


Figure 1. LTV distributions around the lower amortization requirement threshold

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

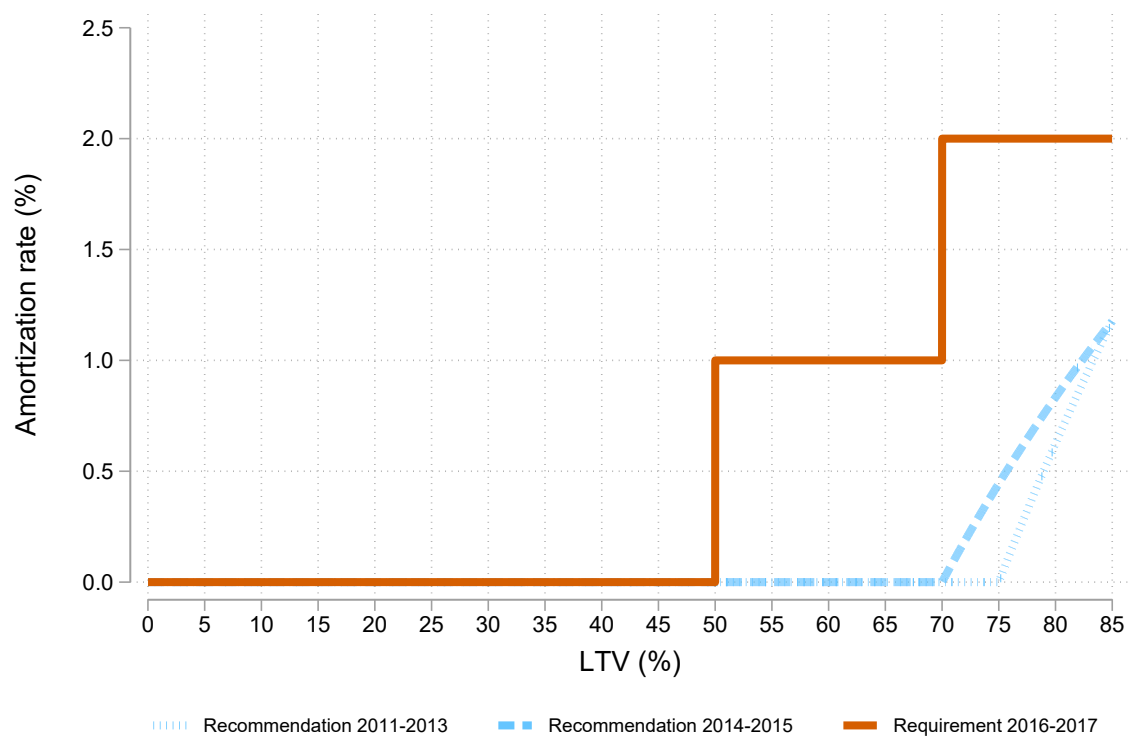
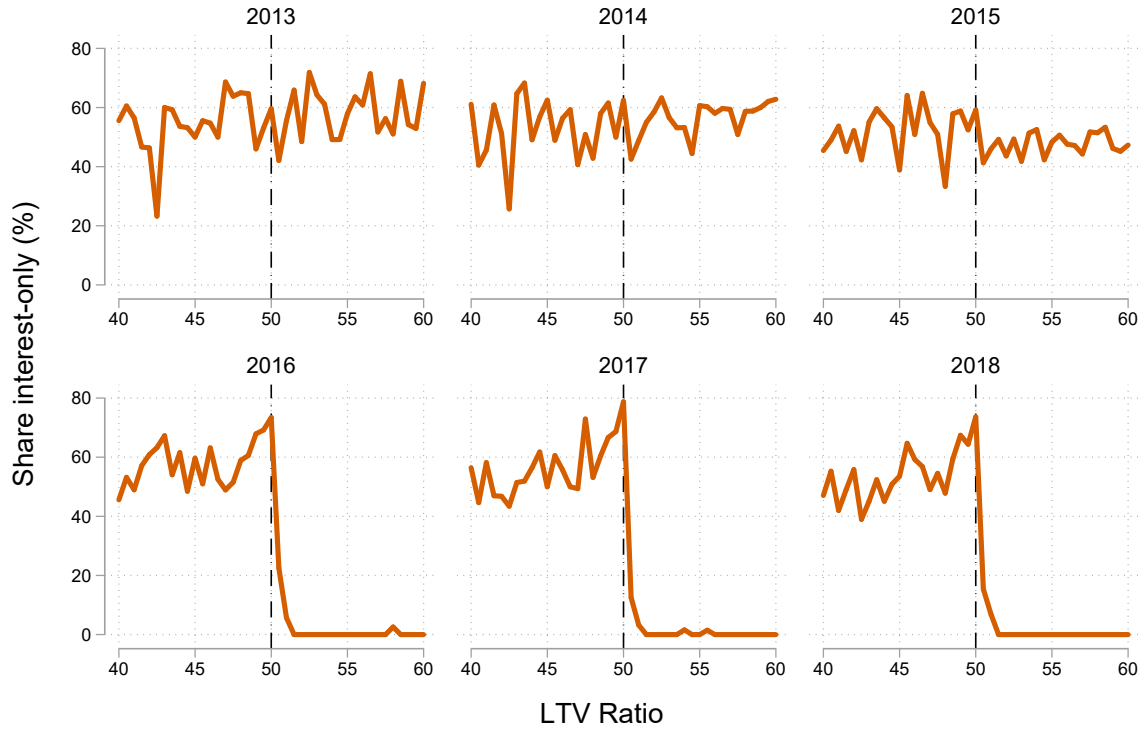
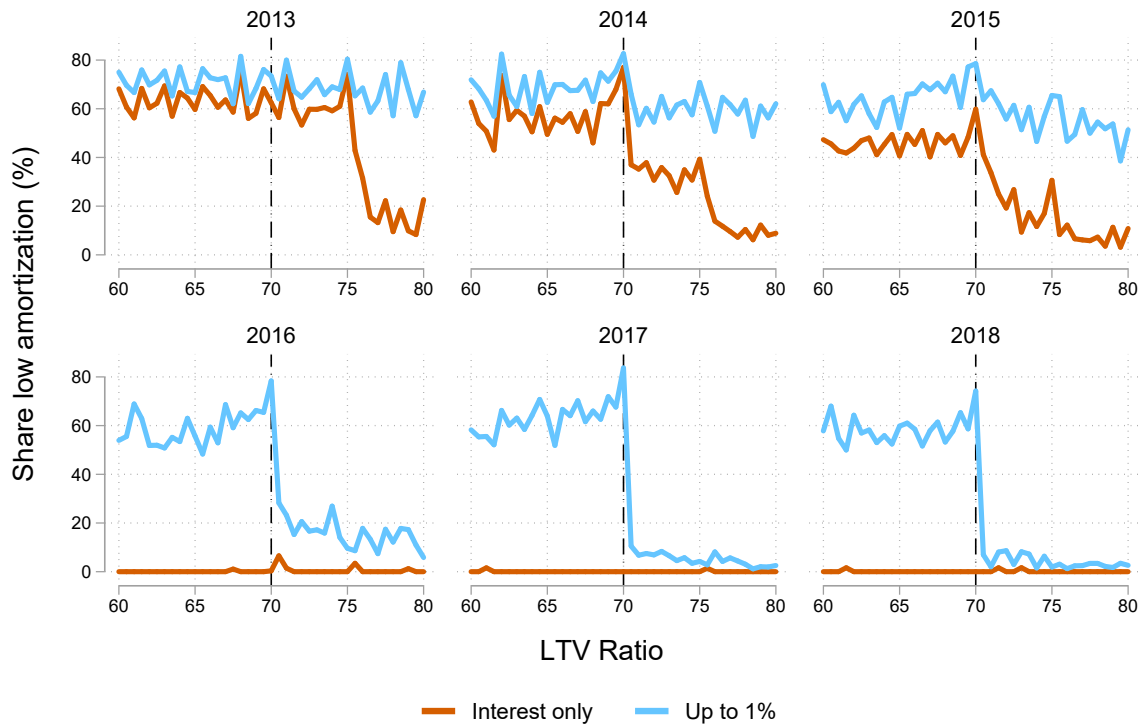


Figure 2. Required Amortization Rates for new mortgages

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 3. 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.

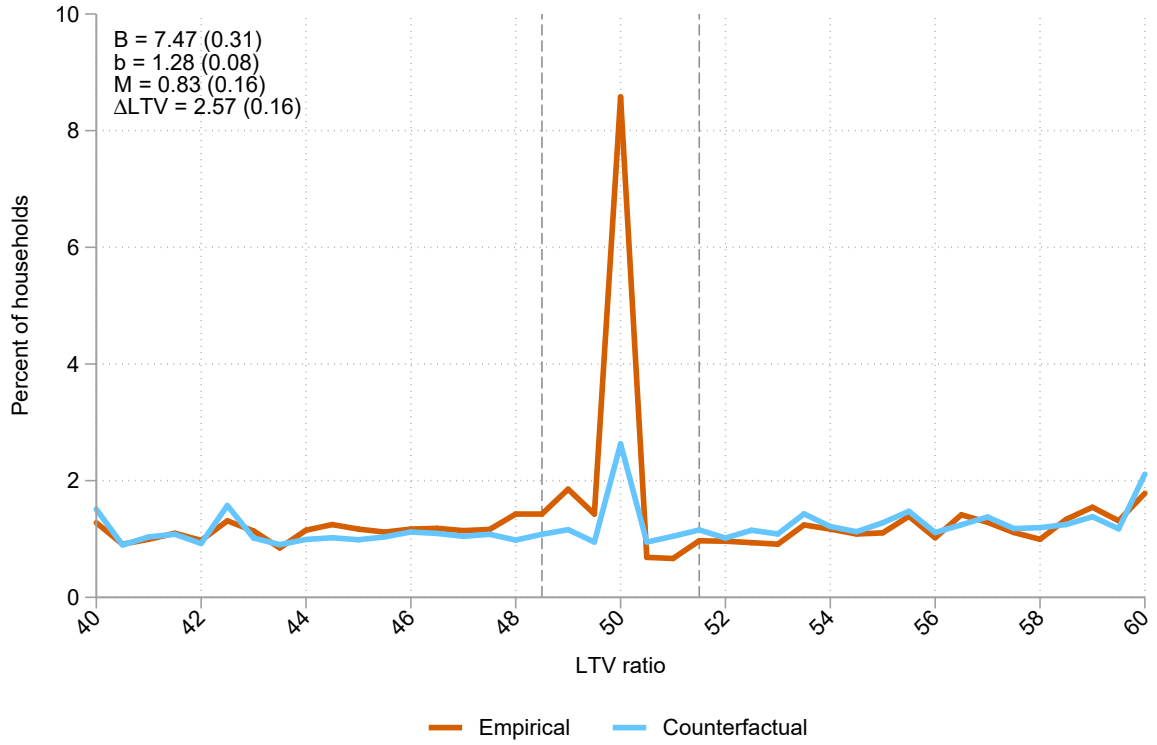


Figure 4. Bunching at LTV=50

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.

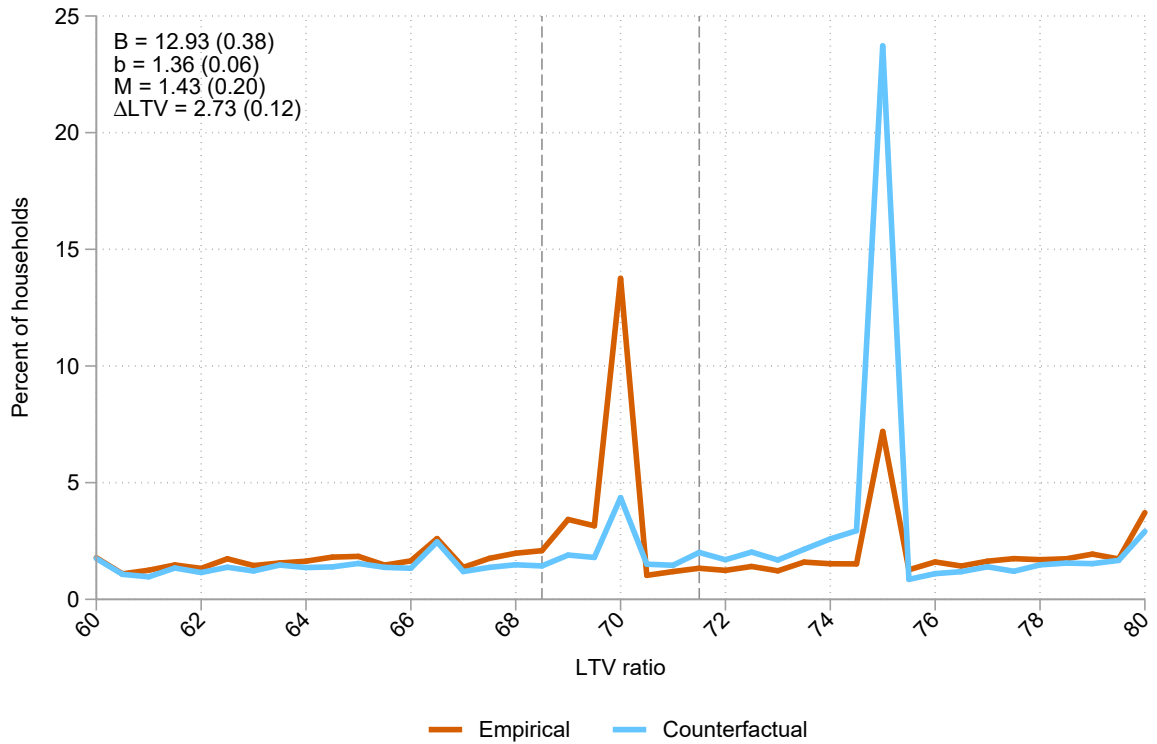


Figure 5. Bunching at LTV=70

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.

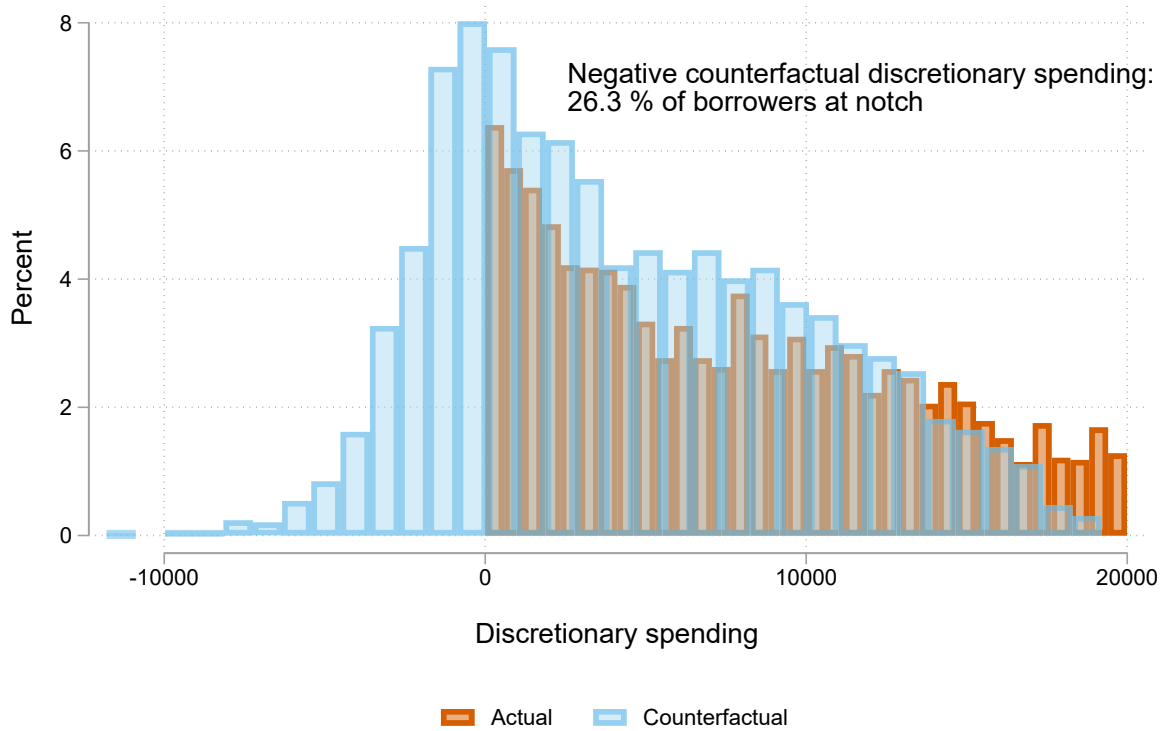
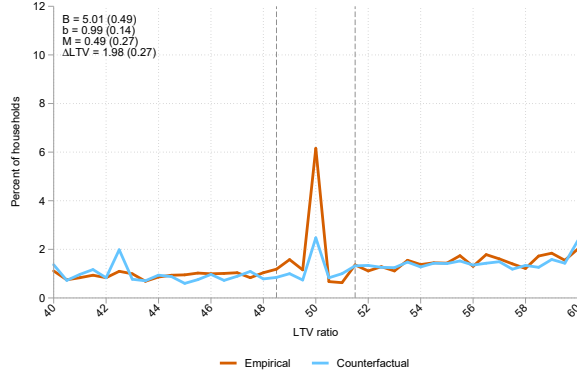
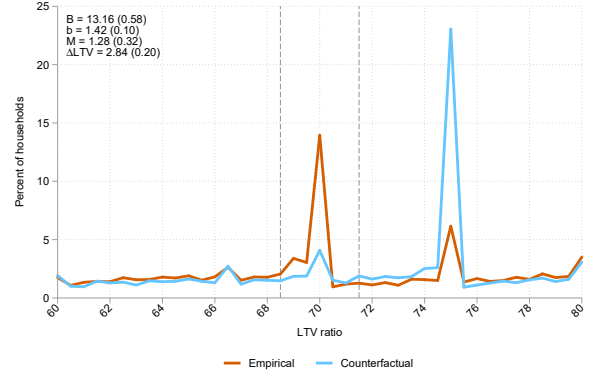


Figure 6. Discretionary income

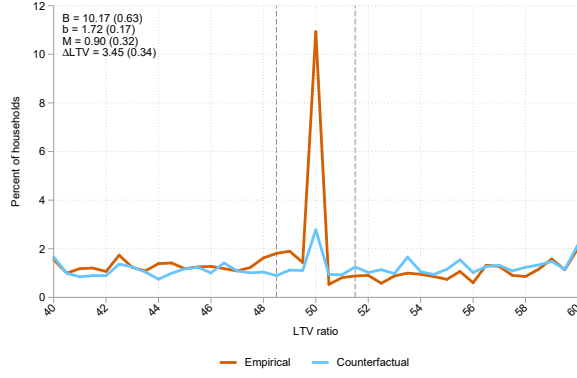
Notes: The figure plots calculations for discretionary spending for borrowers located at the notches. We select borrowers with LTV values between 48.5 and 50, and 68.5 and 70. We update the bank's discretionary income calculation to include higher amortization payments by increasing LTV ratios to one 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.



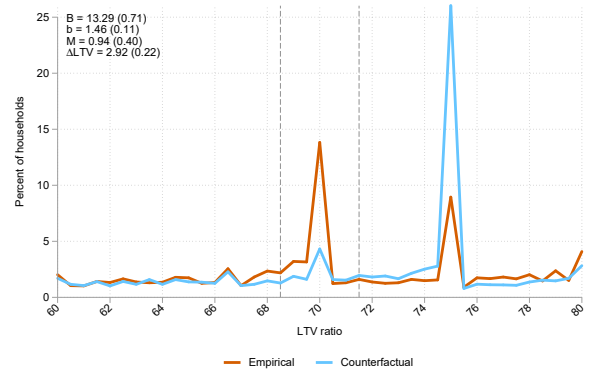
(a) Constrained borrowers, lower threshold



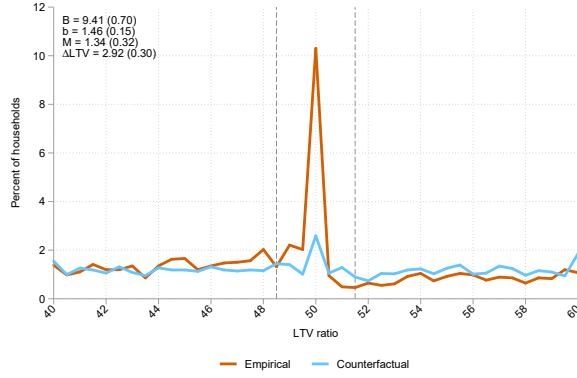
(b) Constrained borrowers, upper threshold



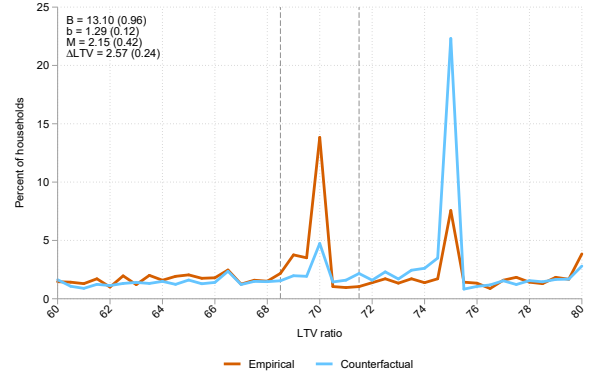
(c) Intermediate, lower threshold



(d) Intermediate, upper threshold



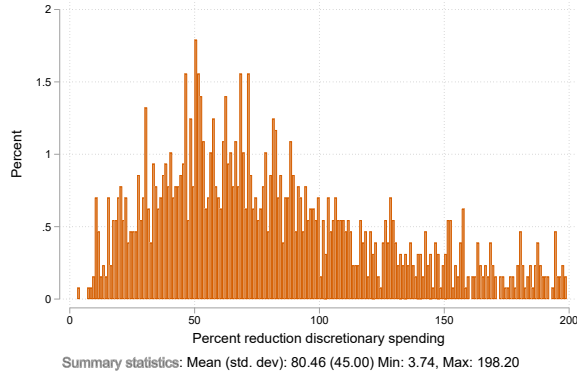
(e) Unconstrained borrowers, lower threshold



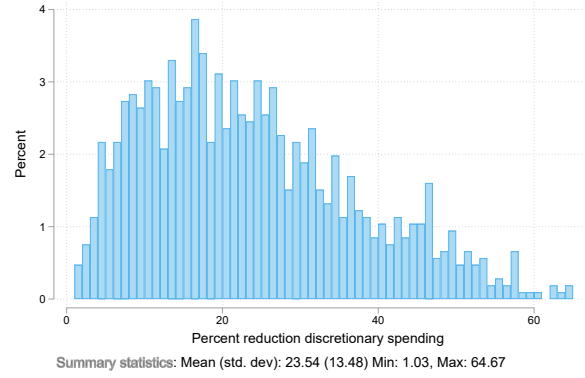
(f) Unconstrained borrowers, upper threshold

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

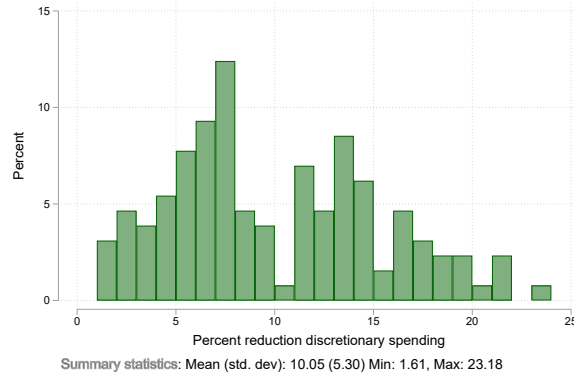
Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio for three different groups based on their counterfactual discretionary income. The estimation for the lower threshold on the left is carried out using all loans with LTV ratios between 20 and 65 percent, but 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



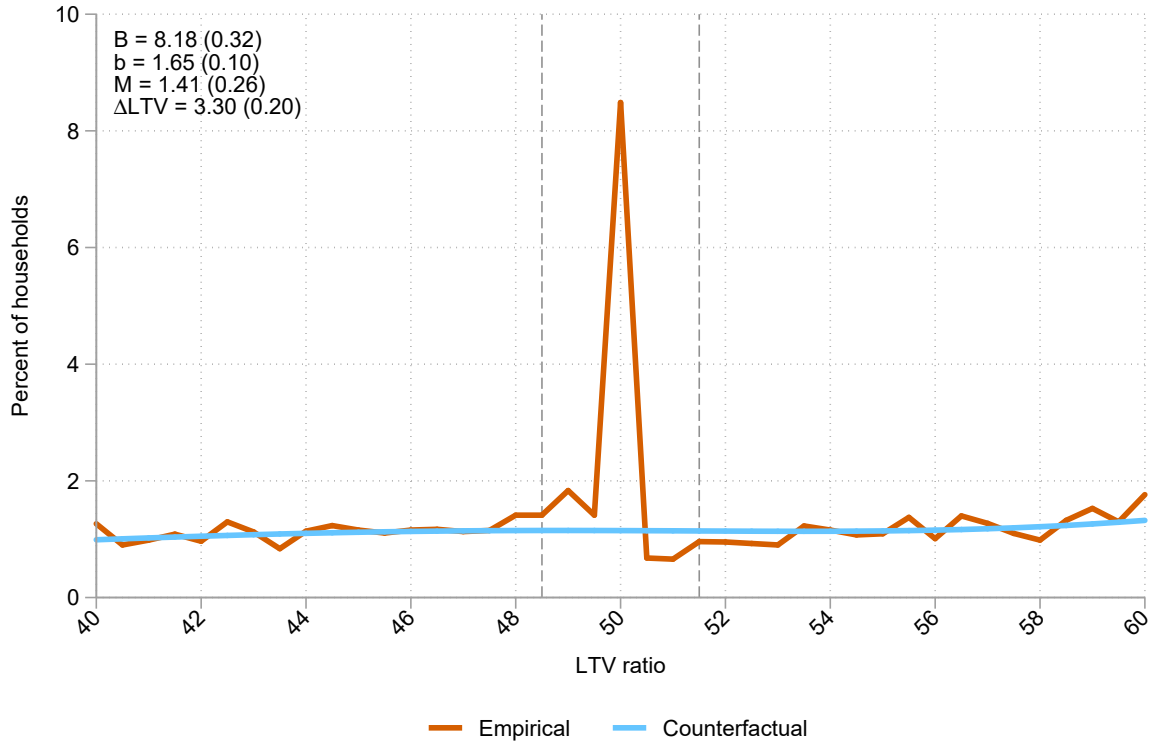
(b) Intermediate



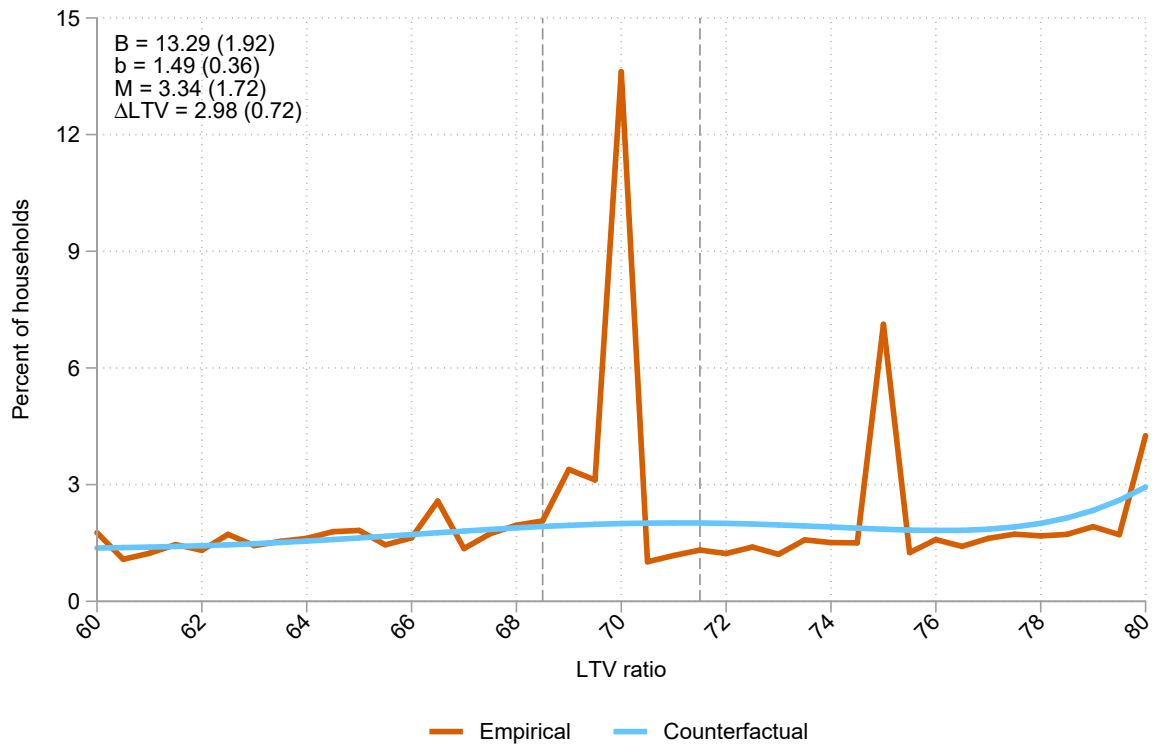
(c) Unconstrained borrowers

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.



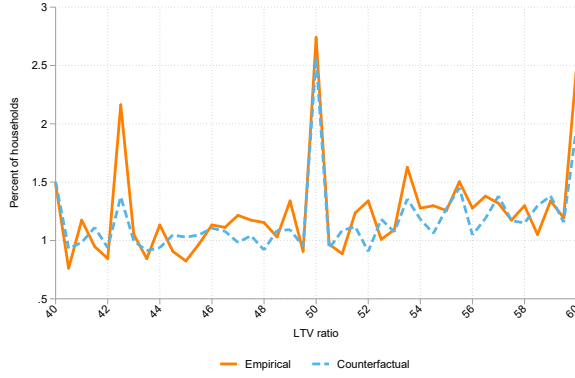
(a) Lower threshold



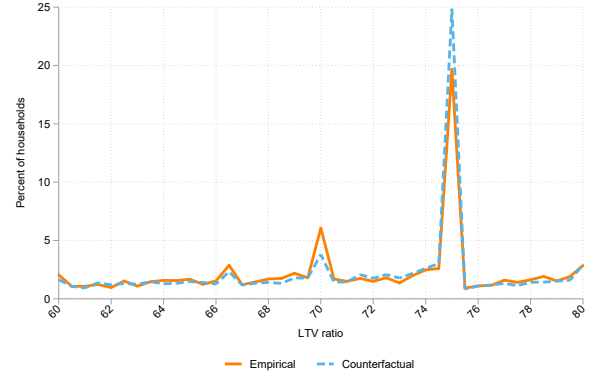
(b) Upper threshold

Figure 9. Bunching estimates from polynomials

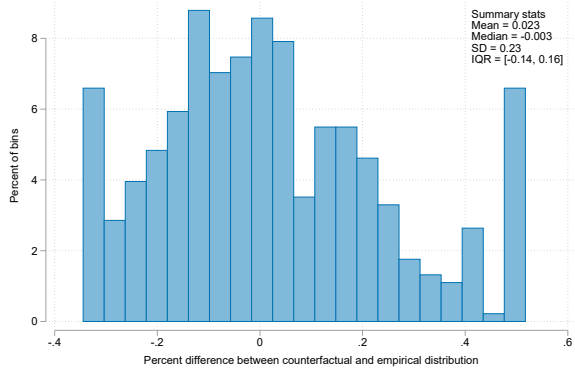
Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio, in the region around the notch at LTV = 50 (Panel a) and the notch at LTV = 70 (Panel b). The orange line is the empirical density, where each dot represents the percent of mortgages within each 0.5 percent 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.



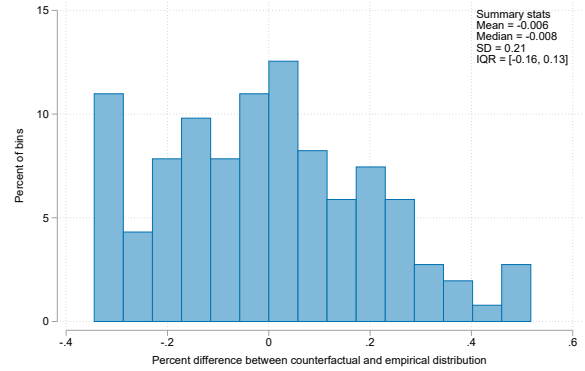
(a) Lower threshold: Placebo reform in 2014



(b) Upper threshold: Placebo reform in 2014



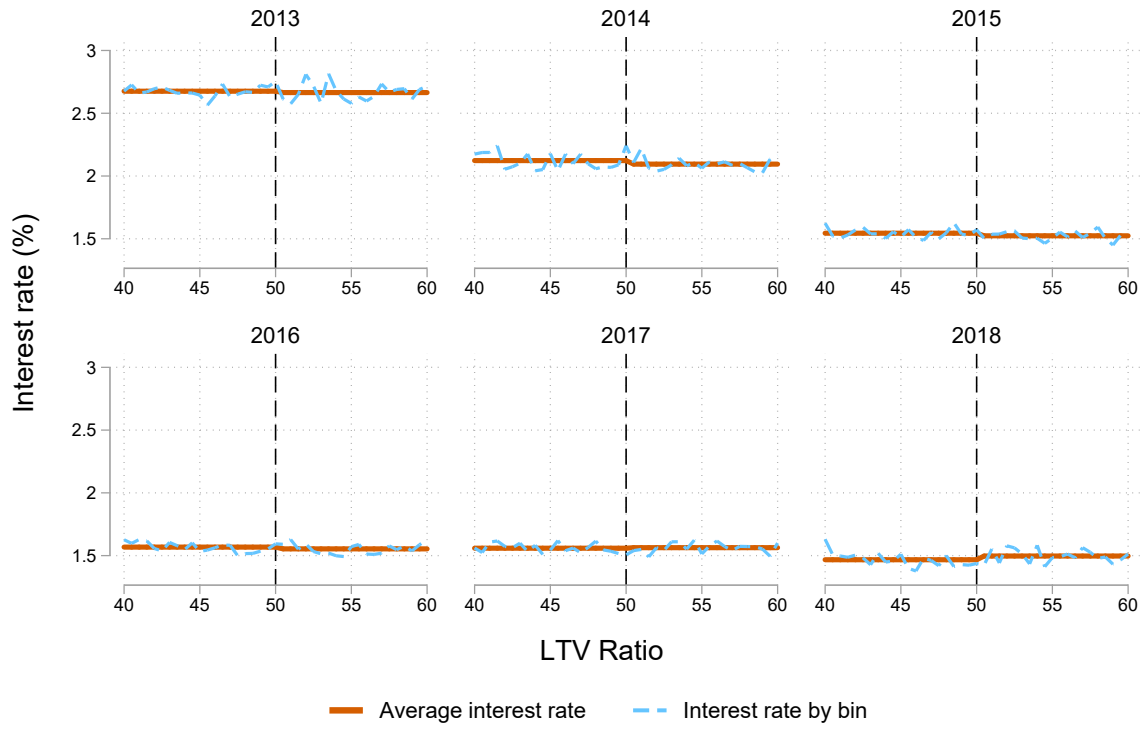
(c) Lower threshold: Ratio, empirical to counterfactual



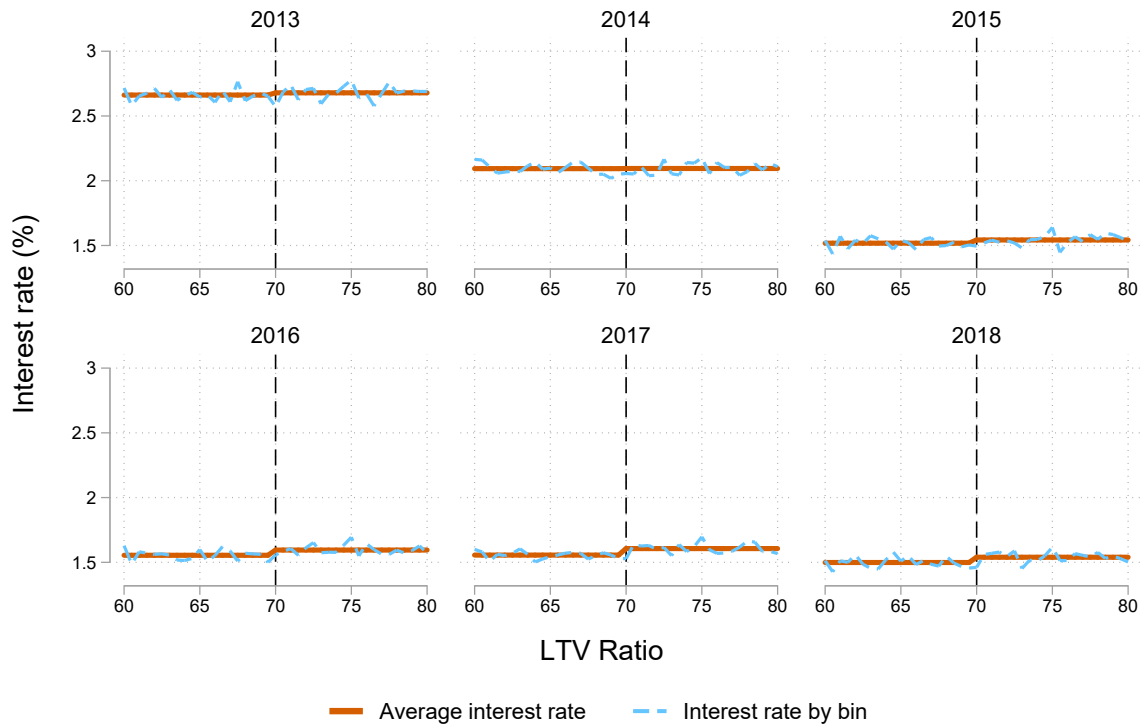
(d) Upper threshold: Ratio, empirical to counterfactual

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 counter-factual 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.

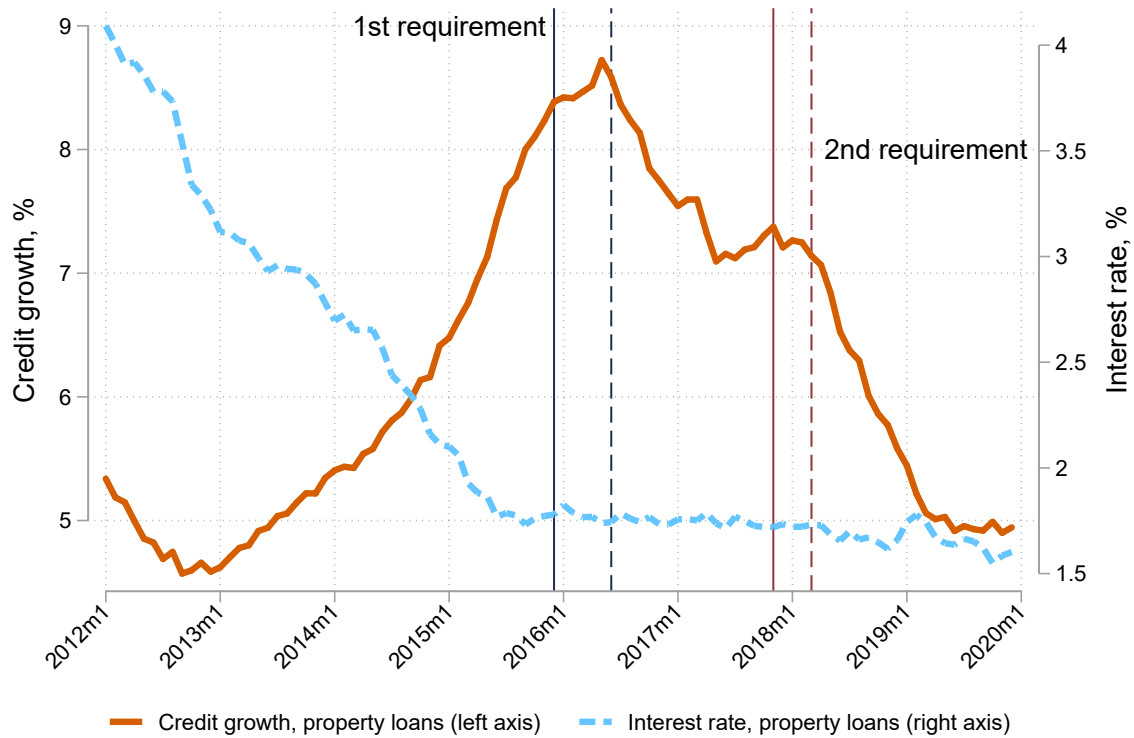


Figure 12. Credit growth for property loans

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.

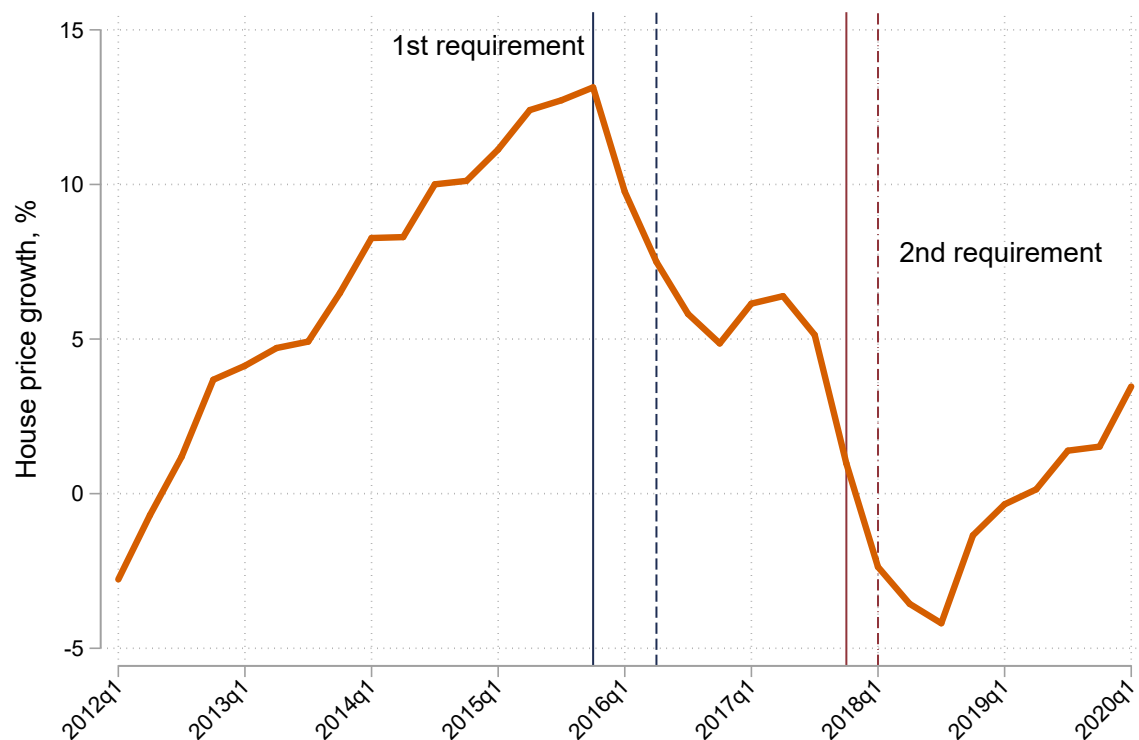


Figure 13. House price growth

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.

10 Tables

Table 1. Summary statistics

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

	Lower threshold (Notch at LTV=50)	Upper threshold (Notch at LTV=70)
Bunching	7.47 (0.31)	12.93 (0.38)
Missing mass	-0.83 (0.16)	-1.43 (0.20)
Δ LTV	2.57 (0.16)	2.73 (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 3. 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 (0.34)	7.92 (0.34)	7.47 (0.31)	7.12 (0.30)	6.43 (0.27)	7.98 (0.36)	7.80 (0.34)	7.03 (0.32)	
Excess mass (b)	1.02 (0.06)	1.16 (0.07)	1.28 (0.08)	1.50 (0.10)	1.80 (0.12)	0.80 (0.05)	0.99 (0.06)	1.22 (0.08)	
Δ LTV	3.05 (0.18)	2.91 (0.18)	2.57 (0.16)	2.26 (0.15)	1.80 (0.12)	3.20 (0.19)	2.97 (0.18)	2.43 (0.16)	
Elasticity	0.35 (0.04)	0.32 (0.04)	0.25 (0.03)	0.19 (0.03)	0.12 (0.02)	0.39 (0.04)	0.33 (0.04)	0.23 (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 (0.41)	13.43 (0.39)	12.93 (0.38)	12.28 (0.37)	10.75 (0.34)	13.82 (0.44)	13.39 (0.41)	12.37 (0.38)	
Excess mass (b)	1.12 (0.05)	1.23 (0.05)	1.36 (0.06)	1.53 (0.07)	1.75 (0.08)	0.85 (0.03)	1.07 (0.04)	1.30 (0.06)	
Δ LTV	3.36 (0.14)	3.06 (0.13)	2.73 (0.12)	2.29 (0.10)	1.75 (0.08)	3.42 (0.14)	3.21 (0.13)	2.61 (0.12)	
Elasticity	0.22 (0.02)	0.18 (0.01)	0.15 (0.01)	0.10 (0.01)	0.06 (0.01)	0.23 (0.02)	0.20 (0.02)	0.13 (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.

Table 4. Bunching estimates by type of payment constraints

PTI Constraint	Constrained	Intermediate	Unconstrained
Panel A: Notch at LTV=50			
Bunching	5.01 (0.49)	10.17 (0.63)	9.41 (0.70)
Excess mass	0.99 (0.14)	1.72 (0.17)	1.46 (0.15)
Missing mass	-0.49 (0.27)	-0.90 (0.32)	-1.34 (0.32)
Δ LTV	1.98 (0.27)	3.45 (0.34)	2.92 (0.30)
Elasticity	0.15 (0.04)	0.45 (0.09)	0.32 (0.06)
Number of households	13350	10471	10182
Panel B: Notch at LTV=70			
Bunching	13.16 (0.58)	13.29 (0.71)	13.10 (0.96)
Excess mass	1.42 (0.10)	1.46 (0.11)	1.29 (0.12)
Missing mass	-1.28 (0.32)	-0.94 (0.40)	-2.15 (0.42)
Δ LTV	2.84 (0.20)	2.92 (0.22)	2.57 (0.24)
Elasticity	0.16 (0.02)	0.17 (0.02)	0.13 (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 (0.34)	7.38 (0.88)	9.30 (1.46)
Excess mass	1.22 (0.08)	1.44 (0.23)	1.09 (0.28)
Missing mass	-0.81 (0.19)	-0.81 (0.48)	-1.25 (0.76)
Δ LTV	2.44 (0.17)	2.89 (0.47)	2.18 (0.56)
Elasticity	0.23 (0.03)	0.32 (0.10)	0.18 (0.09)
Panel B: Notch at LTV=70			
Bunching	12.88 (0.43)	6.40 (1.05)	19.13 (1.01)
Excess mass	1.36 (0.07)	0.58 (0.11)	2.68 (0.32)
Missing mass	-1.38 (0.24)	-0.53 (0.66)	-1.68 (0.54)
Δ LTV	2.72 (0.13)	1.17 (0.23)	5.36 (0.63)
Elasticity	0.15 (0.01)	0.03 (0.01)	0.54 (0.12)

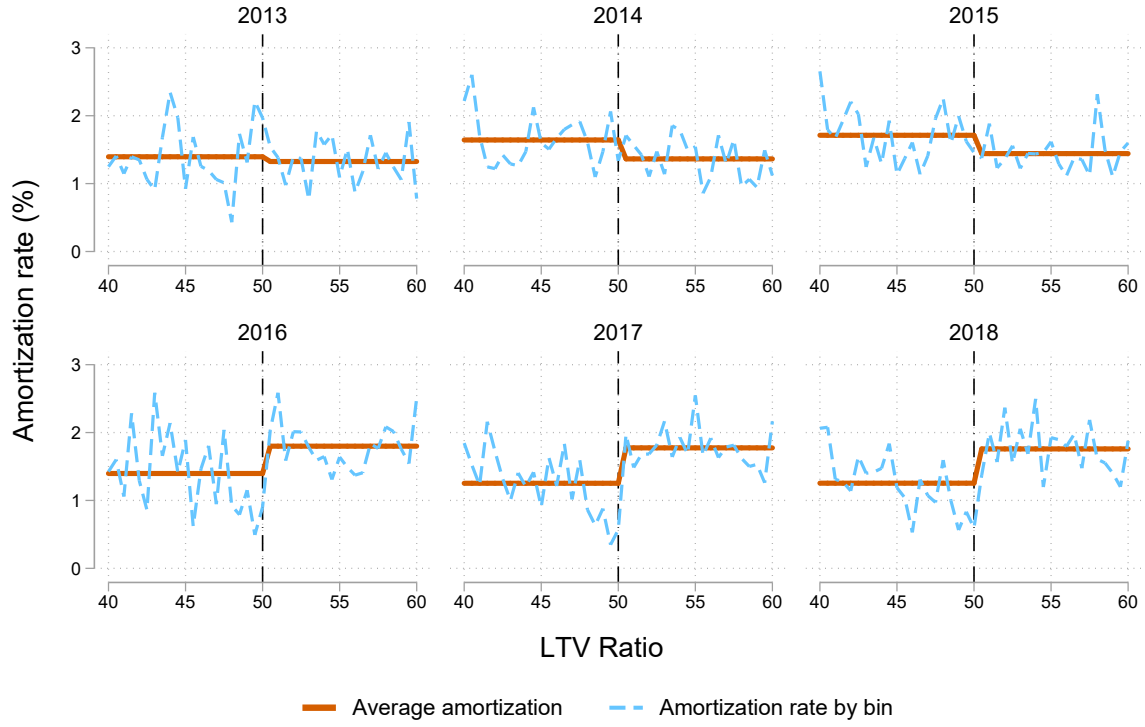
Notes: The table compares the bunching estimates across valuation modes for collateral assessments. *Bunching* is the percent of households bunching, calculated using equation (1). *Excess mass* scales the estimate of bunching by the counterfactual distribution, calculated using equation (2). *Missing 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. Are amortization payments a cost or a form of savings?

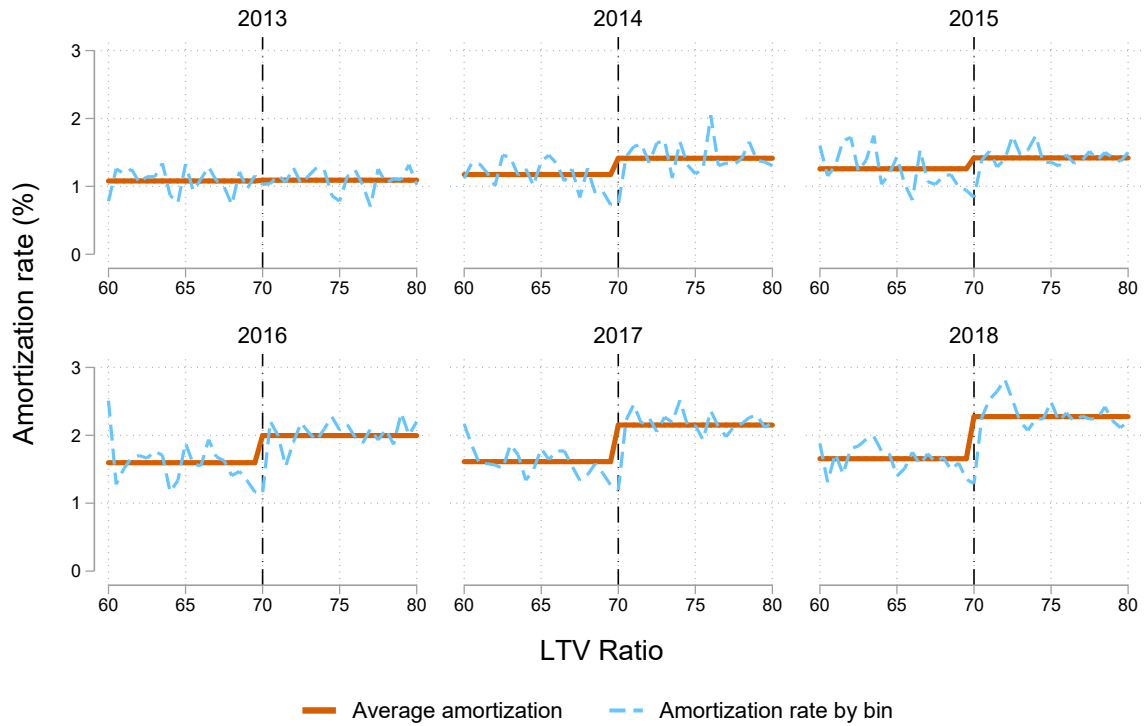
	Cost	Savings	Do not know	Count
All respondents	38%	44%	18%	1004
Gender				
Male	38%	51%	12%	485
Female	38%	38%	24%	519
Age				
18-22	39%	16%	45%	69
23-35	34%	40%	26%	235
36-55	41%	45%	15%	358
56-80	37%	52%	11%	342
Household income before taxes				
Less than 100000 SEK	42%	21%	38%	48
100000 - 300000 SEK	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 \(2018\)](#).

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.

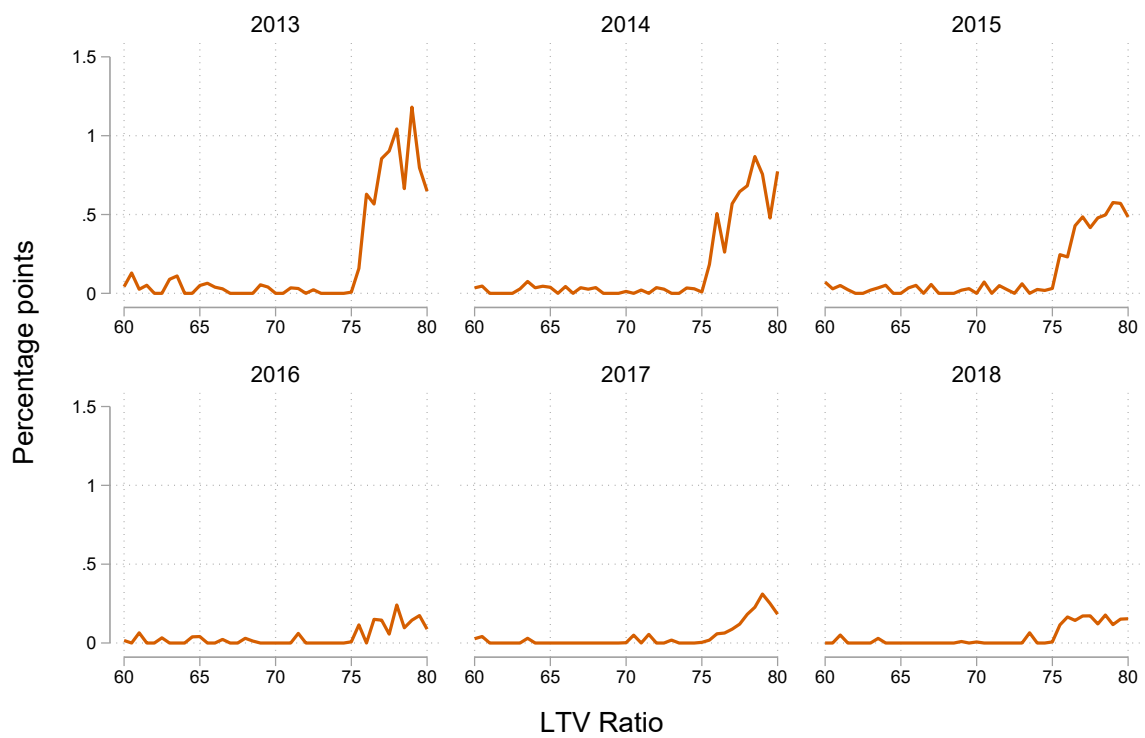
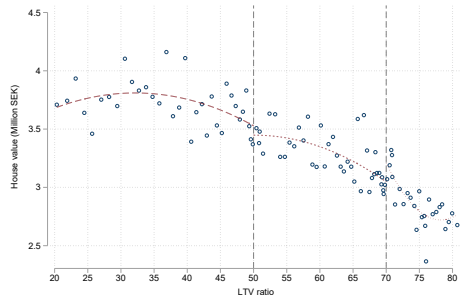
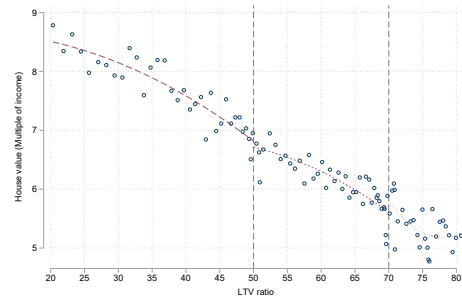


Figure A2. Difference between top and bottom interest rates

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) House value



b) House value to income

Figure A3. Housing values by LTV ratio

Notes: The figure plots the distribution of house values by LTV ratio. Using data for 2016-2018, each dot displays the average house value per LTV bin, after filtering out region-by-year fixed effects. The quadratic fitted curves are estimated separately for the LTV intervals ranging from 20-50, 50-70 and 70-80, respectively. Panel a) plots the distribution of house values in levels. Panel b) plots the distribution of house values as a multiple of annual disposable income. 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%	3%	5%	10%
Payments under each schedule					
Interest-only mortgage	10,000	15,000	30,000	50,000	100,000
Annuity schedule	38,597	41,414	50,592	64,419	105,309
Sweden: Lower threshold	20,000	25,000	40,000	60,000	110,000
Sweden: Upper threshold	30,000	35,000	50,000	70,000	120,000
Reduction in payments (%)					
(Annuity - IO) / Annuity	74.09	63.78	40.70	22.38	5.04
(Lower - IO) / Lower	50.00	40.00	25.00	16.67	9.09
(Upper - Lower) / Upper	33.33	28.57	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: $(\text{Annuity schedule} - \text{Interest-only mortgage}) / \text{Annuity schedule}$. *Lower - IO* and *Upper - Lower* are calculated similarly.

Table B2. Conforming & Non-Conforming Borrower Characteristics

	Lower threshold			Upper threshold		
	(1) Conforming	(2) Non-conforming	(3) Difference	(4) Conforming	(5) Non-conforming	(6) Difference
Demographics						
Main borrowers age	50.13 (15.10)	46.31 (14.51)	-3.82 [-4.92]	41.59 (12.66)	41.86 (12.31)	0.27 [0.54]
Household size	2.11 (1.10)	2.12 (1.21)	0.01 [0.18]	2.34 (1.14)	2.41 (1.28)	0.07 [1.54]
Large city	0.58 (0.49)	0.40 (0.49)	-0.17 [-6.82]	0.59 (0.49)	0.43 (0.50)	-0.16 [-8.06]
Disposable income, KSEK	48.30 (40.85)	41.50 (28.37)	-6.80 [-3.45]	48.79 (44.07)	43.97 (19.20)	-4.83 [-3.09]
Loan sizes (MSEK)						
Total debt	2.57 (2.19)	1.91 (2.15)	-0.66 [-5.85]	2.90 (1.93)	2.35 (1.71)	-0.56 [-7.43]
Mortgage debt	1.87 (1.41)	1.47 (1.20)	-0.41 [-5.80]	2.38 (1.50)	1.97 (1.37)	-0.41 [-6.95]
House price	3.77 (2.83)	2.96 (2.42)	-0.81 [-5.73]	3.41 (2.15)	2.83 (1.97)	-0.58 [-6.88]
Interest Rates						
Mortgage rate	1.47 (0.29)	1.60 (0.32)	0.13 [8.47]	1.50 (0.27)	1.57 (0.32)	0.07 [6.53]
Mortgage fixation period	10.97 (15.10)	12.09 (15.30)	1.12 [1.42]	12.47 (14.62)	11.93 (14.81)	-0.54 [-0.92]
Adjustable rate mortgage	0.72 (0.45)	0.68 (0.47)	-0.05 [-1.97]	0.63 (0.48)	0.67 (0.47)	0.03 [1.68]
Amortization						
Amortization, KSEK	0.00 (0.00)	2.15 (1.97)	2.15 [40.93]	1.82 (1.26)	3.07 (2.18)	1.25 [20.09]
Amortization rate	0.00 (0.00)	2.44 (2.57)	2.44 [35.54]	0.94 (0.24)	2.20 (1.68)	1.27 [35.78]
Amortization to income	0.00 (0.00)	5.57 (4.19)	5.57 [49.78]	3.91 (1.94)	7.12 (4.01)	3.21 [30.39]
Mortgage Characteristics						
Loan to value	49.73 (0.43)	49.62 (0.49)	-0.12 [-5.09]	69.73 (0.42)	69.56 (0.48)	-0.17 [-9.58]
Total debt to income	448.02 (212.11)	359.86 (212.75)	-88.16 [-8.00]	495.70 (189.82)	429.21 (197.13)	-66.50 [-8.69]
Net interest to income	4.52 (2.21)	3.83 (2.09)	-0.69 [-6.06]	5.12 (2.01)	4.56 (2.08)	-0.56 [-6.86]
Debt service to income	4.53 (2.22)	10.50 (6.10)	5.98 [31.37]	9.73 (3.82)	12.90 (6.02)	3.17 [17.66]
N	1,400	505	1,905	2,392	851	3,243

Notes: Summary statistics and *t*-test for different notches and groups. Sample consists of borrowers with LTV ratios of 48.5-50 percent in Columns 1-3, and of borrowers with LTV ratios of 68.5-70 percent in Columns 4-6. Conforming borrowers amortize according to the requirement, i.e. zero percent if they are at the 50-threshold and 1 percent if they are at the 70-threshold. Non-conforming borrowers amortize a higher percentage of their mortgage than required. 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, which in most cases is based on bank's internal valuations of properties, or transaction prices otherwise. 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. *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. Standard deviations in parentheses. Columns 3 and 6 compute the difference between non-conforming and conforming borrowers' averages, with *t*-statistics in square brackets.

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:

$$n_j = \sum_{i=0}^p \beta_i (m_j)^i + \sum_{k=L}^U \gamma_k \mathbf{1}(m_k = m_j) + \epsilon_j, \quad (7)$$

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:

$$\hat{n}_j = \sum_{i=0}^p \hat{\beta}_i (m_j)^i \quad (8)$$

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 7 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

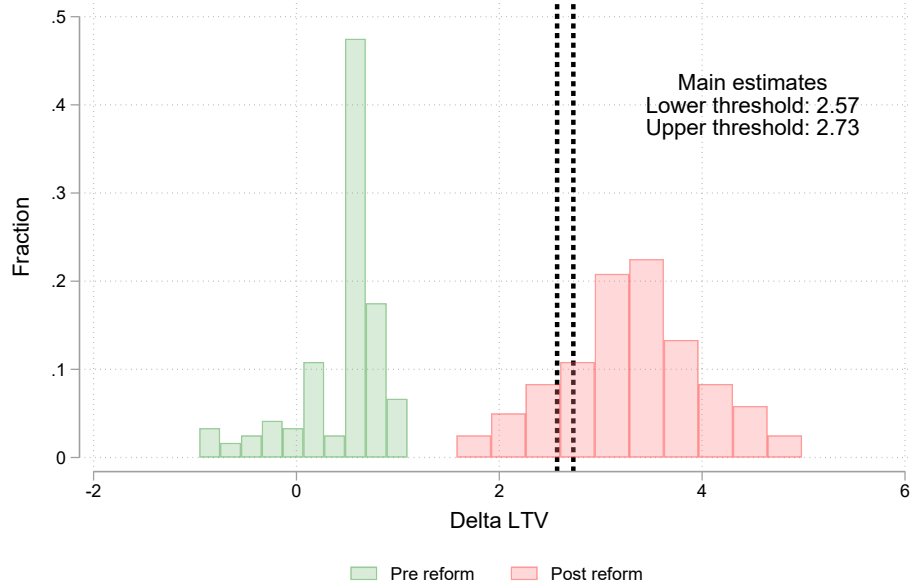


Figure C1. Robustness of estimated behavioral responses

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).

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-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 Appendix: Svensson Model

This section further discusses the model of [Svensson \(2016\)](#). In the model, debt and LTV ratios would increase as a result of implementing amortization requirements. As we show here, the model would not predict any spike in the LTV distribution around the notch.

Households choose consumption, debt and savings in each period, plus constant housing, to maximize their intertemporal utility. Formally,

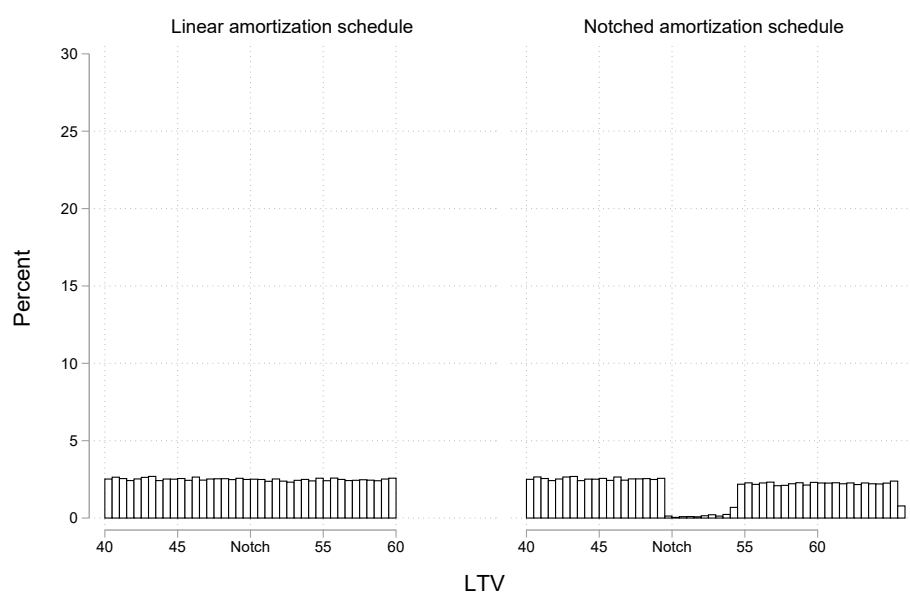
$$\begin{aligned}
 \max_{c, L, s, h} U &= \sum_{t=1}^T \beta^{t-1} \ln \left(c_t^{1-\theta} h^\theta \right) \\
 \text{s.t. } c_1 + s_1 + ph &\leq A_0 + L_1 + y_1 \\
 c_t + s_t + \delta ph &\leq L_t + y_t + (1 + r^s)s_{t-1} - (1 + r^L)L_{t-1}, t = 2..T \\
 A_T &\leq (1 + r^s)s_T + (1 - \delta)ph - (1 + r^L)L_T \\
 L_t &\leq L_{t-1} - \alpha L_1, t = 2..T
 \end{aligned} \tag{9}$$

Here, $c = \{c_t\}_{t=1}^T$ denotes consumption in each period, $L = \{L_t\}_{t=1}^T$ denotes debt, $s = \{s_t\}_{t=1}^T$ denotes savings and h denotes the (constant) number of housing units. Furthermore, $\beta = 1/(1 + \rho)$ is the discount factor, p the (exogenous) house price, y_t denotes (exogenous) income in period t , r^L and r^s are the (constant) interest rates on debt and savings, and δ is the maintenance cost for housing. The last $T - 1$ constraints depict a linear amortization schedule, where debt declines by a fraction α of the initial debt level L_1 .

We solve the model numerically for many households with different levels of initial wealth A_0 . All households in the simulation are identical except for their initial wealth, which is uniformly distributed. Each household optimizes utility under both a linear schedule, where the amortization rate is constant, and a notched schedule, where the amortization rate jumps when debt L_t exceeds the threshold $ph\overline{LTV}$.

Figure [C2](#) plots the simulated LTV distributions. With a linear amortization schedule, the LTV distribution is uniform. With a notched schedule, however, the LTV distribution features missing mass to the right of the notch, and a smooth distribution to the left of the notch. Households close to the LTV threshold in the linear amortization schedule optimally choose *higher* (gross) leverage to finance the required amortization payments in the notched schedule. Note that there is no spike.

Figure C2. LTV distribution from Svensson's model



Notes: The figure plots the LTV distribution using simulated data from the model of [Svensson \(2016\)](#), see section [D](#) in the appendix. We use $T = 10$, $\beta = 1.02^{-1}$, $\theta = 0.3$, $p = 100$, $y_t = 100 \forall t$, $r^L = 0.02$, $r^s = 0.01$, $\delta = 0.05$, $\alpha_0 = 0$ and $\Delta\alpha = 0.01$. There are 100,000 households, differing by their initial wealth A_0 , which is drawn from a uniform distribution on the interval $(120, 280)$.