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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. These results may be relevant for other OECD countries, such as Norway and Canada, that have also not seen a reduction in house prices or indebtedness since the 2007 financial crisis.

JEL Classification: E44, G21, R21

Keywords: Mortgages, Amortization, Heterogeneous Agents, Incomplete Markets, Financial Regulation

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The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Executive Board of Sveriges Riksbank.

†Research Division, Sveriges Riksbank, SE-103 37, Stockholm, Sweden. Email: isaiah.hull@riksbank.se.

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, 2014). 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, 2014).

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 macro-prudential 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.[1] There is still disagreement

[1]Front-loading amortization allows Swedish-style mortgages to avoid the selection problem that de-

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.[2]

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[3] 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 mortgage 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 policy 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 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–

ferred 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.

[2]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.

[3]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.

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 1.17 and 2.79 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.

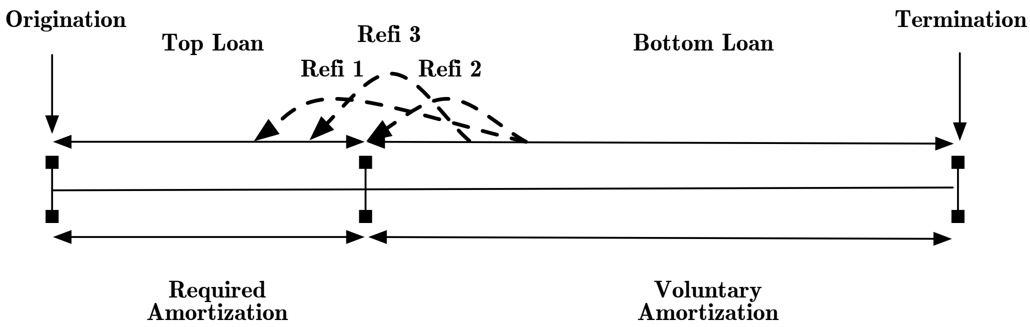
In Section 2, I will describe the essential features of a Swedish-style mortgage contract. I will then construct a quantitative equilibrium model, which reproduces these features in Section 3. Finally, I will detail the model's calibration in Section 4, perform policy experiments in Section 5, and then 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 11 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 stamp duty; 7) the size of the mortgage registration fee; 8) the size of the property tax; 9) the top loan interest rate; 10) the bottom loan interest rate; and 11) the prepayment penalty.

Figure 1 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.

Figure 1: Current Contract Structure



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 some pre-specified window. 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. Top and bottom loans may also bear different interest rates, since they are collateralized against different components of the home's value.[4]

Three alternative refinancing choices–Refi 1, Refi 2, and Refi 3–are shown in Figure 1. 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

[4]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.

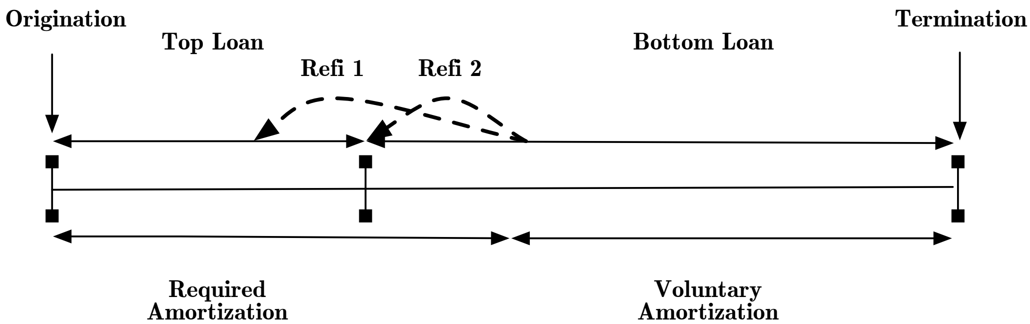
mortgage payment, since it requires the borrower to take on a new top loan. Thus, the threshold that triggers amortization is a critical nonlinearity in the household's mortgage choice problem.[5]

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. This distinction is important, since it suggests that policies that are effective at reducing debt may also come with a substantial negative side effect: they may reduce a household's ability to respond to shocks.

The proposed mortgage amortization guidelines will modify the required amortization threshold. Households will need to amortize 2% of the entire mortgage 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 2 illustrates the proposed contract structure. Consider a household who amortizes down to the new 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, which will trigger 1% amortization, even if it extracts the amount of equity implied by Refi 2. Furthermore, if it instead opts for Refi 1, then it will trigger a 2% amortization rate. Both changes may also incur a prepayment penalty if the period of fixation has not ended.

Figure 2: Proposed Contract Structure



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

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

or consumption–then she 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 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 them. 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.

Finally, 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 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.

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:

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

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

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:

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

Above, ih_{it} is individual i's housing investment at time t, which is generated using the nondurable consumption good, c^h_{it}, but depends on housing productivity, A^h, and capacity utilization, $\eta(IH)$. Since all exercises will compare steady states, A^h will not vary over time, but will serve as a measure of relative productivity across sectors.

Housing investment is assumed to be reversible, 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 $\eta(IH)$. The first 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 second specification will allow $\eta(IH)$ 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 house prices in the steady state.

The assumption that house prices rise permanently in response to an increase in demand is not trivial. Shiller (2007), Sorensen (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.

3.2 Households

Households enter the model at age 25, work for 60 periods, and then perish with certainty. Households differ with respect to their permanent, 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:

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

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.

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} or 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:

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

Above, $b_{it} = b_{it}^B + b_{it}^T + b_{it}^C$. Note also that m_{it} includes payments to the top loan, bottom loan, and consumer loan. The targeted, post-amortization loan amount, b^*, 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.

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. Housing stock movements are infrequent and large when they occur.

In order to reduce the size of the state space, I collapse the three types of debt into a single contract with multiple cutoffs: $\{\gamma_0, \gamma_1, \gamma_2\}$.[6] 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_0, γ_1, and γ_2 are the LTV cutoffs for forced amortization, bottom loan borrowing, and top loan borrowing. Similarly, χ_0, χ_1, and χ_2 are the associated rates of amortization for each component of debt; and r_0, r_1, and r_2 are the corresponding interest rates. The remaining parameters–χ_3 and r_3–are applied to consumer loans. The combined debt payment schedule is given by equation (9).

The first component of (9) is the payment a household makes if it only has a bottom loan and maintains sufficient equity to avoid required amortization. If a household sur-

[6]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.

passes this cutoff, but falls below γ_1, then it must begin to amortize the component of the bottom loan above the γ_0 cutoff. Furthermore, if it is above the γ_1 cutoff, then it must take on a top loan as well, but does not need to amortize the bottom loan until it drops below γ_1. If it is also above the γ_2 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.

$$m_{it} = \begin{cases} (1+r_0)b_{it} & \text{if } b_{it} < \gamma_0 p^h h_{it} \\ (1+r_0)\gamma_0 p^h h_{it} + & \text{if } \gamma_1 p^h h_{it} > b_{it} \geq \gamma_0 p^h h_{it} \\ (1+r_1)(b_{it} - \gamma_0 p^h h_{it}) & \\ (1+r_0)\gamma_0 p^h h_{it} + & \text{if } \gamma_2 p^h h_{it} > b_{it} \geq \gamma_1 p^h h_{it} \\ (1+r_1)(\gamma_1 - \gamma_0) p^h h_{it} + & \\ (1+r_2)(b_{it} - \gamma_1 p^h h_{it}) & \\ (1+r_0)\gamma_0 p^h h_{it} + & \text{if } b_{it} \geq \gamma_2 p^h h_{it} \\ (1+r_1)(\gamma_1 - \gamma_0) p^h h_{it} + & \\ (1+r_2)(\gamma_2 - \gamma_1) p^h h_{it} + & \\ (1+r_3)(b_{it} - \gamma_2 p^h h_{it}) & \\ (1+r_3)b_{it} & \text{if } h_{it} = 0 \end{cases} \tag{9}$$

Next, we construct the amortization schedule that is intended at a mortgage's origination. This, of course, can be avoided through successive refinancing, 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):

$$b_t^* = \begin{cases} b_{it} - \chi_0 b_{it} & \text{if } b_{it} < \gamma_0 p^h h_t \\ b_{it} - \chi_1 \gamma_0 p^h h_{it} & \text{if } \gamma_1 p^h h_{it} > b_{it} \geq \gamma_0 p^h h_{it} \\ b_{it} - \chi_2 \gamma_1 p^h h_{it} & \text{if } \gamma_2 p^h h_{it} > b_{it} \geq \gamma_1 p^h h_{it} \\ b_{it} - \chi_2 \gamma_2 p^h h_{it} - & \text{if } b_{it} \geq \gamma_2 p^h h_{it} \\ \chi_3(b_{it} - \gamma_2 p^h h_{it}) & \\ b_{it} - \chi_3 b_{it} & \text{if } h_{it} = 0 \end{cases} \tag{10}$$

I also apply a lifetime borrowing condition, which is similar to the constraint imposed in Iacoviello and Pavan (2013). 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.

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

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:

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

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

We model Sweden as a small, open economy and allow households to borrow from a foreign lender. 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.[7]

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.

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 and retired agents do not pay taxes. The tax for employed homeowner i is the following:

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

Aggregate incoming revenue is equal to aggregate outgoing transfer payments:

[7] 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.

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

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 housing depreciation rate, 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 (2014).

Since the model contains a substantial degree of heterogeneity, I also attempt to match individual distributions. The GINI target for income comes from the OECD (2014). The GINI coefficient target for net assets comes from Jantti et al. (2008).

The model is also calibrated to capture the lifecycle income profile of households. For this, 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 loan data from one of the largest Swedish banks. The normalized age-wage profiles of the five groups are shown in Figure 1.

In addition to shared parameters in Table 1, the model also contains parameters specific to the original and proposed mortgage contracts. These are given in Table 2 below. 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).

Table 1: Shared Parameter Values

	Parameter	Value/Target
Housing utility curvature	σ_H	3
Cons. utility curvature	σ_C	1
Non-housing shelter	-	1.0 x w
Unemployment rate	-	7.5%
Housing depreciation rate	-	.05
Housing adjustment cost	-	.05
Min house size	$\underline{h}$	1.5 x w
Discount factor	β	.95
Replacement ratio	ζ	0.685
Prepayment penalty	ψ	0.0034
Property tax	ϕ	0.0075
Stamp duty	Ξ	0.015
Income GINI	-	0.27
Net Worth GINI	-	0.617
DSI maximum	κ	0.30
Collateralizable housing	Φ	0.85

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 well with the data.[8]

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

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

loan rates, computed using contract data from one of Sweden's largest banks. The prepayment penalty is computed as 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 is low prior to the regulation.

Table 2: Contract-Specific Parameter Values

	Param	C:I	C:II
Amortization cutoff	γ_0	0.70	0.50
Bottom loan cutoff	γ_1	0.70	0.70
Top loan cutoff	γ_2	0.85	0.85
Risk-free rate	$\bar{r}$	0.028	0.028
Bottom loan rate	r_0,r_1	$\bar{r}$	$\bar{r}$
Top loan rate	r_2	$r_0 + \xi$	$r_0 + \xi$
Consumer loan rate	r_3	$r_2 + x$	$r_2 + x$
Top loan premium	ξ	0.01	0.01
Consumer loan premium	x	0.013	0.013
Bottom loan amortization	χ_1	0	0.01
Top loan amortization	χ_2	0.01	0.02
Consumer loan amortization	χ_3	0.1	0.1

With respect to house prices, we use two different parameterizations for the capacity utilization term:

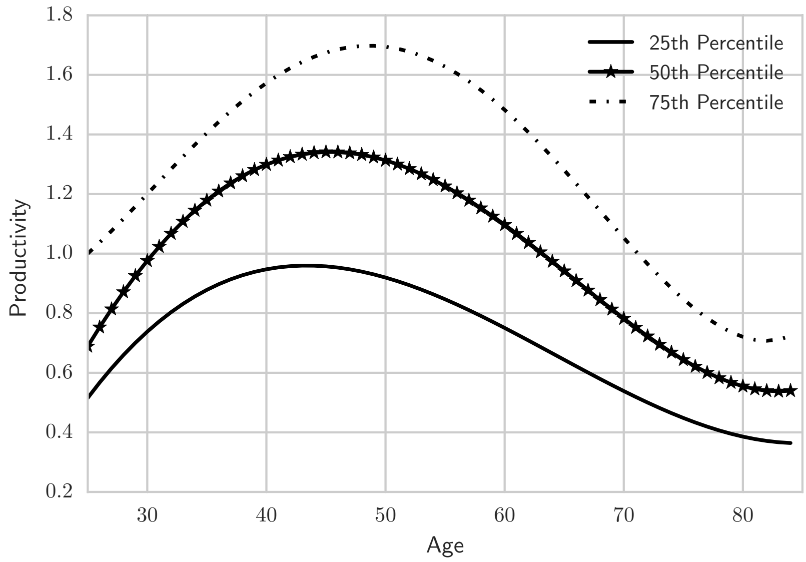
$$\eta(IH_t) = \theta_0 \left(\frac{IH_t}{IH^*}\right)^{\theta_1} \tag{19}$$

$$\eta(IH_t) = \theta_0 IH_t^{\theta_1} \tag{20}$$

The first specification is used in the baseline set of simulations. Imposing this calibration forces house prices to remain unchanged across steady state equilibria. This tests the new contract types under the assumption that housing supply is perfectly elastic in the long run. The simulation results given in Appendix A used the second specification, which allows house prices to fall if steady state housing investment drops. We assume that $\theta_1 = -1$ and set $\theta_0 = IH^*$, which pins down the house price as unity for the case with the current contract structure C:I and fixed prices. This assumption will make simulations comparable by normalizing relative to the house price in simulation S:I.

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.

Figure 1: Age-Productivity Profiles for Three Productivity Groups



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 (S:I and S:II) measures the size of the policy's impact in the complete model. The two additional pairs identify potential channels for the policy's effect. The first simulation in each pair uses contract type I, and the second uses II. I then remove the DSI constraint in the second pair of simulations and quintuple the prepayment penalty in the third pair. Table 3 provides the specification for each of the six simulations.

Table 3: Simulation Specifications

	S:I	S:II	S:III	S:IV	S:V	S: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

The first set of results consists of the percentage differences in aggregate variables across steady states. In particular, each column in Table 4 compares a steady state outcome in one of the counterfactual simulations to the corresponding outcome in the baseline simulation (S:I).

Table 4: Percent Difference in Steady State Aggregate Variables

	II	III	IV	V	VI
Consumption	0.14%	-1.21%	-1.38%	1.99%	2.15%
Debt-to-Income Ratio	-1.17ppt	34.87ppt	34.62ppt	-21.61ppt	-21.35ppt
Debt (B)	0.48%	13.17%	12.82%	-35.33%	-35.32%
Debt (T)	-13.84%	255.34%	252.52%	58.82%	63.34%
Debt (C)	-5.23%	94.86%	95.07%	22.58%	25.18%
Capital	0.36%	4.02%	3.14%	2.53%	3.17%
Homeownership Rate	0.0ppt	0.75ppt	0.75ppt	-8.14ppt	-8.89ppt

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 1.17 percentage points in the new steady state. The largest reductions come from top loan and consumer loan debt, respectively. Bottom loan debt actually increases slightly. Capital holdings and, relatedly, consumption also rise slightly under the new policy. The homeownership rate remains unchanged. 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 S:III and S: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. Furthermore, without the DSI constraint, the impact on the aggregate debt-to-income ratio is virtually identical in S:III and S:IV. This suggests that the DSI constraint not only lowers indebtedness, but plays a critical role in allowing intended amortization to reduce indebtedness.

The remaining pair of simulations quintuples 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. Furthermore, the impact is not uniform across debt types: bottom loan debt drops, but top loan and consumer loan debt rise. The reduction in bottom loan debt comes primarily through the selection channel: individuals who are likely to need equity extraction as a means to smooth consumption choose not to own instead. Those who do own tend to borrow more–using top and consumer loans–and store those borrowed funds in the form of capital.

The next set of results consists of the differences in outcomes between employed and 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 5, which provides the percentage difference in consumption, housing, debt, and capital between employed and unemployed agents in each of the simulations.

Table 5: Percentage Differences Between Employed and Unemployed Agents

	S:I	S:II	S:III	S:IV	S:V	S:VI
Income	48.05%	48.05%	48.05%	48.05%	48.05%	48.05%
Consumption	7.51%	7.42%	7.67%	7.88%	6.63%	6.77%
Housing	0.99%	0.94%	0.61%	0.57%	0.49%	0.42%
Debt	12.94%	14.79%	6.62%	6.58%	-8.48%	-8.64%
Capital	8.93%	9.08%	4.75%	4.22%	9.68%	9.64%

The difference in income between employed and unemployed agents in each simulation is 48.05% 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 from 7.51% to 7.42%. The housing and capital gaps are also small. The largest gap increase comes from total indebtedness, which widens from 12.94% to 14.79%. This suggests that intensified amortization decreases the financial flexibility of households slightly, leaving the unemployed with a diminished capacity to adjust debt holdings. It is important to note, however, that this effect is small and does not hold across all model specifications.

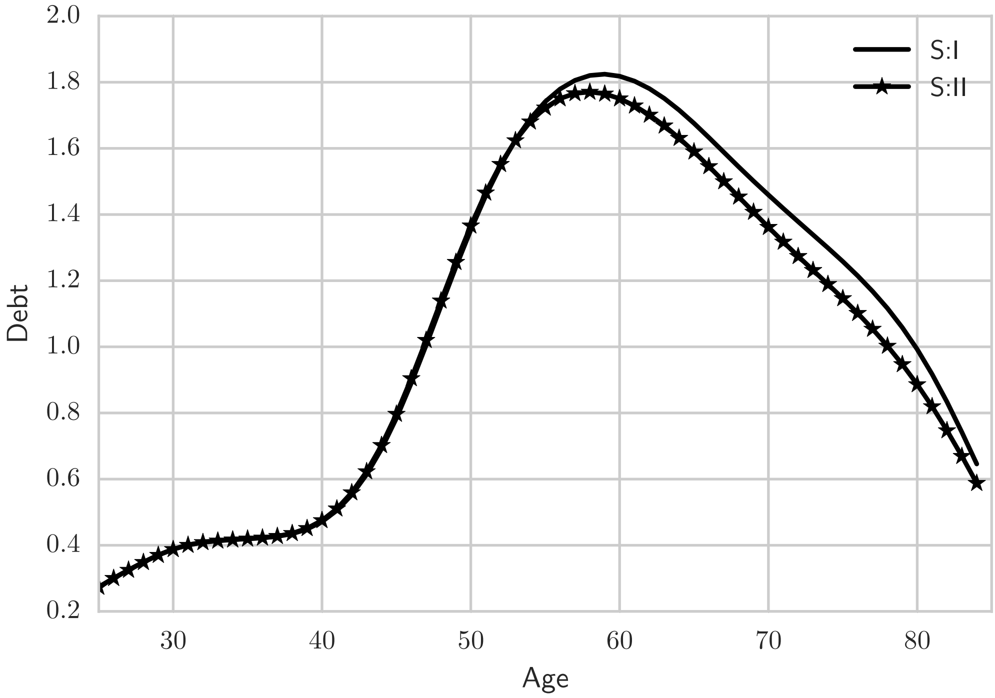
In the remaining two pairs of simulations–S:III and S:IV, and S:V and S:VI–there are no substantial interaction effects across employment status generated by the switch from C:I to C:II. Rather, most of the variation in outcomes comes from the removal of DSI constraint (S:III-S:VI) and the quintupling of the prepayment penalty (S:V-S:VI). We can see that the removal of the DSI constraint alone adds substantial financial flexibility, resulting in a reduction in the debt and capital gaps. However, this does not close the consumption gap to any substantial degree. Instead, agents use their increased financial flexibility to avoid selling their homes when financially distressed. This reduces the housing gap between employed and unemployed agents.

In contrast to S:III and S:IV, the consumption gap drops substantially in S:V and S:VI, where the prepayment penalty is increased; however, this is primarily the result of the reduction in homeownership. Agents who do not own homes only smooth along the consumption dimension when unemployed. They are also more limited in their borrowing and must do this using only capital. This accounts for the substantial rise in the capital holdings gap. The debt gap now changes sign: 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, 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 more than doubles when house prices are endogenous; however, even this larger reduction is still quite small.

Next, we will consider the lifecycle and distributional implications of the new types of contracts. We will focus primarily on the fully-specified version of the model, where the DSI constraint is imposed. Figure 2 shows average debt over the lifecycle for agents in the 25th percentile of the income distribution. Initially, the DSI and lifetime borrowing constraints keep indebtedness low. Delayed homeownership, in particular, tightens the lifetime borrowing constraint, restricting debt to a small amount in the form of consumer loans. As low income agents move further into the lifecycle, more become homeowners, which pushes up indebtedness. The total debt stock for 25th percentile earners peaks around age 55 and begins to decline thereafter. Some debt remains in the final period of life, but is settled using asset holdings.

Figure 2: Average Lifecycle Indebtedness by Contract Type for 25th Percentile Earners



Beyond the shapes of the lifecycle profiles, another regularity is apparent in Figure 2: the average indebtedness of 25th percentile earners is always weakly lower in S:II, where contract C:II is used. Not surprisingly, the gap only becomes apparent later in life, as more agents become homeowners and take on bottom and top loan debt.

Figure 3 shows average indebtedness over the lifecycle for 75th percentile earners. Here, the lifecycle profile takes on a different shape: high income households become homeowners and take on mortgage debt earlier in life. Furthermore, 75th percentile earners are less likely to encounter the lifetime borrowing constraint when they refinance; and are largely able to avoid paying down debt until late in life. The direction of the impact of C:II also changes for 75th percentile earners: under C:II, indebtedness is always weakly higher. Between ages 40 and 55–when agents are most likely to move to a larger home and to pay down consumer loans–indebtedness is strictly higher under C:II, even though the rate of amortization is higher.

Figure 3: Average Lifecycle Indebtedness by Contract Type for 75th Percentile Earners

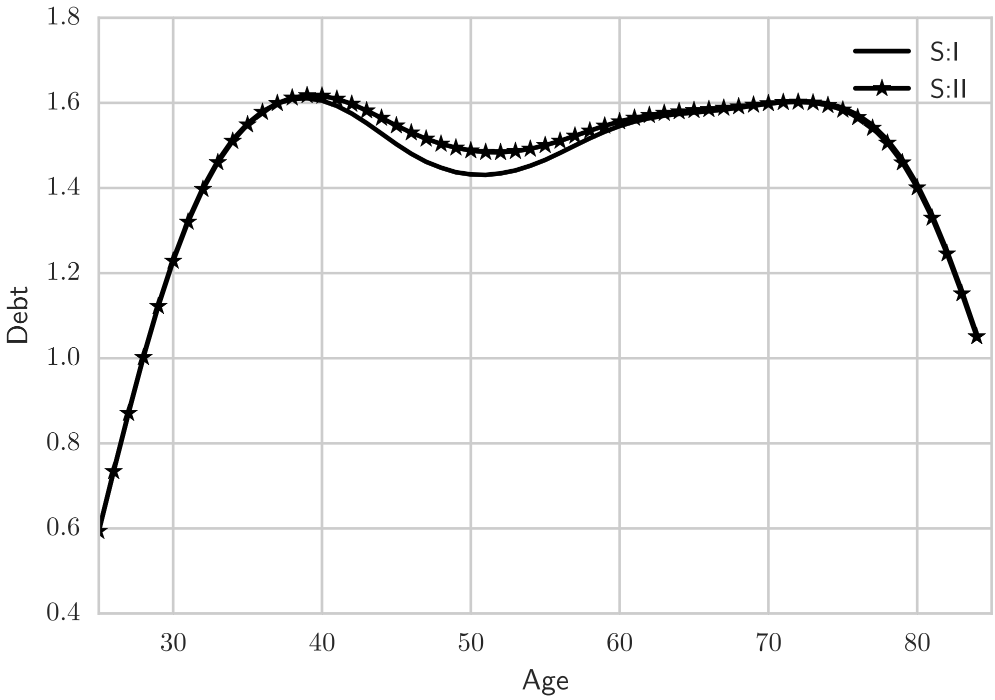
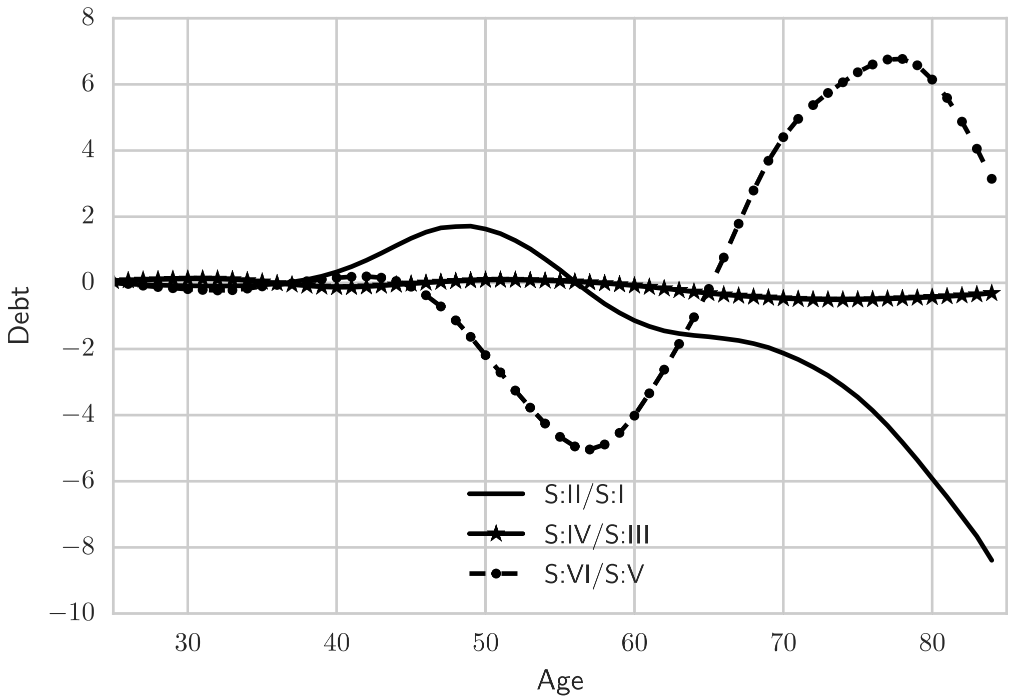


Figure 4 shows the percentage difference in debt profiles between S:II and S:I, S:IV and S:III, and S:VI and S:V. This captures the change in the debt associated with a switch from C:I to C:II, conditional on assumptions about the DSI constraint and the prepayment penalty size. We can see that the removal of the DSI constraint without an increase in the prepayment penalty (i.e. S:IV/S:III) eliminates the impact of switching from C:I to C:II over the lifecycle. In contrast, as we established earlier, imposing the DSI constraint provides a channel for C:II to lower indebtedness; however, it also causes a small, initial increase in indebtedness before reducing it. 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 largely cancel out over the lifecycle, resulting in no average change in indebtedness.

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.

Figure 4: Percentage Differences in Average Debt Profiles



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, but large over the lifecycle. And, finally, if the prepayment penalty is reasonably calibrated, but the DSI constraint is strictly enforced, then the impact on indebtedness is small in aggregate, but larger and almost monotonically negative over the lifecycle.

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 1.17ppt to 2.79ppt; and most of the reduction comes in the form of reduced top and consumer loan debt. Bottom loan debt increases slightly. The consumption and housing gaps between employed and unemployed agents do not drop substantially under the new contracts, but the debt gap increases 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 34% when the DSI constraint is removed, coming primarily from increases in top and consumer loan debt. 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 primarily 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% 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 is unlikely to 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, could 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 6 below provides the results for the case where house prices are endogenous.

Table 6: Percent Difference in Steady State Aggregate Variables

	I	II	III	IV	V	VI
Consumption	0.0%	0.34%	-0.41%	-0.4%	3.01%	2.94%
Debt-to-Income Ratio	0.0ppt	-2.79ppt	33.16ppt	33.09ppt	-24.88ppt	-23.93ppt
Debt (B)	0.0%	-0.35%	14.31%	14.24%	-35.86%	-35.01%
Debt (T)	0.0%	-9.62%	187.65%	187.4%	27.57%	30.88%
Debt (C)	0.0%	-12.74%	72.84%	72.86%	9.01%	10.65%
Capital	0.0%	0.82%	7.06%	7.05%	5.78%	5.69%
Homeownership Rate	0.0ppt	-0.06ppt	0.94ppt	0.89ppt	-8.92ppt	-9.14ppt
House Prices	0.0%	-0.24%	1.82%	1.76%	-9.95%	-10.05%

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 aggregate housing investment. 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** $V_{T-1}, ..., V_1$.

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Sveriges Riksbank
Visiting address: Brunkebergs torg 11
Mail address: se-103 37 Stockholm

Website: www.riksbank.se
Telephone: +46 8 787 00 00, Fax: +46 8 21 05 31
E-mail: registratorn@riksbank.se