Amortization Requirements and Household Indebtedness: An Application to Swedish-Style Mortgages

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Abstract

Since the mid-1990s, many OECD countries have experienced a substantial increase in household indebtedness. Sweden, in particular, has seen indebtedness rise from 90% of disposable income in 1995 to 172% in 2014. The Swedish Financial Supervisory Authority (FSA) has identified mortgage amortization requirements as a potential instrument for reducing indebtedness; and has drafted guidelines that will intensify the rate and duration of amortization. In this paper, I characterize Swedish-style mortgage contracts, which differ substantially from U.S.-style contracts. I then evaluate the policy changes in an incomplete markets model with three types of debt and a novel mortgage contract specification that is calibrated to match Swedish micro and macro data. I find that intensifying the rate and duration of amortization is largely ineffective at reducing indebtedness in a realistically-calibrated model. In the absence of implausibly large refinancing costs or tight restrictions on the maximum debt-service-to-income ratio, the policy impact is small in aggregate, over the lifecycle, and across employment statuses.

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1 Introduction

Since the mid-1990s, household indebtedness has risen in many OECD countries, driven primarily by mortgage debt growth. The United States, Ireland, Spain, Sweden, Norway, Canada, and Denmark experienced debt stock increases of between 50% and 300% over the 1995 to 2007 period (OECD, 2015). While some countries, such as the United States and Spain, experienced a housing crash and a financial crisis, accompanied by a reduction in in the debt stock, other countries retained high house prices and high levels of household indebtedness. Sweden, in particular, has seen household indebtedness rise from 90% of disposable income in 1995 to 172% in 2014 (OECD, 2015).

Not surprisingly, countries that have not experienced a drop in house prices and an accompanying drop in household leverage are attempting to identify viable indebtedness reduction policies to lower the probability of a financial crisis. In Sweden, the Financial Supervisory Authority (FSA) was recently given control over the formulation of macroprudential policy; and will play the chief role in addressing household indebtedness.

One potential problem the Swedish FSA has identified is the structure of Swedish mortgage contracts. In contrast to U.S.-style mortgages, for instance, Swedish-style mortgages do not require full amortization. Rather, households must partially amortize to a pre-specified LTV threshold, but may voluntarily amortize thereafter. Combined with the option to refinance inexpensively, households may avoid amortizing entirely after the initial period; and may periodically refinance to extract equity up to that threshold without triggering required amortization.

It is important to note that something similar can be achieved with U.S.-style mortgages through perpetual refinance: that is, households may avoid gaining equity by refinancing periodically. One difference is that standard mortgage contracts in the U.S. require regular amortization, even if the equity gained through amortization is extracted. This means that a household must be liquid enough to cover both the amortization and interest components of a U.S.-style mortgage, even if they don't plan to stay on the intended amortization path. In contrast, with Swedish-style mortgages, borrowers must only be able to cover the interest payments once the LTV threshold has been reached. The current structure of Swedish-style contracts most closely resembles an interest only mortgage–but with temporary, front-loaded amortization. There is still disagreement about whether interest-only contracts have been generally welfare-enhancing elsewhere, which leaves the implications of Sweden's choice to move away from them ambiguous.

The Swedish Financial Supervisory Authority (FSA) has outlined a plan to change mortgage contract structure by increasing amortization requirements (Swedish FSA, 2014a; 2015). When it comes into effect, new originations will be amortized at an annual rate of 2% until the top loan is paid off. Thereafter, the bottom loan will be amortized at a 1% rate until the total outstanding mortgage balance is lowered to 50% of the property's value.

The purpose of this policy–as stated in FSA memoranda (Swedish FSA, 2014b)–is to reduce demand for housing and subsequently household indebtedness. A common worry revealed in both FSA documents and elsewhere is that the high level of indebtedness makes households vulnerable to shocks. If a household becomes unemployed, for instance, its consumption may drop more if a substantial part of its budget is committed to debt service payments.

This policy is significant for at least two reasons. First, it constitutes a substantial difference in policy response from the United States and Spain, which did not have the opportunity to attempt macroprudential interventions before house prices dropped and deleveraging began. This is particularly relevant for countries such as Norway and Canada, which also remain highly indebted and have retained high house prices. And second, the outcome of the

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Front-loading amortization allows Swedish-style mortgages to avoid the selection problem that deferred amortization contracts create. Households who lack the liquidity to amortize can obtain a deferred amortization mortgage with the intention to refinance out of it to avoid liquidity issues. This is not the case with a Swedish-style mortgage, which begins amortizing at origination.

For an empirical analysis of Alternative Mortgage Products (AMPs), see Cocco (2013), which finds that AMPs can be welfare-enhancing if they are used to smooth consumption over the lifecycle. For a contract-theoretical treatment of AMPs and deferred amortization, see Piskorski and Tchistyi (2010) and LaCour-Little and Yang (2008), which suggest that deferred amortization and interest only mortgages are optimal under certain circumstances, including the ones present during the 1995-2007 period. See Forlati and Lambertini (2014) for a macro analysis of deferred amortization that finds negative welfare effects for borrowers.

A Swedish-style mortgage contract consists of two components: a top loan and a bottom loan. The bottom loan accounts for the larger share of the mortgage and usually amounts to 70% of the property's value. The top loan covers the gap between the property's value, the bottom loan, any consumption loans related to the purchase, and the downpayment. Borrowers are given some period of time to fully amortize the top loan. They are also given a grace period on the bottom loan's amortization at the start of the contract. This structure permits households to defer amortization below 70% indefinitely by refinancing into a new grace period or negotiating directly with lenders to maintain voluntary amortization.

policy experiment could help to guide countries that are contemplating mortgage contract reform to avert future crises or reduce indebtedness.

In this paper, I evaluate Swedish-style mortgages–and the proposed changes to them–through the lens of a quantitative equilibrium model; however, the results can be applied more generally to contracts that attempt to intensify amortization. I calibrate the model to match Swedish micro and macro data; and attempt to reproduce the details of Swedish-style mortgage contracts, as well as the changes proposed in the new guidelines. I focus specifically on the long-run implications of these contracts by comparing stochastic steady states.

I find that intensifying the rate and duration of amortization is largely ineffective at reducing indebtedness in a realistically-calibrated model. Depending on the specification used, the drop in the aggregate debt-to-income ratio is between 0.53 and 2.21 percentage points, which is eclipsed by the increase in indebtedness in Sweden since 1995. More generally, in the absence of implausibly large refinancing costs or tight restrictions on the maximum debt-service-to-income ratio, the policy impact is small in aggregate, over the lifecycle, and across employment statuses.

The small size of the policy effect arises from the empirically low barrier to refinance. In the limit, if refinancing were costless, then households could maintain their optimal amortization path by obtaining a new mortgage in each period to nullify the previous period's amortization. The only "forced" amortization would come from mortgage lock-in when income drops, tightening the borrowing constraint and preventing equity extraction via refinancing. We do not consider this extreme case, but instead calibrate the model to incorporate all known, measurable barriers to to refinance; and set conservatively high values for intangible barriers to refinance. In this setting, we find that households often refinance periodically to undo forced amortization that is individually suboptimal. Furthermore, even when we substantially increase the barriers to refinancing, we still find small effects from the policy, since households may simply reduce the frequency with which they refinance, but extract greater amounts of equity when they do.

In Section 2, I will describe the essential features of a Swedish-style mortgage contract. I will then construct a quantitative equilibrium model, which reproduces these features in Section 3. Finally, I will detail the model's calibration in Section 4, perform policy experiments in Section 5, and then conclude in Section 6.

2 Swedish-Style Mortgage Contracts

I will start by identifying the essential features of a Swedish-style mortgage contract. I will then build a theoretical model around those features. Under current mortgage market norms and regulations, a Swedish-style mortgage contract is characterized by 9 parameters: 1) the LTV ratio threshold for required amortization; 2) the size of the top loan; 3) the amortization rate associated with the top loan; 4) the size of the bottom loan; 5) the amortization rate associated with the bottom loan; 6) the size of the mortgage registration fee; 7) the top loan interest rate; 8) the bottom loan interest rate; and 9) the prepayment penalty. In addition to this, all homeowners–whether or not they hold a mortgage-are subject to two additional costs: 1) a property tax; and 2) a stamp duty.

Figure I shows a typical mortgage contract for a new property owner, described in terms of the parameters above. The stamp duty and mortgage registration fee are paid at origination and are proportional to the property's value and the change in the mortgage's size, relative to its highest historical value. A separate mortgage registration fee is paid when an existing contract is refinanced and is proportional to the increase in the size of the mortgage above its previous peak. The property tax is paid annually and is proportional to the property's value, but has a low maximum cap.

Under the current contract structure, the loan is separated into two pieces: a "top loan" and a "bottom loan." Top loans must be fully amortized within a pre-specified period of time of between 5 and 15 years. Bottom loans are typically of two varieties. Either the bank permits them to be amortized voluntarily or the bank provides a grace period after origination, so that the top and bottom loans do not need to be amortized simultaneously. The latter structure also allows borrowers to avoid amortizing by refinancing into a new grace period or negotiating an extended grace period directly with the lender. Both options permit homeowners to postpone repayment on the bottom loan indefinitely; and many mortgage-holders choose to do so. In 2013, for example, only 40% of homeowners with an LTV lower than 75%–a common cutoff between the top and bottom loan–opted to do a positive amount

Figure I: Current Contract Structure

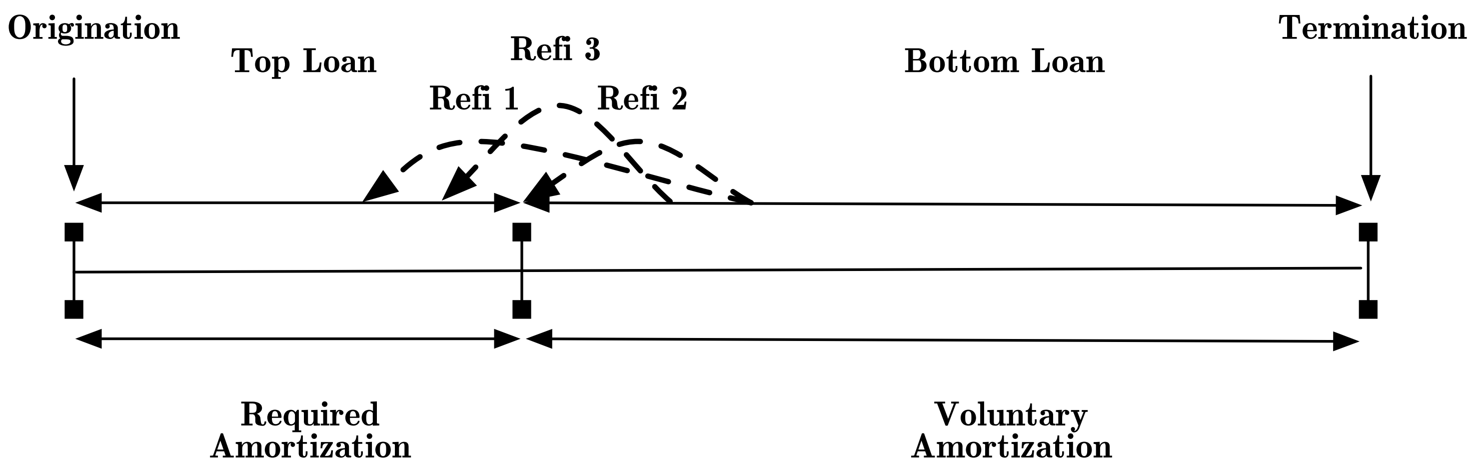

Figure I: This figure illustrates the structure of current, Swedish-style mortgages. Each contract consists of two pieces: a “top loan” and a “bottom loan.” The top loan must be amortized over a set period of time; whereas, bottom loan amortization is typically voluntary. The top and bottom loans may bear separate interest rates. Refi 1, 2, and 3 demonstrate three possible refinancing options, which have different implications for interest rates and amortization. Refi paths 1 and 3 trigger required amortization. Refi path 2 does not.

of amortization (Swedish FSA, 2014a). Top and bottom loans may also bear different interest rates, since they are collateralized against different components of the home's value.

Three alternative refinancing choices–Refi 1, Refi 2, and Refi 3–are shown in Figure I. Notice that Refi 2 does not extract enough equity to require anything other than an extension of the bottom loan. Under a contract in the current system, this will increase the size of the monthly payment to interest–since the same rate is now applied to a larger bottom loan–but it will not trigger any required amortization. To the contrary, Refi 1 requires the borrower to obtain a top loan, which triggers required amortization, increasing both the interest and amortization components of the mortgage payment. Finally, Refi 3 extracts exactly as much equity as Refi 2, but is initiated at a higher LTV ratio. This triggers an increase in both the interest and amortization components of the mortgage payment, since it requires the borrower to take on a new top loan. Thus, the threshold that triggers amortization is a critical nonlinearity in the household's mortgage choice problem.

This setup suggests that a change in the contract structure–including the required amortization threshold–will constrain households in two ways. First, it will have an impact on how much debt a household can accumulate. And second, it will affect the liquidity of the household by changing the size of its mortgage payments, even if its equity position is unchanged. The change in liquidity follows from the change in the size of the amortization component of debt service. If, for instance, a household is required to amortize more in each period, then its liquidity will fall initially, as more of its budget is pre-committed to debt service payments. If the household reduces its indebtedness in the long run–instead of periodically extracting equity to undo the regular amortization–then a stricter amortization requirement may improve liquidity in the long run; however, if it instead chooses to extract equity periodically, then amortization requirements may actually reduce household liquidity in the long run, which could force a household to reduce consumption further in response to shocks.

The interest rate gap between top and bottom loan debt is currently small and is often quoted by lenders as zero. For this reason, some prefer to use the terms "high-ratio" for mortgages with LTVs over 70% and "low-ratio" for mortgages under 70%. Importantly, however, high-ratio loans–mortgages with a "top loan"–must amortize, while low-ratio loans do not.

This differs from standard, one-period mortgage contracts with collateral constraints, which contain one nonlinearity at the maximum LTV ratio.

The proposed mortgage amortization guidelines will modify the required amortization threshold, as well as the amortization rates associated with the top and bottom loans. Households will need to amortize 2% of the entire mortgage annually until the LTV ratio is reduced to 0.70 of the home's value (i.e. the top loan is amortized). Thereafter, they must amortize at 1% until the LTV ratio is lowered to 0.50 (Swedish FSA, 2015).

Figure II illustrates the proposed contract structure. Consider a household who amortizes down to the new required amortization LTV threshold of 0.50. If the household maintains this equity position, then it will not need to amortize further, but can instead pay interest indefinitely on the remainder of the bottom loan. Alternatively, it can refinance up to a 0.70 LTV ratio, which will trigger 1% amortization, as is shown by Refi 2. If it instead opts for Refi 1, which passes the maximum bottom loan size threshold, then it will trigger a 2% amortization rate. Both changes may also incur a prepayment penalty if the period of fixation has not ended.

Notice that the new requirements do not constrain households to amortize to the 0.50 threshold. If a household prefers to have less housing equity–and, instead, more capital or consumption–then it can achieve this by simply refinancing to extract it. The new structure does, however, impose two additional burdens: first, households in the 0.70 to 0.50 LTV range must periodically refinance if they wish to maintain weaker equity positions, which may incur a prepayment penalty. And second, households in the 0.70 to 0.50 LTV ratio range must regularly amortize–even if they later extract the equity–which reduces their liquidity.

Thus, the proposed changes may not reduce indebtedness and could place additional burdens on borrowers. In fact, the baseline version of the changes would make Swedish-style mortgages similar to standard U.S. mortgage products, but with less strict amortization requirements. The parallel run-up in mortgage debt from the mid-1990s to 2007 suggests that the intended amortization schedule associated with U.S.-style mortgages can be circumvented by refinancing, especially if house prices rise.

In addition to explicit, pecuniary costs, there is another cost associated with origination that is not specified in the contract: the opportunity cost of the borrower's time. In order to obtain a new loan or to refinance an existing loan, the borrower must gather information, identify prospective lenders, and complete the required paperwork. The borrower must also

Figure II: Proposed Contract Structure

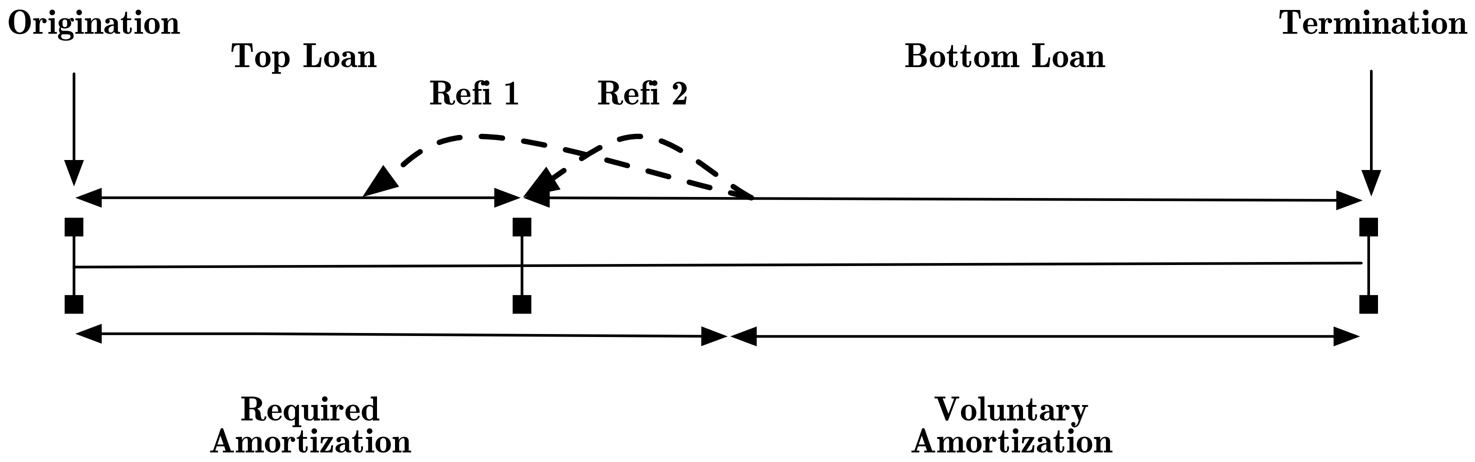

Figure II: This figure illustrates the structure of contracts under the proposed amortization requirements. Each contract consists of two pieces: a “top loan” and a “bottom loan.” The top loan must be amortized at a rate of 2%. After the top loan is fully amortized, the bottom loan is amortized at a rate of 1% until the household achieves an LTV ratio of .50. Thereafter, amortization becomes voluntary again. The top and bottom loans may bear separate interest rates. Refi 1 and 2 demonstrate two possible refinancing options, which have different implications for interest rates and amortization. Refi path 1 triggers amortization at a rate of 2%; whereas, Refi 2 triggers amortization at 1%.

make difficult choices about the timing of the refinance and the period of fixation. In this paper, I will choose a conservatively high value for this parameter.

Finally, it is important to note that mortgage contracts in Sweden are overwhelmingly adjustable-rate. According to the 2015 Swedish Financial Market Report (Sveriges Riksbank, 2015), approximately 70% of mortgages were adjustable-rate from origination. An additional 25% were fixed-rate, but had a period of fixation of under 5 years. The remaining 5% of mortgages had a period of fixation of over 5 years. There has been some variation in these numbers over time, but no clear trend toward either contract type has emerged since 2005–the earliest date covered by the report. This suggests that the prepayment penalty for most mortgage contracts is likely to be small.

In the following section, I will construct a quantitative equilibrium model that reproduces the details of Swedish-style contracts. I will then calibrate the model using micro and macro data; and evaluate the amortization requirements.

3 The Model

There are four categories of agents in the model: firms, households, foreign lenders, and the government. Markets are incomplete, as in Huggett (1993) and Aiyagari (1994). The model is most closely related to Iacoviello and Pavan (2013) and Hull (2015).

3.1 Firms

3.1.1 Consumption Goods

There are two sectors: a nondurable consumption goods sector and a housing sector. The consumption goods sector combines labor and capital using a Cobb-Douglas production function:

$$Y = K^{\alpha} N^{1-\alpha} \tag{1}$$

The firm rents capital and labor from households and maximizes profits, yielding the following factor prices, which are paid to households using units of the nondurable good:

$$w = (1-\alpha)K^{\alpha}N^{-\alpha} \tag{2}$$

$$r = \alpha K^{\alpha-1}N^{1-\alpha} - \delta_k \tag{3}$$

The model does not contain aggregate uncertainty, since the purpose of this exercise is to compare stochastic steady states. I have omitted subscripts on the factor prices and aggregate variables to reinforce this point.

3.1.2 Housing Investment

Housing investment is similar to Glover et al. (2011), but incorporates a capacity utilization term, which depends on aggregate housing investment. Production is done at the individual level using a shared technology:

$$ih_{it} = \eta(IH)A^{h}c^{h}_{it} \tag{4}$$

Above, ih_{it} is individual i's housing investment at time t, which is generated using a nondurable consumption good input, c^{h}_{it}, but depends on housing productivity, A^{h}, and capacity utilization, $\eta(IH)$. The amount of nondurable good used, c^{h}_{it}, is specific to agent i and is unrelated to the nondurable inputs of other agents. Additionally, since all exercises compare steady states, A^{h} will not vary over time, but will serve as a measure of relative productivity across sectors. Finally, note that $\eta(IH)$ is a function of aggregate housing investment, IH, which captures capacity constraints in the construction sector. For now, we will assume that $\eta(IH)$ is weakly decreasing in IH, $\eta'(IH) \leq 0$. Later, we will consider two different functional forms for $\eta(IH)$.

We assume that housing is tradable, but also reversible. Thus, one unit of the nondurable consumption good may be converted into $\eta(IH)A^{h}$ units of housing–or, alternatively, one unit of housing may be reversed into $\frac{1}{\eta(IH)A^{h}}$ units of the consumption good. This implies that no agent will sell a unit of housing for less than $\frac{1}{\eta(IH)A^{h}}$ units of the consumption good;

This can be viewed as purchasing a plot of land and hiring a construction firm to build a single house on it.

and no agent will buy a unit of housing for more than $\frac{1}{\eta(IH)A^h}$ units of the consumption good, which pins down the price as follows:

$$p^h = \frac{1}{\eta(IH)A^h} \tag{5}$$

Notice that the unit house price will not vary–even across individuals–within a given steady state; however, if the relative productivity of housing rises across steady states, house prices will fall.

In the simulation exercises, we will use two different specifications for $\eta(IH)$. One specification assumes that only deviations from steady state housing investment affect $\eta(IH)$. This is akin to assuming that housing supply is perfectly elastic in the long run. The other specification will permit $\eta(IH)$ to depend on the absolute level of housing investment without reference to the steady state value. This will allow policy changes to raise or lower steady state house prices.

The assumption that house prices rise permanently in response to an increase in demand is not trivial. Shiller (2007), Sørensen (2013), and Edvinsson et al. (2014) document the flatness of real house prices from 1890 to the early 1990s in the United States, Sweden, Norway, and the Netherlands. This suggests that substantial increases in population size, real income, real financial wealth, access to credit, and the homeownership rate had essentially no long run impact on real house prices. Thus, housing supply may be highly elastic in the long run. However, real house prices also increased dramatically in the same countries–along with household indebtedness and the homeownership rate–from the mid-1990s to 2007 (and beyond for some). Since it is not clear what part of this house price increase was permanent, I will consider both specifications separately, but will focus on the perfectly elastic supply case, which generates large policy effects.

3.2 Households

Households enter the model at age 25, work for 40 periods, retire and draw a pension for 20 periods, and then perish with certainty. Households differ with respect to their permanent,

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For different model calibrations, the inelastic supply case generates slightly larger policy effects than the perfectly elastic supply case.

g_i, and lifecycle, a_{it}, productivity components, as well as their employment status. At time t, household i receives the following net labor income:

$$y_{it} = \begin{cases} w_t v_{it} - \Gamma_{it} & \text{if employed or retired} \\ x_{it} & \text{if unemployed} \end{cases} \tag{6}$$

Above, v_{it} is the combined permanent and lifecycle-specific productivity weight; Γ_{it} is a proportional tax; and x_{it} is a government transfer. Retired agents will draw a pension in each period, but unlike employed agents, will not encounter employment status shocks. Income payments for all agents will be calibrated using Swedish micro data.

Households receive utility from the consumption of a non-durable good and from the service flows achieved through homeownership:

$$u(c_{it}, h_{it}) = \frac{c_{it}^{1-\sigma_c}}{1-\sigma_c} + \frac{h_{it}^{1-\sigma_h}}{1-\sigma_h} \tag{7}$$

Each household may invest in housing, h_{it} and capital, k_{it}; and may obtain three types of loans: 1) bottom loans, b_{it}^B; 2) top loans, b_{it}^T; and 3) consumer loans, b_{it}^C. Each household who has a loan of any variety makes a payment in each period, m_{it}. Household i faces the following flow budget constraint:

$$\begin{aligned} c_{it} &= y_{it} - p^h(h_{it+1} - (1-\delta_h)h_{it}) + b_{it+1} - m_{it} + (1+r)k_{it} - k_{it+1} \\ &-\Lambda y_{it}\mathbf{1}_{\{b_{it+1}>b_t^*\}} - \psi(b_{it} - b_t^*)\mathbf{1}_{\{b_{it+1}>b_t^*\}} - \phi p^h h_{it} - \Xi p^h h_{it+1}\mathbf{1}_{\{h_{it+1}\neq h_{it}\}} \\ &-\Psi(h_{it}, h_{it+1}) \end{aligned} \tag{8}$$

Above, $b_{it} = b_{it}^B + b_{it}^T + b_{it}^C$. Note also that m_{it} includes full principal and interest payments to the top loan, bottom loan, and consumer loan. The targeted, post-amortization loan amount, b_t^*, is described later. The parameter Λ captures the time cost of refinancing. The remaining parameters–ψ, ϕ, and Ξ–are the prepayment penalty size, property tax, and stamp duty. Each will be calibrated to match its empirical counterpart. The time cost of refinancing is used in addition to the prepayment penalty size and property tax size–which have empirical counterparts and are calibrated to match them–to capture less tangible costs of refinancing, such as leisure time lost to mortgage-related choices and paperwork. Including this cost errs on the side of caution by providing an additional channel through which the policy may have an effect. Without it, the size of policy effects would be reduced further.

As in Iacoviello and Pavan (2013), there's a minimum house size, $\underline{\text{h}}$; and households have access to a small, fixed amount of housing if they do not own. Households also face a concave housing stock adjustment (moving) cost, $\Psi(h_{it}, h_{it+1})$, and a must pay a stamp duty, $\Xi p^h h_{it+1}\mathbf{1}_{\{h_{it+1}\neq h_{it}\}}$, on new home purchases. The stamp cost captures a tangible, pecuniary cost of moving in Sweden. The additional concave cost captures the inconvenience of moving and the related expenses. It also causes housing adjustments to be lumpy, which aligns with the stylized fact that households move infrequently and often adjust home size when they do.

In order to reduce the size of the state space, I collapse the three types of debt into a single contract with multiple cutoffs: $\{\gamma^A, \gamma^B, \gamma^T\}$. This structure assumes a borrowing order restriction for homeowners. First, a homeowner borrows using a bottom loan. Next, she may obtain a top loan. And finally, she may borrow in the form of a consumer loan. This is not a particularly restrictive assumption, since it only requires that homeowners borrow at the lowest possible rate, which is consistent with optimization. Agents who do not own a home in the current period may only borrow using a consumer loan.

Using the structure described above, γ^A, γ^B, and γ^T are the LTV cutoffs for forced amortization, bottom loan borrowing, and top loan borrowing. Similarly, χ^B and χ^T are the associated rates of amortization for the amortizing component of the bottom loan and the top loan; and r^B and r^T are the corresponding interest rates. The remaining parameters–χ^C and r^C–are applied to consumer loans. The payment schedule for interest and principal is given by equation (9).

The first component of (9) is the interest and full principal payment a household makes if it only has a bottom loan. If a household only has a bottom loan and surpasses the γ^A cutoff, but falls below γ^B, then it must begin to amortize the component of the bottom loan above the γ^A cutoff, as shown in (10). Furthermore, if it is above the γ^B cutoff, then it must take on a top loan as well, but does not need to amortize the bottom loan until it drops

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This special structure allows me to remove two continuous state variables, which would otherwise make the problem intractable. It adds several multi-part constraints, which are comparatively easy to handle with a global solution method.

below γ^B. If it is also above the γ^T cutoff, then it may obtain a consumer loan to cover the gap, which will be amortized simultaneously with the top loan. Finally, if it has debt, but not any housing, then it must borrow using a consumer loan.

Note that this setup retains the standard, one-period framework for modeling mortgages in a macroeconomic setting. That is, a household must repay both interest and principal in each period; however, they may borrow when the principal payment is due to roll over debt. They can continue to roll over the debt until they encounter binding constraints. This model contains several novel constraints that transform the one-period contract into something that captures the features of a long term contract. Equation (10), for instance, requires the principal to be lowered in each period by the required amortization amount if the household does not opt to pay the associated costs of refinancing.

$$m_{it} = \begin{cases} (1+r^B)b_{it} & \text{if } b_{it} < \gamma^B p^h h_{it} \\ (1+r^B)\gamma^B p^h h_{it} + & \text{if } \gamma^T p^h h_{it} > b_{it} \geq \gamma^B p^h h_{it} \\ (1+r^T)(b_{it} - \gamma^B p^h h_{it}) & \\ (1+r^B)\gamma^B p^h h_{it} + & \text{if } b_{it} \geq \gamma^T p^h h_{it} \\ (1+r^T)(\gamma^T - \gamma^B) p^h h_{it} + & \\ (1+r^C)(b_{it} - \gamma^T p^h h_{it}) & \\ (1+r^C)b_{it} & \text{if } h_{it} = 0 \end{cases} \tag{9}$$

Next, we construct the amortization schedule that is intended at a mortgage's origination in equation (10). This, of course, can be avoided through successive refinancing when the borrowing constraints do not bind, but will incur both prepayment penalties and time costs. The schedule, b^*, yields the next period level of debt if a household remains in the same set of contracts (e.g. does not voluntarily amortize, take on more debt, or move into a new house).

$$
b_t^* = \begin{cases} b_{it} & \text{if } b_{it} < \gamma^A p^h h_t \\ b_{it} - \chi^B \gamma^B p^h h_{it} & \text{if } \gamma^B p^h h_{it} > b_{it} \geq \gamma^A p^h h_{it} \\ b_{it} - \chi^T \gamma^T p^h h_{it} & \text{if } \gamma^T p^h h_{it} > b_{it} \geq \gamma^B p^h h_{it} \\ b_{it} - \chi^T \gamma^T p^h h_{it} - & \text{if } b_{it} \geq \gamma^T p^h h_{it} \\ \chi^C (b_{it} - \gamma^T p^h h_{it}) & \\ b_{it} - \chi^C b_{it} & \text{if } h_{it} = 0 \end{cases} \tag{10}
$$

I also apply a lifetime borrowing condition, which is similar to the constraint imposed in Iacoviello and Pavan (2013), but applies only at origination. For our purposes, this constraint plays two different roles. First, it limits consumption loan borrowing using discounted lifetime income as a constraint. And second, it acts as a feasibility of repayment constraint over the lifecycle. It also incorporates some fraction, Φ, of the value of the home into the constraint.

$$
b_{it+1} \leq \Phi p^h h_{it} + \lambda E_t \sum_{s=t}^{T-a+s} \beta^{T-a+s} y_{is} \tag{11}
$$

Finally, I will incorporate a separate debt-service-to-income constraint, which will only be applied when a household obtains a new mortgage or refinances an old mortgage (i.e. deviates from b^*):

$$
m_{it+1} - b_{t+1}^* \leq \kappa y_{it} \tag{12}
$$

This constraint will permit banks to explicitly consider the size of mortgage payments (i.e. amortization and interest) relative to income when making lending decisions. The functional form of this constraint matches the data well: the debt-to-income ratio has been increasing in Sweden since 1995, but the debt-service-to-income ratio has been much flatter, suggesting that the ability to make payments at origination may be an important component of the credit supply decision.

This final constraint completes the specification for the household's choice problem. For simplicity, we will collect all of the state variables in a single vector, $z_{it} = \{h_{it}, b_{it}, k_{it}, \epsilon_{it}, a_{it}, g_i\}$; and all the parameters in a separate vector, Ω. The dynamic programming problem (DPP) for the household, subject to equations 1-12, may be written as follows:

$$V_{it}(z_{it};\Omega) = max_{\{c_{it},k_{it+1},h_{it+1},b_{it+1}\}} u(c_{it},h_{it}) + \beta \sum_{\epsilon^{E'} \in \{1,0\}} Pr(\epsilon^{E'}|\epsilon^{E}) V_{it+1}(z_{it+1};\Omega) \tag{13}$$

We solve the DPP with a modified version of backwards recursion that is parallelized on a GPU. The procedure is similar to Aldrich et al. (2011), but uses backwards recursion, rather than value function iteration, since the household's problem is finite horizon. The appendix provides a description of the complete solution algorithm.

3.3 The Foreign Lender

Following Adfolson et al. (2008), Bjørnland and Jacobsen (2010), and Christiano et al. (2011), we model Sweden as a small, open economy. Households borrow from a foreign lender; and interest rates on bottom loans, top loans, and consumer loans are pinned down outside of Sweden and are exogenous to the model. The foreign lender follows the mortgage structure conventions described in the household's problem.

These assumptions are intended to approximate the actual lending conditions in Sweden, where there is a gap between mortgage lending and deposits, which is bridged by covered bonds, issued by mortgage lenders. The presence of foreign lending to banks in the mortgage-funding market suggests that interest rates on debt may be determined outside of Sweden, and may be unresponsive to shifts in domestic mortgage debt demand.

3.4 The Government

The government makes transfer payments to the unemployed and collects taxes from the employed and retired.

Empirically, the "foreign lender" purchases bonds, rather than making loans in the domestic market; however, for simplicity, we assume it makes loans directly to households in the model.

3.4.1 Transfers

The government must allocate the following amount to outgoing transfer payments to the unemployed:

$$\tau = w\zeta\mu^U \tag{14}$$

That is, the government must collect enough in taxes to pay the mass of unemployed, μ^U, in transfers, where ζ denotes the replacement rate.

3.4.2 Revenue

For simplicity, I assume the following about taxes: rates scale with productivity, and unemployed agents do not pay taxes. The tax for employed or retired homeowner i is the following:

$$\Gamma_{it} = \frac{\upsilon_{it}\tau}{(1-\mu^U)} \tag{15}$$

Aggregate incoming revenue is equal to aggregate outgoing transfer payments:

$$\Gamma_t = \frac{1}{N}\sum_{i=1}^{N}\Gamma_{it} = \tau \tag{16}$$

3.5 Aggregate Consistency Conditions

A set of consistency conditions requires that aggregate variables be equal to the corresponding mass-weighted sums of individual variables. The consistency condition for capital pins down factor prices:

$$K = \frac{1}{N}\sum_{i=1}^{N}k_{it} \tag{17}$$

Another consistency condition imposes the same restriction on housing investment:

$$IH = \frac{1}{N}\sum_{i=1}^{N}ih_{it} \tag{18}$$

The above condition is particularly relevant in the version of the model where capacity utilization in the housing sector depends explicitly on the level of housing investment.

4 Calibration

Much of the model's calibration is based on Hull (2015), but is adapted to match Swedish micro and macro data. The utility function parameterization comes from Chambers et al. (2009) and Jeske (2005). The maximum lifetime borrowing parameter, the minimum house size, and the housing adjustment cost all come from Iacoviello and Pavan (2013).

The property tax and stamp duty parameters are taken from the Association for Swedish Covered Bond issuers (ASCB, 2012). The unemployment rate is taken from Statistics Sweden (2015). The replacement ratio for unemployment is taken from the OECD database.

Since the model contains a substantial degree of heterogeneity, I also attempt to match individual distributions. The GINI coefficient target for net assets comes from Jäntti et al. (2008). For the income distribution, I follow Iacoviello and Pavan (2013) in adopting a deterministic profile for age-specific productivity. I construct a separate profile for the 25th, 50th, and 75th income percentiles, using micro data from one of the largest Swedish banks. The normalized age-wage profiles of the three groups are shown in Figure III.

In addition to shared parameters in Table I, the model also contains parameters specific to the original and proposed mortgage contracts. These are given in Table II. Columns C:I and C:II refer to the two different contract types. C:I is the original contract, currently in effect. C:II is the contract described by FSA guidelines (Swedish FSA, 2014a; 2015).

The housing depreciation rate and capital depreciation rates for Sweden are taken from Wilhelmsson (2008) and Finocchiaro and von Heideken (2013), respectively. The debt-to-income ratio and homeownership rate targets are taken from the OECD database and Eurostat, respectively. Both values are calibrated using 2004 data, since this is approximately the midpoint of the period of strong, positive debt-to-income growth in Sweden.

The loan cutoffs are taken from reports issued by the Association for Swedish Covered Bond Issuers (ASCB, 2012) and by the Swedish Financial Stability Authority (Swedish FSA, 2014c; 2015). The base interest rate, the premiums for the bottom loan and top loans, and the premium for the consumer loan are taken for the year 2012 from the FSA's report (Swedish FSA, 2014c). The assumption that mortgages are not fixed for a substantial period aligns

Table I: Shared Parameter Values

	Parameter	Value	Target (Model)	Source
Housing utility curvature	σ_H	3	-	Chambers et al. (2009)
Cons. utility curvature	σ_C	1	-	Chambers et al. (2009)
Non-housing shelter	-	1.4 x w	-	-
Unemployment rate	-	-	7.5%	Statistics Sweden (2015)
Housing depreciation rate	-	0.011	1.1% IH	Wilhelmsson (2008)
Housing adjustment cost	-	0.05	-	Iacoviello & Pavan (2015)
Min house size	$\underline{h}$	1.5 x w	-	Iacoviello & Pavan (2015)
Discount factor	β	0.95	-	-
Replacement ratio	ζ	0.685	-	OECD (2015)
Prepayment penalty	ψ	0.0034	-	Swedish FSA (2014c)
Property tax	ϕ	0.0075	-	ASCB (2012)
Stamp duty	Ξ	0.015	-	ASCB (2012)
Income GINI	-	Fig. III	-	Swedish Bank Microdata
Net Worth GINI	-	-	0.617 (0.604)	Jäntti et al. (2008)
DSI maximum	κ	0.30	-	-
Collateralizable housing	Φ	0.85	-	Swedish FSA (2015)
Capital Depreciation	δ	0.12	-	Finocchiaro & Heideken (2013)
Debt-to-Income Ratio	-	-	137.04% (137.31%)	OECD (2004)
Homeownership Rate	-	-	66.6% (64%)	Eurostat (2004)

Table I: This table shows parameter values that are shared across all simulations. The value column provides the numerical value of the parameter. The target (model) column provides any relevant numerical targets that the parameter was selected to achieve, as well as the baseline model's actual value for that variable in parenthesis when it cannot be set directly with a single parameter.

well with the data.

The prepayment penalty parameter is the product of the average period of fixation (Swedish FSA, 2014c) and the average difference between fixed and adjustable bottom loan rates, computed using contract data from one of Sweden's largest banks. The prepayment penalty is calculated to be the product of this parameter and the size of the mortgage payment.

The top loan maturity is set to approximately 15 years, which implies a 1% rate of amortization in the baseline specification. This is the upper bound of the Swedish Bankers' Association 2014 recommendation, which suggests that households amortize to 70% within 10-15 years of origination. Selecting the upper bound should generate the largest possible effect from the mortgage regulation, since it assumes that the amortization rate is low prior to the regulation.

With respect to house prices, we set $A^h = 1$ and use two different parameterizations for the capacity utilization term:

$$\eta(IH_t) = \frac{IH}{IH_t} \tag{19}$$

$$\eta(IH_t) = \frac{IH^1}{IH_t} \tag{20}$$

The first specification is used in the baseline set of simulations; and forces house prices to remain unchanged across simulations, since $IH_t = IH$ in the steady state. This tests the new contract types under the assumption that housing supply is perfectly elastic in the long run, resulting in a fixed house price of unity. The second specification allows house prices to fall if steady state housing investment drops. Here, we use the aggregate level of steady state investment in the baseline simulation (I), IH^1, rather than the simulation-specific level of steady-state investment, IH. This pins down the house price as unity for the case with the baseline contract structure C:I; and makes simulations comparable by normalizing relative to the house price in simulation I. Notice that an increase in housing investment relative

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According to a Swedish FSA (2014c) report, 80-90% of mortgages had a fixed period of fewer than 5 years.

Table II: Contract-Specific Parameter Values

	Param	C:I	C:II	Source
Amortization cutoff	γ^A	0.70	0.50	Swedish FSA (2014a; 2015)
Bottom loan cutoff	γ^B	0.70	0.70	ASCB (2012)
Top loan cutoff	γ^T	0.85	0.85	Swedish FSA (2014a; 2015)
Risk-free rate	$\bar{r}$	0.028	0.028	Swedish FSA (2014c)
Bottom loan rate	r^B	$\bar{r}$	$\bar{r}$	-
Top loan rate	r^T	$r^B + \xi$	$r^T + \xi$	-
Consumer loan rate	r^C	$r^C + x$	$r^C + x$	-
Top loan premium	ξ	0.01	0.01	Swedish FSA (2014c)
Consumer loan premium	x	0.013	0.013	Swedish FSA (2014c)
Bottom loan amortization	χ^B	0	0.01	Swedish FSA (2014a; 2015)
Top loan amortization	χ^T	0.01	0.02	Swedish FSA (2014a; 2015)
Consumer loan amortization	χ^C	0.1	0.1	Swedish FSA (2014a; 2015)

Table II: This table provides parameter values that are specific to simulations. The C:I and C:II columns refer to the two different contract types used in simulations. C:I refers to current contracts. C:II refers to the proposed contracts under the amortization requirements.

to the baseline case increases capacity utilization in the construction sector, which lowers $\eta(IH_t)$. This causes house prices to rise. The results for this set of simulations is reported in Appendix A. In general, the policy effects are smaller; however, alternative calibrations yield effects that are slightly larger.

It is important to note that using the second specification is not equivalent to adjusting A^h, as is sometimes done to evaluate the impact of a policy that is likely to lower house prices. Rather, if p^h drops in the new steady state, it indicates that demand for housing has fallen; and, thus, household indebtedness is likely to have also fallen. In contrast, if A^h increases, then housing will become less expensive, which may have qualitatively different effects on both the housing and debt stocks.

Finally, with respect to the time cost of refinance, we assume that $\Lambda = 0.01$. This imposes a fee on refinance that is 1% of annual net income. This will further disincentivize equity extraction. Notice that an agent may amortize more than is required without incurring the cost.

5 Results

I perform three pairs of simulations. The first pair (I,II) measures the size of the policy's impact in the complete model. The two additional pairs of simulations identify potential channels for the policy's effect. The first simulation in each pair uses contract type C:I, and the second uses C:II. I then remove the DSI constraint in the second pair of simulations and quintuple the prepayment penalty in the third pair. Table III provides the specification for each of the six simulations.

The first set of results consists of the percentage differences in aggregate variables across steady states. In particular, each column in Table IV compares a steady state outcome in one of the counterfactual simulations to the corresponding outcome in the baseline simulation (I).

The first column measures the policy impact under the fully-specified version of the model. We can see that switching from C:I to C:II reduces the aggregate debt-to-income ratio by 2.21 percentage points in the new steady state. The largest proportional reductions

Figure III: Age-Productivity Profiles for
Three Productivity Groups

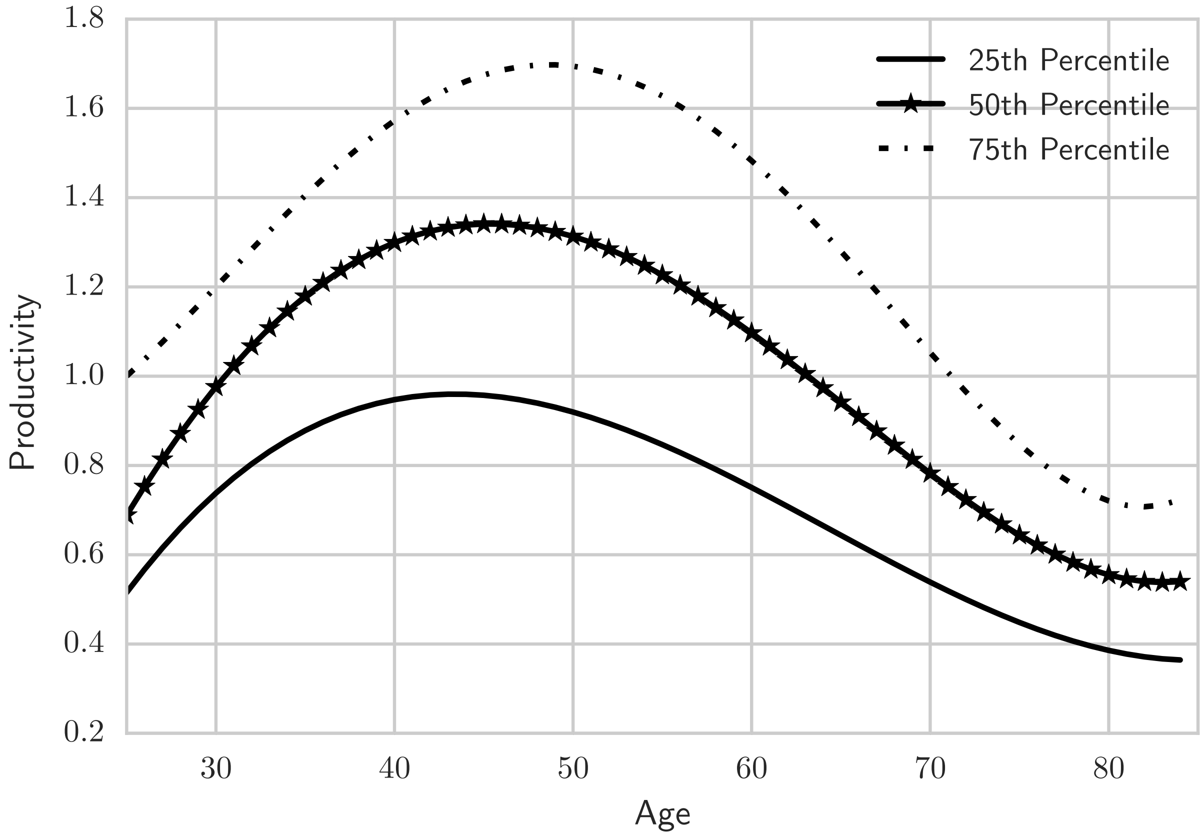

Figure III: The figure above shows age-productivity profiles for three permanent productivity types in the model: 25th, 50th, and 75th percentile. The profiles were estimated using Swedish micro data on income, which was taken from bank loans originated at one of Sweden's largest banks. The profiles were then normalized.

Table III: Simulation Specifications

	I	II	III	IV	V	VI
Contract Type	C:I	C:II	C:I	C:II	C:I	C:II
DSI Constraint	Yes	Yes	No	No	No	No
Increased Penalty	No	No	No	No	Yes	Yes

Table III: This table provides the specification for the six different simulations performed. Under "Contract Type," C:I refers to current contracts and C:II refers to the proposed contracts under the amortization requirements. "DSI Constraint" indicates whether or not the DSI constraint is imposed. "Increased Penalty" indicates whether or not the simulation uses the baseline prepayment penalty calibration or a prepayment penalty that is substantially higher than that is currently imposed.

come from top loan debt. Capital holdings and the homeownership rate decline slightly under the new policy. All agent types are affected, but high income and retired agents experience the largest debt reductions. Overall, the effects are small relative to the size of the empirical increase in indebtedness: 90% to 172% of disposable income.

The second and third columns show the results for simulations III and IV. Both remove the DSI constraint; however, the first uses C:I and the second uses C:II. We can see that removing the DSI constraint has one particularly pronounced effect: it increases all three types of debt. The largest proportional increases come in the form of top loan and consumer loan debt; and from low income and retired agents. Furthermore, without the DSI constraint, the impact on the aggregate debt-to-income ratio is identical in III and IV. This suggests that the DSI constraint not only lowers indebtedness, but plays a critical role in enabling intended amortization to reduce indebtedness by facilitating mortgage lock-in during certain points in the lifecycle.

The remaining pair of simulations quintuple the prepayment penalty. This lowers the debt-to-income ratio under both contract types, but generates no substantial interaction effect, which further reinforces the DSI constraint as the channel for C:II to reduce indebtedness. The reduction in debt comes partly through the selection channel: individuals who are likely to need equity extraction as a means to smooth consumption choose not to own instead. Furthermore, the reduction is concentrated exclusively in higher income agents.

The next set of results consists of the differences in outcomes between employed and

Table IV: Percentage Difference in Steady State Aggregate Variables

	II	III	IV	V	VI
Consumption	0.03%	-3.17%	-3.2%	1.68%	1.7%
Housing	-0.48%	8.21%	8.21%	-5.08%	-5.11%
Debt-to-Income Ratio	-2.21%	19.0%	19.0%	-37.79%	-37.81%
Debt (B)	-1.55%	10.86%	10.86%	-32.38%	-32.66%
Debt (T)	-4.42%	19.88%	19.88%	-42.52%	-41.99%
Debt (C)	-1.21%	27.7%	27.7%	-13.39%	-12.94%
Capital	-0.92%	-26.09%	-26.09%	-3.72%	-3.25%
Homeownership Rate	-0.11%	3.72%	3.72%	-2.08%	-2.08%
Debt (25th Pct.)	-0.46%	62.11%	62.11%	48.93%	48.73%
Debt (50th Pct.)	-1.19%	3.17%	3.17%	-48.78%	-49.25%
Debt (75th Pct.)	-1.83%	26.1%	26.1%	-22.56%	-22.22%
Debt (Working Age)	-0.4%	12.9%	12.9%	-35.12%	-34.89%
Debt (Retired)	-4.67%	29.98%	29.98%	-19.83%	-20.75%

Table IV: This table shows the percentage difference in steady state aggregate variables across simulations (II)-(VI) and the baseline simulation (I). House prices cannot vary within a steady state, but are permitted to vary across steady states in this set of simulations, following the specification given by (19). Debt (B), Debt (T), and Debt (C) show the results for bottom, top, and consumer loans. Debt (Xth Pct.) shows results for the Xth income percentile agents.

unemployed agents. A common rationale for increased amortization is that it makes households less vulnerable to income shocks in the long run. We examine this claim in Table V, which provides the percentage difference in consumption, housing, debt, and capital between employed and unemployed agents in each of the simulations.

The difference in income between employed and unemployed agents in each simulation is 50.01% and is pinned down by the replacement ratio. The policy impact in the fully-specified version of the model is small: the consumption gap drops slightly from 14.98% to 13.63%. The housing gap reduction is also small. In contrast, the debt and capital gaps actually rise. This suggests that intensified amortization decreases the financial flexibility of households slightly, leaving the unemployed with a diminished capacity to adjust debt holdings.

In the remaining two pairs of simulations–III and IV, and V and VI–there are no substantial consumption interaction effects across employment status generated by the switch from C:I to C:II. Rather, most of the variation in outcomes comes from the removal of the DSI constraint (III-VI) and the quintupling of the prepayment penalty (V-VI). We can see

Table V: Percentage Differences Between Employed and Unemployed Agents

	I	II	III	IV	V	VI
Income	50.1%	50.1%	50.1%	50.1%	50.1%	50.1%
Consumption	14.98%	13.63%	16.66%	16.62%	9.01%	9.14%
Housing	0.04%	-0.54%	0.24%	0.24%	1.03%	1.03%
Debt	20.54%	24.27%	1.52%	1.52%	-3.86%	-5.19%
Capital	17.25%	21.56%	6.29%	6.29%	23.35%	23.08%

Table V: This table shows the percentage difference in individual variables by employment status. Retired agents are excluded, since they are not subject to employment status shocks. Part of the rationale behind the proposed policy is to make unemployed households less vulnerable to income shocks. Thus, the consumption gap between employed and unemployed agents can be used to measure the effectiveness of the policy in achieving that particular objective.

that the removal of the DSI constraint alone adds substantial financial flexibility, resulting in a reduction in the debt and capital gaps. The growth in debt also increases the consumption gap.

Relative to III and IV, the consumption gaps drop substantially in V and VI, where the prepayment penalty is increased; however, this is partly the result of the reduction in homeownership. Agents who do not own homes only smooth along the consumption dimension when unemployed. As with III and IV, unemployed agents hold more debt than employed agents. This, in part, is caused by the larger prepayment penalty, which makes equity extraction unattractive. Only low income households with no other source of liquidity are likely to use refinance as a means to smooth consumption.

Appendix A provides the same results as Table IV, but with endogenous variation in house prices across stochastic steady states. There are no substantial qualitative differences between the results with and without endogenous house prices, so I will not comment on them extensively, but instead include them as a robustness check. The only substantive result is that the size of the debt-to-income ratio reduction shrinks to -.53 percentage points when house prices are endogenous; however, the direction of this change depends on the model calibration. Under alternative specifications, endogenous house prices lead to a slight increase in the magnitude of the effect.

Next, we will consider the lifecycle implications of the new types of contracts. Figure VI shows the percentage difference in debt profiles between simulations II and I, IV and III, and VI and V, averaged across all homeowners. This captures the change in the debt associated with a switch from C:I to C:II, conditional on assumptions about the DSI constraint and the prepayment penalty size. We can see that the removal of the DSI constraint without an increase in the prepayment penalty eliminates the impact of switching from C:I to C:II over the lifecycle. In contrast, imposing the DSI constraint provides a channel for C:II to lower indebtedness; and it does so later in the lifecycle, but only after raising indebtedness during midlife. Finally, removing the DSI constraint, but imposing a much larger prepayment penalty provides a channel for C:II to change indebtedness; however, it generates opposing effects that partially cancel out over the lifecycle, resulting in no substantial change in indebtedness for the average income homeowner under the two different contract types.

In general, these opposing effects arise from reducing the liquidity of unconstrained households. When households are forced to amortize faster, but are not borrowing constrained, they may use top loan and consumer loan debt to finance the amortization. In particular, they may extract equity and obtain consumer loans; and then convert those borrowed funds into capital, which can then be used to make larger mortgage payments as needed without the need to repeatedly refinance, incurring the prepayment and time costs.

Overall, the mechanisms that enforce the amortization requirements (i.e. make them difficult to avoid)–the DSI constraint and the prepayment penalty–generate larger changes in indebtedness than the actual amortization requirements in isolation. Furthermore, the impact of the amortization requirements depends critically upon which enforcement mechanisms are present when they are implemented. If the DSI constraint is weakly enforced and if the prepayment penalty is reasonably calibrated, then the impact of the amortization requirements is weak in aggregate, over the lifecycle, and across employment statuses. If the prepayment penalty is made very large, then the effects are small in aggregate and small, but non-monotonic over the lifecycle. And, finally, if the prepayment penalty is reasonably calibrated and the DSI constraint is strictly enforced, then the impact on indebtedness is small in aggregate and over the lifecycle, but negative and decreasing monotonically late in life.

Figure IV: Average Percentage Difference in Lifecycle Indebtedness by Contract Type for All Homeowners

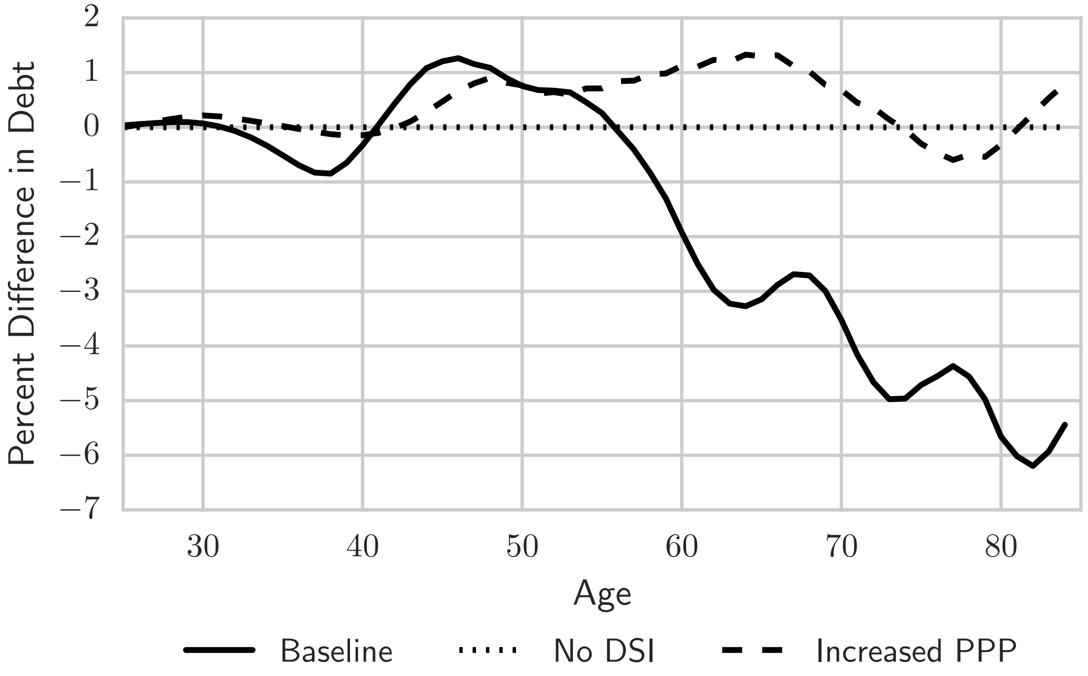

Figure IV: The figure above shows percentage differences between the proposed (C:II) and current (C:I) contract types over the course of the lifecycle. These lifecycle differences are given for each of the three simulation pairs: 1) baseline (I,II); 2) no DSI (III,IV); and 3) increased PPP (V,VI). All results shown are averages over all homeowners.

6 Conclusion

I evaluate mortgage amortization requirements as a tool for reducing household indebtedness and income shock vulnerability in the long run. I use an incomplete markets model with three types of debt and a novel mortgage contract specification that is calibrated using Swedish micro and macro data. I evaluate current, Swedish-style mortgage contracts; and compare them to the contracts proposed by the Swedish FSA. Current contracts require households to amortize down to a 0.70 LTV ratio, but allow purely voluntary amortization thereafter. The proposed contracts would require households to amortize mortgages at a rate of 2% until a 0.70 LTV ratio is achieved; and then 1% until a 0.50 LTV ratio is achieved.

I find that the policy effect in the fully-specified model is small. The debt-to-income ratio drops, but only by 0.53ppt to 2.21ppt. The consumption and housing gaps between employed and unemployed agents do not drop substantially under the new contracts, but the debt and capital gaps increase slightly as a result of the reduced financial flexibility of households under the amortization requirements.

When the debt-service-to-income (DSI) constraint is removed and the prepayment penalty is realistically-calibrated, the proposed amortization requirements have no substantial impact on the debt-to-income ratio in aggregate, over the lifecycle, or across employment statuses. Furthermore, regardless of contract type, the debt-to-income ratio increases by approximately 19% when the DSI constraint is removed. This suggests that the policy's efficacy will rely on amortization requirements having a substantial impact on credit supply decisions. If banks use the required rate of amortization to determine how much to lend to households, then the policy impact may mechanically reduce indebtedness; however, if this channel is weak, then the effect may be even smaller. It is important to note, however, that agents unconstrained by the DSI condition may actually increase indebtedness in response to the policy, since the model does not force all agents to stay on the intended amortization path, as is often assumed in the literature.

When the prepayment penalty size is increased substantially, the debt-to-income ratio also drops substantially. However, this reduction does not come entirely from enforcing the intended amortization path. Instead, it reduces housing demand among agents that are likely to need to extract equity in the future. It also causes households to delay buying until they are further along in the lifecycle and have accumulated a sufficient capital buffer to smooth consumption in response to income shocks.

Overall, the impact of the proposed policy is small relative to the increase in indebtedness in Sweden since the mid-1990s. One possible reason for this is that required amortization may not be an effective channel for reducing household indebtedness. Even with a reasonably calibrated prepayment penalty and a time cost of refinance equal to 1% of the household's net income, households do not appear to dramatically deviate from their optimal amortization paths to follow the one intended by a particular mortgage contract. Rather, they refinance as needed to achieve a similar path after the change in amortization requirements. Implausibly large refinance costs or tight DSI requirements are needed to generate a reduction in indebtedness; however, these effects are not primarily driven by their interaction with amortization requirements.

A second possibility is that the proposed amortization requirements are not sufficiently strict. At most, the new contracts will increase the rate of amortization by 1 percentage point from an LTV ratio of 0.85 to an LTV ratio of 0.50. A stricter policy might instead require households to fully amortize contracts within a shorter period of time. However, unless an unrealistic calibration is used, this policy cannot generate effects sufficiently large to deal with the increase in indebtedness since the mid-1990s.

A third possibility is that the model is missing a critical ingredient, such as non-optimizing households. A large mass of "rule of thumb" amortizers, who simply remain on the intended amortization path, might generate a larger policy effect. However, it is not clear whether such a group exists, is large, and follows that particular rule of thumb. It is entirely possible–and perhaps more consistent with the recent empirical evidence–that some non-optimizers follow a rule of thumb that results in higher, rather than lower, indebtedness.

Finally, it is important to state a limitation of this exercise: all comparisons are performed across stochastic steady states, and it is not feasible to compute a transition path or introduce aggregate uncertainty. Thus, it is possible that the intensification of the rate and duration of amortization could generate larger effects on the transition path; however, this work suggests that such changes are unlikely to persist in the new steady state.

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8 Appendix A: Endogenous House Price Results

Table VI provides the results for the case where house prices are endogenous.

Table VI: Percentage Difference in Steady State Aggregate Variables

	II	III	IV	V	VI
Consumer	-1.15%	-3.78%	-3.8%	1.56%	1.51%
Housing	-1.95%	6.89%	6.89%	-12.02%	-11.93%
Debt-to-Income Ratio	-0.53%	27.03%	27.04%	-40.76%	-40.36%
Debt (B)	4.6%	19.71%	19.68%	-34.45%	-34.4%
Debt (T)	-17.72%	16.74%	16.71%	-47.02%	-45.47%
Debt (C)	-12.95%	27.09%	27.15%	-15.46%	-15.05%
Capital	-14.88%	-26.5%	-26.5%	-8.38%	-8.51%
Homeownership Rate	-0.86%	2.67%	2.67%	-6.25%	-6.19%
House Prices	-1.95%	6.89%	6.89%	-12.02%	-11.93%
Debt (25th Pct.)	-16.52%	38.02%	38.14%	-16.5%	-16.5%
Debt (50th Pct.)	3.01%	10.17%	10.17%	-45.98%	-45.43%
Debt (75th Pct.)	-0.2%	36.22%	36.18%	-24.89%	-24.71%
Debt (Working Age)	1.0%	20.49%	20.47%	-35.36%	-35.18%
Debt (Retired)	-1.05%	35.37%	35.37%	-30.93%	-30.12%

Table VI: This table shows the percentage difference in steady state aggregate variables between simulations (II)-(VI) and the baseline simulation (I). House prices vary endogenously across steady states in this set of simulations, following the specification given by equation (20). Debt (B), Debt (T), and Debt (C) show results for bottom, top, and consumer loans. Debt (Xth Pct.) shows results for the Xth income percentile agents.

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9 Appendix B: Solution Method

I solve two different versions of the model. Both are Aiyagari-style (1994) incomplete markets models. One version has endogenous house prices. The other does not. When house prices are not endogenous, the aggregate state is summarized by the capital stock. In the version with endogenous house prices, the aggregate state consists of both the aggregate capital stock and the aggregate housing stock. The algorithm below was used to solve the version of the model with endogenous house prices. The version without omits the condition for housing investment, but is otherwise identical.

9.1 Steady State Equilibrium

- **Step 0: Initialization.** Compute the steady state employment rate, N, and guess initial values for the aggregate capital stock, K, and housing stock, H. Use K and N to compute factor prices, w and r. Use H to compute the unit house price, p^h.
- **Step 1: Household's Problem.** Solve the household's problem. Recover the decision rules for capital, k; housing, h; debt, b; and consumption, c.
- **Step 2: State Distribution Simulation.** Simulate the distributions of individual-level capital and housing.
- **Step 3: Price Update.** Update K and H by aggregating individual holdings of capital and housing. Recompute r, w, and p^h.
- **Step 4: Convergence Check.** Let the subscript, n, denote the iteration number. Let ϵ_k and ϵ_h denote the tolerance values for capital and housing. If $|K_n - K_{n-1}| < \epsilon_k$ and $|H_n - H_{n-1}| < \epsilon_h$, then terminate the program. Otherwise, return to Step 1.

9.2 Household's Problem

The household's problem is solved using a version of backwards recursion that is parallelized using a GPU. The approach is similar to the one proposed in Aldrich et al. (2011), but is adapted for finite horizon problems:

- **Step 0: Vectorize States and Preallocate Memory.** Construct a single-index state, s, which maps to each unique set of endogenous states. Compute the dimensionality of the state space, $|s|$=d. Choose a segment length, n, such that the GPU contains enough memory to hold $\frac{d^2}{n}$ floats.
- **Step 1: Initialize.** Take the prices as given from the outer loop. Initialize the age-specific value functions: $V_1, ..., V_{T+1}$ and set the post-terminal period values for capital, $k_{T+1} = 0$; housing, $h_{T+1} = 0$; and debt, $b_{T+1} = 0$. Set all post-terminal period values: $V_{T+1} = 0$.
- **Step 2: Solve for V_T.** Compute a segment of V_T–$V_T(s_{j*n}, ...s_{(j+1)*n})$–by performing the maximization step in parallel on the GPU. Iterate over all $\frac{d}{n}$ segments. Update the

values of V_T.

- **Steps 3,..,T+1. Repeat Step 2 for** $V_{T-1}, ..., V_1$.