The Amortization Elasticity of Mortgage Demand

Claes Bäckman and Peter van Santen*

March 8, 2021

Abstract

We study how amortization payments affect household borrowing. We argue that forced amortization payments are costly in several standard models, and therefore affect credit demand. Exploiting notches in the Swedish amortization requirement, we provide causal evidence that new borrowers act as if amortization payments are costly and reduce their leverage by 4-5 percent. Borrowers who avoid higher payments have higher income, higher debt-to-income ratios, and 15 percent face binding credit constraints with higher payments. We argue that changes in amortization payments are important for debt dynamics around periods of financial innovation, such as the Great Recession.

*Bäckman: Department of Economics and Business Economics, Aarhus University. Address: Aarhus University, Fuglesangs Allé 4, 8210 Aarhus V. Email: claes.backman@econ.au.dk. van Santen: Faculty of Economics and Business, University of Groningen. Address: Landleven 2, 9747 AE Groningen, Netherlands. Email: p.c.van.santen@gmail.com. We thank Rob Alessie, Johan Almenberg, Olga Balakina, Vimal Balasubramaniam, Tobin Hanspal, Kaveh Majlesi, Nikodem Szumilo, and seminar participants at Sveriges Riksbank, University of Groningen, Lund University, Nordic Junior Macro Seminar, EFA 2020, and Central Bank of Ireland workshop on Borrower finances, financial stability assessment and macroprudential policies 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.

1 Introduction

Lower amortization payments were a common feature of mortgage product innovations during the run-up to the Great Recession in the United States. For example, interest-only mortgages, option ARMs, and balloon mortgages all feature lower amortization payments in the first years after origination, and Justiniano *et al.* (2017) report such products increased from 3 percent of origination in 2000 to 44 percent of origination in 2005.[1] If amortization payments affect borrowing, the rapid expansion of these mortgage products in the run-up to the financial crisis could help explain the increase in mortgage debt. Moreover, since products with lower amortization payments were popular among high-income borrowers, an amortization-driven increase in borrowing could help explain the proportional increase in mortgage debt across the income distribution (Foote *et al.*, 2021; Adelino *et al.*, 2016). And yet, the role of amortization payments in the household leverage crisis has received considerably less attention than the role of the interest rate (Glaeser *et al.*, 2012), the expansion of credit supply (Mian & Sufi, 2009), or the relaxation of credit constraints (Favilukis *et al.*, 2017; Greenwald, 2017).

The focus on the interest rate and credit constraints is natural. Only costs or constraints should affect borrowing, and even though amortization payments can comprise 40-50 percent of total mortgage expenses at prevailing interest rates, they are at first glance simply a form of savings. We argue, however, that *forced* amortization payments can be costly for several reasons and, as such, should affect credit demand. As one of several examples we discuss below, forcing a young household with growing income to amortize may cause a sub-optimally high savings rate, a utility cost in any standard consumption model. Consequently, amortization payments should affect credit demand.

The question then becomes one of magnitudes: how much do amortization payments affect credit demand? This is a challenging question to answer, due to a lack of plausible exogenous variation in amortization rates. For

[1] Both Barlevy & Fisher (2020) and Amromin *et al.* (2018) report that just under 30 percent of mortgage origination in 2005 and 2006 consisted of similar products.

example, there could be adverse selection of borrowers into different mortgage products (Garmaise, 2013), complicating the identification of causal effects. We overcome the empirical challenge by documenting considerable bunching in response to non-linear jumps in amortization payments, evidence consistent with the idea that amortization payments are costly for borrowers. Specifically, we study a macroprudential policy introduced in Sweden in 2016, the amortization requirement, that creates two notches where mortgage payments exhibit a discontinuous jump at specified loan-to-value (LTV) thresholds. Due to the policy, the minimum amortization rate jumps from zero to one percent of the entire mortgage at an LTV ratio of 50 percent, and from one to two percent at an LTV ratio of 70 percent. Our identification strategy uses bunching in response to these notches to estimate the behavioral response by households. This methodology was 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). Intuitively, the presence of bunching provides a test for whether households consider amortization payments to be costly or not. If amortization payments are simply a form of savings and not a cost, the higher payments above the notches should not affect how much households borrow and we should not observe any bunching. If amortization payments are costly, the policy would induce some borrowers to reduce their borrowing to avoid higher payments. This is precisely what we find: 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 and that borrowing is reduced by 5 percent. The corresponding number for the upper LTV threshold at 70 percent is 12.9 percent of borrowers and a 4 percent reduction in borrowing. We thus provide new, causal, evidence that higher amortization payments affect household borrowing.

The identification strategy and main results are easily illustrated in Figure 1. The requirement created a discontinuous jump in amortization payments for mortgages just above the thresholds. Focusing on the lower of the two thresholds, the figure plots the percent of new borrowers in specific LTV bins in the pre- and post-requirement years. Prior to the introduction

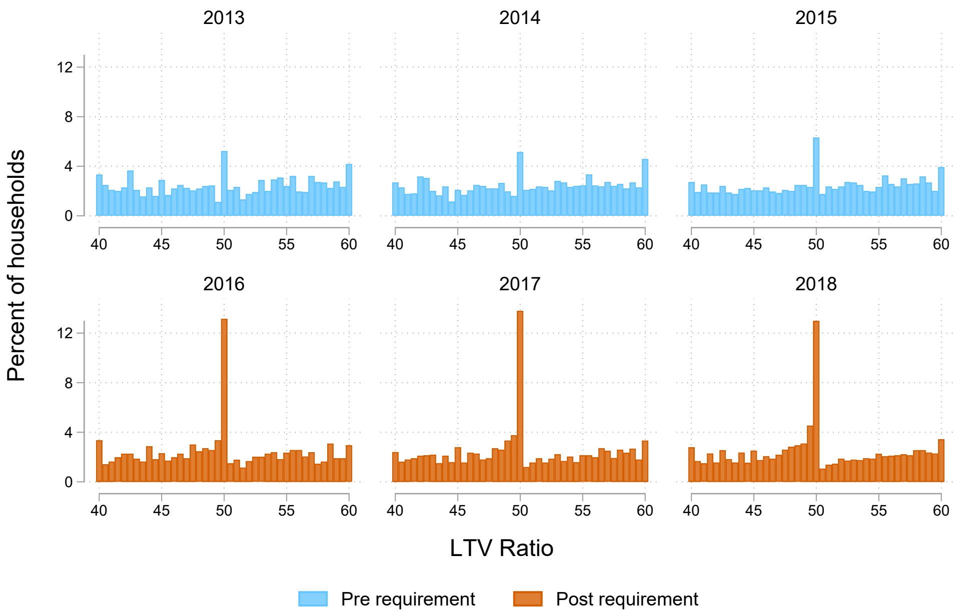


Figure 1: Share of borrowers by loan-to-value bins for the lower threshold

Notes: The figure plots the number of borrowers per loan-to-value bin for each year. Pre requirement years are in the top row, and post requirement years are in the bottom row. Loan-to-values are calculated using consolidated household debt levels divided by the value of the collateral.

of the requirement in 2016, there is only a small spike at the LTV ratio of 50 percent.[2] Once the requirement is introduced, a large number of new borrowers choose lower LTV ratios to minimize their amortization payments, leading to a large spike in the number of borrowers with an LTV ratio of exactly 50 percent. The spike is 2.5 times as large as what we would expect based on previous years and shows that higher amortization payments lead to lower household borrowing.

In our empirical strategy, we formally estimate the amount of bunching using pre-requirement years to form counterfactuals. We thereby account for the small spike at the threshold prior to the requirement and avoid the stan-

[2]In our view, the most likely explanation for the small spike at the notch is a preference for round numbers, which can also be observed at LTV ratios of 60 and 40 percent. While the spike may be related to other factors, such as higher capital requirements for higher LTV mortgages, we find no evidence consistent with an increase in costs around the threshold. In addition, as we use previous years to estimate the counterfactual distribution, any round-number bunching or spike at this threshold that is constant over time would be differenced out.

dard approach of fitting a flexible polynomial to the observed distribution to estimate the counterfactual distribution (Chetty *et al.*, 2011; Kleven & Waseem, 2013). We follow DeFusco *et al.* (2020) and validate this approach using placebo tests, where we show that bunching for each pre-requirement year can be well approximated by using other pre-requirement years to form the counterfactual distribution. Our identifying assumption is that there was no change other than the requirement that causes households to bunch at the threshold in the post-requirement period. Our strategy thereby allows bunching to occur at the threshold due to round number bunching, higher interest rates, or capital requirements above the notch, as long as the extent of the bunching due to these factors is unchanged over time. We consider several factors unrelated to the requirement that could potentially affect the amount of bunching but conclude that none can explain our results. Most importantly, we find flat interest rates around the notches for all years in our sample, evidence inconsistent with jumps in the mortgage rate at the amortization requirement thresholds.

At each threshold, borrowers reduce their leverage by approximately 2.5 percentage points, which translates into a reduction in mortgage demand of 0.14 to 0.25 percent for a 1 percentage point higher marginal amortization rate. These results are in general more conservative compared to the parametric approach and are robust to different specifications. In addition, before 2016 the Swedish Bankers' Association recommended that households amortize on the part of the mortgage with an LTV ratio above 70 percent. While this was only a recommendation and represents an increase in the marginal amortization rate in the pre-requirement period, as opposed to an increase in the average amortization rate in the post-requirement period, we note that this represents a potential source of downward bias. If households were already choosing an LTV ratio of 70 percent because of the recommendation, our pre-reform distribution will already reflect this, which will lower the estimated effect at the upper threshold. For the upper threshold, therefore, the estimate is conservative. At the lower threshold, there is no such confounder, as this threshold appeared as a surprise.

We leverage our data to investigate the type of borrowers who place themselves at the threshold in post-requirement years. Whereas the requirement specifies minimum amortization rates, households can still choose their preferred amortization rate, as long as it complies with the regulation. Around 70 percent of households that choose an LTV ratio of exactly 50 percent make only interest payments.[3] We find that borrowers who choose an LTV ratio just below the thresholds and choose minimum amortization payments have higher debt, higher income, and higher debt-to-income ratios compared to borrowers with the same LTV ratio that choose to amortize more than required. This pattern suggests that cash flow considerations are important, as high debt-to-income borrowers would see a sizeable share of their income go to debt servicing if they were forced to amortize.

For a share of the borrowers at the threshold, trading off payments for less borrowing is not necessarily a choice by the borrower but is instead imposed by the bank. Because of the discretionary income limit imposed by Swedish banks, 15 percent of borrowers would be ineligible for higher credit and a large share would be close to the borrowing limit. Moreover, 40 percent of borrowers would have a greater than 30 percent reduction in their discretionary income. This suggests that many borrowers are close to the limit, even though they are not formally facing a binding credit constraint. The evidence thus suggests that a majority of new borrowers at the threshold deliberately make a larger down payment to free up monthly cash flows, but that a share of new borrowers faces binding credit constraints because of higher amortization payments.

The bunching estimate identifies a local average treatment effect around the notches. Translating our reduced-form estimate into a structural estimate would require a model (Kleven, 2016). Constructing a theoretical model is challenging in this context, however, as there are several reasons why households may want to bunch. For example, young households may desire lower amortization payments to help smooth consumption, while older borrowers may wish to save in retirement accounts instead of amortizing. This complicates the construction of a model that can match the empirical estimates. Instead, we believe that the aggregate trends in credit growth indicate whether the effect that we identify is local or global: If the effect

[3] Note that this percentage includes borrowers who would place themselves at the threshold even without the requirement and that it is not necessarily a case of "defiers".

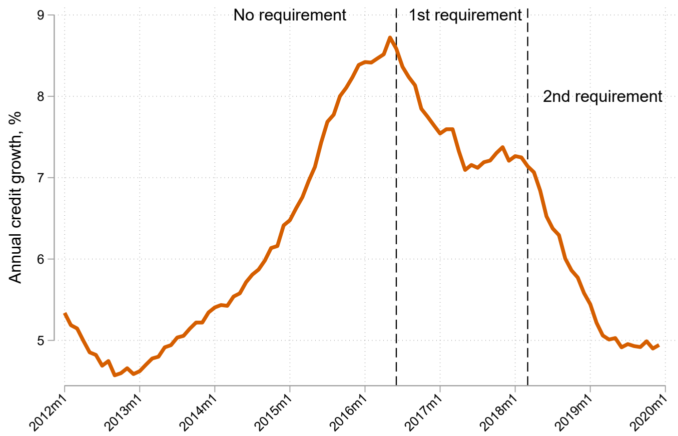


Figure 2: Credit growth for property loans

Notes: The figure plots time series on credit growth for property loans. The first dashed line in June 2016 indicates the introduction of the first amortization requirement. This is the policy that we study. The second dashed line in March 2018, indicates the second amortization requirement, which 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.

is local, we should not see an effect on aggregate credit growth. On the other hand, if higher amortization payments led to a decline in borrowing away from the threshold, aggregate credit growth would decline.

Figure 2 plots the growth in housing credit over time in Sweden, showing that the amortization requirement coincided with a sharp reduction in the growth rate. The 8.2 percent average growth rate in credit in the year before the requirement was introduced declined to a 7.8 percent average growth rate in credit in the year after the requirement was introduced. The sharp decline in the growth rate observed in Figure 2 suggests that the amortization requirement led to lower credit growth, as alternative explanations for credit growth are typically more slow-moving. For example, the interest rate falls steadily from 4 percent to a little above 1 percent between 2012 and mid-2015 but is then relatively flat between mid-2015 and 2020. The aggregate-level evidence thus suggests that the effect that we identify is not simply a local effect around the threshold, but that it applies throughout the distribution.

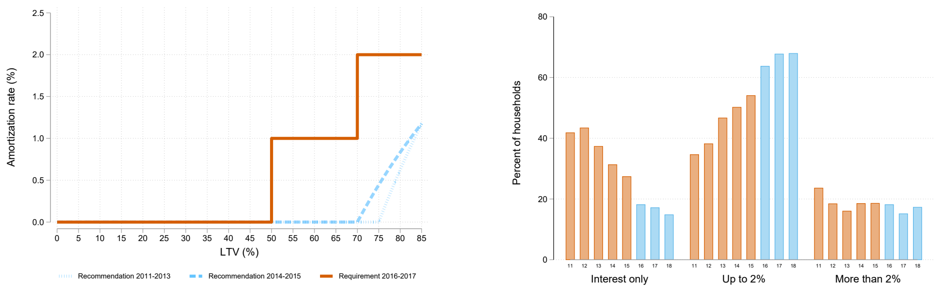
In conclusion, our main contribution is to provide credible and novel evidence that amortization payments affect household borrowing. Borrowers act as if amortization payments are costly, and they are willing to trade off higher borrowing for lower payments. Looking forward, the existence of such an elasticity suggests that central banks and regulators have an additional policy tool for affecting credit growth. By changing required amortization rates as in Sweden, the regulator can directly impact household borrowing without having a direct impact on borrowing costs for firms or the exchange rate. This channel comes in addition to the direct cash-flow effects studied in Campbell *et al.* (2020), who analyze a model where the option to stop amortization payments in a recession helps stabilize consumption and reduces the interest rate. Moreover, it suggests that a policymaker looking into adjusting amortization rates should be aware that such a reform could have large consequences for credit growth. Our results therefore contribute to the expanding literature on the effect of macroprudential policies (e.g. Cerutti *et al.*, 2017; Bernstein & Koudijs, 2020; Laufer & Tzur-Ilan, 2019; Van Bekkum *et al.*, 2019; Peydró *et al.*, 2020).

Looking backward, our results are relevant for understanding the role played by mortgage innovation that lowered amortization payments in the run-up to the financial crisis. A growing literature has shown that interest-only mortgages and similar products with lower initial mortgage repayment were a considerable part of this run-up. Moreover, these products disappeared in 2008 in the United States (Amromin *et al.*, 2018).[4] While the decline in the real interest rate is not sufficient to explain the run-up in mortgage debt and house prices (Glaeser *et al.*, 2012), 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.

2 The Amortization Requirement

The Swedish amortization requirement mandates that all new mortgages issued after June 1st, 2016, with LTV ratios above 50 percent have to be amortized. New mortgages with LTV ratios below 50 percent are exempt.

[4]See Dokko *et al.* (2019), Barlevy & Fisher (2020) and Bäckman & Lutz (2020b) for the impact of such products on house prices.



a) Required Amortization Rates by Period

b) Actual Amortization Rates by Year

Figure 3: Actual and Required Amortization Rates

Notes: Panel a) 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. Panel b) plots the percentage of households who amortize a certain percentage for each year.

The Swedish Financial Supervisory Authority (*Finansinspektionen*) introduced this macroprudential policy to reduce debt levels over time to limit macroeconomic risks posed by high household debt levels. Households with higher leverage were considered a higher risk and consequently had to reduce their debt level more rapidly.

The requirement was introduced following a long period of rapid house price and credit growth. Concerned with financial and macroeconomic stability, the Financial Supervisory Authority (FSA) and the Central Bank (Riksbank) had previously discussed a requirement (e.g. Riksbank, 2012). Even though the Swedish Bankers Association (SBA) had issued recommendations on amortization rates to its members, the Financial Supervisory Authority announced that they would propose new regulation about amortization payments in November 2014. The amortization requirement was finally proposed in December 2015, and the law went into effect in June 2016.[5]

The requirement, along with the previous recommendations from the SBA,

[5]The first amortization requirement had to be withdrawn following a court ruling that the FSA lacked legal authority. The government, therefore, had to introduce new regulation, which gave the FSA the authority to propose new regulations. An additional amortization requirement was introduced on March 1, 2018, and mandates that any mortgage where the debt-to-income ratio is above 4.5 has to be amortized by an additional percentage point. We do not assess the effects of this additional amortization requirement.

is summarized in panel a) of Figure 3. Before 2016, the SBA recommended that highly levered loans be amortized starting from LTV ratios of 75 percent (2011-2013, blue line) and 70 percent (2014-2015, red line), respectively. Compared to the requirement that was 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 mandates that the valuation can only be made every 5 years. Moreover, any re-valuation has to be based on changes to the property value that are due to renovation or rebuilding of the property, not due to house price changes. A borrower can be granted an exception to the requirement due to extenuating circumstances, such as unemployment, illness, or a death in the family. These exceptions have to occur after the origination of the loan. Due to the spread of the Corona-virus in 2020, the FSA allowed exceptions to the requirement for all borrowers until June 2021.[6]

The requirement had a large impact on amortization rates. Panel b) in Figure 3 plots how the share of households that amortize at a certain rate changes over time. The share of households with an interest-only mortgage drops from approximately 40 percent of households in 2011 and 2012 to less than 20 percent in 2016 and 2017. Concurrently, the share of households who amortize up to 2 percent increased from 15 percent in 2011 to 50 percent in 2017. This jump in payments is consistent with the amortization requirement affecting amortization rates.

Figures 10 and 11 in Appendix B illustrate how amortization rates vary by LTV ratio, with and without the requirement. Interestingly, the average amortization rate exhibits a sharp decline just below the threshold in years where the requirement was in place, consistent with borrowers placing themselves at the threshold to avoid making amortization payments. There

[6]See https://www.fi.se/en/published/press-releases/2020/banks-may-grant-all-mortgagors-amortisation-exemption/ .

is no such effect for the lower threshold in pre-requirement years.

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. Mortgage rates are set by the banks. 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").[7]

Swedish banks are required to assess the borrower's financial status, including their ability to pay borrowing expenses. This is enforced through a *discretionary income limit*, which requires the household to have enough disposable income to afford consumption and housing expenses (including amortization payments). This limit, which is 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 that they are willing to lend to the borrower, given for example household income and household size. Importantly, this pledge is given *before* the borrower makes a housing purchase. As we discuss later, this makes manipulation of the LTV ratio from the bank unlikely.

3 Previous literature and theoretical background

In this section, we present several arguments for why amortization payments affect household borrowing and present a simple theoretical framework to provide intuition for our empirical strategy. The arguments are

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

mainly derived from standard models in economics and finance and provide rational explanations for why households may prefer lower amortization payments if given the choice. Our theoretical framework incorporates a consumption smoothing argument, but we note that this framework excludes many of the reasons why households may wish to avoid making amortization payments. Instead of providing a unified theoretical framework that incorporates all the below arguments, we simply note that amortization payments are costly for several reasons.

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. This applies in particular to older households who intend to live off their savings, as their current income is lower than their permanent income, and to younger households with rising incomes. 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. Essentially, not all households want to save, and by placing themselves at the threshold borrowers can achieve a lower savings rate and higher consumption.

Second, even if households want to save, they do not necessarily wish to save by paying down the mortgage. A borrower may wish to save in risky assets because of the higher expected return or may wish to 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, compared to for example stock holdings. By reducing amortization payments, the borrower may be able to improve portfolio returns, increase diversification and improve liquidity.

Third, 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 calculation is done to ensure that after-tax household income is sufficient to cover subsistence consumption, borrowing payments, 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 leverage threshold.

Fourth, households might suffer from temptation, and therefore want to save in illiquid assets, for example by paying down their mortgage. Attanasio *et al.* (2020) present a two-asset model with temptation preferences that generates 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. As a consequence, 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. Consistent with this theory, Figure 3 show that the share of households amortizing more than 2 percent a year is not affected by the requirement.

Fifth, households may not realize that amortization payments are savings and may instead consider them a cost similar to interest rate cost. Selecting an LTV ratio to minimize amortization payments is then a rational response, even though it comes from a misunderstanding of amortization payments. Survey results reported in SBAB (2018) indicate that about half of Swedish households consider amortization payments to be a cost: 44.2 percent stated that amortization payments were savings, 37.7 percent stated that they were a cost, and 18 percent did not know what amortization payments were (SBAB, 2018). The survey was conducted on a representative sample of the Swedish population but did not distinguish between borrowers and non-borrowers. Older Swedes were more likely to see amortization payments as savings (44.7 percent for 36-55 years old versus 40.4 percent for 23-35 years old). Full results from the survey are reported in Table 5. Note that this does not necessarily imply that households confused amortization payments and interest payments, and might instead refer to any other reason presented above for why amortization payments are costly.

Sixth, households may want to maintain a high debt level to receive higher mortgage interest deductions to reduce the tax burden. Finally, interest-only mortgages are beneficial for borrowers who wish to speculate on rising house prices (Barlevy & Fisher, 2020). By maintaining high debt levels, a borrower who does not amortize keeps the default option high. 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.[8] An interest-only mortgage may even be preferred by Swedish banks, as this maintains high debt levels and thus high interest income for a longer period while keeping costs for mortgage origination low.

An amortization requirement can also lead to *higher* leverage (Svensson, 2016). An unconstrained borrower can simply 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 and leverage will be higher. We shall return to this below, where we show that the implied distribution of LTV ratios in that model will be different from the empirical distribution that we observe in the data.

3.1 Simple theoretical framework

To guide the empirical analysis, we present a simple three-period model of mortgage choice. The highly stylized model emphasizes the most important feature of the amortization requirement and shows how households respond to a notch in the amortization payment schedule. In reference to

[8]Note that this implies that a borrower in the US may value an interest-only mortgage *more*, as they have the option to default.

the channels above, the model provides intuition through the consumption smoothing channel. Adding the other channels to this exposition would entail complicating the model unnecessarily. Note also that we require at least three periods for amortization payments to matter for consumption smoothing. In a two-period model, any required mortgage repayments in the first period could be undone by simply borrowing more directly. Amortization payments and the increase in debt would therefore be interchangeable, allowing no scope for amortization payments to affect borrowing.

Households live for three periods. In period 1, households purchase a home at price p and consume c_1, financed by a mortgage loan L, income y_1 and predetermined wealth A_0. We assume an exogenous, constant housing price without choice of housing size to keep the model as simple as possible. In period 2, the household simply consumes its income minus debt service, which consists of interest rL plus amortization αL. In period 3, the house is sold at the same price p, the remaining mortgage (plus interest) is repaid, and the household consumes its remaining wealth. Formally, the household maximizes:

$$\begin{aligned} \max_{c_1,c_2,c_3} U(c_1,c_2,c_3) &= u(c_1) + \beta u(c_2) + \beta^2 u(c_3) \\ \text{s.t. } c_1 + p &= A_0 + L + y_1 \\ c_2 &= y_2 - (r+\alpha)L \\ c_3 &= y_3 + p - (1+r)(1-\alpha)L \\ 0 &< L < p \end{aligned} \tag{1}$$

We assume that households in the population are identical in all aspects except for initial wealth, which is smoothly distributed according to the density function $f(A_0)$. Each household can therefore be uniquely indexed by its position in the initial wealth distribution. Given A_0, the utility function $U(\cdot)$ is concave in the loan size L. Hence, every household simply chooses the loan size L to maximize its lifetime utility. It does so under each of two amortization schedules:

$$\text{Linear schedule: } \alpha = \alpha_0$$
$$\text{Notched schedule: } \alpha = \alpha_0 + \mathbb{1}(L/p > \overline{LTV})\Delta\alpha$$

Under the linear schedule, the amortization rate is constant. This linear amortization schedule yields a smooth loan size distribution, and LTV ratios are perfectly negatively correlated with initial wealth. Denote this distribution by $g_{linear}(LTV)$. The left panel in Figure ?? depicts this distribution.[9] Under the notched schedule, however, the amortization rate increases by $\Delta\alpha$ whenever the household's LTV ratio exceeds the threshold at $\overline{LTV}$. With a notched amortization schedule, a fraction of households located to the right of the threshold $\overline{LTV}$ will find it optimal to borrow less in period 1 compared to the linear amortization schedule. For households close enough to the threshold, borrowing exactly $\overline{LTV}$ is optimal. These households are willing to invest a larger share of their initial wealth into housing to avoid paying higher rates of amortization. The right panel of Figure ?? shows the LTV distribution with a notched schedule, which we denote $g_{notched}(LTV)$.

Comparing the left and right panels in Figure ??, the right panel is characterized by a spike at the threshold, and a missing mass to the right of the threshold, whilst being identical to the left of the notch. We can calculate the number of households bunching at the threshold as:

$$B = \int_{\overline{LTV}}^{\overline{LTV}+\Delta LTV} g_{linear}(LTV)dLTV \approx g_{linear}(\overline{LTV})\Delta LTV \qquad (2)$$

where the approximation assumes a constant density at the notch. Equation (2) implicitly defines ΔLTV for the *marginal buncher*, the household located furthest away from the threshold in the linear case that still chooses to bunch at the threshold with the notched schedule. The marginal buncher would have borrowed $\overline{LTV} + \Delta LTV$ with a linear amortization schedule, but is indifferent between borrowing $\overline{LTV}$ and the best interior point be-

[9]Figure ?? is generated assuming uniformly distributed initial wealth levels and log per-period utility.

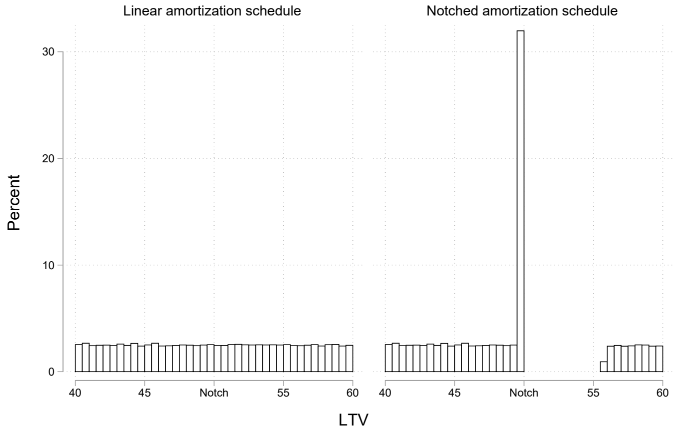


Figure 4: LTV distribution from the model

Notes: The figure plots the LTV distribution using simulated data from equation (1). We use log per-period utility, $\beta = 1.02^{-1}$, $p = 1$, $y_t = 1\ \forall t$, $r = 0.02$, $\alpha_0 = 0$ 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 $(0.75, 1.2)$.

yond the threshold. The marginal buncher, therefore, tells us how much initial wealth households are willing to invest in housing to avoid an increase in the amortization rate given by $\Delta\alpha$. With an estimate of $\widehat{B}$ and $\widehat{g_{linear}}$, we can solve for ΔLTV :

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

The above equation shows the intuition behind our identification strategy. With an estimate of both the amount of bunching $\widehat{B}$ and the counterfactual density around the notch $\widehat{g_{linear}}(\overline{LTV})$, we can calculate the behavioral response $\Delta\widehat{LTV}$, the reduction in leverage induced by the amortization requirement. The reduction in leverage that we estimate will then provide an intensive margin response around the notch.

In this stylized model, households just above the threshold optimally choose to borrow less under a notched amortization schedule. Leverage therefore decreases, as households reduce their borrowing to achieve lower payments. In an alternative framework, Svensson (2016) shows that higher amortization payments would instead increase borrowing. In the model, households would borrow more in response to higher amortization payments, invest the additional borrowing in a savings account and make amortization payments out of this savings account. The result would be an increase in debt and leverage, with unchanged consumption. In Appendix C, we show that in the Svensson model, a notched amortization schedule would lead to an LTV distribution with missing mass to the *left* of the notch and no bunching, inconsistent with the distribution we observe in the microdata.

4 Data and empirical strategy

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 a certain number of 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.[10] 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, the interest rate, monthly amortization payments, and value of the collateral. Collateral values are usually based on banks' internal valuation models, which use previous transaction prices and local hedonic price indices. For new mortgages to new home buyers, the transaction price is typically used. Less than 2 percent of new mortgages are collateralized by more than a single property. We use the total mortgage debt divided by collateral value to calculate LTV ratios. We are unable to link our mortgage data to other register data as households are reported anonymously. Table 2 in Appendix A provides summary statistics.

[10]The number of days and exact dates vary per year. Typically, banks report all issued mortgage loans for 5 days in late August and another 5 days in early October. To the extent the chosen days are representative for the rest of the year, the sample is representative of the flow of new mortgage loans.

4.1 Empirical Strategy

We now describe our approach to estimating the counterfactual distribution and the amount of bunching induced by the amortization requirement. Based on section 3.1, the empirical strategy allows us to calculate the behavioral response to the requirement, and in the end the amortization elasticity of mortgage demand.

Our empirical strategy hinges on the estimation of the counterfactual LTV distribution that would have occurred in the absence of the amortization requirement. We exploit the availability of repeated cross-sections to estimate the counterfactual distribution. In other words, we compute a *difference-in-bunching* estimate, where the distribution observed in the years before the requirement will serve as the counterfactual distribution in the post-requirement years. The advantage of this approach is that the spikes at LTV ratios of 50 and 70 percent observed before the introduction of the amortization requirement are accounted for. These spikes are presumably due to round-number bunching (Kleven, 2016; Best *et al.*, 2020) or the SBA's recommendation (see Figure 3).[11]

We group borrowers into LTV bins, with a width of half a percentage point. The goal is to estimate the counterfactual fraction of borrowers in each LTV bin j in the post-requirement period had the amortization requirement not been introduced, denoted $\hat{n}_j^{post}$. 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.

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

[11] The standard polynomial approach to estimating the counterfactual is undesirable in our setting. This approach to estimating the counterfactual in the now large literature in public finance involves fitting a flexible polynomial to the observed distribution while excluding data around the threshold (Saez, 2010; Chetty *et al.*, 2011; Kleven & Waseem, 2013). The polynomial can then be extrapolated to the distribution around the threshold. The main assumption behind this approach is that the counterfactual distribution is smooth over all values of the running variable. See Kleven (2016) for a review of the bunching literature.

caused the distribution of LTV ratios to shift between the pre- and post-reform periods. We measure the amount of bunching $\widehat{B}$ as the difference between the observed and counterfactual bin fractions in the region at and to the left of any amortization requirement threshold located at R:

$$\widehat{B} = \sum_{j=L}^{R} (n_j^{post} - \hat{n}_j^{post}). \tag{4}$$

The amount of bunching is equal to the fraction of additional borrowers who place themselves at the threshold, beyond what the counterfactual distribution based on previous years would predict. Similarly but to the right of the threshold, the amount of missing mass is equal to:

$$\widehat{M} = \sum_{j>R}^{U} (n_j - \hat{n}_j^{post}) \tag{5}$$

The missing mass is equal to the difference between the observed and counterfactual distribution in the region to the right of the threshold. Note that borrowers making up the missing mass could choose to 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 is equal to 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 towards the threshold. In our setting, there can be intensive margin responses for households located to the right of the notch that do not bunch, which makes estimating the extensive margin difficult. For example, a household might choose an LTV ratio of 55 percent, whereas it (counter-factually) 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 (3). The equation states that the response to the requirement by the marginal borrower, ΔLTV, is equal to the amount of bunching $\widehat{B}$ divided by the counterfactual density around the notch. In the stylized theoretical model, ΔLTV identifies the most extreme bunching household, i.e. the household with the lowest wealth that still bunches at the threshold. In practice, there are likely differences between these households that the simple model outlined above does not capture. Suppose, for example, that we introduce another source of heterogeneity, denoted by z, which captures differences in incomes, discount rates, housing preferences, utility functions, or some other variable. Equation (2) would then generalize to

$$B = \int_z \int_{\overline{LTV}}^{\overline{LTV}+\Delta LTV_z} g_{linear}(LTV, z) dLTV dz \approx g_{linear}(\overline{LTV}) E(\Delta LTV_z)$$

The bunching estimate is now approximately proportional to the *average* behavioral response $E(\Delta LTV_z)$ among bunching households for a given level of z. We can therefore still back out an estimate of the average reduction in LTV ratios, $E(\Delta LTV_z)$.

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 upper and lower thresholds, located at LTV ratios of 50 and 70 percent, respectively. The estimates and associated standard errors for the lower and upper threshold are summarized in Table 3 in Appendix A. We then compute elasticities and examine who seeks to avoid amortization payments.

5.1 Bunching at the lower threshold

The main result for the lower threshold is presented in Figure 5. The figure plots the observed distribution of loans by LTV ratio and the counterfactual 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 (4) and (5)). Our estimates of ΔLTV, B, and M are robust to changing these limits of the excluded area in either direction. The orange

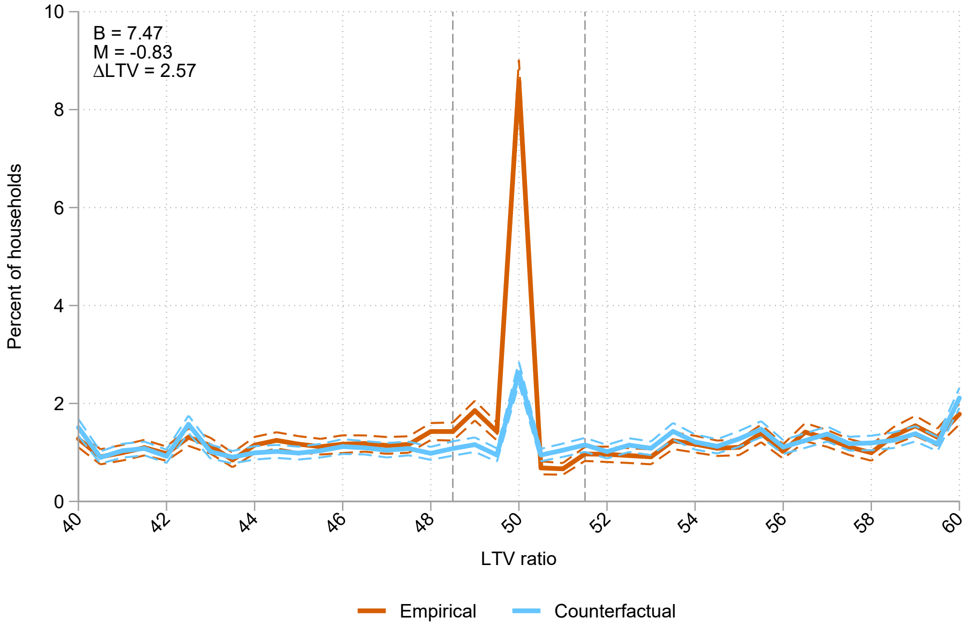


Figure 5: Bunching at LTV=50

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 below 65 percent, but only shows the distribution between 40 and 60. The orange line plots the empirical density, where each dot represents the fraction (count) of mortgages within each 0.5 percent LTV bin. The blue line plots the counterfactual density estimated using the procedure described in Section 4.1. The figure reports the estimated percent of loans that bunch at the threshold (B), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 4.1. Standard errors are calculated using a bootstrap procedure and are plotted using dashed lines.

solid line plots the empirical distribution, i.e. the distribution in 2016-2018, and the solid blue line plots the counterfactual distribution. Standard errors from the bootstrap procedure are marked with dashed lines.

There are several key results in the figure. First, the counterfactual 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 counterfactual density. We find 7.47 percent ($\widehat{B} = 7.47$, standard error 0.31) more borrowers with LTV ratios between 48.5 and 50 percent in the post-requirement years compared to the pre-requirement years. Dividing this bunching estimate by the counterfactual distribution, we find that the marginal buncher changes their LTV ratios 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) less borrowers to the right of the notch in the post-requirement years compared to the pre-requirement years. This estimate of missing mass would suggest a large extensive margin response, that is, borrowers exiting the market altogether because of the notch in amortization rates. However, in our setting, there can be intensive margin responses for households located to the right of the notch that do not bunch, which makes estimating the extensive margin difficult.[12]

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 are leverage constrained. However, they can still face credit constraints related to payments due to the discretionary income limit applied in Sweden. Bäckman & Khorunzhina (2019) show that payment constraints are more likely to bind if house value to income ratios are high, as this implies that the payments on the mortgage are larger relative to income for a given leverage level.

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, albeit less strict, recommendation that households amortize on the portion of the mortgage in excess of a 70 percent LTV ratio. This presents a potential source of downwards 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

[12]For example, a household might choose an LTV ratio of 55 percent, whereas it (counter-factually) 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.

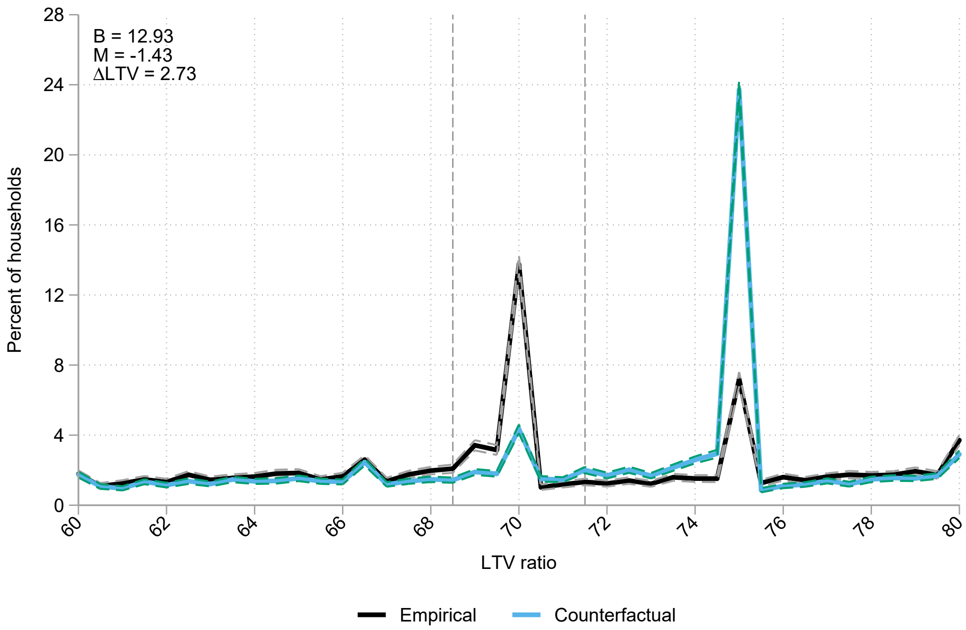


Figure 6: Bunching at LTV=70

Notes: The figure plots the empirical and counterfactual density of mortgage loans by LTV ratio. The black line is the empirical density, where each dot represents the fraction (count) of mortgages within each 0.5 percent LTV bin. The blue line is the counterfactual density, estimated using the procedure described in Section 4.1. The figure also reports the estimated percent of loans that bunch at the threshold (B), the missing mass (M), and the behavioral response by borrowers (ΔLTV). The calculation of these numbers is described in Section 4.1. Standard errors are calculated using a bootstrap procedure and are plotted using dashed lines.

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. This implies that the marginal interest rate changes above LTV ratios of 75 percent, and that a borrower may want to reduce their borrowing to avoid this higher interest rate. This threshold is clearly noticeable in the counterfactual distribution in Figure 6. Figure 13 in Appendix B 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 6. Similar to Figure 5, the figure plots the observed distribution using data from the post-requirement years, and the counterfactual distribution estimated using pre-requirement data. The estimation procedure uses data from borrowers with LTV ratios between 60 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 6. 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 counterfactual densities are almost identical, showing that the procedure is well able to approximate the distribution. The bunching statistic $\widehat{B}$ shows that 12.93 percent of borrowers decide to bunch (standard error 0.38). Dividing the bunching statistic by the counterfactual distribution at the threshold, we find that the marginal buncher reduces their LTV ratio by 2.73 percentage points (standard error 0.12) due to the amortization requirement. This is marginally higher than the reduction in LTV ratios of 2.57 percent at the lower threshold. Finally, we find 1.43 percent ($\widehat{M} = -1.43$, standard error 0.2) less borrowers to the right of the notch in the post-requirement years compared to the pre-requirement years.

5.3 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, where the rate above the threshold applies to the entire mortgage instead of to 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. This implies that we cannot use the jump in payments created by the requirement to calculate an elasticity, as elasticities relate marginal changes in costs to marginal changes in quantities. 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 leverage 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:

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

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

$$\alpha^* = \alpha_0 + \Delta\alpha + \Delta\alpha \cdot \frac{\overline{LTV}}{(LTV - \overline{LTV})} \tag{7}$$

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 therefore imply a very large marginal amortization rate that decreases as we move further away from the threshold: 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 reduction in borrowing. The semi-elasticity of borrowing with respect to the amortization rate is equal to:

$$e^{\alpha} = \frac{\Delta LTV}{\alpha^*(\overline{LTV} + \Delta LTV) - \alpha_0} \tag{8}$$

where we relate the change in the LTV ratio induced by the requirement to the implicit marginal amortization rate for the marginal buncher. Plugging in the bunching estimates and the marginal amortization rate, the semi-elasticity at the lower threshold at LTV ratios of 50 percent is equal to 0.25: a one percentage point increase in amortization rate decreases leverage by

0.25 percent. For the upper threshold, the corresponding elasticity is 0.14.[13] Mortgage debt therefore declines by 0.14 to 0.25 percent for a percentage point increase in the amortization rate.

5.4 Who seeks to avoid amortization payments?

We now examine the characteristics of borrowers who place themselves at the threshold. To isolate the households who actively seek to avoid amortization payments, Table 1 divides the sample at each threshold into borrowers who minimize their amortization outlays (*Conforming*), and borrowers at the thresholds that amortize more than required (*Non-conforming*). At the 50 percent LTV notch, conforming households do not amortize. At the 70 percent LTV notch, conforming households amortize 1 percent. We proceed to highlight some relevant differences.

There are 1,400 Interest-only borrowers and 505 Amortizing borrowers at the lower LTV threshold, giving an interest-only share of 73 percent. The numbers in the table are in Swedish krona, which we convert to US dollars using an exchange rate of approximately 8.8 SEK to 1 USD. Those who do not amortize, i.e. those borrowers who conform to the requirement, have approximately USD 75,000 higher debt, USD 90,000 higher housing values, approximately USD 775 higher monthly income, 130 percentage points higher debt-to-income, and half the debt service compared to households in the same LTV range who do amortize. Note that this is primarily due to lower amortization payments. Given the average income and mortgage size, moving just above the requirement implies an annual amortization expense of 18,700 SEK, (3.2 percent of annual income), and would naturally raise mortgage debt by 18,700 SEK. As we estimate that the marginal buncher reduces LTV by 2.5 percentage points to conform to the requirement, this implies that on the margin, borrowers are willing to give up 46,750 SEK (USD 5,300) of mortgage debt for 18,700 SEK (USD 2,125) lower payments.

[13] The numerator is equal to the percent change in LTV ratios. With the estimated ΔLTV of 2.57 evaluated at the lower threshold, the numerator is then equal to $2.57/50 = 0.0514$. Using the implicit rates from equation (7), the denominator is equal to $\alpha^* = 0+0.01+0.01 \cdot \frac{50}{(52.57-50)} = 0.204$, and the semi-elasticity is equal to $0.0514/0.204 = 0.25$.

The fraction of borrowers who conform to the minimum amortization payments at the upper threshold is 73 percent (2,392/3,243), similar to the fraction at the lower threshold. Borrowers who conform to the requirement and only amortize 1 percent of the mortgage have slightly higher disposable income than borrowers who amortize more than the minimum set by the requirement. Conforming borrowers also have higher total and mortgage debt, and higher house values. This may be because conforming households are more likely to live in large cities with higher house price levels. Even though house values are higher for conforming households, their total debt to income is significantly higher. Finally, total debt service to income is again substantially lower because of the lower amortization payments. In sum, the table provides evidence that borrowers who would make larger amortization payments relative to income are more likely to conform to the requirement. This is consistent with the idea that the cost of amortizing is increasing in the amount that the borrower has to amortize.

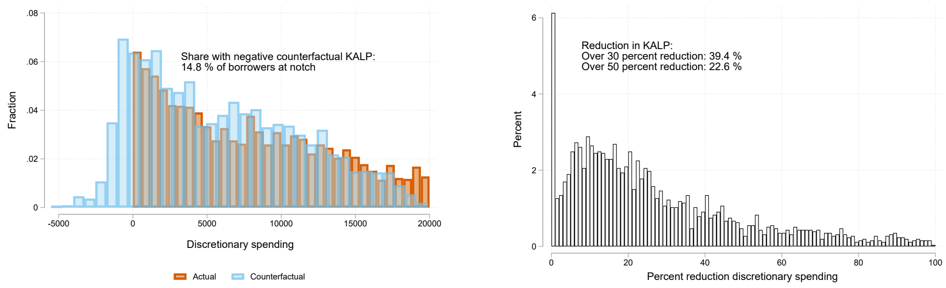
While we unfortunately lack data on savings, consumption, and investment decisions, we can examine one potential explanation for the observed bunching directly: the payment-to-income constraint. Recall that Swedish banks include amortization payments into credit assessments, and that binding payment-to-income constraints therefore could force households to lower their borrowing.

For the average borrower in Table 1, debt service to income for conforming households is 4.81 and 10.50 percent at the lower and upper threshold, respectively. Moving from 0 to 1 percent amortization would increase debt service from 4.8 to 8 percent of income for households at the lower 50 percent LTV threshold, and from 10.5 to 14.7 percent of income at the 70 percent threshold. This understates the possibility that borrowers face binding borrowing constraints, however, as the Swedish version of a payment-to-income constraint takes the form of a "discretionary income" limit with a stressed interest rate to evaluate borrowing. When evaluated with an interest rate of 6 percent, interest payments would sum to 20 percent of income for the conforming borrower at the lower threshold. If the average borrower at the lower threshold were to amortize 1 percent, their debt service to income would increase this to 23 percent. For the average borrower

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



a) Discretionary spending

b) Reduction in discretionary spending

Figure 7: Discretionary spending

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. 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.

at the 70 LTV threshold, the average stressed debt service to income ratio would increase from 25 percent of income to 29 percent of income.

For a substantial share of borrowers, higher amortization payments would entail a large decrease in their discretionary income. Panel a) of Figure 7 plots the distribution of discretionary spending with actual amortization payments (orange solid line) and with counterfactual amortization payments (blue dashed line), where we increase the LTV ratio by 1 unit and consequently increase amortization payments to comply with the requirement. The figure pools borrowers at both thresholds. Overall, 14.8 percent of borrowers would have negative discretionary income, and thus would not comply with the payment-to-income constraint set by Swedish banks. A large fraction of borrowers would also end up close to the limit. Panel b) shows the reduction in discretionary spending that higher amortization payments would entail: 39.4 percent of borrowers would have a reduction of 30 percent or more of their discretionary income, and 22.6 percent would have a reduction of over 50 percent. While some of those higher payments may be compensated for by a change in the composition of savings, amortizing clearly implies a large reduction in discretionary spending for a substantial portion of borrowers who bunch.

6 Assessing threats to identification

In this section, we discuss several threats to identification, starting with the counterfactual LTV distribution in the post-requirement years. Note that our difference-in-bunching strategy eliminates many possible confounders that might affect LTV distributions, as they will be differentiated 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 discuss interest rates around the threshold, bank incentives, collateral assessments by banks, LTV dynamics, and salience. We conclude that none of these factors can explain the observed bunching.

Placebo tests – We start by providing 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 in the absence of the requirement (DeFusco *et al.*, 2020). Specifically, each pre-requirement year from 2011 to 2015 is designated as a "placebo" year. We then estimate the counterfactual distribution for both requirement thresholds in these years. By estimating the counterfactual distribution as if the requirement had passed in a placebo year, we can assess whether the procedure can yield a good match between the empirical and 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 8 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.[14] Importantly, the spikes at 50, 70, and 75 percent LTV ratios are well approximated by this procedure. Panels c) and d) provide histograms of the ratio between each bin in the empirical and counter-factual distribution for all the pre-requirement years.

[14]Using other years than 2014 yields similar charts.

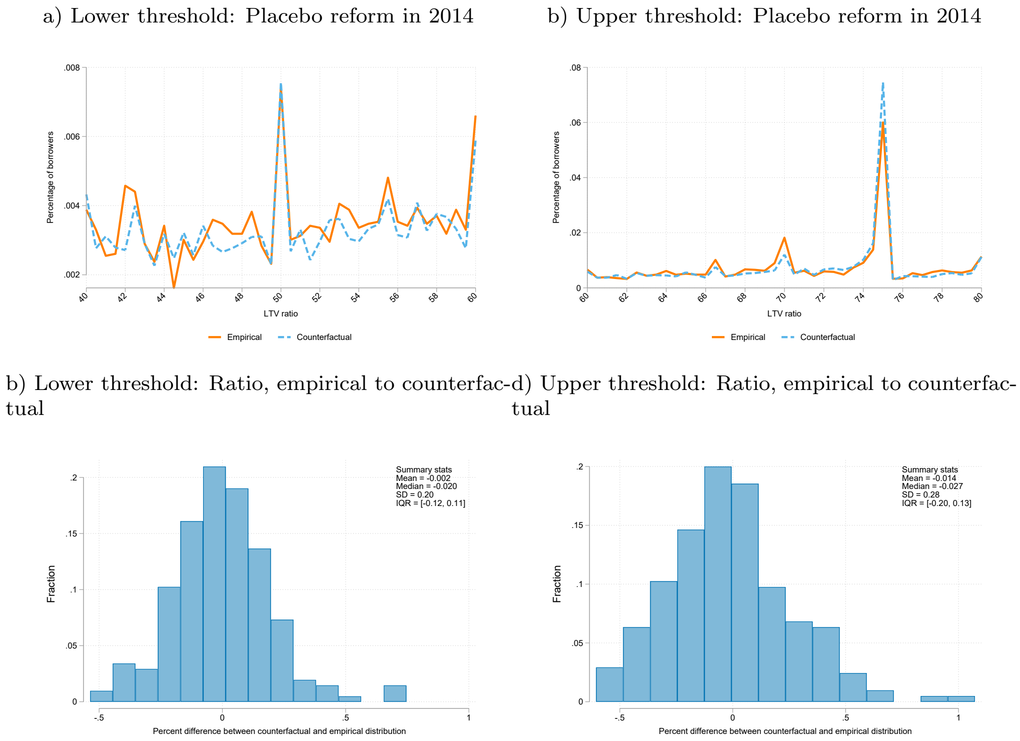


Figure 8: Counter-factual and empirical distribution in placebo years

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

In both panels, the mean and median percentage difference is close to zero, and the inter-quartile range covers zero. There is therefore little evidence that our approach creates a systematic bias in either direction. Overall, we conclude that previous years can closely approximate the distribution in years without the requirement.

Mortgage interest rates around the notches – Figure 9 shows that a plausible explanation for why borrowers place themselves at the thresholds, the mortgage interest rate, does not vary around the threshold. While it is possible that banks charge different interest rates for borrowers around the threshold in response to higher credit risk for borrowers who do not amortize (Garmaise, 2013), we do not find any evidence of this in our

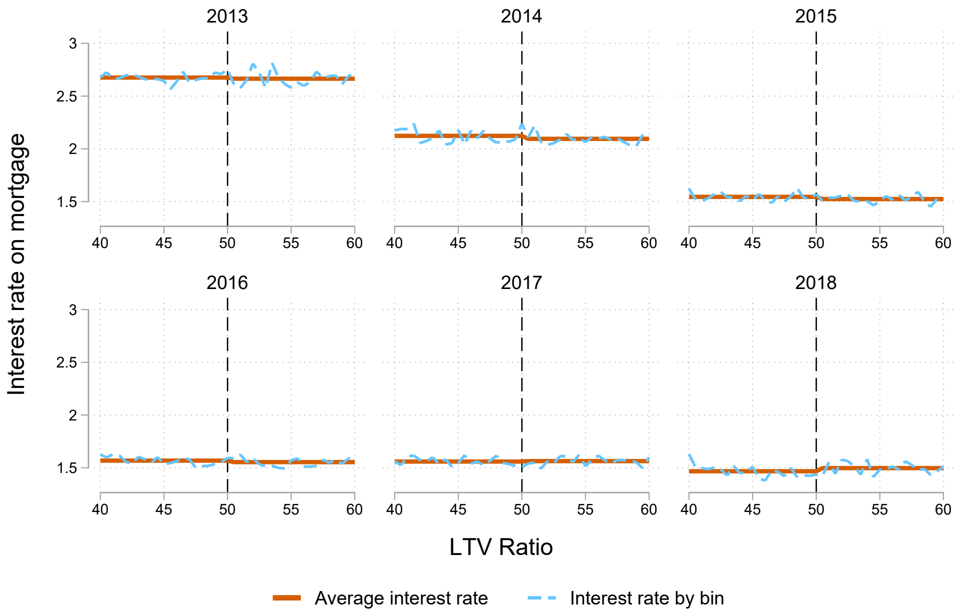


Figure 9: Interest rates by LTV ratio over time

Notes: The figure plots the average mortgage rate by LTV bin (blue dashed line) and the average mortgage rate above or below the threshold at LTV of 50 percent marked by the dashed black line.

setting. Figure 9 plots the interest rate by LTV ratios around the lower threshold. Although the level of the interest rate is different in each year, reflecting Swedish monetary policy, there are no systematic differences in the interest rate over the threshold in any year. Similar results hold for the upper threshold, available in Figure 12. There is therefore little evidence that mortgage banks charged higher mortgage rates to households placing themselves right 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. Figure 9 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.

Despite the evidence displayed in Figure 9, there might be an additional premium charged for borrowing more than 50 percent of the property value due to, for example, capital requirements. Because of selection, the average rates displayed in the chart would not reveal this premium, as borrowers not wanting to pay the premium would already choose to borrow less, and these individuals might be different from non-bunchers. If this premium is constant over time, however, our identification strategy would difference these effects away.

Banks' incentives – Banks may have an incentive to recommend their clients to place themselves below the threshold. In general, however, we do not expect banks to push for lower leverage, simply because a higher debt balance would lead to increased revenues. Indeed, Svensson (2016) argues that banks have an incentive to provide more credit to offset amortization payments. The fact that we observe lower leverage in the data is consistent with active choices made by borrowers, not lenders.

Even though revenues increase with borrower leverage, 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. In either case, the expected recovery cost is more than sufficient to compensate the lender in case of default. Furthermore, a shock that pushes a loan with a 51 percent LTV ratio "underwater" is highly unlikely. Finally, given full recourse, households have no strategic motive to default.

Regarding funding costs, all loans with LTV below 75 percent are eligible for covered bond funding. In addition, according to the standardized approach to credit risk, all loans secured by residential real estate receive the same (35 percent) risk weight. In practice, most Swedish banks use the IRB approach to credit risk, and higher LTV ratios should therefore require more (expensive) capital funding. We are not aware of any evidence to suggest that risk weights increase discontinuously at the thresholds. Even if they do, the effect would be differenced out by the counter-factual distribution if it stays constant over time.

Collateral assessments – The LTV ratio could be manipulated by over-stating collateral assessments (Mayordomo *et al.*, 2020), which could reduce capital requirements and required amortization rates when crossing the threshold. We observe market values in our data, as reported by the banks. In many cases, these values come from transaction prices, which can (in principle) be audited. Other valuations are done by appraisers or statistical models employed by the bank. 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.[15] More importantly, however, the Swedish institutional setting makes manipulation unlikely: borrowers apply for a pledge by the bank, stating the maximum amount the bank is willing to lend (which depends on the household's income and composition). Based on this maximum loan promise and available net worth, the household purchases a home. The household's borrowing decision comes after the assessment provided the requested amount does not exceed the promised amount. Manipulating the home value purely for amortization purposes is therefore unlikely.

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

It also suggests that banks may have an incentive to nudge borrowers just below the threshold. Indeed, if borrowers do not actively apply for lower amortization payments, the bank may get higher interest income when borrowers enter an interest-only loan compared to a loan just above the lower threshold, simply because over the lifetime of the loan (typically 6-7 years), the average debt balance is larger for the non-amortizing loan.[16] The

[15] Nearly 50 percent of total funding comes from wholesale funding, half of which is covered bonds (Sandström *et al.*, 2013).

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

extra interest income from this nudge is likely small and depends on how long the loan stays on the banks' balance sheet and the interest margin. In any case, such a strategy is second-best for the bank: simply informing the borrower when they cross the LTV threshold yields higher revenues.

Salience – Finally, 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.

7 Conclusion

We show that the amortization requirement in Sweden had a direct impact on household leverage choices at the time households were taking out mortgages. Overall, our results indicate that household borrowing depends on the total mortgage payments including amortization, and not simply on the interest rate. By extension, explaining credit growth requires that we examine all features of the mortgage contract, including amortization payments.

While the elasticity that we estimate is modest, the aggregate effects of changing amortization payments can still be large. A naive comparison would suggest that the 1 percentage point higher amortization rate would have led to a 0.25 percent decline in leverage, which seems unlikely to explain the large decline in aggregate credit growth. However, 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 calculation of the marginal rate: 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

threshold.

low, the aggregate effect may well be largely due to the large change in payments. Looking at the developments in the United States in the run-up to the financial crisis, the rapid expansion of mortgages with lower payments therefore 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 contraction of credit. The change in cash-flow for a borrower who previously had an interest-only mortgage but who 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 4). The disappearance of interest-only mortgages in the United States in 2008 would by itself cause a decline in borrowing.

Our results speak towards the intensive margin of amortization payments. There may also be extensive margin effects of the requirement that affect aggregate credit growth. We have deliberately chosen not to estimate extensive margin effects, as we feel this would entail making difficult-to-motivate assumptions over the counterfactual distribution. DeFusco *et al.* (2020) estimates the extensive margin by examining missing mass induced by the Dodd-Frank "Ability-to-Repay" requirement. This requirement effectively led to a reduction in high debt-to-income mortgages and affected roughly 5 percent of the total loan market in 2014. In contrast, the amortization requirement affected almost the entire market – 90 percent of mortgages in the pre-requirement years had an LTV ratio above 50 percent. While the extensive margin may be an important channel for quantifying the effect on the requirement for credit growth, our main point remains: forced amortization payments are costly and cause borrowers to change their behavior. We believe that the evidence on the intensive margin is sufficient to prove this point.

Finally, 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 slow down the growth of debt. If rising debt levels represent a danger to financial stability (Mian *et al.*, 2017), the policy reduced macroeconomic risk. Higher amortization payments could also lead to higher wealth accumulation and a larger buffer for borrowers. However, a shift from liquid to illiquid savings because of higher amortization payments could also reduce households' ability to smooth consumption in response to income or house price 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 requirement improves financial stability is an empirical question not ideally suited to our data. Recent work by Bernstein & Koudijs (2020) find that an amortization requirement for new homeowners in the Netherlands raised the overall savings rate, with little impact on other types of savings. This suggests that such policies raise the savings rate without impacting savings in liquid assets.

References

Adelino, Manuel, Schoar, Antoinette, & Severino, Felipe. 2016. Loan originations and defaults in the mortgage crisis: The role of the middle class. *The Review of Financial Studies*, **29**(7), 1635–1670. 1

Amromin, Gene, Huang, Jennifer, Sialm, Clemens, & Zhong, Edward. 2018. Complex mortgages. *Review of Finance*, **22**(6), 1975–2007. 1, 7, 36

Attanasio, Orazio, Kovacs, Agnes, & Moran, Patrick. 2020. Temptation and Commitment: Understanding Hand-to-Mouth Behavior. *National Bureau of Economic Research Working Paper No. 27944*. 12

Bäckman, Claes, & Khorunzhina, Natalia. 2019. Interest-Only Mortgages and Consumption Growth: Evidence from a Mortgage Market Reform. 22

Bäckman, Claes, & Lutz, Chandler. 2020a. The impact of interest-only loans on affordability. *Regional Science and Urban Economics*, **80**. 11

Bäckman, Claes, & Lutz, Chandler. 2020b. Mortgage Innovations and House Price Booms. 7

Barlevy, Gadi, & Fisher, Jonas DM. 2020. Why Were Interest-Only Mortgages So Popular During the U.S. Housing Boom? 1, 7, 13

Bernstein, Asaf, & Koudijs, Peter. 2020. Mortgage Amortization and Wealth Accumulation. *Available at SSRN 3569252*. 7, 37

Best, Michael Carlos, Cloyne, James S, Ilzetzki, Ethan, & Kleven, Henrik J. 2020. Estimating the elasticity of intertemporal substitution using mortgage notches. *The Review of Economic Studies*, **87**(2), 656–690. 2, 18

Campbell, John Y, Clara, Nuno, & Cocco, Joao F. 2020. Structuring mortgages for macroeconomic stability. *The Journal of Finance, forthcoming.* 7

Cerutti, Eugenio, Claessens, Stijn, & Laeven, Luc. 2017. The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability*, **28**, 203–224. 7

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, 4, 18

Cocco, Joao F. 2013. Evidence on the benefits of alternative mortgage products. *The Journal of Finance*, **68**(4), 1663–1690. 11

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, 24

DeFusco, Anthony A, Johnson, Stephanie, & Mondragon, John. 2020. Regulating household leverage. *The Review of Economic Studies*, **87**(2), 914–958. 4, 30, 36

Dokko, Jane K, Keys, Benjamin J, & Relihan, Lindsay E. 2019. Affordability, Financial Innovation, and the Start of the Housing Boom. 7

Favilukis, Jack, Ludvigson, Sydney C, & Van Nieuwerburgh, Stijn. 2017. The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium. *Journal of Political Economy*, **125**(1), 140–223. 1

Foote, Christopher L, Loewenstein, Lara, & Willen, Paul S. 2021. Cross-sectional patterns of mortgage debt during the housing boom: evidence and implications. *The Review of Economic Studies*, **88**(1), 229–259. 1

Garmaise, Mark J. 2013. The attractions and perils of flexible mortgage lending. *Review of Financial Studies*, **26**(10), 2548–2582. 2, 31

Glaeser, Edward L., Gottlieb, Joshua D., & Gyourko, Joseph. 2012. Can cheap credit explain the housing boom? *In: Housing and the Financial Crisis*. University of Chicago Press. 1, 7

Greenwald, Daniel L. 2017. *The Mortgage Credit Channel of Macroeconomic Transmission*. Working Paper, MIT Sloan. 1

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. 12

Justiniano, Alejandro, Primiceri, Giorgio E, & Tambalotti, Andrea. 2017. The mortgage rate conundrum. *National Bureau of Economic Research Working Paper No. 23784*. 1

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, 4, 18, 24

Kleven, Henrik Jacobsen. 2016. Bunching. *Annual Review of Economics*, **8**, 435–464. 2, 5, 18

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*. 7

Mayordomo, Sergio, Rachedi, Omar, & Moreno, Maria Rodriguez. 2020. Bank Regulatory Capital Arbitrage: Evidence from Housing Overappraisals. 34

Mian, Atif, & Sufi, Amir. 2009. The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis. *The Quarterly Journal of Economics*, **124**(4), 1449–1496. 1

Mian, Atif, Sufi, Amir, & Verner, Emil. 2017. Household debt and business cycles worldwide. *The Quarterly Journal of Economics*, **132**(4), 1755–1817. 36

Peydró, José-Luis, Rodriguez Tous, Francesc, Tripathy, Jagdish, & Uluc, Arzu. 2020. Macroprudential policy, mortgage cycles and distributional effects: Evidence from the UK. 7

Riksbank. 2012. Annual Report. 8

Riksbank. 2014. From A to Z: the Swedish mortgage market and its role in the financial system. 10

Saez, Emmanuel. 2010. Do taxpayers bunch at kink points? *American Economic Journal: Economic Policy*, **2**(3), 180–212. 2, 18

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. 34

SBAB. 2018. Mer än var tredje svensk ser amorteringen som en kostnad. https://www.sbab.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]. 12, 45

Schlafmann, Kathrin. 2020. Housing, Mortgages, and Self-control. *Review of Financial Studies*. 12

Svensson, Lars EO. 2016. Amortization requirements may increase household debt: a simple example. *IMF Working Paper No. 16/83*. 13, 16, 33, 50, 51

Van Bekkum, Sjoerd, Gabarro, Marc, Irani, Rustom M, & Peydró, José-Luis. 2019. Take It to the limit? The effects of household leverage caps. 7

FOR ONLINE PUBLICATION

A Appendix: Tables

Table 2: Summary Statistics

	(1) Full Sample	(2) LTV 40-60	(3) LTV 60-80
Demographics			
Main borrowers age	44.64	49.73	43.74
	(14.88)	(14.48)	(13.49)
Household size	2.18	2.15	2.23
	(1.14)	(1.15)	(1.17)
Large city	0.45	0.49	0.49
	(0.50)	(0.50)	(0.50)
Disposable income, KSEK	40.76	43.23	41.86
	(83.03)	(105.75)	(30.64)
Loan sizes (MSEK)			
Total debt	1.87	1.95	2.16
	(1.63)	(1.81)	(1.75)
Mortgage debt	1.50	1.57	1.78
	(1.25)	(1.32)	(1.40)
House price	2.47	3.12	2.52
	(2.16)	(2.63)	(2.01)
Interest Rates			
Mortgage rate	2.18	2.04	2.14
	(0.83)	(0.81)	(0.82)
Mortgage fixation period	13.28	12.13	13.34
	(15.64)	(15.54)	(15.57)
Adjustable rate mortgage	0.61	0.67	0.60
	(0.49)	(0.47)	(0.49)
Amortization			
Amortization, KSEK	1.60	1.17	1.62
	(1.92)	(1.87)	(2.06)
Amortization rate	1.72	1.45	1.40
	(2.60)	(2.48)	(1.92)
Amortization to income	4.08	2.97	3.98
	(4.15)	(4.15)	(4.34)
Mortgage Characteristics			
Loan to value	65.44	50.37	71.27
	(22.89)	(5.74)	(5.32)
Total debt to income	379.00	379.88	424.43
	(218.74)	(224.31)	(225.20)
Net interest to income	5.55	5.11	6.05
	(3.75)	(3.55)	(3.89)
Debt service to income	10.82	8.70	10.81
	(6.79)	(6.03)	(6.16)
N	121,313	18,283	35,449

Notes: The table reports means and standard deviations (in parentheses). Column 2 and 3 splits the sample according to LTV ratio. KSEK is thousands of Swedish krona, and MSEK is million of Swedish krona. Demographic variables include the main borrower age and household size. *Large city* is a dummy variable equal to one if the borrower lives in one of the three largest cities (Stockholm, Malmö or Gothenburg). *Disposable income, KSEK* is disposable income adjusted for inflation in thousands of Swedish krona per month. *Total debt* is defined as mortgage debt plus unsecured credit. *House price* is the collateral value in millions of SEK, which in most cases is based on bank's internal valuations of properties, or transaction prices otherwise. These internal valuations use previous transaction prices and local hedonic price indices. *Mortgage fixation period* is the number of months for which the mortgage has a fixed interest rate. *Adjustable rate mortgage* is a dummy equal to one if the fixation period 3 months or less, i.e. if the mortgage has a variable interest rate. *Mortgage amortization, KSEK* is the monthly amortization payment in thousands of SEK. *Mortgage amortization rate* is calculated as mortgage amortization divided by mortgage debt. *Mortgage amortization to income* is calculated as mortgage amortization divided by disposable income. *Loan to value* is calculated as mortgage debt divided by house price. *Total debt to income* is calculated as total debt divided by annual disposable income. *Net interest to income* is calculated as interest payments divided by disposable income. *Debt service to income* is calculated as the sum of interest payments and amortization payments, divided by disposable income.

Table 3: Summary of main estimates

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

Notes: The figure summarizes the main result of the bunching estimates. *Bunching* is the estimate of the amount of bunching, calculated using equation (4). *Missing mass* is the estimate of the missing mass, calculated using equation (5). Δ LTV is the estimate of the behavioral response, or the change in LTV ratio for the marginal buncher, calculated using equation (3). Bootstrapped standard errors in parentheses are calculated by drawing random samples with replacement from the full sample of borrowers. We then re-calculate the LTV distribution and re-estimate all parameters at each iteration.

Table 4: 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: (Annuity schedule - Interest-only mortgage)/Annuity schedule. *Lower - IO* and *Upper - Lower* are calculated similarly.

Table 5: 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: Source: SBAB (2018).

B Appendix: Figures

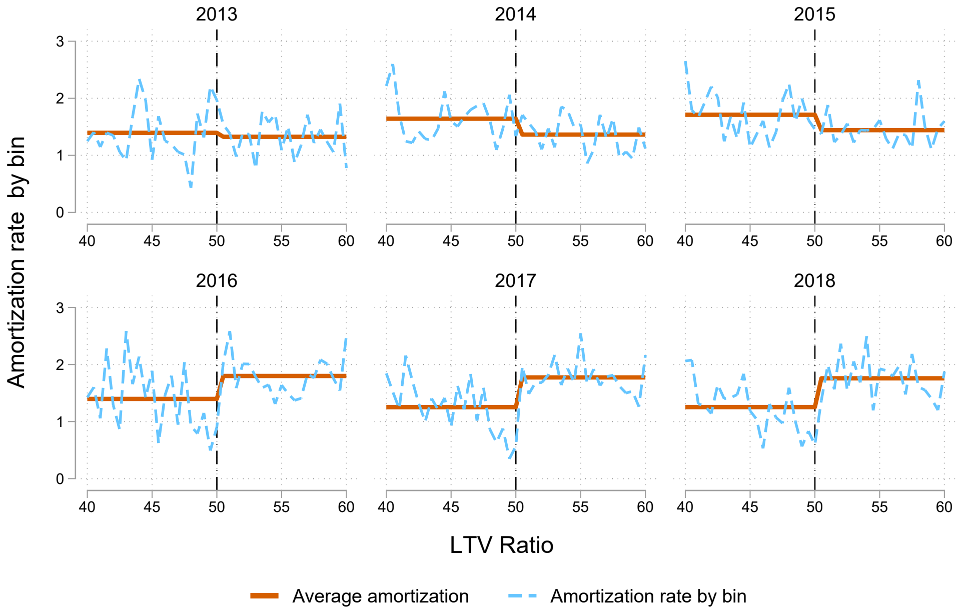


Figure 10: Amortization rate by year and LTV ratio at lower threshold

Notes: The figure plots the average amortization rate by LTV bin (dashed blue line) and the average amortization rate (orange solid line) above or below the lower LTV threshold marked by the black dashed line.

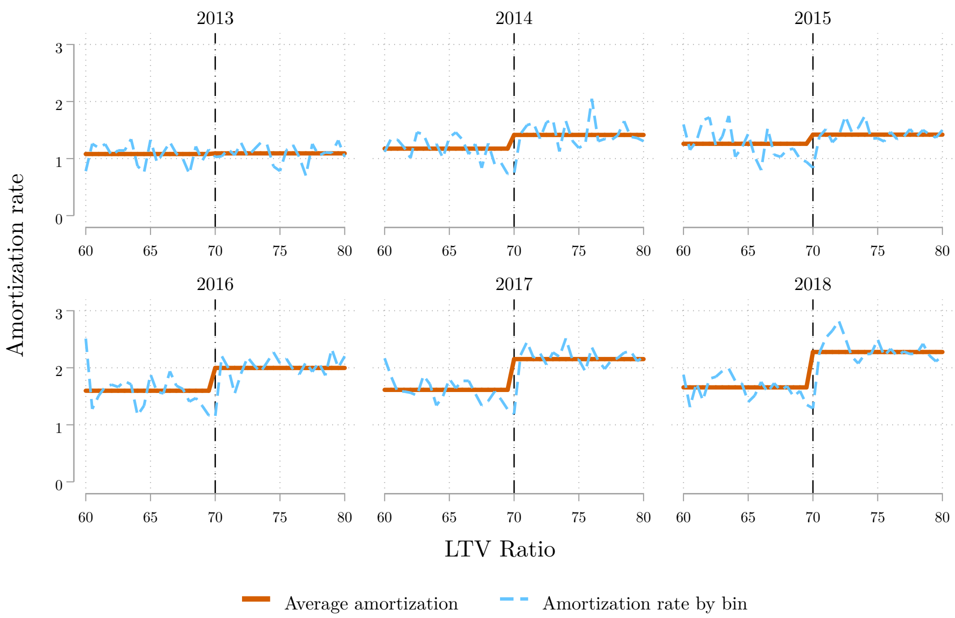


Figure 11: Amortization rate by year and LTV ratio at upper threshold

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 upper LTV threshold marked by the black dashed line.

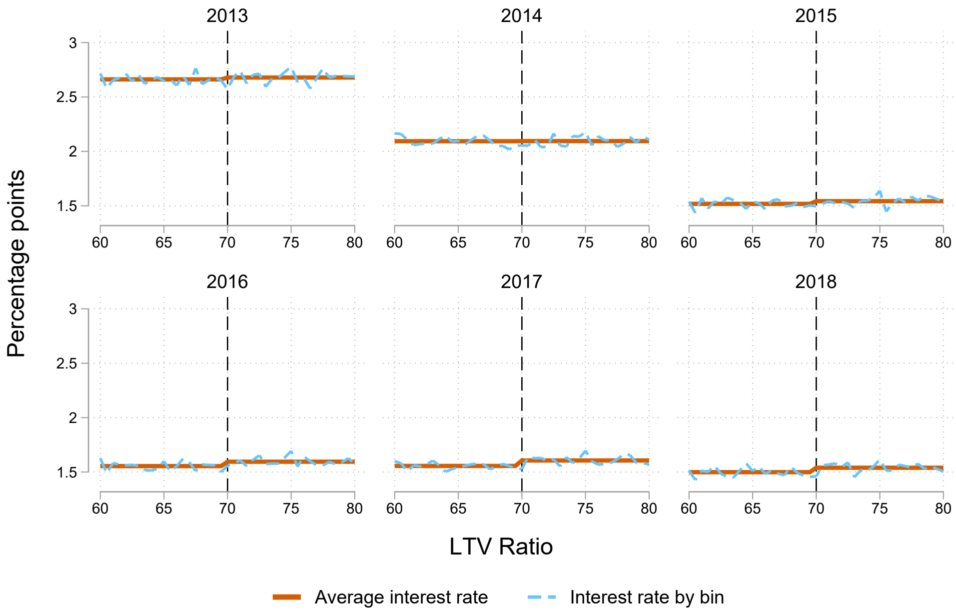


Figure 12: Interest rates by LTV ratio over time

Notes: The figure plots the average mortgage rate by LTV bin (blue dashed line) and the average mortgage rate above or below the upper LTV threshold marked by the black dashed line.

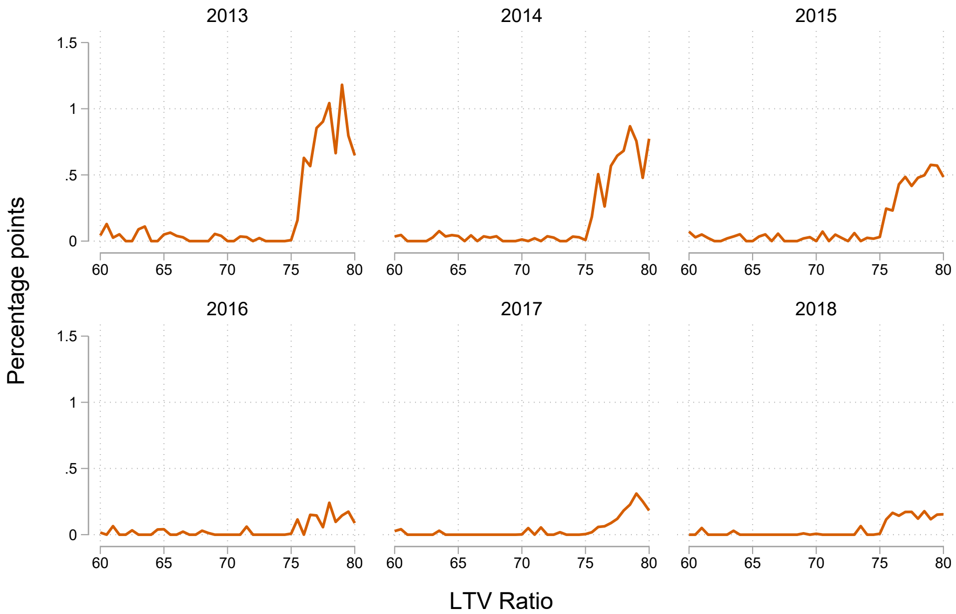


Figure 13: Difference between top and bottom interest rates

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.

C Appendix: Svensson's model

This appendix presents some details of Svensson (2016)'s model. Households choose consumption, debt and savings in each period, plus constant housing, to maximize their intertemporal utility. Formally,

$$\max_{c,L,s,h} U = \sum_{t=1}^{T} \beta^{t-1} \ln\left(c_t^{1-\theta} h^{\theta}\right) \tag{9}$$

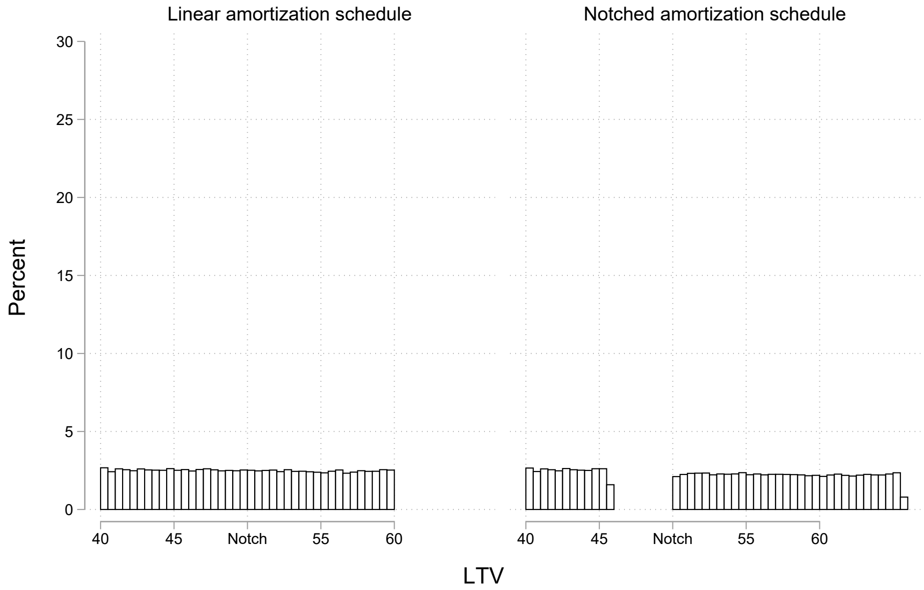
$$\begin{aligned}
\text{s.t. } c_1 + s_1 + ph &\leq A_0 + L_1 + y_1 \\
c_t + s_t + \delta ph &\leq L_t + y_t + (1 + r^s)s_{t-1} - (1 + r^L)L_{t-1}, t = 2..T \\
A_T &\leq (1 + r^s)s_T + (1 - \delta)ph - (1 + r^L)L_T \\
L_t &\leq L_{t-1} - \alpha L_1, t = 2..T
\end{aligned}$$

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 either a linear schedule, where the amortization rate is constant, or a notched schedule, where the amortization rate jumps when initial debt L_1 exceeds the threshold $ph\overline{LTV}$. The setup thus corresponds to the situation around the situation around the 70 LTV threshold, where required amortization payments below the threshold are positive but exhibit a jump above the threshold.

Figure 14 plots the LTV distribution that follows from Svensson's framework. With a linear amortization schedule, the LTV distribution is uniform.

Figure 14: LTV distribution from Svensson's model



Notes: The figure plots the LTV distribution using simulated data from the model of Svensson (2016), see section C 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 $(120, 280)$.

With a notched schedule, however, the LTV distribution features missing mass to the *left* of the notch, and a smooth distribution to the right of the notch. In other words, there is no bunching with the model from Svensson (2016). This is in sharp contrast to the prediction of the model in section 3.1. The LTV distribution from that model (Figure ??) has missing mass to the *right* of the notch, and a large spike exactly at the notch.