# The Amortization Elasticity of Mortgage Demand

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**Abstract**

We study how amortization payments affect household borrowing exploiting notches in the Swedish amortization requirement. We argue that amortization payments are costly for borrowers under a number of scenarios, and that they therefore affect credit demand. We provide causal evidence that a percentage point increase in amortization payments reduce LTV ratios by 2-3 percentage points, implying a sizable amortization elasticity of mortgage demand. Borrowers who seek to avoid making payments generally have higher debt, higher income and higher debt-to-income ratios. On the aggregate level, credit growth falls sharply after the introduction of the amortization requirement.

*JEL Classification: G51, G21, E21, E6*

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# 1 Introduction

Lower amortization payments were a common feature of mortgage product innovations during the run-up to the Great Recession. For example, interest-only mortgages, negative amortization mortgages or balloon mortgages all feature zero amortization payments in the first years after origination. Justiniano *et al.* (2017) report that 44 percent of mortgages were either Interest-only, Balloon or Option ARM in 2005, having grown from 2 percent of origination in 2000.[1] Yet the role of amortization payments in the household leverage crisis has received considerably less attention than the mortgage interest rate, the relaxation of credit standards or the expansion of subprime mortgages.

The focus on the actual costs associated with borrowing is natural. Only costs or credit frictions should affect how much households borrow, 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 amortization payments can be costly for a number of reasons and, as such, should affect credit demand. As one of several examples discussed below, forcing a young household with growing income to amortize may cause a sub-optimally high savings rate, a utility cost in any standard model of consumption. Consequently, amortization payments should affect credit demand.

We document considerable bunching in response to non-linear jumps in amortization payments, evidence consistent with the idea that amortization payments are costly for borrowers. 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. For example, the amortization rate jumps from 0% to 1% of the entire mortgage at an LTV ratio of 50 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

[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.

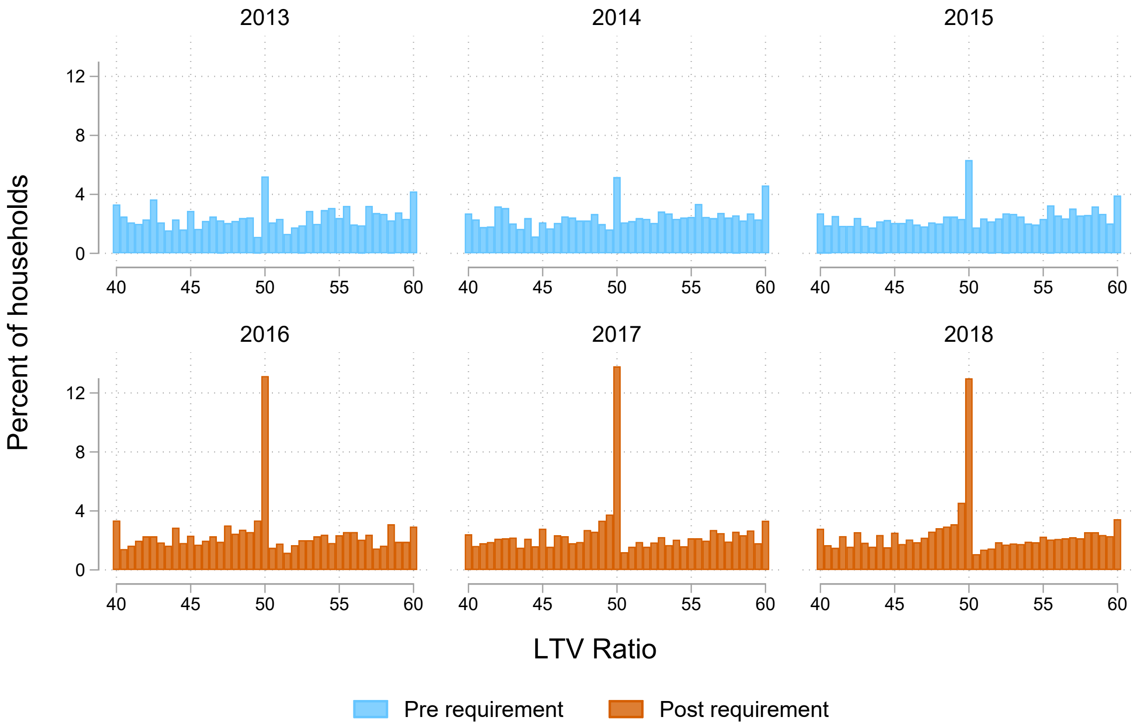



Figure 1: Number of borrowers by LTV ratio year-by-year

*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.

in the context of mortgage markets by DeFusco & Paciorek (2017) and Best *et al.* (2020). Intuitively, this 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, this notch should not affect how much households borrow. If amortization payments are in fact costly, the policy would induce some borrowers to reduce their borrowing from just above the LTV threshold to the threshold to avoid higher payments. This is precisely what we find: Our preferred specification indicates that 7.5 percent of borrowers place themselves at the 50% LTV threshold because of the higher amortization payments. The corresponding number for the 70% LTV threshold is 12.9 percent of borrowers. We thus provide new, causal, evidence that higher amortization payments affect household borrowing, what we call the "amortization elasticity of mortgage demand".

The identification strategy and main results are easily illustrated in Figure 1. The Swedish amortization requirement states that new borrowers must amortize at least 1 percent per year of *the entire mortgage* if the initial loan-to-value ratio exceeds 50 percent (lower threshold), and at least 2 percent per year when the LTV ratio exceeds 70 percent (upper threshold). The requirement thereby creates a discontinuous jump in mortgage payments for mortgages just above the thresholds. Focusing on the lower of the two thresholds, Figure 1 plots the number of borrowers in LTV bins in the pre- and post-requirement years. Prior to the introduction of the requirement in 2016, there is only a small spike at the LTV ratio of 50. Once the requirement is introduced, however, a large number of 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. The spike is 2.5 times as large as what we would expect based on previous years, and shows that higher amortization payments leads to lower household borrowing. Consistent with bunching, the fraction of borrowers just to the right of the threshold diminishes after the requirement, creating missing mass in the distribution of LTV ratios.

In our empirical strategy, we formally estimate the amount of bunching using pre-requirement years to form counter-factuals. We thereby account for the small spike at the threshold prior to the requirement and avoid the standard parametric assumption when estimating the counter-factual 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 counter-factual. 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 investigate whether higher interest rates at the threshold cause bunching, but find flat interest rates around the notch for all years in our sample. We also discuss collateral assessments, bank incentives and LTV dynamics around the thresholds, but argue that none of these are likely to explain our results. Moreover, we argue that higher salience because of the requirement cannot explain the empirical facts that we observe, as salience would imply bunching from above and *below*.

At both thresholds the marginal buncher reduces leverage by 2.5 percentage points, which translates into an elasticity of amortization rate to household leverage of 0.25 percentage points. These results are in general more conservative compared to the parametric counter-factual, and are robust to different specifications. A one percentage point higher amortization rate therefore reduces leverage by 0. 25 percent. In particular for the threshold at 70, this is a conservative estimate. Prior to 2016, the Swedish Bankers' Association recommended that households amortize on the part of the mortgage with an LTV above 70. 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 in the estimates. Specifically, if households were already placing themselves at this threshold because of the recommendation, our pre-reform distribution will already include bunching, which will lower the estimated effect at the upper LTV threshold. At the lower 50% LTV 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% of households that choose an LTV ratio of exactly 50% make only interest payments. [2] We find that borrowers who choose an LTV ratio of exactly 50 and chose not to amortize have higher debt, higher income and higher debt-to-income ratios compared to borrowers that choose an LTV ratio of exactly 50 but still amortize. These households deliberately make a larger down payment to free up monthly cash flows after origination.

While it is possible that confused borrowers simply mistake amortization payments for interest payments, there are several conventional reasons why borrowers may wish to

[2]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".

reduce their amortization payments. First, if forced amortization payments are higher than the desired savings rate, this represents a utility cost in any standard consumption model. For a young household with growing incomes, for example, a mortgage without amortization payments allows for better consumption smoothing (Cocco, 2013; Piskorski & Tchistyi, 2010). This reasoning also applies to older or retired households that wish to live off their savings – amortizing forces them to accumulate wealth through savings, in a period when they may wish to decumulate wealth. Second, amortization payments force the household to save in a specific asset, the mortgage, that is illiquid and has a low rate of return. This is a cost to households that instead wish to save in riskier assets with a higher expected rate of return, or have a preference for more liquid or diversified savings (Cocco, 2013). Third, the borrower may wish to pay down more expensive debt first. Fourth, amortizing also reduces the tax-shielding effect of mortgage debt deductability, again a potential cost. Fifth, mortgages without amortization payments are valuable for households who wish to speculate on higher house prices (Garmaise, 2013; Barlevy & Fisher, 2020). In the Swedish setting, full recourse mortgages with lifetime garnishing reduces the incentives to speculate-and-default, but we note that it would apply in other countries, such as the United States. Finally, the borrower may face credit constraints related to mortgage payments. In Sweden, this takes the form of a "discretionary income" calculation that acts similar to a payment-to-income constraint (Greenwald, 2017; Kaplan *et al.*, 2020; Gorea & Midrigan, 2017; Grodecka, 2020). Borrowers need to have a certain amount of income left over after paying housing and mortgage expenses. Crucially, amortization payments are a part of this calculation in Sweden. By reducing amortization payments, the borrower can alleviate credit constraints. In sum, amortization payments are not a cost if the borrowers wishes to save by paying down the mortgage, and if the amount that they are forced to amortize coincides with the amount that they wish to save. Otherwise, any of the above reasons could cause borrowers to bunch in our setting.

An amortization requirement could, however, also lead to *higher* borrowing (Svensson, 2016). An unconstrained borrower could achieve their optimal consumption path by simply increasing borrowing in response to higher required amortization payments, invest the excess amount in a savings account, and make amortization payments from this savings account. We show, however, that such behavior would imply missing mass *below* the upper threshold and no bunching at the threshold, which is not supported by the data. Moreover, this argument implies that credit growth would *increase* following the requirement. We show instead that credit growth declined dramatically once the requirement was introduced. This aggregate-level fact is consistent with households reducing their borrowing in response to the requirement throughout the LTV distribution, implying that the effect that we locate is not a local effect just around the thresholds.

In conclusion, our main contribution is to provide credible and novel evidence that a sizable amortization elasticity exists. 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 a 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.* (2018), who analyze a model where the option to stop amortization payments in a recession helps stabilize consumption and reduces the interest rate. Looking backwards, our results are relevant for understanding the role played by mortgage innovation that lowered amortization payments, in the run-up to the financial crisis in the United States. 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.[3] 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; Favilukis *et al.*, 2013), our results suggest that the increased availability of non-traditional mortgages with lower amortization payments can make up at least a part of the unexplained increase in debt and house prices.

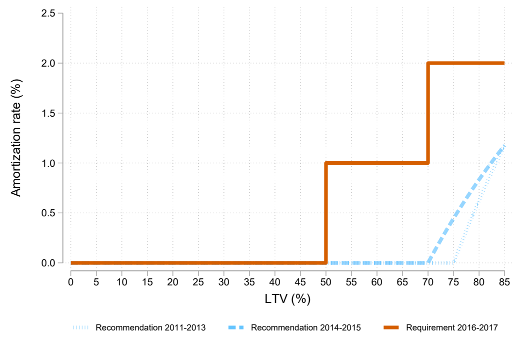
[3] See Dokko *et al.* (2019) and Bäckman & Lutz (2018, 2020) for the impact of such products on house prices, and Bäckman & Khorunzhina (2019) for the impact of IO mortgages on consumption.

As these types of products were popular among prime borrowers with high income levels and credit scores (Amromin *et al.*, 2018), this also provide a potential explanation for the proportional increase in mortgage debt across the income distribution documented in Foote *et al.* (2016) and Adelino *et al.* (2016). If lower amortization payments leads to more borrowing and high income households use such products, this potentially provides an explanation for the rise in household debt for high income borrowers that is unrelated to house price expectations (see Foote *et al.*, 2016; Adelino *et al.*, 2016). Finally, regulators in several countries have recently used higher amortization payments as a macroprudential tool. Our results therefore also contribute to the expanding literature on the effect of macroprudential policies (e.g. Cerutti *et al.*, 2017; Kuttner & Shim, 2016; Bernstein & Koudijs, 2020; Laufer & Tzur-Ilan, 2019; Van Bekkum *et al.*, 2019; Peydró *et al.*, 2020; Han *et al.*, 2020).

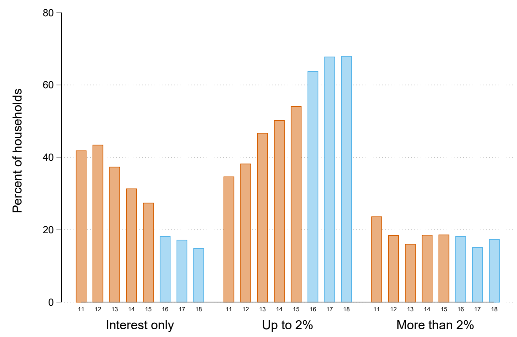
## 2 The Amortization Requirement

The Swedish amortization requirement mandates that all mortgages issued after June 1st 2016 above 50% LTV have to be amortized. Mortgages with LTV ratios of 50% or lower are exempt. The Swedish Financial Supervisory Authority (*Finansinspektionen*) introduced the amortization requirement to reduce debt levels over time in order to limit perceived macroeconomic risks posed by high 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 De-




a) Required Amortization Rates by Period




b) Actual Amortization Rates by Year

Figure 2: 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.

cember 2015, and the law went into effect in June 2016.[4] 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.

The requirement, along with the previous recommendations from the SBA, is summarized in panel a) of Figure 2. Prior to 2016, the SBA recommended that highly levered loans be amortized starting from LTV ratios of 75 (2011-2013, blue line) and 70 (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 2 percent per year on any mortgage where the LTV exceeds 70 percent. The value of the collateral is decided by the bank giving out the mortgage based on market values. Since continuous revaluation of property values could have pro-cyclical effects, the law mandates that the valuation can only be made every 5 years. Moreover, any revaluation 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

[4]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.

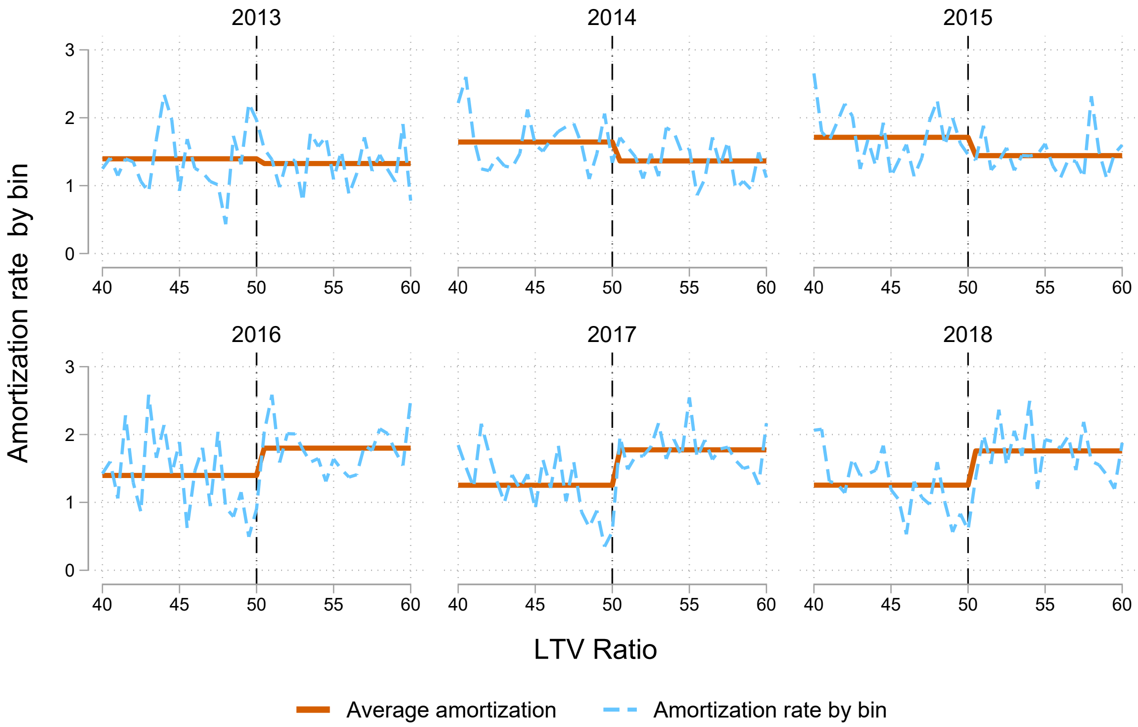



Figure 3: Amortization rate by year and LTV ratio

*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 threshold at LTV of 50% marked by the black dashed line.

can be granted an exception to the requirement due to extenuating circumstances. These exceptions have to occur after the origination of the loan. For instance, an exception can be granted by the mortgage bank in case of unemployment, illness or a death in the family. Due to the spread of the Corona-virus in 2020, the FSA allowed all bank to make exceptions to the requirement for all borrowers until June 2021.[5]

The requirement had a large impact on amortization rates. Panel b) in Figure 2 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 an effect of the amortization requirement.

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

Figure 3 provides an alternative illustration of the effect of the requirement. The figure shows that amortization payments around the 50% LTV threshold changed in the post-requirement years: the amortization rate exhibits a sharp decline just below threshold only in the post-requirement years. For example, the average amortization rate for mortgages issued in 2016 with an LTV ratio of 49% equals 0.5% (the dashed blue line), compared to an average rate of 1.2% for all LTV levels between 40 and 50 (the solid red line). This suggests that borrowers are placing themselves at the threshold to avoid making amortization payments. A figure plotting the amortization rate around the 70% LTV threshold is available in figure 12 in the appendix.

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 labour income. Several Swedish banks use a system where the part of the mortgage with an LTV above 75 has a higher interest rate (a so-called "top loan").[6] This creates a higher marginal interest rate for LTV values above 75.

Swedish banks are required to assess the borrower's financial status, including their ability to pay the cost for borrowing. 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 works as a payment-to-income constraint, is calculated using a stressed interest rate to ensure that the borrower can afford higher payments. 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

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

the LTV threshold 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 mainly derived from standard models in economics and finance and provide rational explanations for why households may choose 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.

## 3.1 Why are amortization payments costly?

Why are amortization payments costly? First, amortization payments may lead to suboptimal saving rates. In life-cycle models of consumption, 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. Required amortization payments induces 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, Kuchler (2015) finds that Danish households with interest-only mortgages save less, and Bäckman & Lutz (2018) report that a large fraction of borrowers above the retirement age in Denmark use an amortization-free mortgage. Essentially, not all rational households want to save, and by placing at the threshold borrowers can achieve a lower savings rate and higher consumption. This increase in consumption can also be in the form of a larger house (Corbae & Quintin, 2015).

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, 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 own 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 in order to have a lower level of commitment. Households with higher temptation needs can always amortize more than the requirement stipulates. Consistent with this theory, we later show in Figure 2 that the share of households amortizing more than 2 percent a year is not affected by the requirement.

Fourth, 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 and housing expenses. Importantly, amortization payments are included under housing expenses, and thereby act as a direct constraint on borrowing. In practice, this calculation functions like a payment-to-income constraint (Grodecka, 2020), where payments comprise both interest and amortization payments. Borrowers facing binding constraints may be unable to borrow more because of the discontinuous jump in mortgage payments above the leverage threshold. Finally, maintaining a high debt level leads to higher mortgage interest deductions, which may reduce the tax burden.

It is also worth noting that interest-only mortgages are beneficial for borrowers who wish to speculate on rising house prices (Barlevy & Fisher, 2018). By maintaining high debt levels, a borrower who does not amortize keeps the default option high. In our case, this channel is limited by enforced full recourse mortgages, which removes the option for 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. 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). Here, the argument is that an (unconstrained) borrower can simply borrow more than necessary to pay for the home, invest the 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 thus leverage will be higher. Svensson (2016) shows that this holds even when the interest rate on savings is below the interest rate on debt. We shall return to this below, where we show that the implied distribution of LTV ratios will be very different from the empirical distribution in our data.

## 3.2 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 responds to a notch in the amortization payment schedule. In reference to the channels above, the model provides intuition for 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 coincide, 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 $\alpha L$. 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:

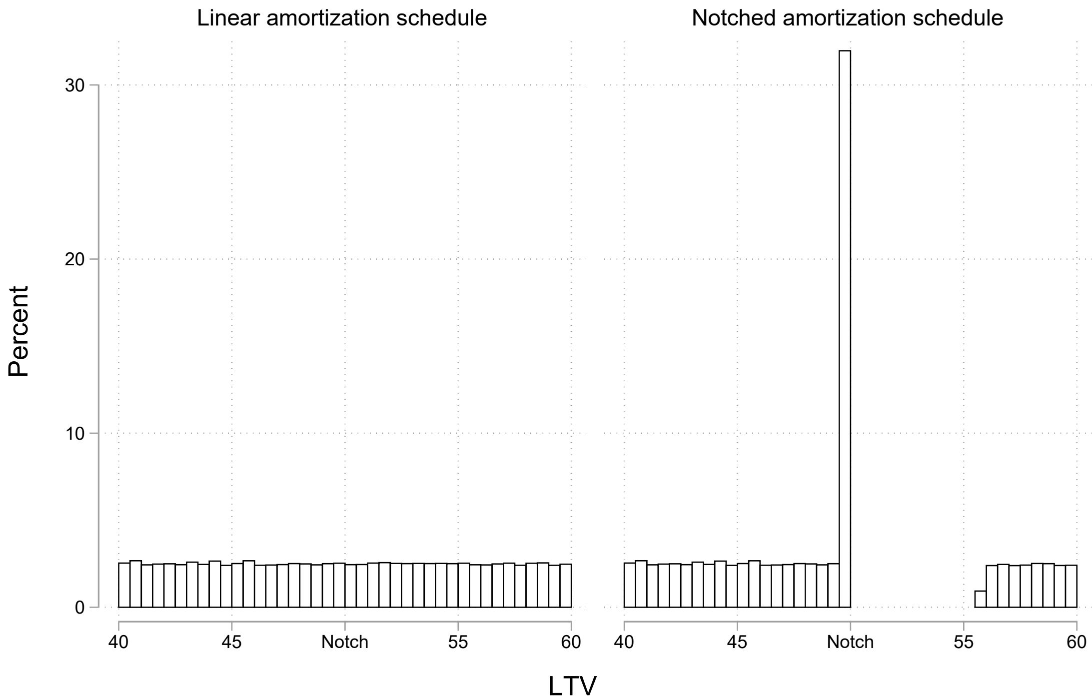
$$\begin{aligned} \max_{c_1,c_2,c_3} U(c_1,c_2,c_3) &= u(c_1)+\beta u(c_2)+\beta^2 u(c_3) \\ \text{s.t. } c_1+p &= A_0+L+y_1 \\ c_2 &= y_2-(r+\alpha)L \\ c_3 &= y_3+p-(1+r)(1-\alpha)L \\ 0 &< L < p \end{aligned} \tag{1}$$

We assume that households in the population are identical in all respects 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:

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

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 4 depicts this distribution.[7] Under the notched schedule, however, the amortization rate increases by $\Delta\alpha$ whenever the households' 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 4 shows the LTV distribution with a notched schedule, which we denote $g_{notched}(LTV)$. Comparing the left and right panel of Figure 4, the right panel is characterized by a spike

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 $(0.75, 1.2)$.

at the threshold, and a missing mass to the right of the threshold, whilst being identical

[7] Figure 4 is generated assuming uniformly distributed initial wealth levels and log per-period utility.

to the left of the notch. We can calculate the number of households bunching at the threshold as:

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

where the approximation assumes a constant density at the notch. Equation 2 implicitly defines $\Delta LTV$ 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 beyond 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 $\Delta LTV$ :

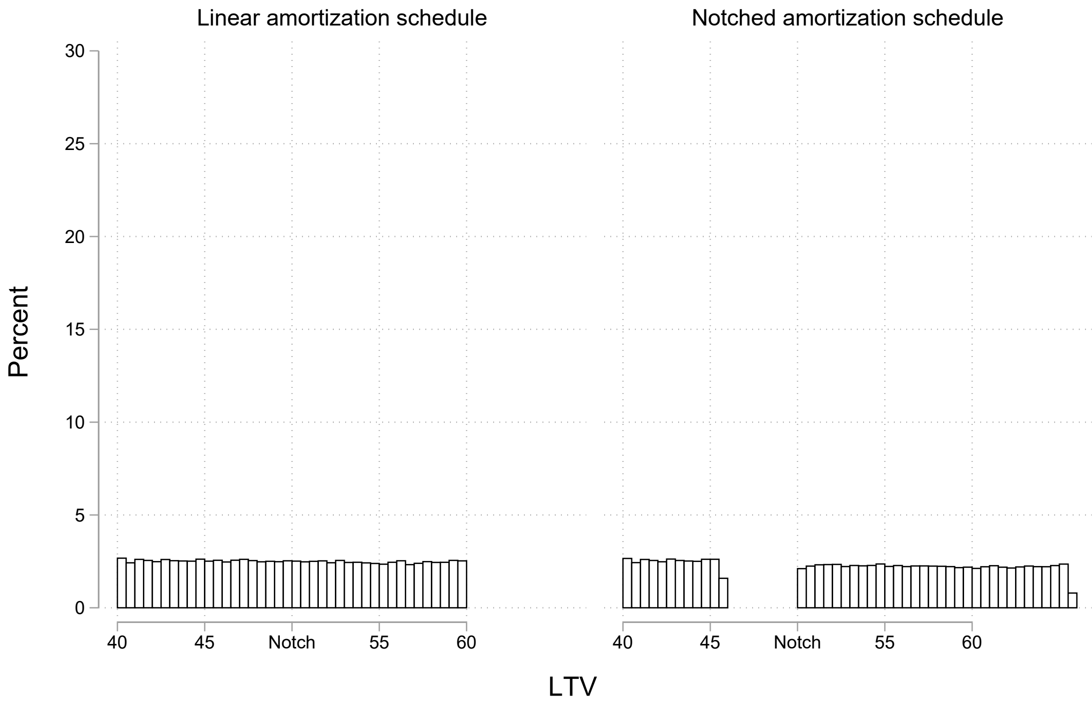
$$\Delta\widehat{LTV} = \frac{\widehat{B}}{\widehat{g_{linear}}(\overline{LTV})} \tag{3}$$

The above equation shows the intuition behind our identification strategy. With an estimate of both the amount of bunching $\widehat{B}$ and the counter-factual density around the notch $\widehat{g_{linear}}(\overline{LTV})$, we can calculate the behavioral response $\Delta\widehat{LTV}$, the reduction in leverage induces by the amortization requirement. The reduction in leverage that we estimate will then provide an intensive margin response around the notch, and we can relate this response to the marginal amortization rate implied by the notch to calculate an elasticity of amortization payments to mortgage demand.

### 3.3 Alternative theoretical framework

In our stylized model, households just above the threshold optimally choose to borrow less under a notched amortization schedule. Leverage therefore decreases. This prediction is in contrast to the model in Svensson (2016). As alluded to above, in Svensson's framework, households would instead increase their (gross) leverage by investing the additional borrowing in a savings account. Amortization payments are made out of the

Figure 5: LTV distribution from Svensson's model




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

savings account.

Figure 5 shows the LTV distribution under either amortization schedule that follows from Svensson's framework (for details, see section D in the appendix). Again, all households in the simulation are identical except for their initial wealth, which is uniformly distributed. As a result, with a linear amortization schedule, the LTV distribution is uniform as well. 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. This is very different from the LTV distribution in figure 4, where there is missing mass to the *right* of the notch, and a large spike exactly at the notch. In other words, there would be no bunching in Svensson's model, in contrast to our empirical findings.

# 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 8 largest banks as part of its micro- and macroprudential mandate. It 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 afterwards, in order to surprise the banks and prevent them from applying different credit standards during these survey dates. [8] The survey includes household-level data on (gross and disposable) incomes, total debt divided into secured and unsecured loans and certain household characteristics. The data also included detailed loan-level data, including 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.

## 4.1 Summary statistics

Table 1 provides summary statistics. Borrowers in our sample are approximately 40 years old with an average household size of 2.19. A majority of them live in an urban area (Stockholm, Gothenburg and Malmö are classified as urban areas and make up 45 percent of our sample). The average disposable income is 43,310 SEK per month, which corresponds to approximately $5,000 per month. In comparison, the average pre-tax income in 2017 in Sweden was 33,700.[9] The average house value is 2.86 million SEK. Average total debt was 2.13 million SEK, where a majority is mortgage debt, and the

[8] 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 early October. To the extent the chosen days are representative for the rest of the year, the sample is representative for the flow of new mortgage loans.

[9] See Statistics Sweden - medellöner i Sverige.

Table 1: Summary Statistics

| | (1) Full Sample | (2) Urban | (3) Rural |
|---|---|---|---|
| **Demographics** | | | |
| Main borrower age | 43.27 | 42.22 | 44.12 |
| | (14.65) | (13.85) | (15.21) |
| Household size | 2.19 | 2.20 | 2.18 |
| | (1.14) | (1.14) | (1.14) |
| Stockholm | 0.28 | 0.63 | 0.00 |
| | (0.45) | (0.48) | (0.00) |
| Gothenburg | 0.10 | 0.22 | 0.00 |
| | (0.30) | (0.41) | (0.00) |
| Malmo | 0.07 | 0.15 | 0.00 |
| | (0.25) | (0.36) | (0.00) |
| Rest | 0.55 | 0.00 | 1.00 |
| | (0.50) | (0.00) | (0.00) |
| Real disposable income, KSEK | 42.31 | 46.68 | 38.76 |
| | (29.55) | (37.97) | (19.61) |
| **Loan sizes** | | | |
| Total debt, MSEK | 2.13 | 2.79 | 1.59 |
| | (1.75) | (1.98) | (1.32) |
| Mortgage debt, MSEK | 1.73 | 2.33 | 1.24 |
| | (1.33) | (1.50) | (0.93) |
| House price, MSEK | 2.86 | 3.97 | 1.95 |
| | (2.38) | (2.76) | (1.50) |
| **Interest Rates** | | | |
| Mortgage rate | 1.63 | 1.53 | 1.71 |
| | (0.30) | (0.28) | (0.30) |
| Mortgage fixation period (months) | 12.17 | 10.86 | 13.24 |
| | (15.64) | (14.20) | (16.64) |
| Adjustable rate mortgage | 0.67 | 0.69 | 0.66 |
| | (0.47) | (0.46) | (0.47) |
| **Amortization** | | | |
| Mortgage amortization, KSEK | 2.24 | 2.64 | 1.92 |
| | (2.15) | (2.55) | (1.69) |
| Mortgage amortization rate | 1.92 | 1.45 | 2.30 |
| | (2.42) | (1.54) | (2.89) |
| Mortgage amortization to income | 5.52 | 6.00 | 5.13 |
| | (4.39) | (4.85) | (3.93) |
| **Mortgage Characteristics** | | | |
| Loan to value | 65.71 | 63.64 | 67.40 |
| | (21.82) | (21.83) | (21.67) |
| Total debt to income | 409.21 | 501.32 | 334.63 |
| | (215.12) | (208.04) | (190.45) |
| Mortgage debt to income | 372.36 | 464.75 | 297.57 |
| | (207.74) | (204.35) | (178.28) |
| Net interest to income | 4.55 | 5.31 | 3.93 |
| | (2.34) | (2.31) | (2.17) |
| Debt service to income | 11.29 | 12.24 | 10.51 |
| | (6.67) | (6.87) | (6.41) |
| N | 33,384 | 14,936 | 18,448 |

*Notes:* The table reports summary statistics. Column 2 and 3 splits the sample into Urban and Rural households. Urban areas are defined as XXX and Rural areas are defined as XXX. Demographic variables include the main borrower age, household size and indicators for location. *Real 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, MSEK* is the collateral value in millions of SEK, which in most cases is based on bank's internal valuations of properties. 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 is equal to zero, i.e. if the mortgage interest rate is fully floating. *Mortgage amortization, KSEK* is the monthly amortization payments 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* and *Mortgage debt to income* are calculated as total debt and mortgage debt divided by disposable income. *Net interest to income* is calculate interest payments in SEK divided by disposable income. *Debt service to income* is calculated as the sum of interest payments and amortization payments, divided by disposable income.

average mortgage rate was 1.63 percent.

Swedish borrowers can fix the interest rate for a number of years, although the fixation period is substantially shorter than in for example the United States. The average fixation period in our sample was 12 months, and a majority (67%) of the sample had an adjustable rate mortgage with no fixation period. The average mortgage amortization payment was 2,240 SEK, which corresponds to 1.92 percent of the mortgage or 5.52 percent of disposable income. The average LTV ratio is 66 percent, the average borrower had a total debt-to-income ratio of 409 and a mortgage debt to income ratio of 372. Finally, the net interest to income and debt service to income ratios are both low, at approximately 2.5 and 11 percent of income, respectively. Debt service to income is the sum of interest and amortization payments divided by disposable income, and is used to assess credit worthiness. This number understates the evaluated debt-service-to-income ratio, as banks use a stressed interest rate instead of the actual interest rate reported in the table.

## 4.2 Empirical Strategy

We now describe our approach to estimating the counter-factual distribution and the amount of bunching induced by the amortization requirement. Based on section 3.2, 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 counter-factual distribution - the distribution that would have occurred in the absence of the amortization requirement. In our case, the pre-requirement distribution features large spikes at LTV ratios of 50 and 70 percent make the standard polynomial approach to estimating the counter-factual undesirable.[10] In our main analysis we address this issue with a *difference-in-bunching* estimate, where the distribution observed in the years prior to the requirement will serve

[10]The standard approach to estimate this counter-factual 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 counter-factual distribution is smooth over all values of the running variable. See Kleven (2016) for a review of the bunching literature, and Appendix C for an overview of this approach.

as the counter-factual distribution in the post-requirement years. The goal is to estimate the counter-factual fraction of borrowers in each LTV-bin $j$ in the post-requirement period had the amortization requirement not been introduced, denoted $\hat{n}_j^{post}$. We calculate standard errors for all parameters described below by bootstrap. Specifically, we draw random samples with replacement from the full sample of borrowers, re-calculate the LTV distribution and then 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. In words, no other change or policy 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 counter-factual 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 counter-factual distribution based on previous years would predict. Similarly but to the right of the threshold, the amount of missing mass is equal to:

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

The missing mass is equal to the difference between the observed and counter-factual distribution in the region to the right of the threshold. We use the difference between the missing mass and the bunching to back out the intensive and extensive effect of the requirement. 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. The extensive margin effect is therefore equal to the difference between the missing mass and the bunching estimate (DeFusco *et al.*, 2020).

We use these estimates to calculate the behavioral response to the requirement, $\Delta LTV$, using equation 3. The equation states that the response to the requirement by the marginal borrower, $\Delta LTV$, is equal to the amount of bunching $\widehat{B}$ divided by the counter-factual density around the notch. In the stylized theoretical model, $\Delta LTV$ 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 capture differences in incomes, discount rates, housing preferences, utility functions or some other variable. Equation 2 would then generalize to

$$B = \int_z \int_{\overline{LTV}}^{\overline{LTV}+\Delta LTV_z} g_{linear}(LTV, z) dLTV dz \approx g_{linear}(\overline{LTV}) E(\Delta LTV_z) \tag{6}$$

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, $E(\Delta LTV_z)$.

# 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 50 and 70 LTV thresholds. We then assess threats to our identification strategy, 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 graphically in Figure 6. The figure plots the observed distribution of loans by LTV value and the counter-factual distribution estimated from the bunching procedure around the notch at LTV ratios of 50. The estimation procedure uses LTV ratios up to 65 percent to avoid the upper threshold affecting the results. The y-axis shows the percent of loans in each bin, where each bin is 0.5 percentage point wide. The orange solid line plots the empirical distribution, i.e. the distribution in 2016-2018, and the solid blue line plots the counter-factual distribution. Standard errors from the bootstrap procedure are marked with dashed lines.

There are several key results in the figure. First, the counter-factual distribution fits the empirical distribution well up until a LTV ratio of 47.5, and again starting from an LTV ratio of 52. 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 threshold contains approximately 9 percent of borrowers, compared to around 3 percent in the same bin in the counter-factual density. We find 7.47 percent ($\hat{B} = 7.47$) more borrowers with LTV ratios between 48.5 and 50 percent in the post-requirement years compared to the pre-requirement years. [11] Dividing this bunching estimate by the counter-factual distribution, we find that the marginal buncher changes their LTV ratios by 2.57 percentage points 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 ($\hat{M} = -0.83$) less borrowers to the right of the notch in the post-requirement years compared to the pre-requirement years.This small 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]

[11] We choose $L = 48.5$ and $U = 51.5$ as our main specification (see equations 4 and 5), although our estimates of $\Delta LTV$, $B$ and $M$ are robust to changing these limits of the excluded area in either direction.

[12] For example, a household might choose an LTV ratio of 55%, whereas it (counter-factually) would have chosen an LTV of 60% had there been no notch. These households fill up the missing mass to the right of the notch.

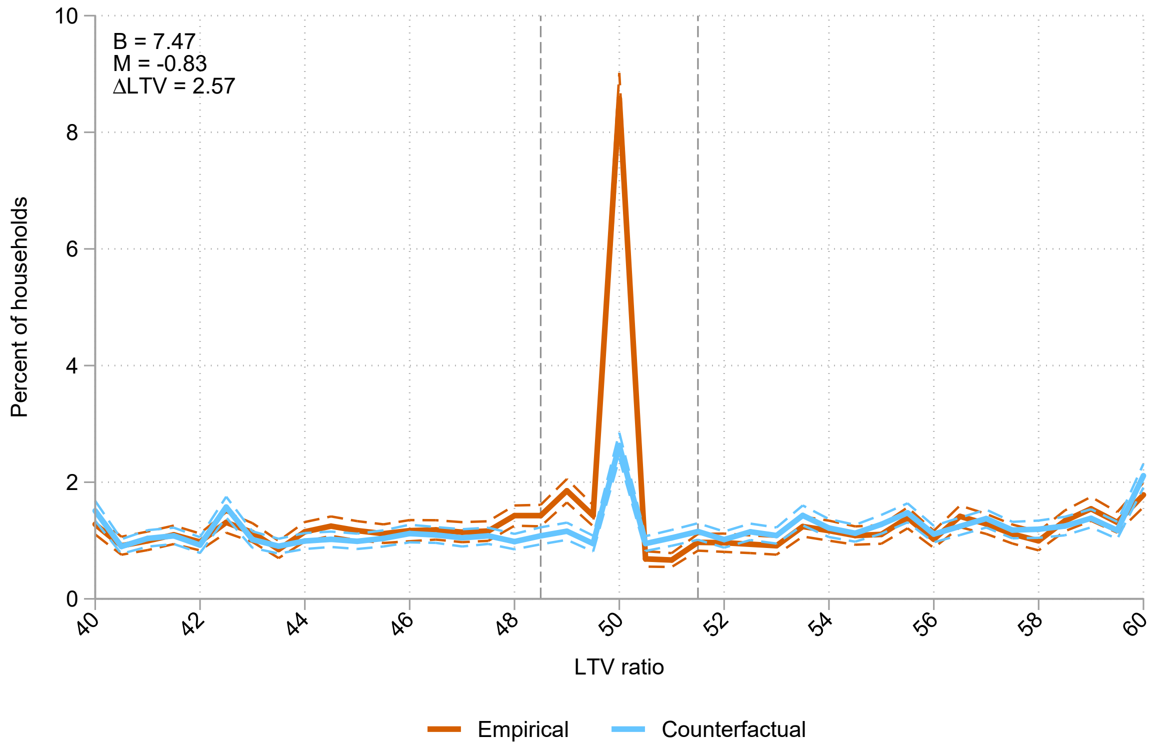



Figure 6: Bunching at LTV=50

*Notes:* The figure plots the empirical and counter-factual 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 solid orange line plots the empirical density, where each dot represents the fraction (count) of mortgages within each 0.5 percent LTV bin. The solid blue line plots the counter-factual density, estimated using the procedure described in Section 4.2. The figure reports the estimated percent of loans that bunch at the threshold (B), the missing mass (M) and the behavioral response by borrowers ($\Delta LTV$). The calculation of these numbers is described in Section 4.2. Standard errors are calculated using a bootstrap procedure and are plotted using dashed lines.

## 5.2 Bunching at the upper threshold

Figure 7 presents results for the upper threshold. Recall that there are a number of potential confounding effects relevant to this threshold. First, a previous, albeit less strict, recommendation that households amortize on the portion of the mortgage above 70 may lead some household to bunch at 70 in the pre-requirement years. This presents a potential source of downwards bias in our estimates, as borrowers may bunch even in the-requirement period. Second, several banks offer mortgages with a higher marginal interest rate on the part of the mortgage with an LTV above 75 (a so-called "top loan") . This incentive was phased out over time as banks abolished the top-loan system, but does provide an incentive to bunch at a nearby threshold in the years prior to the requirement. This implies that the marginal interest rate changes above LTV ratios of 75, and that

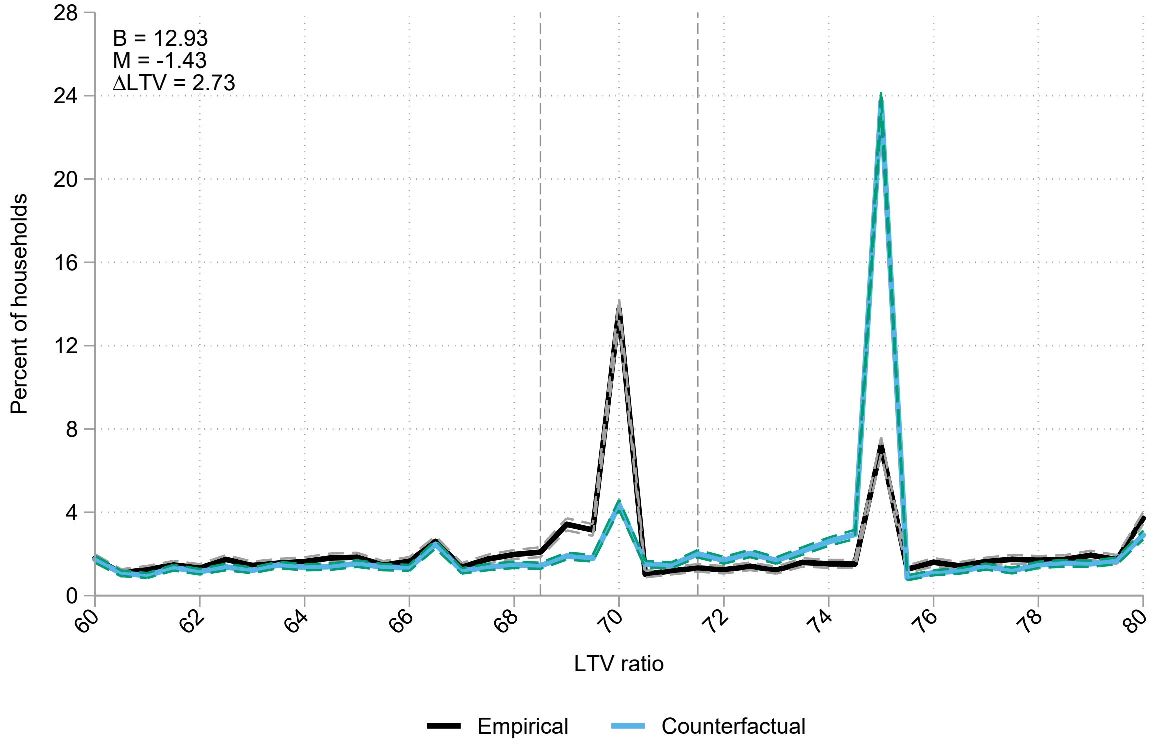



Figure 7: Bunching at LTV=70

*Notes:* The figure plots the empirical and counter-factual density of mortgage loans by LTV ratio. The solid black line is the empirical density, where each dot represents the fraction (count) of mortgages within each 0.5 percent LTV bin. The dashed blue line is the counter-factual density, estimated using the procedure described in Section 4.2. 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 ($\Delta LTV$). The calculation of these numbers is described in Section 4.2. Standard errors are calculated using a bootstrap procedure and are plotted using dashed lines.

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 7. Figure 14 in the appendix shows, however, that the interest rate differential between the top and bottom loan only comes into effect at the 75 threshold. This presents a concern only insofar as it affects the incentives to bunch at 70. This concern does not apply to the lower threshold.

The results for the amortization threshold at LTV ratios of 70 is presented in figure 7. Similar to before, the figure plots the observed distribution using data from the post-requirement years, and the counter-factual distribution estimated using pre-requirement data. The estimation procedure uses data from LTV ratios of 60 until 80 to avoid the earlier requirement and the maximum LTV ratio affecting the results. There are two peaks in the figure, at LTV ratios of 70 and 75, respectively. For the black line, the empirical distribution in the post-requirement period, the peak is larger at the amortization requirement threshold of 70. Conversely, for the pre-requirement period the peak at 75 is considerably larger than the peak at 70. For lower LTV ratios, the empirical and counterfactual densities are almost identical, showing that the procedure is well able to approximate the distribution. In the post-requirement period, approximately 13 percent of borrowers have an LTV ratio of exactly 70. Overall, the bunching statistic $B$ show that 12.93 percent of borrowers decide to bunch. Dividing the bunching statistic $B$ by the counter-factual distribution at the threshold, we find that the marginal buncher reduces their LTV ratio by 2.73 percent due to the amortization requirement. This is marginally higher than the reduction in LTV ratios of 2.57 percent at the lower amortization requirement.

### 5.3 Bunching at higher interest rates

How does bunching due to higher amortization payments compare to bunching in response to higher interest rates? We answer this question using another feature of the Swedish mortgage market. As previously mentioned, certain Swedish banks used loan with higher interest rates for loans above LTV ratios of 75 during several years of our sample. The top loan system creates another threshold where borrowers may bunch.[13] Conceptually, this increase in the interest rate on the part of the mortgage above a certain threshold is different from the amortization requirement. The top loan system creates a *kink* in the interest rate, where the *marginal* interest rate increases discontinuously at the threshold. In contrast, the amortization requirements creates a *notch* in the amortization rate, where the *average* amortization rate increases discontinuously at the threshold. In other words, the interest rate kink applies to the portion of the mortgage above the threshold, whereas the amortization rate notch applies to the entire mortgage.

The empirical strategy that we used previously is no longer feasible, as either the top loan system or the amortization requirement was in effect for our entire sample period.

[13] Four out of eight banks had top loans at 75 percent LTV in 2011 and 2012, three banks had top loans in 2013-2015, two had top loans in 2016 and only one in 2017.

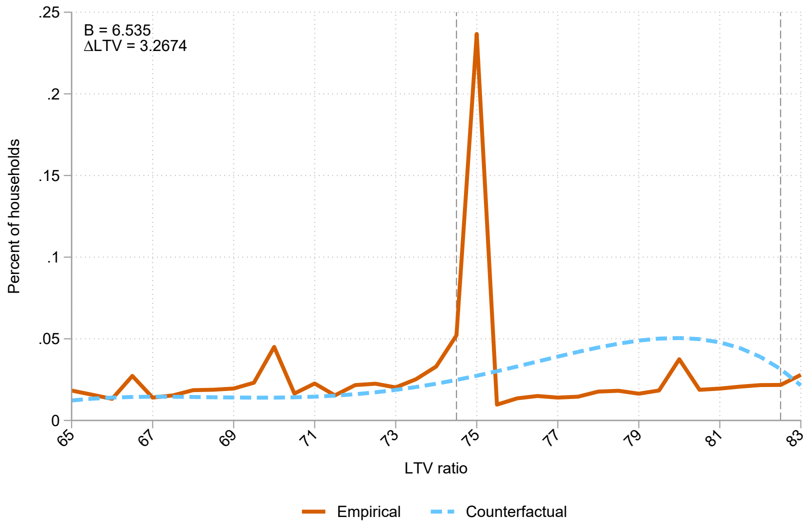



Figure 8: Bunching at higher interest rates

*Notes:* The figure plots the empirical and counter-factual distribution around the top loan threshold at LTV ratios of 75 for the pre-requirement years (2012-2015). The counter-factual distribution is estimated with the procedure described in Appendix C. The bin width is 0.5, and the counter-factual distribution is obtained using an 11th degree polynomial, omitting the area between 74 and 82 (marked by dashed lines). The figure reports the estimated number of bunched loans (B) and the behavioral response $\Delta LTV$.

We therefore use the standard approach of fitting a flexible polynomial. The procedure is described in more detail in Appendix C and has been used extensively in the literature (Chetty *et al.*, 2011; Kleven & Waseem, 2013; Kleven, 2016). Compared to the difference-in-bunching strategy we use before, the polynomial approach makes different identifying assumptions. In particular, the counter-factual distribution is assumed to be smooth over the bunching interval. Any bunching at the threshold must be because of the top loan feature, not due to some other factor. In practice, this makes it more difficult to control for round-number bunching, as we do not have previous years that we can use to construct the counter-factual.

With these caveats mind, figure 8 provides the results for the full sample in the pre-requirement period. There is a considerable amount of bunching around the LTV threshold of 75. The bunching statistic $B$ shows that 6.5 percent of borrowers decide to bunch, giving a corresponding reduction in LTV values because of the higher interest rate of 3.27. This response is larger than the response to both the lower and the upper amortization requirement.

### 5.4 Calculating Elasticities

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 payments 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. Following DeFusco & Paciorek (2017), define the implicit marginal amortization rate $\gamma^*$ for $LTV > \overline{LTV}$ as:

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

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

$$\gamma^* = \gamma + \Delta\gamma + \Delta\gamma \cdot \frac{\overline{LTV}}{(LTV - \overline{LTV})} \tag{8}$$

The equation shows that $\gamma^*$ 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 $\gamma = 0 + 0.01 + 0.01 \cdot \frac{50}{(51-50)} = 51$ percent. In our case, the behavioral response at the lower threshold was 2.57, giving us an implicit marginal amortization rate of $\gamma = 0 + 0.01 + 0.01 \cdot \frac{50}{(52.57-50)} =$ 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 reduced form elasticity of borrowing with respect to amortization payments is equal to:

$$e^{\gamma} = \frac{\Delta LTV}{\gamma^{*}(\overline{LTV} + \Delta LTV) - \gamma} \tag{9}$$

where we relate the change in the LTV ratio induced by the required to the implicit marginal amortization rate for the marginal buncher. Plugging in the estimates from the bunching estimates above and the marginal amortization rate, the semi-elasticity at the notch at LTV ratios of 50 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.[14]

### 5.5 Who seeks to avoid amortization payments?

While it is difficult to categorically state the reason for the observed bunching, borrower characteristics can at least give an indication of who decides to avoid amortization payments. Unfortunately we lack data on savings and investment decisions, meaning that we are unable to examine if households consume or save the lower payments. Nonetheless, it is useful to provide some statistics on which households decide to avoid payments. Table 2 provides such statistics for borrowers with an LTV ratio between 49 and 50.

The table divides borrowers who are at the threshold and who do not amortize (*Interest-only*), and borrowers who are the threshold but who still amortize (*Amortizing*). There

[14]The numerator is equal to the percent change in LTV ratios. With the estimated $\Delta LTV$ of 2.57 evaluated at the threshold of 50, the numerator is then equal to $2.57/50 = 0.0514$, and the denominator is equal to the implicit marginal amortization rate for the marginal buncher. Using the implicit rates from equation 8, the denominator is equal to $\gamma^{*} = 0 + 0.01 + 0.01 \cdot \frac{50}{(52.57-50)} = 0.204$, and the semi-elasticity is equal to $0.0514/0.204 = 0.25$.

Table 2: Conforming & Non-Conforming Borrower Characteristics

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Notch = 50 | | | Notch = 70 | | |
| | Interest-only | Amortizing | T-test | Interest-only | Amortizing | T-test |
| **Demographics** | | | | | | |
| Disposable income | 47.98 | 40.47 | -7.51 | 47.57 | 43.70 | -3.87 |
| | (56.56) | (20.77) | | (23.96) | (19.83) | |
| Main borrowers age | 49.27 | 46.92 | -2.35 | 41.57 | 42.72 | 1.15 |
| | (14.87) | (14.05) | | (12.81) | (12.63) | |
| Household size | 2.13 | 2.19 | 0.06 | 2.30 | 2.38 | 0.08 |
| | (1.12) | (1.19) | | (1.13) | (1.22) | |
| Stockholm | 0.39 | 0.24 | -0.15 | 0.38 | 0.25 | -0.13 |
| | (0.49) | (0.43) | | (0.49) | (0.43) | |
| Gothenburg | 0.13 | 0.10 | -0.03 | 0.15 | 0.11 | -0.05 |
| | (0.33) | (0.30) | | (0.36) | (0.31) | |
| Malmo | 0.08 | 0.04 | -0.04 | 0.07 | 0.07 | -0.01 |
| | (0.27) | (0.19) | | (0.26) | (0.25) | |
| Rest | 0.40 | 0.62 | 0.22 | 0.39 | 0.57 | 0.18 |
| | (0.49) | (0.49) | | (0.49) | (0.50) | |
| **Loan size and house value** | | | | | | |
| Total debt, MSEK | 2.59 | 1.68 | -0.91 | 2.94 | 2.25 | -0.69 |
| | (2.22) | (1.42) | | (2.06) | (1.68) | |
| Mortgage debt, MSEK | 1.91 | 1.37 | -0.54 | 2.39 | 1.90 | -0.49 |
| | (1.47) | (1.05) | | (1.56) | (1.39) | |
| House price, MSEK | 3.88 | 2.80 | -1.08 | 3.45 | 2.76 | -0.69 |
| | (2.99) | (2.16) | | (2.25) | (2.01) | |
| **Interest Rates** | | | | | | |
| Mortgage rate | 1.50 | 1.65 | 0.15 | 1.52 | 1.59 | 0.07 |
| | (0.29) | (0.31) | | (0.27) | (0.29) | |
| Fixation period | 10.45 | 11.73 | 1.28 | 11.87 | 11.99 | 0.12 |
| | (15.05) | (15.32) | | (14.57) | (15.47) | |
| Adjustable rate | 0.75 | 0.70 | -0.04 | 0.66 | 0.69 | 0.03 |
| | (0.43) | (0.46) | | (0.47) | (0.46) | |
| **Amortization** | | | | | | |
| Amortization, KSEK | 0.00 | 2.25 | 2.25 | 1.99 | 2.77 | 0.77 |
| | (0.00) | (2.12) | | (1.30) | (2.00) | |
| Amortization rate | 0.00 | 2.67 | 2.67 | 1.00 | 2.13 | 1.13 |
| | (0.00) | (2.72) | | (0.00) | (1.71) | |
| Amortization to income | 0.00 | 5.77 | 5.77 | 4.35 | 6.62 | 2.27 |
| | (0.00) | (4.46) | | (1.87) | (3.95) | |
| **Mortgage Characteristics** | | | | | | |
| Loan to value | 49.36 | 48.99 | -0.38 | 69.41 | 69.12 | -0.29 |
| | (0.88) | (0.99) | | (0.83) | (0.92) | |
| Total debt to income | 467.38 | 335.91 | -131.47 | 512.41 | 422.50 | -89.91 |
| | (230.83) | (192.56) | | (207.11) | (203.20) | |
| Mortgage to income | 420.66 | 309.25 | -111.41 | 476.19 | 389.64 | -86.55 |
| | (222.70) | (182.69) | | (205.03) | (193.31) | |
| Net interest to income | 4.79 | 3.73 | -1.06 | 5.36 | 4.58 | -0.78 |
| | (2.44) | (2.13) | | (2.17) | (2.20) | |
| Debt service to income | 4.81 | 10.74 | 5.94 | 10.50 | 12.26 | 1.76 |
| | (2.45) | (6.73) | | (4.14) | (5.84) | |
| N | 1,210 | 512 | 1,722 | 1,725 | 857 | 2,582 |

*Notes:* Summary statistics and t-test for different notches and groups. Sample consists of borrowers with LTV ratios of 49-50 percent in Columns 1-3, and of borrowers with LTV ratios of 69-70 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.

are 1,210 Interest-only borrowers and 512 Amortizing borrowers, giving an interest-only share of 70 percent. Those who do not amortize, i.e. those borrowers who conform to the requirement, have approximately 100,000 Euro higher debt and housing values, approximately 750 Euro higher monthly income, 130 percentage points higher DTI and half the debt service compared to households in the same LTV range who do amortize. Given the average income and mortgage size, moving just above the requirement implies an annual amortization expense of 19,100 SEK, (3.3 percent of income), and would naturally raise mortgage debt by 19,100 SEK. As we estimate that the marginal buncher reduces LTV by 2.5 percent to conform to the requirement, this implies that on the margin borrowers are willing to give up 47,750 SEK of mortgage debt for 19,100 SEK lower payments.

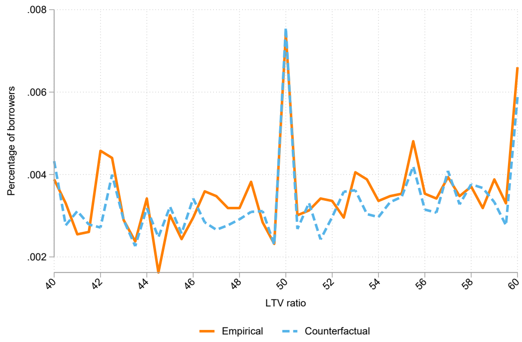
It is noticeable that there is considerable bunching even at relatively low LTV ratios. These borrowers have access to considerable amount of home equity, making it difficult to argue that they are facing leverage credit constraints. However, they can still face credit constraints related to payments, with the discretionary income limit applied in Sweden. Bäckman & Khorunzhina (2019) show that such payment constraint 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. Consistent with borrowers wishing to avoid payment-to-income constraints, borrowers who do not amortize have higher debt to income ratios, higher house value to income ratios and higher net interest to income ratios. Moving from 0 to 1 percent amortization would increase debt service from 4.8 to 8 percent of income. 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. This limit includes amortization payments. When evaluated with an interest rate of 6 percent , interest and amortization payments would sums to 23 percent of disposable income on average for the average borrower with a LTV between 49 and 50 who does not amortize.

Finally, households could confuse amortization payments and interest 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 4. However, that responding that amortization payments are costly is not the same as confusing them for interest payments. For example, amortization payments are costly if they enforce a higher savings rate than the household would chose themselves.

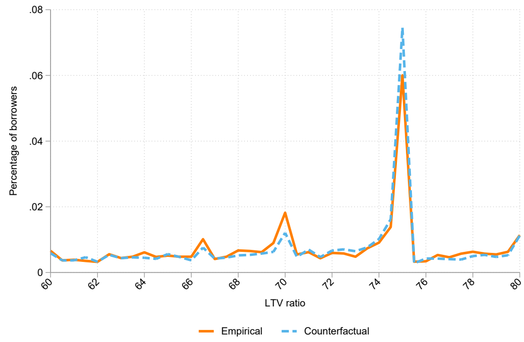
# 6 Assessing threats to identification

Our main assumption for identifying the causal effect of amortization on household leverage is that the pre-requirement LTV distribution represents a good estimate of the counterfactual LTV distribution post-requirement. While this assumption is not testable, we assess potential threats in this section. Notice 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.

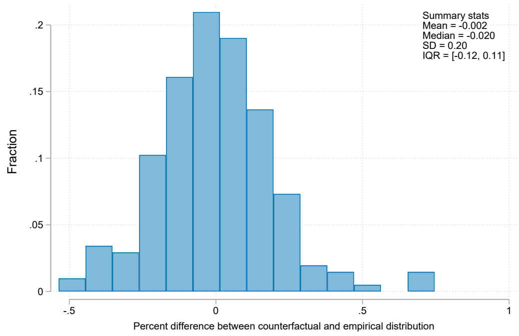
**Placebo tests** – We start by providing evidence that the counter-factual density presents a good estimate of the fraction of borrowers in each bin. To do this, we create a placebo test for the lower threshold at LTV ratios of 50 to assess whether the counter-factual distribution presents a good estimate of the fraction of borrowers in the absence of the requirement (DeFusco *et al.*, 2020). Specifically, each pre-requirement year from 2012 to 2015 is designated as a "placebo" year, that we then use to estimate the counter-factual distribution in those years. By estimating the counter-factual distribution as if the requirement had passed in a placebo year, we can assess whether the procedure



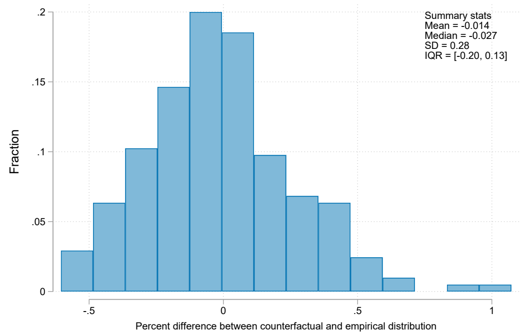

a) LTV50: Placebo reform in 2014




b) LTV70: Placebo reform in 2014




b) LTV50: Ratio between empirical and counterfactual




d) LTV70: Ratio between empirical and counterfactual

Figure 9: Counter-factual and empirical distribution in placebo years

*Notes:* Panel 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. 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 from 2011, 2012, 2013 and 2015 to create the counter-factual. Panel c) and d) provide a histogram of the ratio between the empirical and counter-factual distribution for each bin using data for all placebo years. Each observation is a ratio between the empirical and counter-factual distribution for each bin. LTV ratios are restricted to between 40 and 60 in panel c) and to between 60 and 80 in panel d). For each year we use data from the other pre-requirement years as the counter-factual.

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 distribution should be the same.

Figure 9 shows that using other years as the counter-factual closely approximates the distribution in years without the requirement. Panel 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. Importantly, the spike at 50 and at 75 is well approximated by this procedure. Panel c) and d) provide a histogram of the ratio between each bin in the empirical and counter-factual distribution for all the pre-requirement years. In both panels the mean and median

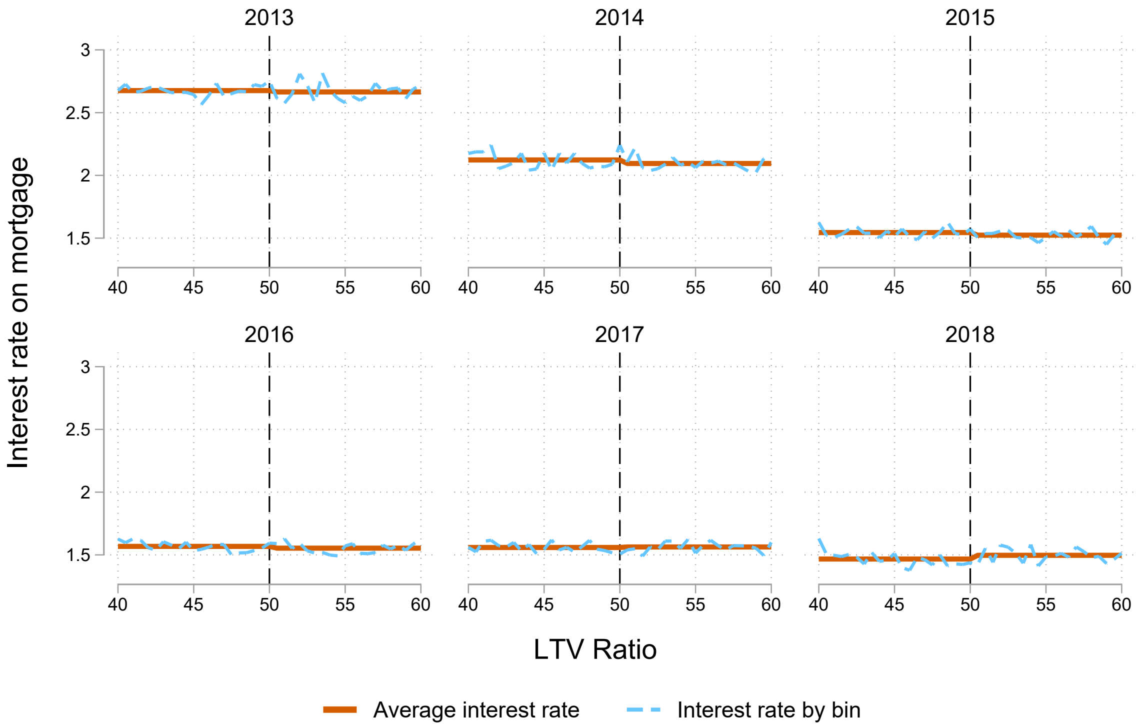



Figure 10: Interest rates by LTV ratio over time

*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% marked by the dashed black line.

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** – In addition to this validation exercise, we show that a plausible candidate for why households bunch, 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 setting. Figure 10 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 13. This graph 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 periods would lead to lower interest rates, but this is not apparent in the figure. There is therefore little evidence that borrowers responded to the requirement by changing the other major feature of the Swedish mortgage contract, or that mortgage banks charged higher mortgage rates to households placing themselves right below the threshold.

Despite the evidence displayed in figure 10 and our knowledge of Swedish banks, there might be an additional premium charged for borrowing more than 50% of the property value. Because of selection, the average rates displayed in the chart would not reveal this premium, as those not wanting to pay the premium would already choose to borrow less, and these individuals might be different from non-bunchers. This is still no concern to our identifying assumptions, to the extent the premium and selection are the same across years, which differentiates these confounders away.

**Banks' incentives** – In our analysis so far we have assumed that borrowers choose to bunch. It is worth considering whether banks have an incentive to nudge borrowers towards the thresholds. In general, we do not expect banks to push for lower leverage, simply because higher debt balances increase 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 higher LTV ratio should be riskier than a corresponding loan with lower LTV ratio. However, we expect the marginal increase in credit risk to be negligibly small when moving from a loan with 50% LTV ratio to a loan with a 51% LTV ratio. 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 51% LTV ratio "under water" is highly unlikely. Finally, given full recourse, Swedish households have no strategic motive to default.

Regarding funding costs, all loans with LTV below 75% 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%) 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, and this increase is constant over time, it poses no threat to our identifying assumption.

**Collateral assessments** – The LTV ratio could be manipulated by overstating 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 bond and other wholesale funding to a large extent[15], manipulation could have large repercussions for the banks' reputation and funding costs. Moreover, 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 households' borrowing decision comes after the house purchase, provided the requested amount does not exceed the promised amount. Manipulating the home value purely for amortization purposes is therefore not possible.

**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 bor-

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

rowers 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. However, this does nto necessarily pose a threat to the identification.

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 50% 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 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 Aggregate Implications of higher amortization payments

In this section we discuss the implications of our bunching estimates for aggregate credit growth. Our estimates show that the requirement had an impact on borrowing at the household level, illustrated by the considerable bunching around the thresholds. Because the requirement applies to all borrowing with a LTV ratio over 50 percent, however, the higher amortization rates likely has aggregate implications as well. Figure 11 plots the growth in housing credit over time in Sweden, showing that the introduction of both the

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

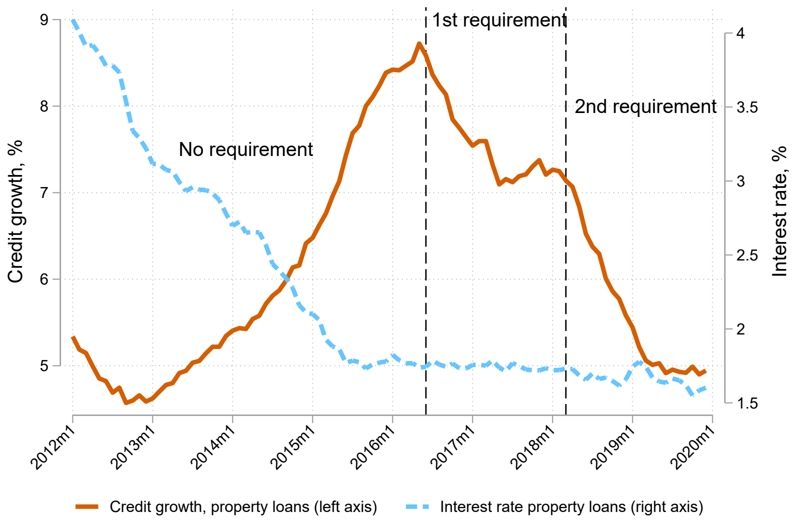



Figure 11: Credit growth and interest rate, property loans

*Notes:* The figure plots time series on credit growth (orange solid line, left axis) and the interest rate (blue dashed line, right axis) for housing loans. The data comes from Statistics Sweden.

first and second 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 difference is even more stark if we consider growth rates in credit growth. In the year prior to the requirement the growth rate in credit growth was increasing by 1.7 percent, but in the year after the requirement the growth rate in credit growth decreased by 1.5 percent. The sharp decline in the growth rate observed in the figure suggests that the amortization requirement led to lower credit growth, as alternative explanations for credit growth are typically more slow-moving. Indeed, the figure also plot one alternative factor that clearly has a large impact on household borrowing, the interest rate. 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. Clearly, while the decline in the interest rate had an impact on credit growth from 2013 to 2016, a flat interest rate is unlikely to explain the sharp decline in credit growth around either the first or second amortization requirement.

# 8 Conclusion

This paper shows that the amortization requirement in Sweden had a direct impact on household borrowing at the time households were taking out mortgages. Overall, this shows that household borrowing depends on not only the interest rate, but also other payments on the mortgage such as amortization payments. By extension, explaining crediting growth therefore requires that we examine all features of the mortgage contract, including amortization payments.

It is noticeable that there is considerable bunching even at relatively low LTV ratios. These borrowers have access to considerable amount of home equity, making it difficult to argue that they are facing leverage credit constraints. However, they can still face credit constraints related to payments, with the discretionary income limit applied in Sweden. Bäckman & Khorunzhina (2019) show that such payment constraint 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.

Our results do not necessarily imply that amortization requirement 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 will have 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 reduces 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 recession.[17] In the end this is an empirical question not ideally suited to our data. Recent work by Bernstein & Koudijs (2020) find that an amortization requirements for new homeowners in the Netherlands raised the overall savings rate, with

[17]The requirement could have no impact on macroeconomic stability if households are able to undo the requirement by either refinancing or by borrowing to fund amortization payments at a later stage (Hull, 2017; Svensson, 2016).

little impact on other types of savings. This suggest that such policies raise the savings rate without impacting savings in liquid asset, but due to data limitations we are unable to verify if Swedish households acted similarly.

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# A Appendix: Tables

Table 3: Mortgage payments for payment schedules and interest rates

| | Interest rate | | | | |
|---|---|---|---|---|---|
| | 1% | 1.5% | 3% | 5% | 10% |
| **Payments under each schedules** | | | | | |
| Interest-only mortgage | 5,000 | 7,500 | 15,000 | 25,000 | 50,000 |
| Annuity schedule | 19,298 | 20,707 | 25,296 | 32,209 | 52,654 |
| Sweden: Lower threshold | 10,000 | 12,500 | 20,000 | 30,000 | 55,000 |
| Sweden: Upper threshold | 15,000 | 17,500 | 25,000 | 35,000 | 60,000 |
| **Reduction in payments (%)** | | | | | |
| (Annuity - IO) / Annuity | 0.74 | 0.64 | 0.41 | 0.22 | 0.05 |
| (Lower - IO) / Lower | 0.50 | 0.40 | 0.25 | 0.17 | 0.09 |
| (Upper - Lower) / Upper | 0.33 | 0.29 | 0.20 | 0.14 | 0.08 |

*Notes:* The table reports mortgage payments in the first year under different interest rates and payment 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* is is calculated as the interest costs from a interest-only mortgage plus an amortization rate of 1% and 2%, respectively. The numbers under **Reduction in payments (%)** calculates the reduction in total mortgage payments from chosing a mortgage with a lower amortization rate. In the first case, (*IO - Annuity*) we compare 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 - the difference in payments between the IO mortgage and the annuity schedule as a fraction of the cost for the annuity schedule. *Lower - IO* and *Upper -lower* are calculated similarly.

Table 4: 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

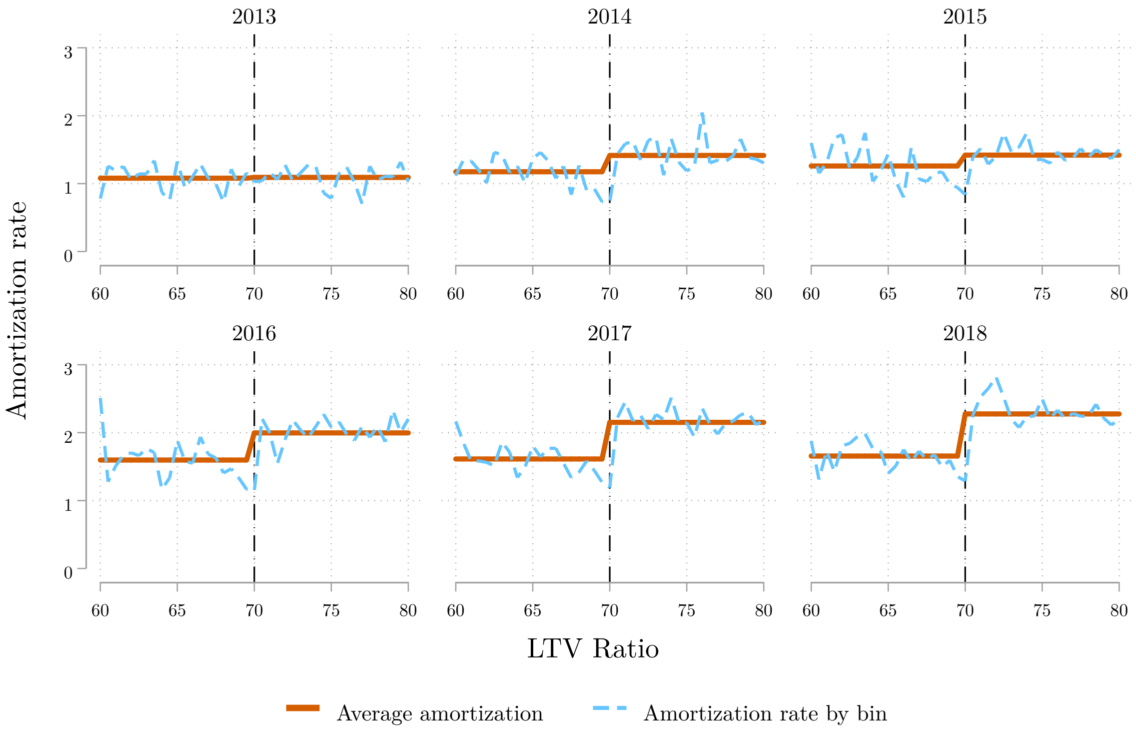


Figure 12: Amortization rate by year and LTV ratio

*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 threshold at LTV of 70% marked by the black dashed line.

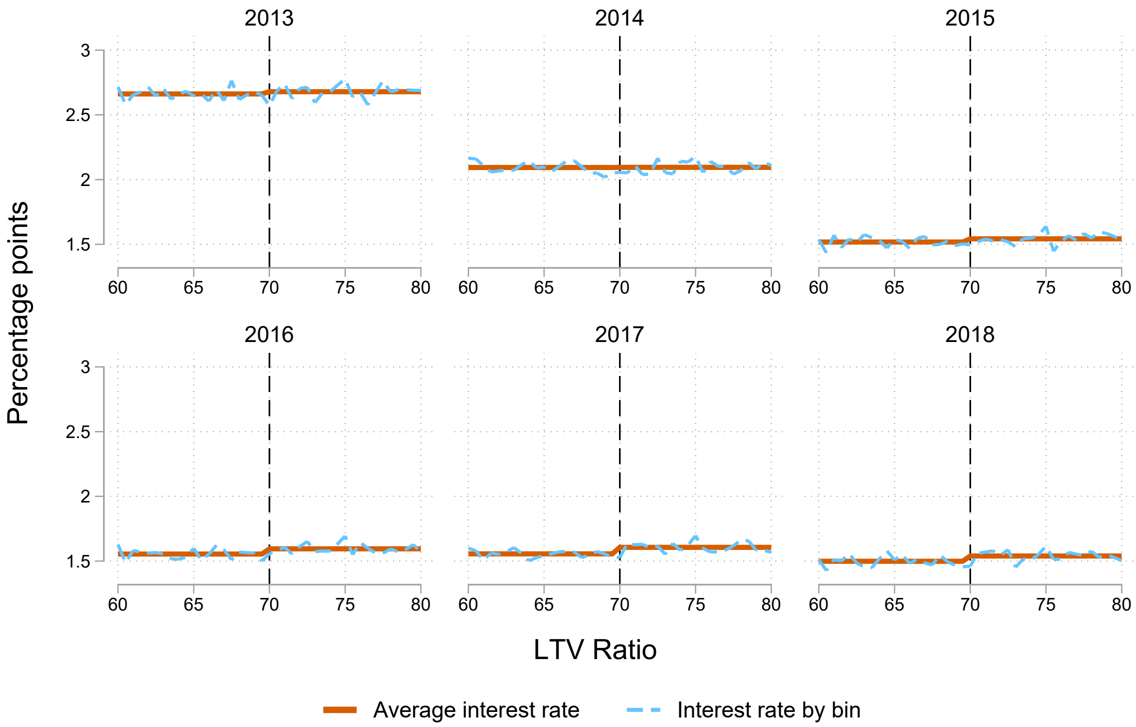


Figure 13: Interest rates by LTV ratio over time

*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 70% marked by the black dashed line.

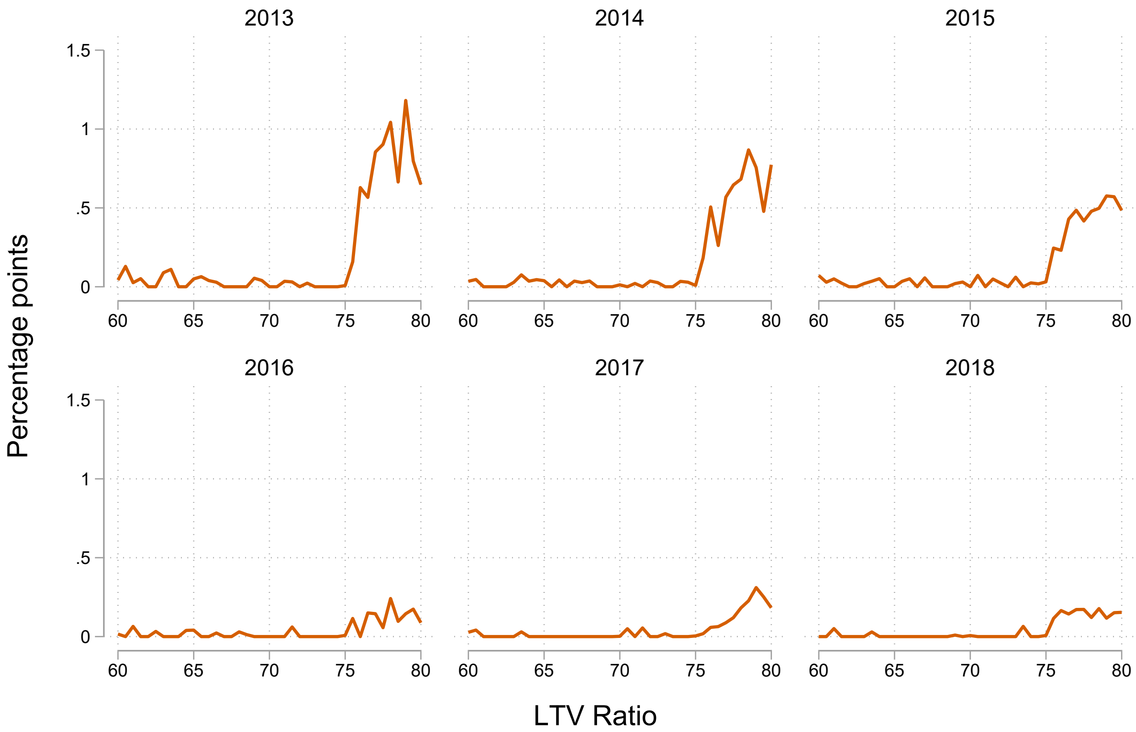


Figure 14: Difference between top and bottom interest rates

*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: Bunching Estimates from Polynomials

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

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

$$n_j = \sum_{i=0}^{p} \beta_i (m_j)^i + \sum_{k=L}^{U} \gamma_k \mathbf{1}(m_k = m_j) + \epsilon_j, \tag{10}$$

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

$$\hat{n}_j = \sum_{i=0}^{p} \hat{\beta}_i (m_j)^i \tag{11}$$

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

As in the main analysis, the estimates of bunching and missing mass are calculated by comparing the counter-factual distribution to the empirical distribution in the relevant regions (see equations 4 and 5). We use the procedure in Chetty *et al.* (2011) to calculate standard errors for all estimated parameters. Specifically, we randomly draw from the residuals in equation 10 with replacement to generate new bootstrapped bin counts. We then re-estimate the bunching parameters. Standard errors are calculated as the standard deviation of the bootstrap estimates.

# D Appendix: Svensson's model

This appendix presents some details of Svensson (2016)'s model described in section 3.3. Households choose consumption, debt and savings in each period, plus constant housing, to maximize their intertemporal utility. Formally,

$$\max_{c,L,s,h} U = \sum_{t=1}^{T} \beta^{t-1} \ln\left(c_t^{1-\theta} h^{\theta}\right) \tag{12}$$

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

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 $\delta$ is the maintenance cost for housing.

The last $T-1$ constraints depict a linear amortization schedule, where debt declines by a fraction $\alpha$ of the initial debt level $L_1$. We solve the model numerically for many households with different levels of initial wealth $A_0$. 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 $ph\overline{LTV}$.