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Macprudential and Monetary Policy Interactions in a
DSGE Model for Sweden

by Jiaqian Chen and Francesco Columba

I N T E R N A T I O N A L M O N E T A R Y F U N D

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Macprudential and Monetary Policy Interactions in a DSGE Model for Sweden

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Authorized for distribution by Craig Beaumont

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Abstract

We analyse the effects of macroprudential and monetary policies and their interactions using an estimated dynamic stochastic general equilibrium (DSGE) model tailored to Sweden. Households face a ceiling on their loan-to-value ratio and must amortize their mortgages. The government grants mortgage interest payment deductions. Lending rates are affected by mortgage risk weights. We find that demand-side macroprudential measures are more effective in curbing household debt ratios than monetary policy, and they are less costly in terms of foregone consumption. A tighter macroprudential stance is also found to be welfare improving, by promoting lower consumption volatility in response to shocks, especially when using a combination of macroprudential instruments.

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1 Introduction

In the aftermath of the Global Financial Crisis a consensus is emerging around a paradigm that tasks financial stability to macroprudential policies, with a role for monetary policy reserved for extraordinary times (IMF., 2015). Monetary policy remains assigned to macroeconomic stability, often via an inflation targeting framework. Current thinking is that macroprudential tools, if deployed in a timely manner, can effectively contain most vulnerabilities, although their effects, especially on welfare, need further study (Claessens, 2014). Yet, as macroprudential policies are still unproven, risks to financial stability cannot be completely excluded from the considerations behind monetary policy decisions (Bernanke, 2015). Indeed, it is possible that, threats to financial stability arise that cannot be adequately addressed by macroprudential instruments, but given their macroeconomic impact, any “leaning against the wind” by monetary policy against such threats can only be justified after a thorough cost-benefit analysis (Svensson, 2016). Coordination between macroprudential instruments and monetary policy, which may support their effectiveness in periods of stress, also needs further analysis (Angelini et al., 2014).

High and rising house prices and household mortgage debt in Sweden have prompted financial stability concerns. Moreover, Swedish banks are large, at some 400 percent of GDP, and have a large exposure to mortgages increasing the potential for mounting vulnerabilities in the housing market and household balance sheets to undermine the resilience of the financial system. The banking system is dominated by four large conglomerates that are highly interconnected through cross holding of covered bonds. It is therefore important to understand the potential for macroprudential policies to curb such risks. Nonetheless, the potential stability benefits of macroprudential policies from moderating household debt have to be assessed taking into account the welfare costs from their impact on the economy. Monetary policy effectiveness in halting such dynamics in housing markets are also examined, even though there seems to be no scope at this time for monetary policy to lean against the wind as low inflation expectations have prompted the Riksbank to focus on fighting low inflation to protect the credibility of the inflation targeting framework.

This paper contributes to the literature in two ways. First, it compares the costs and benefits of macro-prudential and monetary policies in reducing household debt in a fully-fledged general equilibrium model, aiming to shed some light on the difficult trade-offs that policymakers face. In particular, we compare the effect of a number of demand-side macro prudential measures, being loan-to-value (LTV) ratios, amortization requirements and tax

deductibility of mortgage interest payments, with a supply-side measure, the mortgage risk weight. This is motivated by the circumstance that in the case of Sweden there may be more room for tightening the macro-prudential stance via demand-side instruments, as supply-side measures have already been tightened in recent years (Chen, 2014). We use a modified form of the dynamic stochastic general equilibrium (DSGE) model of Gerali et al. (2010) for this purpose, making it suitable for a small open economy, adding additional macroprudential measures, and estimating it with Swedish data. Second, we study the welfare implications of these policies to shed some light on whether macroprudential policies are welfare improving, whether macroprudential measures are subject to decreasing effectiveness, and whether there are complementarities among the measures.

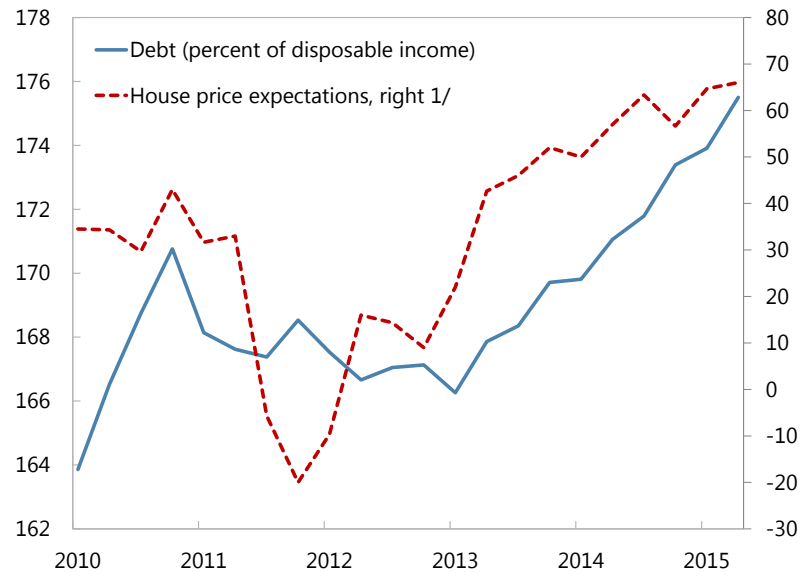
The remainder of the paper is structured as follows. Section II highlights key developments in housing and mortgage markets in Sweden. Section III describes the model. Section IV discusses its calibration and presents the estimation results and section V illustrates the properties of the estimated model. Section VI discusses the impact of macroprudential policies and section VII studies the welfare implications. Section VIII concludes with policy implications.

2 The Swedish Housing Market

Swedish households' debt is high and rising. Debt as a share of disposable income reached 176 percent in June 2015 and 195 percent if the debt of tenant-owned housing associations is included. The continued increase in house prices reflects the lack of housing supply alongside strong housing demand fostered by historically low interest rates, rising incomes and wealth, and population growth especially in the main cities (Turk, 2015). The record high share of households expecting further house prices increases could support further borrowing.

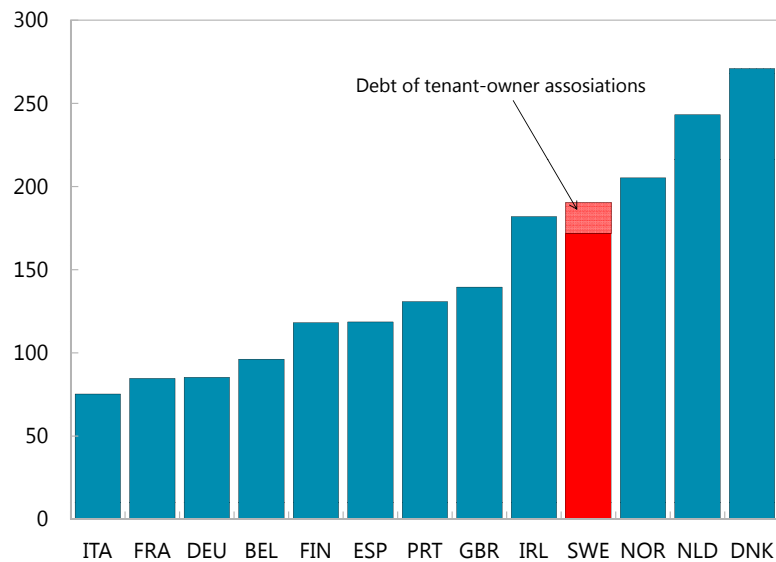
Other factors have contributed to high and rising household debt. The Swedish tax system has favored home ownership, with very low effective property taxes since 2008, and it incentivizes households to not pay down their mortgage since they can deduct 30 percent of their interest payments (21 percent above SEK 100,000) from taxes due.

Figure 1: Swedish household indebtedness and housing price expectations



Sources: SEB, Sveriges Riksbank and authors' calculation.
1/Net share of households expects house price to rise.

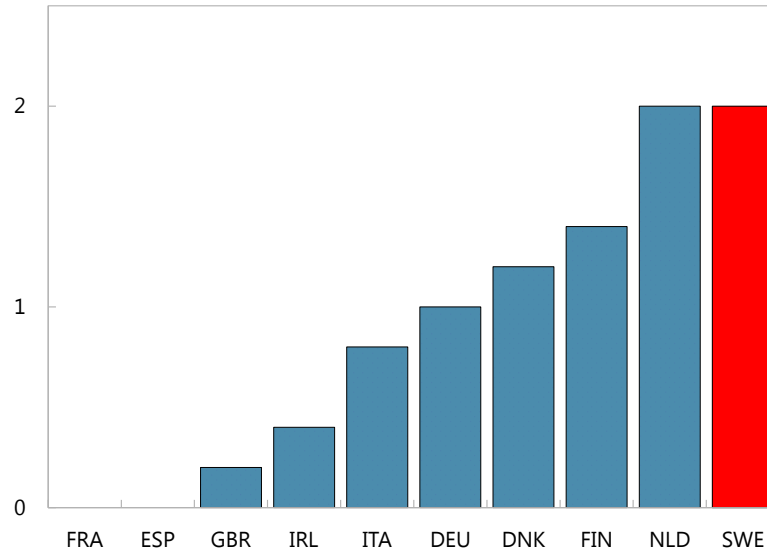
Figure 2: Household debt as share of disposable income



Sources: Statistics Sweden, National Statistics Offices and authors' calculation.
Note: 2014Q4 or latest available.

Sweden's per capita housing stock remains almost unchanged since the early 90s reflecting structural impediments in the construction sector. For instance, complex and time consuming land acquisition and planning systems have been pulling down supply despite

Figure 3: Tax incentives for home ownership, 2013.



Sources: European Commission and authors' calculation.

Note: Composite tax index range: 0 (Low) 3 (High)

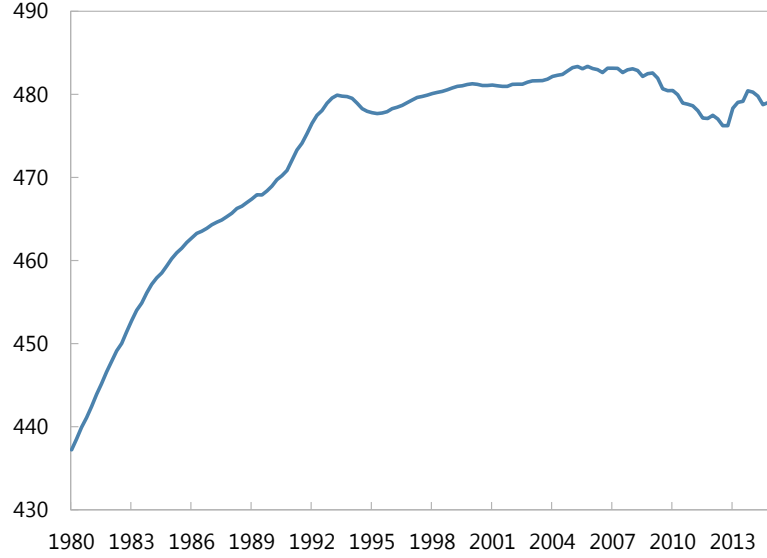
rising profitability in the construction sector (Emanuelsson, 2015). The housing supply issue is most evident in the major cities, where dwellings per capita have been declining over time, which has been associated with a rise in prices relative to the national average (Ho, 2015). Such supply constraints increase the risk that house price gains continue to exceed income growth. Lower mortgage rates combined with tax incentives have made the associated increase in household borrowing more affordable.

Mortgage contracts in Sweden often run for 30-50 years, but it is not common practice to have a fixed amortization schedule. The rate of amortization varies notably across households, with Riksbank analysis¹ suggesting that only about 60 percent of indebted households reduced their debts in 2013, with the pace of reduction implying an average remaining amortization period of 99 years.² More recent borrowers tend to amortize more than in the past, with 69 percent of all households with new loans amortizing their mortgage in 2014 up from 42 percent in 2011. Notwithstanding this recent increase in amortization for new mortgages, the share of the mortgage stock which is being amortized remains largely unchanged from previous years at 62 percent. Amortization is also more common for more leveraged loans,

¹See Deputy Governor Skingsley's speech, (Skingsley, 2007)

²In a random sample taken in the autumn of 2012 in conjunction with FSA's mortgage survey, the average repayment period among households with a LTV below 75 percent, and which actually amortized, was 140 years. Note that the repayment period in this case refers to the maturity implied by the amortization payments made and not the maturity specified in the loan agreement. (Sveriges Riskbank, 2014)

Figure 4: Housing stock to population



Sources: Statistics Sweden and authors' calculation.

Note: Ratio of dwellings to population in thousand

as 85 percent of households with LTV above 70 percent amortized their mortgage, but only 40 percent for loans with LTV between 50 and 70 percent.

Relatively low amortization in Sweden in part reflects costs of amortizing mortgage debt faster than that stipulated in the contract. In particular, households need to pay compensation for the interest rate differential over the remaining interest rate fixation period (Leonhard et al., 2012). This is in sharp contrast with other countries such as the US, Denmark and Germany, where the penalty for early repayment is either very low or does not exist. The interest differential compensation is calculated as follows.³

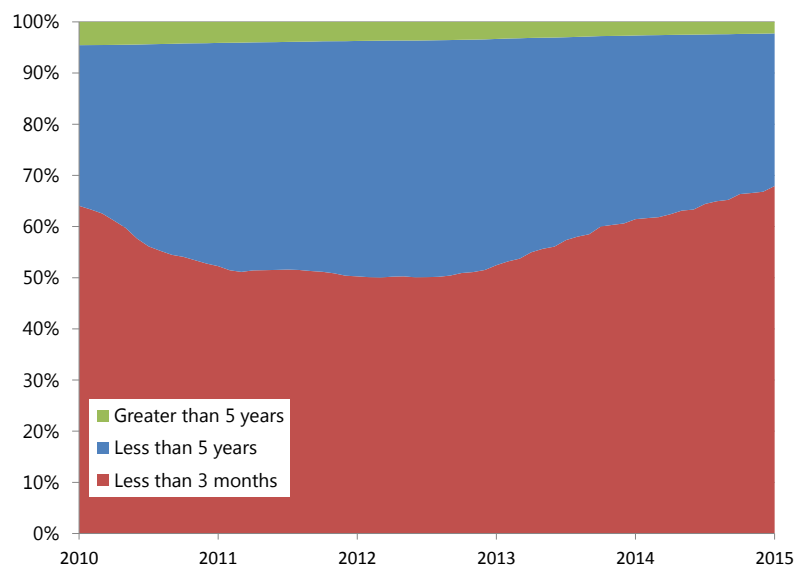
$$\begin{aligned} \text{Interest rate differential compensation} = \\ (\text{mortgage interest rate} - (\text{ask rate for a government bond with the same fixed period} \\ + 1 \text{ percentage point})) * \text{outstanding debt} * \text{remaining period} \end{aligned}$$

The differences between mortgage interest rates and government (or covered since 2014) bond yields averaged to about 2 percent between 2010 and 2015. This circumstance together with the high outstanding debt, implies that the penalty costs of early repayment of mortgages could be quite high on average, providing the Swedish households with little incentive

³The formula was modified in 2014 replacing government bond with covered bond.

to repay more than the low amortization requirement established when the mortgage was issued.⁴

Figure 5: Interest rate fixation periods for Swedish mortgages



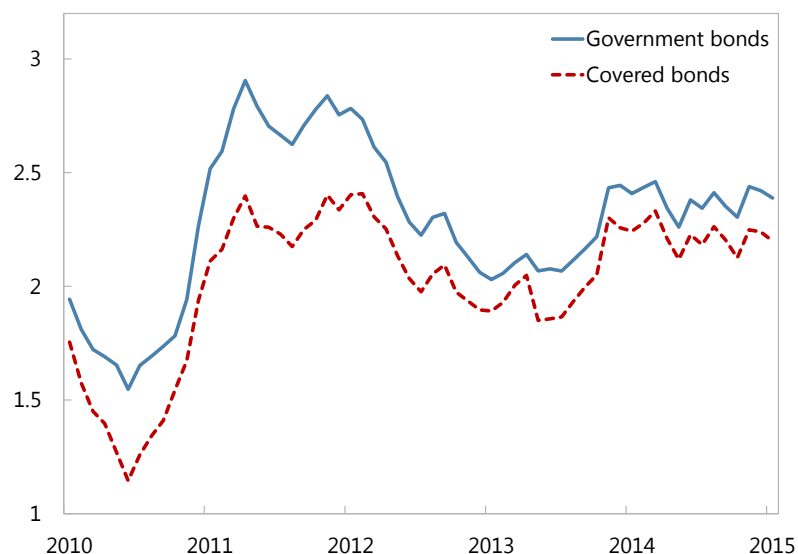
Sources: European Commission and authors' calculation.

Both government and covered bond yields have fallen since 2011, yet banks have increased the interest rate margin on mortgage loans so that the differences between mortgage interest rates and government (or covered since 2014) bond yields averaged to about 2 percent between 2010 and 2015. (Figure 6) This circumstance together with the high outstanding debt, implies that the penalty costs of early repayment of mortgages could be quite high on average, providing the Swedish households with little incentive to repay more than what the low amortization requirement decided when the mortgage was issued requires.

The composition of debt has shifted towards variable rate contracts, as about 75 percent of the new mortgages have an initial interest rate fixation period of less than 3 months while in 2012 about 50 percent were at variable rate. This preference for variable rate contracts is consistent with households' expectation for interest rates to remain low, as the Riksbank has turned to a very accommodative monetary policy stance and signaled its commitment to

⁴The penalty cost of an early repayment could be around 1.8 times of disposable income for households with variable rate mortgages, and much larger for households with fixed rate mortgages. This simple calculation assumes households with a debt-to-income ratio of 366 percent, as observed for the new mortgage borrowers in 2014, a spread between mortgage rate and bond yields of 2 percent and a residual maturity of 3 months on the contract.

Figure 6: Spread between mortgage interest rates and bond yields



Sources: Severige Riksbank, Statistics Sweden and authors' calculation.

Note: Weighted average of the differences between mortgage rates over bond yields with corresponding remaining maturities. We assume that covered bonds with less than 1 year maturity have the same yields as the Swedish government bonds.

raise inflation. Overall, some 69 percent of the existing stock of mortgages has a variable rate.

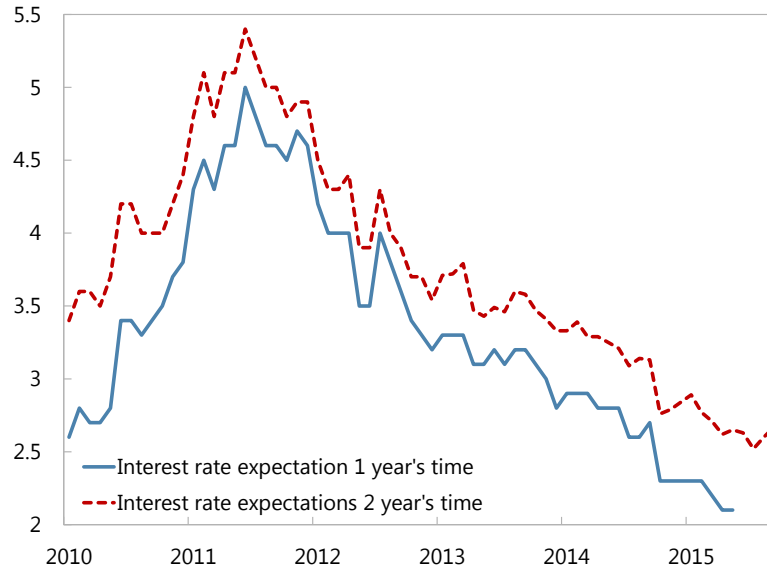
Household debt and housing prices have continued to rise from already high levels, as 29 percent of new mortgage borrowers in 2014 had a Debt-to-Income (DTI) ratio of over 450 percent, notwithstanding a range of measures taken in recent years to enhance the financial resilience of banks and households. Macroprudential policy measures have focused on the credit supply side by strengthening bank capital buffers, as the Financial Supervisory Authority (FSA) has rolled out Basel III measures ahead of schedule, including the introduction in 2013 of a capital conservation buffer at 2.5 percent, in 2014 of minimum risk weights of 25 percent for mortgages, and in 2015 of a systemic risk buffer at 3 percent, a 2 percent capital surcharge for the four systemically important banks, and a countercyclical risk buffer at 1 percent.⁵

Macroprudential measures on the credit demand side have been taken to a more limited extent. In 2010 the FSA established an 85 percent cap for the LTV ratio. The measure

⁵The countercyclical capital buffer is to be raised to 1.5 percent in June 2016.

produced some effect as the average LTV ratio for new mortgage borrowers has stabilized at around 70 percent, halting a rising trend which led the average LTV ratio to reach about 72 percent in 2010. Nonetheless, about half of the new borrowers in 2014 had an LTV ratio just below the cap. In a context of double digit growth rates for house prices, house purchasers could thereby increase their DTI ratio while still meeting the 85 percent LTV cap.

Figure 7: Swedish household indebtedness and housing price expectations



Sources: NIER and authors' calculation.

3 The Model

To analyze the costs and benefits of macroprudential and monetary policies in reducing household debt we use a DSGE model with financial frictions and an imperfectly competitive banking sector that is based on the model of Gerali et al. (2010). We modify that model along two dimensions. First, we tailor the model to Sweden's characteristics by dividing the world into a small open economy and the rest of the world or foreign economy. Second, we introduce three macroprudential measures in addition to the LTV ratio: the amortization requirement, the tax deductibility of mortgage interest payments, and mortgage risk weights.

The home economy is affected by the foreign economy while the reverse is not true. The fact that Final consumption goods are traded and home savers can invest in foreign bonds. The home economy is populated by two types of households, patient P and impatient I and

by entrepreneurs. Households consume, work and accumulate housing (in fixed supply),⁶ while entrepreneurs produce a homogenous intermediate good using physical capital bought from capital-good producers and labor supplied by households. Agents (households and entrepreneurs) have different degree of impatience reflected in different discount factors for their future utility. The heterogeneity in agents' discount factors provides a simple way to generate financial flows in equilibrium: patient households (savers) purchase a positive amount of saving assets (deposits at domestic banks and foreign bonds) and do not borrow, while impatient households (borrowers) and entrepreneurs borrow from the domestic banking system.

When taking a bank loan, borrowers face a borrowing constraint. In the case of the entrepreneurs, they can only borrow up to a fraction of tomorrow's collateral i.e. the value of private physical capital. Whereas for households, the model includes two constraints. We incorporate an LTV ceiling by allowing impatient households to borrow up to a fraction of the value of new housing acquisitions each period. We allow for an amortization requirement by assuming that the impatient households must repay a fixed fraction of the loan principal each period. These repayments of loan principal make the average LTV on outstanding mortgages lower than the average LTV of new mortgages.

In addition, we model the tax deductibility of mortgage interest payments by having the borrowers receive, from the government, a transfer that covers a portion of their mortgage interest payments. The government imposes a tax on entrepreneur's profit to finance its expenditure. For simplicity, we assume the government runs a balanced budget using a lump sum transfer from/to the households to ensure this balance is respected each period.

Financial flows are channeled through an imperfectly competitive banking sector. Banks supply deposits and loans to the agents, and set interest rates on both deposits and loans in order to maximize profits. For instance, a reduction in bank profit would lead to a cut in deposit rates, in turn lowering saver's income. The amount of loans issued by each intermediary can be financed through the deposits they raise and by reinvested profits (bank capital). Banks need to respect a minimum risk weighted capital requirement, and since any deviation from the required ratio would be costly, they adjust interest rates in order to converge back to the requirement.

Households supply their differentiated labor services through unions which set wages to

⁶This assumption may not be that implausible given the housing stock per capita has remained largely unchanged since 1990s in Sweden.

maximize members' utility subject to adjustment costs. Labor services are sold to competitive labor packers which aggregate them into a single labor input sold to firms.

There are two additional sectors which produce goods, the retail sector and the capital good producer sector. In the monopolistically competitive retail sector retailers buy intermediate goods from entrepreneurs at the wholesale price, then re-sale the goods at a mark-up over the purchasing cost and that is subject to adjustment costs. In the capital-goods producing sector, producers buy old capital and turn it into new productive capitals. As in Gerali et al. (2010), producers of physical capital goods are used as a modeling device to make explicit the expression for the price of capital, which enters entrepreneurs' borrowing constraint. In the Appendix we describe the key features of the model borrowing largely from Gerali et al. (2010) for the common sections.

4 Calibration and Estimation

Model parameters are derived through a combination of calibration and estimation. The parameters determining the steady state are calibrated in order to obtain reasonable values for some key steady-state values and ratios. We estimate the parameters that are difficult to calibrate, or the ones that we have very little information about, using a Bayesian approach. Estimation of the implied posterior distribution of the parameters is done using the Metropolis algorithm (see Smets and Wouters (2003) and Lindé et al. (2009)). We use twelve observed series: real GDP, real consumption, real investment, interest rate on mortgages, interest rates on corporate loans, deposit rates, the Riksbank's repo rate, real loans to households, real loans to firms, wage inflation, CPIF inflation, and real house prices.⁷ The sample period runs from 1996Q1 to 2014Q4 and we remove the trend from the variables using the Hodrick-Prescott filter.

4.1 Calibrated parameters and prior distributions

Calibration. Table 1 reports the values of the calibrated parameters. To calibrate the model to resemble the Swedish economy we use parameters that have already estimated in the RAMSES model for the Swedish economy, see Adolfson et al. (2008). For example, the patient households' discount factor is set to 0.99631, and those of impatient households and entrepreneurs at 0.975, the same as in Gerali et al. (2010) and in the range suggested by Iacoviello (2005) and Angelini et al. (2014). The mean value of the weight of housing in

⁷See Appendix B for a description of the data.

households’ utility function is calibrated at 0.2 following Gerali et al. (2010).

Table 1: Calibrated parameters

Parameter	Description	Value
β_P	Patient households’ discount factor	0.9963
β_I	Impatient households’ discount factor	0.975
β_E	Entrepreneurs’ discount factor	0.975
ϕ	Inverse of the Frish’s elasticity	2.98
μ	Share of unconstrained households	1/3
ϵ^h	Weight of housing in the households’ utility function	0.2
α	Capital share in the production function	0.35
δ	Depreciation rate of physical capital	0.025
ϵ_y	$\frac{\epsilon_y}{\epsilon_y-1}$ is the markup in the goods market	6
ϵ_y	$\frac{\epsilon_l}{\epsilon_l-1}$ is the markup in the labor market	5
m_I	LTV for new mortgages	0.85
m_E	LTV for firm loans	0.25
ν^b	Risk weighted/loan ratio in steady state (requirement)	0.12
ϵ^d	$\frac{\epsilon_d}{\epsilon_d-1}$ markdown on deposit rate	-1.1
ϵ^{bH}	$\frac{\epsilon_{bH}}{\epsilon_{bH}-1}$ markup on loans to households	3.2
ϵ^{bE}	$\frac{\epsilon_{bE}}{\epsilon_{bE}-1}$ markup on loans to entrepreneurs	2.4

For the loan-to-value (LTV) ratios, we set it m_i at 0.85 in line with the current LTV cap for new mortgages set by the Swedish FSA. The calibration of m_e , i.e. the “loan-to-value” constraint for the entrepreneurs is more challenging; we calibrate it to 0.25 so that the ratio between mortgages and loans to entrepreneurs is about 1.3 as indicated by the lending data from Swedish monetary financial institutions. We calibrate the amortization period for existing mortgages to be 50 years and mortgage interest rate deductability to be 30 percent.

The capital share is set at 0.35 with a depreciation rate of 0.025 which is standard in the literature. Similar to Gerali et al. (2010) we assume a markup of 25 percent and set ϵ_t at 5. In the goods market, a value of 6 for ϵ_y delivers a markup of 20 percent in the steady state. We calibrate the elasticity of substitution of deposits ϵ_t^d to -1.0738 matching the steady-state spread between the deposit rate and interbank rate that is in the range of 50-100 bps (see Table 2).

We set the minimum bank (risk weighted) capital ratio to 12 percent—higher than the Basel III requirements at 10.5 percent—reflecting the mortgage risk weight floor. Moreover, we set the bank risk weights to 50 percent for corporate loans and to 25 percent for mortgages to according to the existing risk weights floor. We assume that bank capital “depreciates”

(i.e. it is used for managerial purposes) at the rate of 0.0658, which ensures that the ratio of bank capital to risk weighted loans is 0.19, which is consistent with the Swedish bank's high risk weighted capital ratios.

Prior distributions. Tables A1 and A2 list our priors. These are guided by previous literature, in particular Adolfson et al. (2008), Lindé et al. (2009), Gerali et al. (2010), and Walentin (2014). In cases where we did not find suitable examples we keep the prior relatively uninformative. In particular, we choose a beta-distribution with a prior mean of 0.75 and standard deviation of 0.05 for the persistence parameters. We assume that all agents have the same habit persistence parameters in consumption (i.e. $a^h = a^P = a^I = a^E$) with mean value of 0.65 and standard deviation of 0.1. For the monetary policy rule, we set the prior mean of ρ_R , Φ_π and Φ_y to 0.8, 1.7, and 0.13 respectively, in line with Adolfson et al. (2008). For the LTV, we set the prior mean on ρ_{mi} to 0.75 implying it takes some time for any announced LTV to be implemented.

4.2 Posterior estimates

Tables A1 and A2 report the posterior mean and 90 per cent probability intervals for the structural parameters, together with the mean and standard deviation of the prior. In addition, the tables report the marginal density of the parameters and Figure 7 reports the prior and posterior marginal densities of the parameters in the model. Draws from the posterior distribution of the parameters are obtained using the random walk version of the Metropolis algorithm. We run 2 parallel chains each of length 12,000,000; the small number of chains was in part due to their length. The scale factor was set in order to deliver acceptance rates in the neighborhood of 0.3. Convergence was assessed by means of the convergence statistics taken from Brooks and Gelman (1998) on individual structural parameters as well as the multivariate version.

We find a relatively high degree of interest rate inertia in the monetary policy rule, which is consistent with Adolfson et al. (2008), but our estimates suggest more responsiveness of monetary policy to inflation and output (i.e. higher estimated Φ_π and Φ_y). One explanation could be that the Riksbank has changed its reaction function, becoming more aggressive during the crisis, as Adolfson et al. (2008) naturally covers the pre-crisis period. Regarding nominal rigidities, we find that wage stickiness is much more significant than price stickiness. This may reflect the fact that wages are in general only re-negotiated every three years, and the goal of collective wage bargaining is to preserve a steady rise in wages based on trends

in productivity in Sweden.

Regarding the degree of stickiness in bank interest rates, we find that deposit rates adjust more rapidly than the rates on loans to changes in policy rates. This is not surprising given that Swedish households can easily switch their deposits into other financial instruments, thereby banks tend to adjust deposit rates more frequently. Finally, we found mortgage rates adjust faster compared with the lending rate to firms, reflecting the high share of variable rate mortgage contracts in Sweden.⁸

5 Model Properties

To illustrate the broad properties of the model we provide impulse responses, focusing on the impact of a contractionary monetary policy shock. We also analyze how the impact of such a shock varies with different levels of macroprudential requirements, because the model has a number of features besides the traditional interest rate channel which shape the transmission of an interest rate increase:

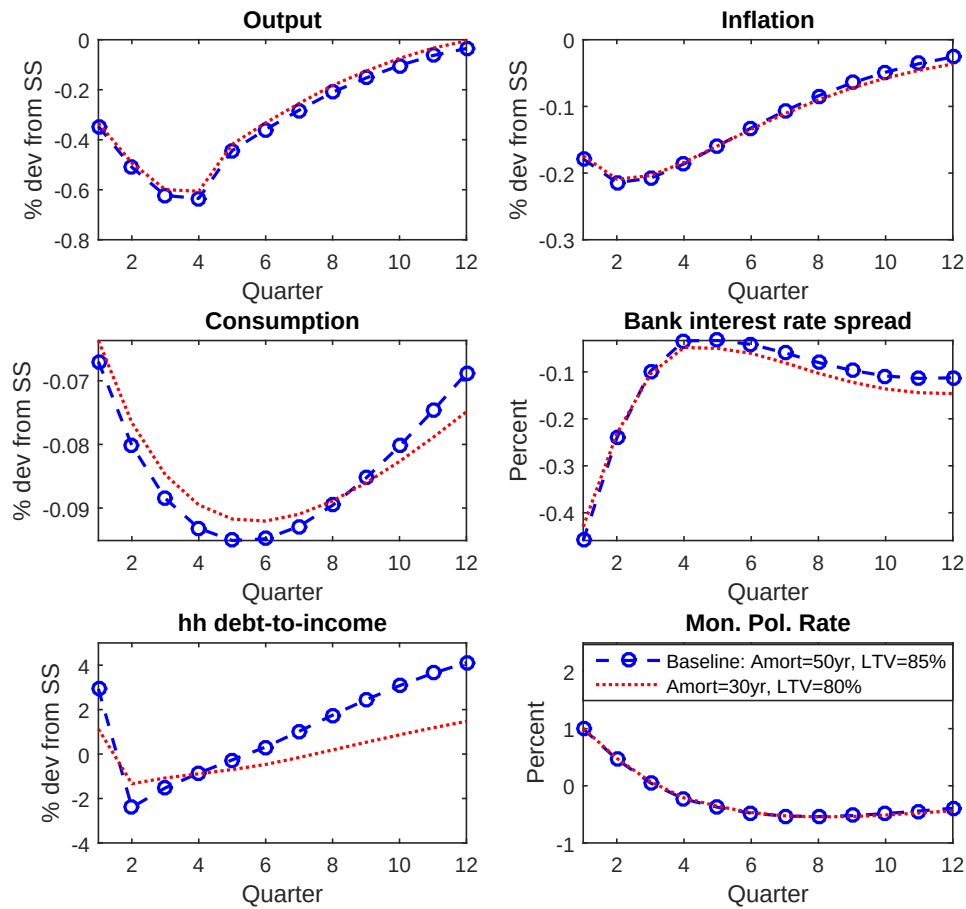
- A balance sheet channel reflects the collateral constraint on household borrowing. A tighter monetary policy stance lowers housing prices, restricting household capacity from borrowing and amplifying the effects of the monetary policy shock.
- Amortization requirements imply that households cannot re-optimize the total mortgage debt stock each period as they must carry forward the unpaid mortgage principal. The introduction of amortization requirements is a key distinction between this model and the main models in the literature (Gerali et al., 2010) which assume that households repay the mortgage debt in full at the beginning of each period and get a new mortgage at the end of the period. The “stickiness” of the mortgage debt in our model provides an additional amplification channel for an increase in monetary policy rates on the macroeconomy, while dampening the impact on household debt.
- The banking sector dampens the response of retail interest rates to a monetary policy shock, especially owing to the stickiness of bank lending rates. This moderates the reduction in lending, consumption and investment following a monetary tightening compared with Gerali et al. (2010). Moreover, the bank capital constraint introduces a further wedge between the bank lending and deposit rates and monetary policy rates.

⁸The estimated lending rate adjustment cost parameters are higher than other estimates, but using these lower estimates is not found to significantly alter the impact of monetary policy shocks.

- The fact that households can choose between to save in domestic banks or to purchase foreign bond affects the transmission of monetary policy.

Figure 8 shows the impacts on output, inflation, and the household DTI ratio of an exogenous 100 basis point hike in the monetary policy rate. The responses of the main macroeconomic variables are qualitatively comparable with estimates in the literature (Adolfson et al., 2008). Hence, our model has the advantage of introducing new elements enriching the inter-linkages between macroeconomic and financial variables, while maintaining properties that are consistent with the research on Swedish business cycles.

Figure 8: Monetary policy shock



The figure depicts the impulse responses to a 1 percentage point exogenous increase in repo rate. Moreover, the figure compares how would the responses differ between cases with higher and lower amortization requirements.

Following a 100 basis point rise in interest rates, output and inflation fall by about 0.6 percent and 0.2 percent respectively relative to the steady state. Loans to both households

and firms fall, reflecting the decline in asset prices, i.e. the price of housing and the value of firm’s capital, and the increase in the real interest rate. Bank loan rates increase much less than the policy rate reflecting the imperfect pass-through of lending rates; however, the deposit rate increases by almost the full 100 basis points, implying a decline in that banks’ interest rate margins. The response of bank capital is initially negative, reflecting the decrease in bank profitability, but it subsequently increases as margins recover. The policy rate responds endogenously to the output and inflation deviations, thus it would fall below the steady state value to stimulate the economy, and reverse these impacts over time.

The interaction with macroprudential policies can be best described by looking at borrower’s consumption responses for a given shock with varying levels of macroprudential instruments. Comparing a scenario with lower household debt owing to faster amortization requirement and lower LTV cap (red dotted line) with the baseline (blue dotted line), the consumption response to interest rates shocks is smaller. The intuition is that a smaller household debt in equilibrium implies that household’s debt service burden rises less when a given rate shock hits the economy, requiring a smaller reduction in consumption and demand for housing.⁹

6 Exploring the impact of macroprudential policies

We use the framework developed above to study the effectiveness of macroprudential policies and assess the potential side effects of macroprudential policies on the macroeconomy. The transmission mechanisms of the different macroprudential measures are discussed, highlighting some important features of these measures.

The approach is to make a permanent change in one of the macroprudential policy instruments—which would change the structure of the economy—and to study transition paths of the variables in the model from one steady state to another. For example, a permanent reduction in LTV ratio would reduce borrower’s capacity to borrow hence the debt level. Such changes in the borrower’s behavior would in turn interact with the savers, entrepreneurs, banks and other agents in the model, until the new equilibrium is reached. However, as the LTV requirement only affects new mortgages and as amortization rates are currently very low, it can take some years for any newly introduced LTV requirements to “work their

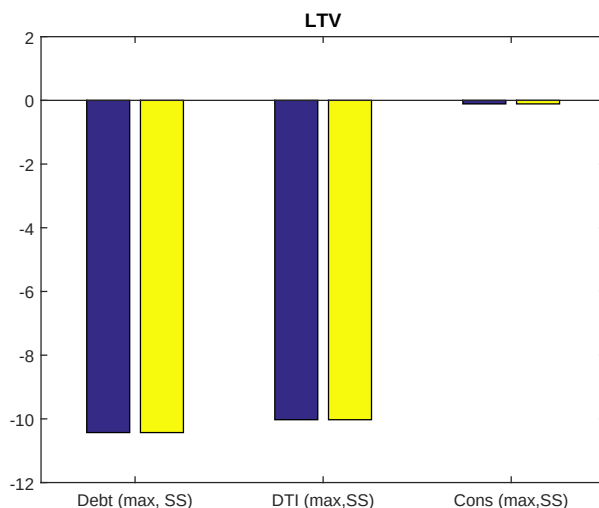
⁹It is also interesting to note that banks’ interest rate margin is squeezed more by interest rate hikes as the loan stock increases implying a lower ability for banks to pass on the increasing financing costs. Moreover, a larger loan stock requires banks to maintain a higher level of deposits, and given that households have the option to invest abroad, deposit rates would have to increase more the larger the mortgage stock.

way through” the mortgage stock implying a long time to reach the new steady state. We will therefore discuss the transition path in two parts: the short-term dynamics and the long-term when the new steady state is reached.

6.1 Loan-to-Value Ratio

A cap on the LTV ratio constrains how much households can borrow against their housing collateral when a mortgage is originated. Housing prices fall as borrower’s effective housing demand is cut by their reduced amount of mortgage financing they can access. Moreover, falling house prices reduce collateral values, reinforcing the impact of the initial tightening of the LTV cap. In what follows, we consider a scenario in which the LTV cap is reduced by 5 percentage points to 80 percent.

Figure 9: Impacts from a permanent reduction in LTV:
85 $\rightarrow$ 80



The figure depicts maximum impacts on household mortgage debt, debt-to-income (DTI) and consumption (Cons) following a permanent reduction in loan-to-value (LTV) ratio from 85 to 80 percent. And changes in the three variables in the new steady state (LTV= 80) compared with the baseline (LTV= 85).

Over the short run. Borrowers’ consumption falls by about 0.2 percent one year after the LTV is lowered—the modest impact in part reflecting that, by construction, only new housing acquisition is affected by the change in LTV cap. Savers’ consumption falls too, although by less, as the fall in the stock of mortgages lowers bank profitability, hence the deposit rate offered to the savers declines and falling house prices imply a negative wealth effect. Moreover, market clearance in the housing market implies that savers need to increase

housing purchases aided by falling house prices. Altogether, the tightening of the LTV cap has a contractionary effect on the economy lowering consumption by 0.02 percent one year after the shock, and GDP would remain lower by 0.1 percent three years after the shock.

In the new steady state. Borrowers' debt declines by about 10 percent cumulatively, in part because house prices fall about 1.5 percent. The relatively modest fall in house prices reflects to some extent the significant price elasticity of saver's demand for housing demand compensating for the decline in borrowers' demand (as supply relative to population is assumed to be fixed). Notably, borrower's consumption of goods will be permanently higher by about 1.8 percent in the new steady state, as their debt service burden is lower, partly offsetting the decline in their consumption of housing services. But saver's consumption would continue to decline during the transition, and will be 0.4 percent lower in the new steady state. This result is driven by bank profits falling by about 4 percent, as banks cut back on mortgage lending. Lower bank profits also imply that banks deleverage, cutting loans to firms by about 1.2 percent implying lower investment and production. As a result output will be about 0.5 percent lower in the new steady state.

6.2 Amortization requirements

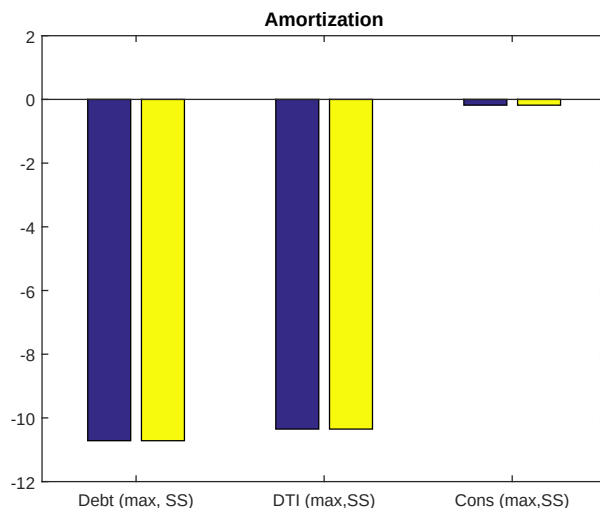
With the introduction of amortization requirements, a portion of the mortgage principal must be repaid each period, in an amount set by the amortization plan in the loan contract. Yet, households can borrow more each period, up to the LTV ceiling, for new housing investment, implying that household debt is positive in the steady state. Re-writing impatient household's borrowing constraint (see Appendix A), it is clear that household debt at any given time t equals the present discounted value of the portion of the initial debt principal that is not amortized (first part of the equation 1) plus a stream of new loans that were taken out for new housing investment (net of any repayments of such loans). Thus, by specifying a faster amortization plan, household debt is reduced.

$$b_t = \frac{(1 - \rho)^n}{\prod_{j=0}^{n-1} \pi_{t-j}} b_{t-n} + \sum_{i=0}^{n-1} \frac{(1 - \rho)^i}{\prod_{j=0}^{i-1} \pi_{t-j}} m_t q_t \Delta h_t \quad (1)$$

At the same time, it is important to note that, if a household signed up for a lengthier mortgage contract it would be forced to carry a larger portion of the debt from one period to the next, and could not reduce the debt stock by more than what has been defined in the contract for the amortization plan. We choose this modeling approach as early repayment of mortgage debt can be very expensive in Sweden as discussed in section II. Figure

10 illustrates the impact of tightening of amortization requirements equivalent to a 5-year reduction in maturity to 45 years.

Figure 10: Impacts from a permanent change in amortization requirement: 50 $\rightarrow$ 45



The figure depicts maximum impacts on household mortgage debt, debt-to-income(DTI) and consumption(Cons) following a permanent reduction in amortization requirement from 50 to 45 years. And changes in the three variables in the new steady state (Amortization= 45years) compared with the baseline (Amortization= 50years).

Over the short run. The impact on consumption partly depends on the balance between a tightening of household's cash flow constraint from larger amortization due and from a reduction in their debt—hence lower future interest payments—which would relax household's budget constraint. The model suggests that borrower's consumption would fall by a very small amount, i.e., 0.03 percent by 4 years after the shocks. This result partly reflects the significant endogenous policy response as the monetary authority lowers the repo rate by almost 1 percentage point. These accommodative monetary conditions imply that saver's consumption would increase but to a lesser extent. In aggregate, a tightening of the amortization requirement has a small negative impact on growth reducing GDP by 0.02 percent, and inflation by almost 0.05 percent. Monetary policy therefore plays an important role in cushioning the adverse impact on the macroeconomy over the short run.

In the new steady state. Borrower's debt will fall by about 10 percent, with household DTI ratio falling by the similar amount, and house prices down by 0.5 percent. In addition, borrower's housing stock will be about 0.5 percent lower in the new steady state. Borrower's

consumption will be about 1.7 percent higher permanently. Saver's consumption will decline by 0.4 percent. This again reflects a lower bank profit by almost 5 percent leading to a decline in credit to firms by more than 1 percent. As a result, output is lowered by about 0.4 percent.

Despite both a reduction of the LTV cap and a tightening of the amortization requirement lead to qualitatively similar new steady states, there are interesting differences for the transitional path of the variables. In particular, household debt falls almost linearly over time if the amortization requirement is tightened. Instead, following a reduction of the LTV cap the fall of household debt accelerates, re-enforced by the falling house prices. This has implications for the transition path of the borrower's consumption which would fall much faster over the short term in the case of a reduction of the LTV cap than in the case of a tightening of the amortization requirement.

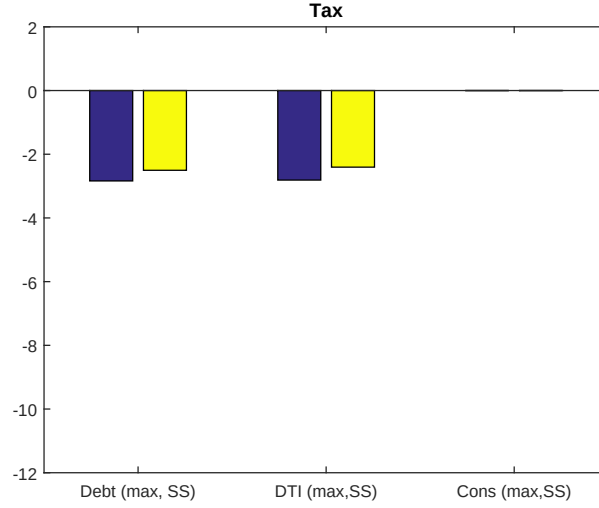
6.3 Tax deductibility of mortgage interest

A reduction in the tax deductibility of mortgage interest payments increases the cost of servicing a mortgage thereby tightening households' budget constraint—a negative income effect. Moreover, such a reduction would make debt-financed housing purchases more costly relative to the price of consumption goods—a substitution effect. These two effects have opposing implications on households' consumption. The negative income effect suggests that a reduction in tax deductibility lowers household's consumption, while the substitution effect implies that households consume more as the relative prices have made consumption relatively cheaper than housing. Figure 11 illustrates the impacts on household debt and debt-to-income ratio, consumption, and borrowers' housing stock following a 5 percentage point reduction in tax deductibility to 25 percent.

Over the short run. The negative income and substitution effects noted above lower borrower's demand for housing, with house prices falling by about 0.6 percent in the near term, and household debt would also fall. However, borrower's consumption increases in the short run as consumption becomes cheaper relative to housing, and also because it is assumed the government would fully redistribute the savings from the reduction in tax deductions, which offsets some of the negative income effects. Savers would increase their housing investment as the price declines, but they also benefit from the higher transfers leading to higher consumption. The overall impact is slightly higher aggregate consumption, output and inflation.

In the new steady state. Borrower's household debt is lowered by about 2.2 percent, with

Figure 11: Impacts from a reduction in mortgage tax deductibility: 30 $\rightarrow$ 25

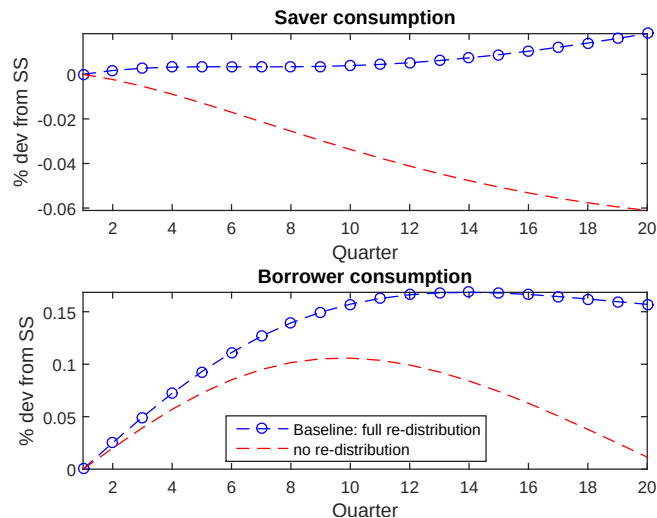


The figure depicts maximum impacts on household mortgage debt, debt-to-income(DTI) and consumption(Cons) following a permanent reduction in mortgage tax deductibility from 30 to 25 percent. And changes in the three variables in the new steady state (tax= 25) compared with the baseline (tax= 30).

a similar change in the DTI ratio. Their consumption will be higher by about 0.1 percent, with a 2 percent lower holding of the housing stock. Savers' consumption also increases in this case by about 0.1 percent, driven by higher transfers as explained above. The latter would be sufficient to offset the decline in bank profit such that a decline in saver's consumption is avoided.

Importantly, the impact on total consumption depends on how the government utilizes the savings that came from a reduction in tax deductibility. Figure 12 compares the baseline scenario the saving arising from the 5 percentage point reduction in tax deductibility is fully re-distributed back to all households with the assumption that these savings are not redistributed. The figure illustrates that the re-distribution of the savings clearly helps to mitigate the negative impact on consumption from reducing tax deductibility.

Figure 12: Households' consumption responses from a reduction in mortgage tax deductibility: 30 $\rightarrow$ 25



The figure depicts households (savers and borrowers) consumption responses to a reduction in mortgage tax deductibility over the initial 20 quarters. It compares consumption dynamics between a full re-distribution of the savings from reduction in tax deductibility via lump sum transfers with no re-distribution.

6.4 Mortgage risk weights

An increase in mortgage risk weights raises bank's required capital in proportion to their mortgage exposure. To accumulate more capital through profits¹⁰, banks would increase the profit margins by raising the lending rates. A higher borrowing rate then leads to a reduction in mortgage demand thus lowering household debt. Yet, a decline in mortgage credit erodes banks profitability suggesting limited impact on household debt, or, in some cases, banks would reduce mortgage rates to stimulate higher mortgage demand. In general, the higher bank capital requirement leads to less bank credit including lending to firms, reducing output and aggregate consumption. Thus monetary policy acts immediately to cushion such a demand shock. Figure 13 illustrates a 5 percentage point increase in mortgage risk weights to 30 percent.

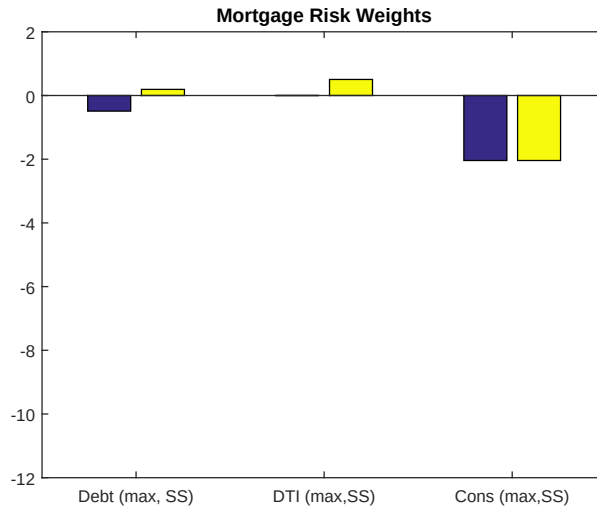
Over the short run. Household debt would decline by about 0.5 percent 2 quarters after the shock. Borrower's consumption would, by 2 years after the shock, decline by a marginal

¹⁰In practice, requiring that all capital accumulation come from profits is an extreme case, as part of an increase in capital requirements could be met by issuing new equity. At the same time, the higher requirement would imply a need for banks to generate additional profits in order to generate an adequate return on equity, such that wider margins may be needed even if capital is instead raised in the financial markets.

0.1 percent, and aggregate consumption by about 0.05 percent. Lower aggregate consumption reduces output and inflation, which triggers monetary policy to react by reducing the repo rate. The reduction in interest rate leads mortgage rates to decline, as well as firm lending rates. Thus aggregate consumption begins to recover, and borrower's debt level will start to rise.

In the new steady state. Borrower's debt remains almost unchanged, similarly with the house prices. Yet, borrower's DTI ratio increases by 0.5 percent. Both saver's and borrower's consumption will decline, implying a 2 percent permanently lower aggregate consumption. This result is largely driven by the fact that banks need to reduce credit supply to the firms. A lower firm lending affects the investment, capital stock thus output. The simulation suggests output would be 2.4 percent lower in the new steady state.

Figure 13: Impacts from a increase in mortgage risk weights: 25 $\rightarrow$ 30



The figure depicts maximum impacts on household mortgage debt, debt-to-income(DTI) and consumption(Cons) following a permanent increase in mortgage risk weights from 25 to 30 percent. And changes in the three variables in the new steady state (risk weight = 30 percent) compared with the baseline (risk weight = 25 percent).

7 Welfare optimal macroprudential policies

Are borrowers better off if policy makers tighten macroprudential policies to reduce the probability of a crisis down the road? More generally, is the society better off? The results from the previous section indicate that tightening demand side macroprudential policies can

reduce household indebtedness with relatively small negative impacts on consumption, partly because the borrowing households with lower debt would have more resources available to consume. Moreover, a lower debt stock implies less volatility in household's consumption when shocks hit the economy. However, in the steady states that are associated with stricter macroprudential requirements the borrowers in general own less housing. So borrowers could be worse off if they valued a higher housing stock more than a higher level of consumption. One way to address this question is through a welfare function which takes into account consumption, housing accumulation and labor supply for all the agents in the economy. Moreover, the welfare function also considers the distribution of the housing stock as well as stochastic shocks to the economy, for instance shocks to household borrowing constraint and shocks to bank funding.¹¹

With a welfare function, we can search for the macroprudential policy settings that would maximize welfare. For this purpose, we follow Schmitt-Grohé and Uribe (2007) and Quinta and Rabanal (2014) in performing a second-order approximation to the model's equilibrium conditions and to welfare, simulating the model subject to the stochastic shocks at the posterior mean of the model's parameters, and reporting the mean of welfare. We assume that policymakers maximize the welfare function of all citizens in the economy using the population weights of the different household types. We define the welfare function as:

$$\begin{aligned} W &= W^{\text{saver}} + W^{\text{borrower}} + W^{\text{entrepreneur}} \\ W_t^i &= U_t^i + \beta^i W_{t+1}^i \quad i = \text{saver, borrower, entrepreneur} \end{aligned} \quad (2)$$

Where W^i is the welfare of the i^{th} type of borrowers, U^i corresponds to agent's utility function, which increases with higher consumption and housing stock, but decreases with more hours of labor supply. Moreover, the distribution of housing stock among the borrowers and savers, for a given level, matters as the utility function is concave in housing.

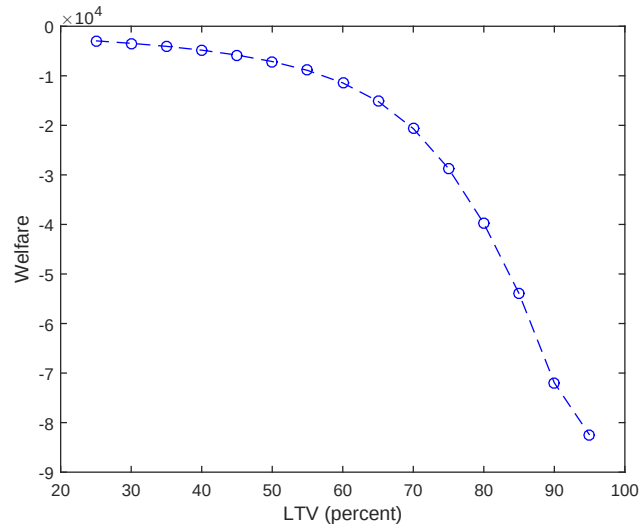
7.1 Macroprudential measures

Loan-to-value requirement. We calculate welfare over a range of LTV requirements. There are two countervailing forces to determine the LTV cap that would maximize welfare: on one hand, if the LTV cap is too low, most of the housing stock will be owned by savers

¹¹For instance if the representative saver and borrower households each owed half of the stock of housing the level of social welfare would clearly differ with respect to the case where saver households own all the housing stock.

as borrowers are more credit constrained; on the other hand, if the LTV cap is too high, more indebted households will need to go through deeper deleveraging process in response to adverse shocks, reducing mean welfare. We find that the welfare improvements become very small after the LTV cap reaches 60 percent, but that mean welfare continues to improve as the LTV cap tightens.

Figure 14: Welfare: loan-to-value ratio

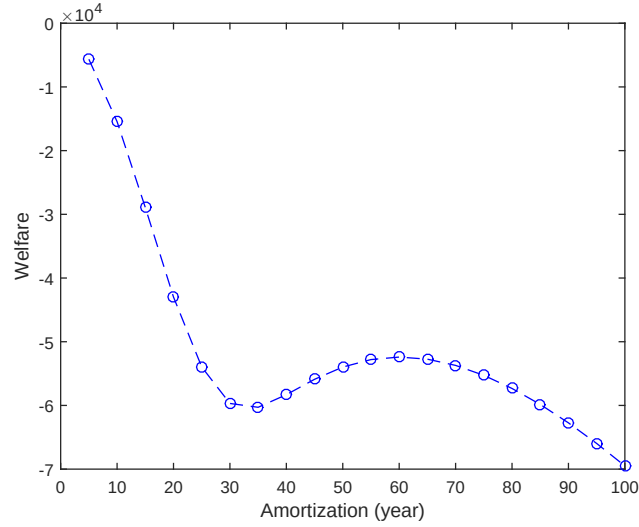


The figure depicts welfare over a range of loan-to-value ratios

Amortization requirement. Next, we examine welfare over a range of amortization requirements which apply to the existing mortgage stock. Higher amortization requirements imply households make a larger mortgage principal payment in every period, in proportion to their mortgage stock. We find a highly non-linear relationship between required amortization period and welfare. Starting from an amortization plan that requires households to repay their mortgages in 100 years, tightening the required amortization would increase welfare indicating that the benefit from lower debt for mean welfare outweighs the costs from larger repayments that lead to lower housing stocks for borrowers. The relationship reaches a “local” maximum around an amortization requirement of 60 years, then welfare starts to decline until the amortization requirement reaches 30 years. After that, it becomes optimal to further tighten amortization requirements.

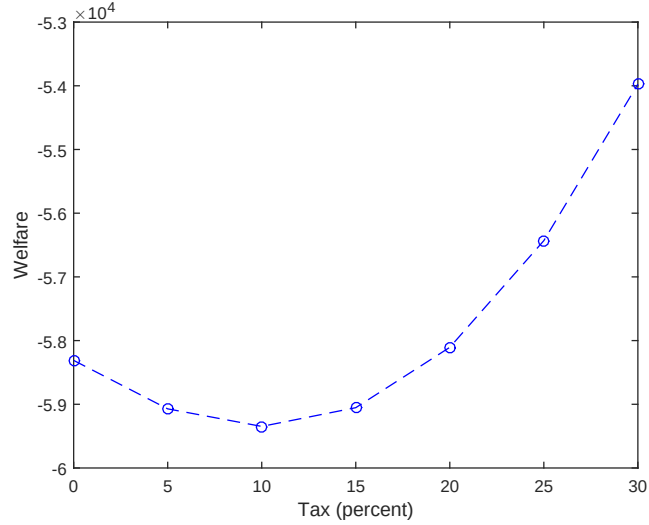
Tax deductibility on mortgage interest payments. We then investigate the welfare implications of varying the degree of tax deductibility for mortgage interest rates. The baseline model is calibrated for a 30 percent deduction of mortgage interest payments, and any reduction of this ratio would imply that the borrowers need to pay higher interest on the existing mortgage stock, inducing them to borrow less and shift towards goods consumption

Figure 15: Welfare: amortization



The figure depicts welfare over a range of amortization requirements.

Figure 16: Welfare: tax deductibility on mortgage interest repayments



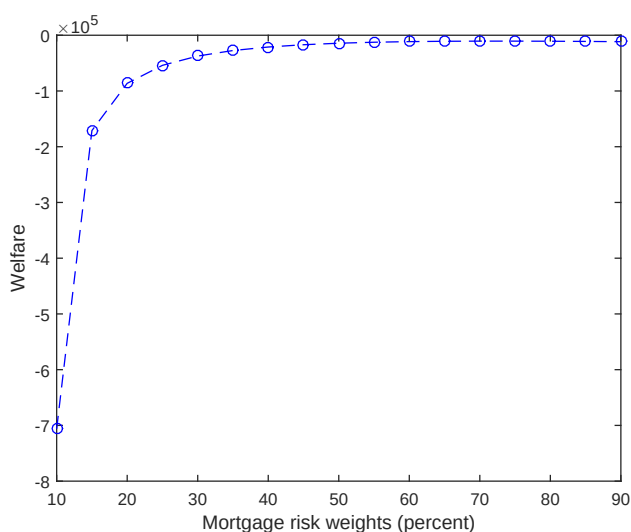
The figure depicts welfare over a range of tax deductibility.

as discussed in the previous section. We find that welfare would decrease from lowering deductibility even though lowering deductibility would lead to a reduction in household debt in our baseline model, which aids mean welfare in case of shocks.

Risk weights on mortgages. Finally, we analyze supply-side measures investigating whether higher risk weights on mortgages improve welfare as banks with stronger capital

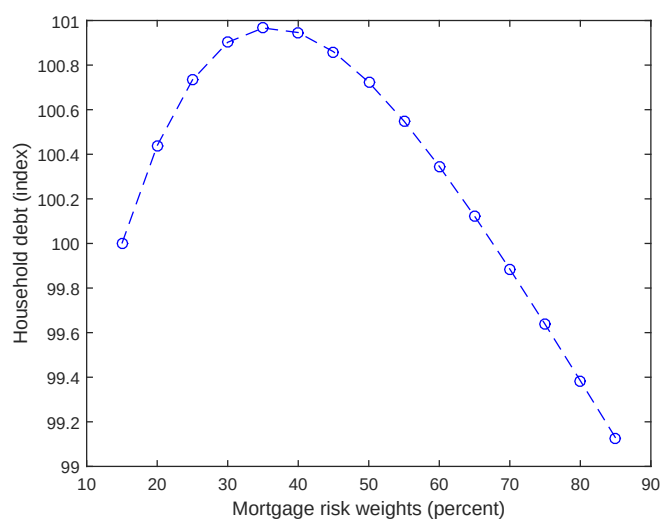
buffers should have greater ability to preserve funding intermediation function during periods of stress (i.e. shocks to bank funding costs and profit margin) thereby reducing macroeconomic volatility and improving welfare. On the other hand, higher mortgage risk weights may lower mortgage credit for households reducing borrower's housing stock, which may reduce welfare (see figure 18). We find that welfare improves as risk weights on mortgages increase with the marginal improvements diminishing notably when the risk weight exceeds 40 percent.

Figure 17: Welfare: mortgage risk weights



The figure depicts welfare over a range of mortgage risk weights.

Figure 18: Household debt: mortgage risk weights



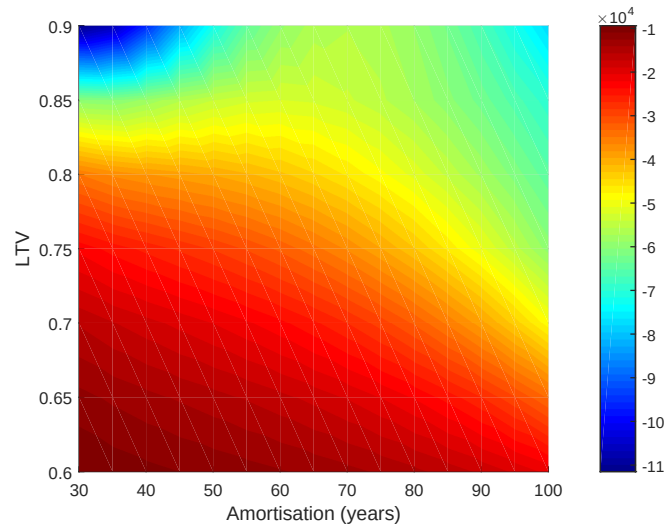
The figure depicts household real debt over a range of mortgage risk weights.

7.2 Interaction between macroprudential measures

Amortization and loan-to-value ratio. As illustrated above, welfare displays a non-linear relationship with amortization requirements for a given level of the LTV cap. However, this relationship can change with different levels of LTV. For instance, a high LTV cap implies that households have more capacity to borrow when shocks hit the economy suggesting that it might be optimal to have a higher debt and amortize little. At the same time, a lower LTV cap would limit the negative impact on households when the amortization requirement is tightened, as a tighter LTV implies a lower debt level in steady state, and the cost of a shorter amortization plan is proportional to the debt level. Thus the welfare gain from tightening amortization requirements in the context of a lower LTV cap could be larger.

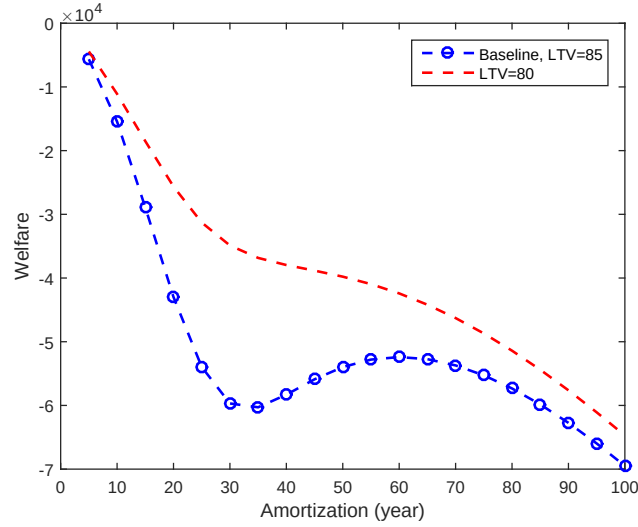
Indeed, our simulation suggests that welfare strictly increases with a tightening of amortization requirements when mortgage loans have LTV cap of less than 80 percent. However, above that threshold, the welfare maximizing amortization period is in the neighborhood of 60 years. More interestingly, our results suggest that policymakers can achieve higher welfare using a combination of the two measures.

Figure 19: Welfare: interaction between amortization requirements and LTV



The figure depicts welfare over a combination of amortization requirements and loan-to-value (LTV) ratios. The dark red color corresponds to the highest level of welfare, and dark blue represents the opposite. The scale is displayed by the vertical bar on the right.

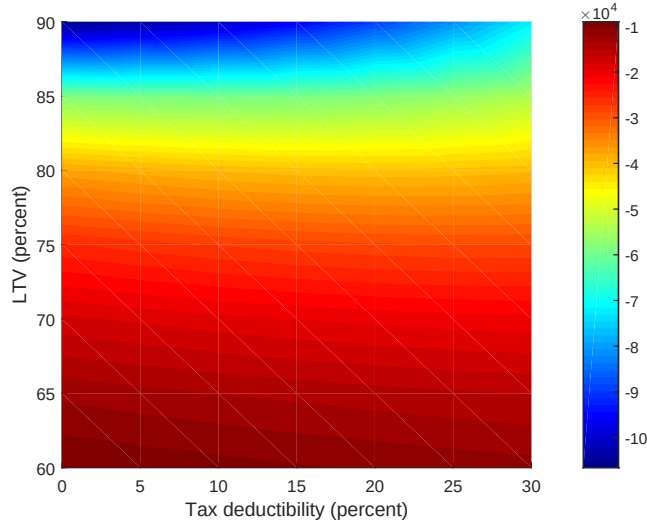
Figure 20: Welfare: amortization requirement



The figure compares the welfare over the same range of amortization requirements, but with different level of loan-to-value ratios: baseline associates a LTV of 85 percent, and another scenario considers a LTV of 80 percent.

Tax deductibility and loan-to-value ratio. Similarly, we are interested to analyze how welfare varies with different combinations of tax deductibility for mortgage interest payments and LTV ratios. Interestingly, we find that when LTV ratio is relatively loose, at about 90 percent, it is welfare improving to have high tax deductibility. The results could reflect the fact that a relatively loose LTV cap is associated with higher debt level in the steady state. Thus a reduction in tax deductibility would be too costly for the households, which is sub optimal. However, for mortgages with LTV lower than 75 percent, it becomes strictly welfare improving to have lower tax deductibility. Similarly, it is found that the highest welfare is achieved through a combination of lower tax deductibility and tighter LTV cap.

Figure 21: Welfare: interaction between mortgage tax deductibility and LTV I



The figure depicts welfare over a combination of mortgage tax deductibility and loan-to-value (LTV) ratios. The dark red color corresponds to the highest level of welfare, and dark blue represents the opposite. The scale is displayed by the vertical bar on the right.

8 Discussion and Robustness Checks

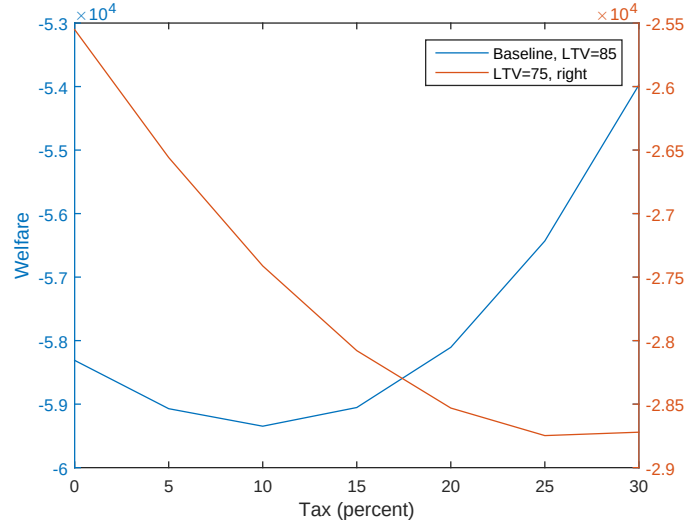
8.1 Model estimation

Model fit. The estimated model does a good job in matching some of the key ratios in the data as shown in table 2, yet, it does not perform as well in matching some of the second moments from the data. In particular, the estimated model overpredicts the volatility of household credit, both in absolute terms and relative to the standard deviation of GDP or consumption.

In order to check the robustness of our policy experiments in sections 6 and 7, we repeated all the policy experiments with a calibrated version of the model that matched well some of key second moments in the data. Specifically, we calibrated the standard deviation of the shock processes to match the standard deviations of GDP, consumption, investment, household credit, corporate credit, and house prices. The results for the policy experiments remain qualitatively unchanged.¹²

¹²These results are available upon request.

Figure 22: Welfare: interaction between mortgage tax deductibility and LTV II



The figure compares the welfare over the same range of mortgage tax deductibility, but with different level of loan-to-value ratios: baseline associates a LTV of 85 percent, and another scenario considers a LTV of 75 percent.

Table 2: Steady state ratios

Variable	Interpretation	Value
c/y	Ratio of consumption to GDP	0.55
i/y	Ratio of investment to GDP	0.21
g/y	Ratio of government consumption to GDP	0.25
DI/GDP	Disposable income to GDP	0.47
B/y	Ratio of bank credit to households and firms to GDP	1.2
B^h/B^E	Share of loans to households over corporate loans	1.3
$4 * r^d$	Annualized bank rate on deposits (percent)	1.5
$4 * r$	Annualized policy rate (percent)	2.9
$4 * r^{bH}$	Annualized bank rate on loans to households (percent)	3.5
$4 * r^{bE}$	Annualized bank rate on loans to firms (percent)	3.2
B^h/DI	Borrower's debt-to-disposable income	1.4
B^h/y	Mortgage to GDP ratio	0.7
m_i^{avg}	Average LTV for mortgage stock	0.68

Model comparison. We investigated whether the inclusion of an amortization requirement and a borrowing constraint that applies to the change in household credit (i.e. new mortgage loans) in the model improves its goodness-of-fit to the data. We find some supportive evidence that our model fits better than one that excludes amortization requirement or one that applies a borrowing constraint to the aggregate level of household credit. Yet the

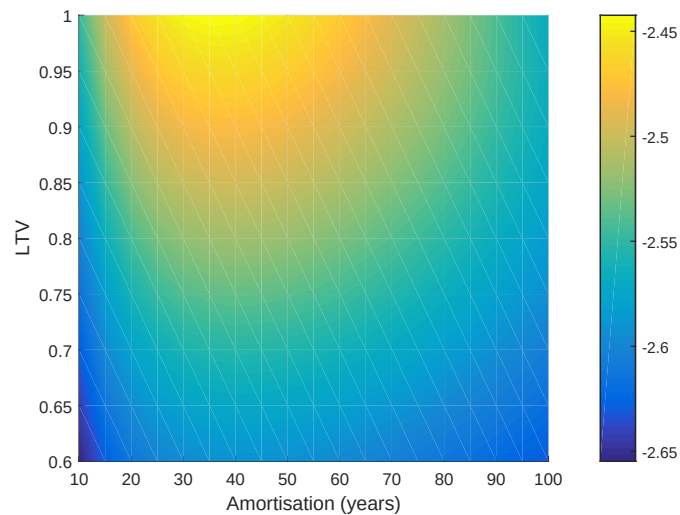
improvement in the likelihood is modest.

8.2 An alternative specification of welfare

An alternative way to study welfare is to look at sum of the households' utilities. In particular, how saver and borrower utilities change with different intensities of macroprudential measures. This way of measuring welfare factors in consumption, leisure as well as housing stock of the savers and the borrowers in different steady states, yet it does not consider the stochastic shocks to the economy differently than in the case of the welfare defined in Section 7.

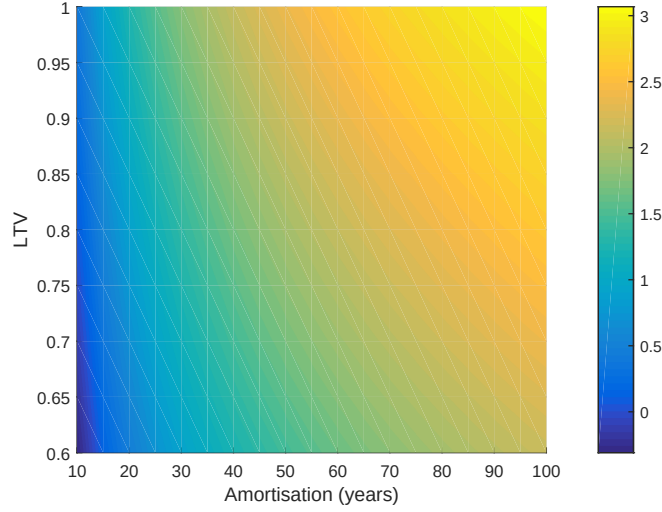
With this alternative specification we find that welfare would improve with less stringent LTV caps, yet it reaches the peak with an amortization requirement of 40 years (see Figures 23 and 24). Taking this at the face value, the result would imply that in Sweden it could be optimal to calibrate the amortization requirement to 40 years, while allowing the households the option to refinance by leaving the LTV cap on new mortgage loans at high values. However, we prefer our baseline welfare function as it fully considers all the future shock to the economy.

Figure 23: Aggregate of saver's and borrower's utilities: interaction between amortization requirements and LTV



The figure depicts the sum of saver's and borrower's utilities in different steady states that are characterized by a combination of amortization requirements and loan-to-value caps. The light yellow color corresponds to the highest level of utility.

Figure 24: Household debt over amortization requirements and LTV



The figure compares borrower's (mortgage) debt level across the same, as in Figure 23, distribution of macroprudential measures.

9 Conclusion

We analyze the effectiveness of macroprudential and monetary policies in addressing the most pressing financial stability risks in Sweden. We also study the impact of macroprudential policies on welfare. We find that a monetary policy shock initially results in a rise in households' debt-to-income ratio as the stock of household debt is very "sticky" and responds more slowly than household income. Yet, over time the net effect of the increase in the policy rate is a reduction of the household debt-to-income ratio. However, we find that demand-side macroprudential instruments reduce the household debt-to income ratio more effectively than monetary policy, as the adverse effects on consumption are more limited over the short term. These findings are consistent with the view that macroprudential policies are the right policies to address financial stability risks, while monetary policy has a higher cost in terms of foregone consumption that raises questions about the net benefits in most circumstances.

We find that tighter demand side macroprudential policies in Sweden could significantly reduce households' DTI ratios, while decreasing consumption and output by a small amount. The housing stock for the borrowing households would be slightly lower. Moreover, a tighter supply side measure, namely mortgage risk weights, could lead to an increase in households' DTI ratios, as its impact on output, thus households' income, could be much larger than the

impact on household debt. This finding reminds that the impact of macroprudential policies goes beyond curbing mortgage debt, it also decreases households' consumption, and affects distribution of the housing stock and other sectors in the economy, namely the banking sector. When taking these factors into account, the welfare analysis suggests that it can be welfare improving to further tighten macroprudential measures, and that a combination of macroprudential measures would achieve a higher welfare level.

Policymakers might be interested in the three main findings of our welfare analysis when implementing macroprudential policies. First, tighter LTV requirements on new mortgages and higher mortgage risk weights improve welfare, although with diminishing returns. Second, the sequence with which macroprudential measures are introduced matters, i.e. it is optimal to tighten amortization and reduce tax deductibility only when LTV on new mortgages falls below 80 percent. Third, a mix of the macroprudential measures studied is needed to deliver the maximum level of welfare. Importantly, we find that tighter macroprudential policies lead to a more muted response of the economy to banking system shocks including shocks to bank capital and its monopoly power in setting deposit rate that affects its funding costs. This would indicate that sound macroprudential policies are beneficial to the safeguard of the intermediation function of the financial system and of its support to the real economy's financing needs.

Finally, we are aware that a number of potential extensions could affect the findings reported in this paper. In particular, the model could be extended to take into account the distribution of LTV ratios, household default and a housing construction section. Also, it would be interesting to introduce an additional DTI requirement and study its interaction with the existing LTV constraint. The model estimation could also benefit by utilizing some external variables, i.e. foreign GDP, consumption, trade as well as financial flow data. We have added these points to our research agenda.

Appendices

A Additional Tables and Figures

Table A1: Prior and posterior distribution of the structural parameters I

Variable	Prior Distribution			Posterior Distribution		
	Distribution	Mean	St.Dev	Mean	5 percent	95 percent
κ_i	Gamma	10	5	9.89	5.52	14.13
κ_d	Gamma	10	5	0.06	0.01	0.10
κ_{be}	Gamma	10	5	45.81	35.63	55.66
κ_{bh}	Gamma	10	5	32.16	21.14	42.81
κ_p	Gamma	25	15	64.78	39.41	89.63
κ_w	Gamma	25	15	228.1	182.6	272.6
ϕ_π	Normal	1.7	0.1	2.01	1.93	2.07
ρ_{ib}	Beta	0.82	0.05	0.82	0.79	0.85
ϕ_y	Normal	0.13	0.15	0.34	0.28	0.40
ι_P	Beta	0.5	0.15	0.28	0.13	0.43
ι_w	Beta	0.5	0.15	0.40	0.16	0.63
a_h	Beta	0.65	0.1	0.98	0.97	0.99

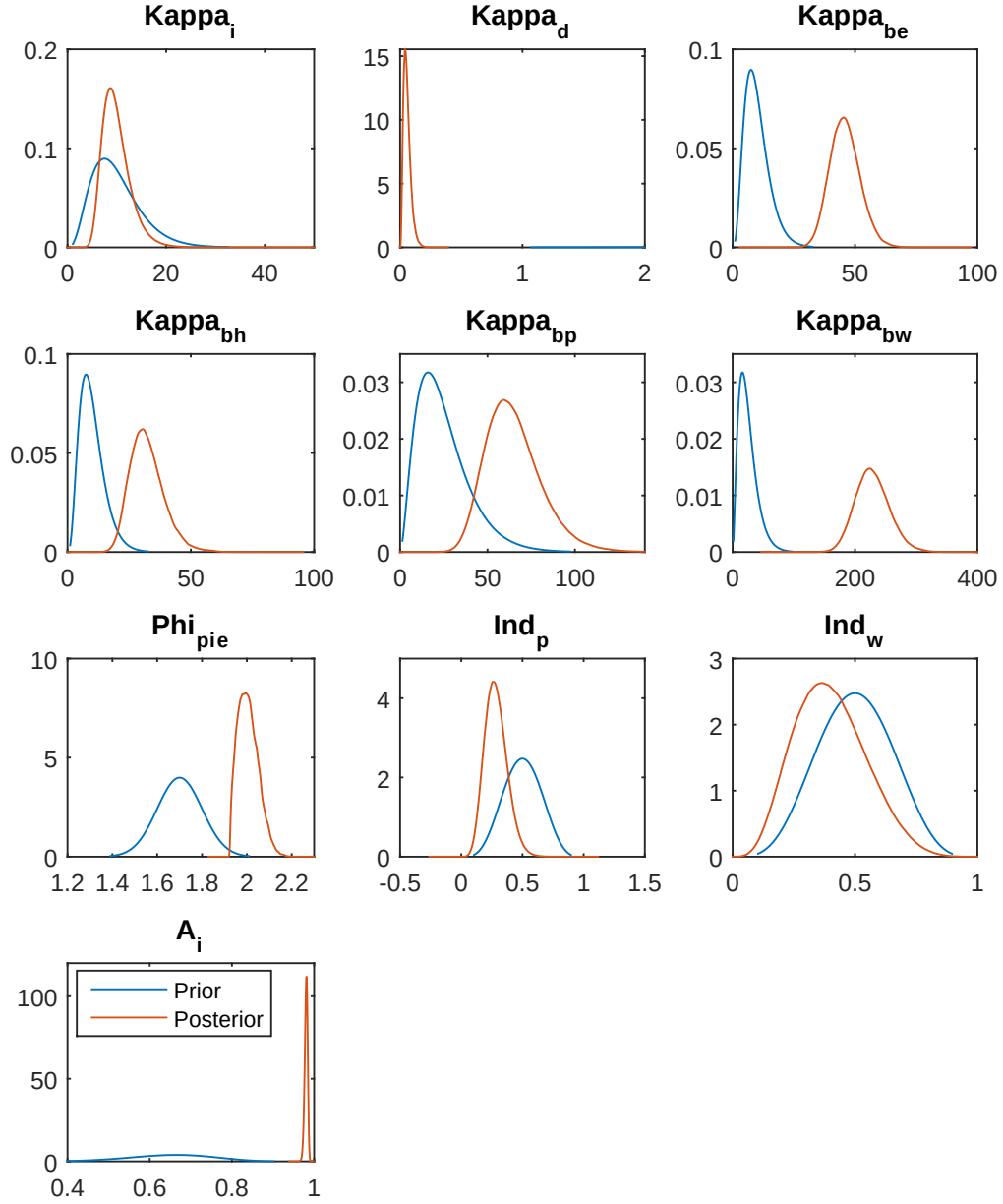
Note: Results based on 2 chains, each with 12,000,000 draws Metropolis algorithm.

Table A2: Prior and posterior distribution of the structural parameters II

Variable	Prior Distribution			Posterior Distribution		
	Distribution	Mean	St.Dev	Mean	5 percent	95 percent
ρ_a	Beta	0.75	0.05	0.62	0.54	0.71
ρ_z	Beta	0.75	0.05	0.44	0.37	0.50
ρ_{Ae}	Beta	0.75	0.05	0.99	0.98	0.99
ρ_j	Beta	0.75	0.05	0.75	0.67	0.83
ρ_{mE}	Beta	0.75	0.05	0.86	0.82	0.91
ρ_{mI}	Beta	0.75	0.05	0.61	0.54	0.68
ρ_d	Beta	0.75	0.05	0.79	0.74	0.84
ρ_{bh}	Beta	0.75	0.05	0.71	0.64	0.78
ρ_{be}	Beta	0.75	0.05	0.74	0.67	0.81
ρ_{qk}	Beta	0.75	0.05	0.45	0.39	0.52
ρ_y	Beta	0.75	0.05	0.88	0.83	0.93
ρ_l	Beta	0.75	0.05	0.75	0.67	0.83
ρ_{kb}	Beta	0.75	0.05	0.33	0.27	0.39
σ_a	Inv. gamma	0.01	10^5	0.02	0.02	0.03
σ_z	Inv. gamma	0.01	10^5	0.70	0.52	0.86
σ_{Ae}	Inv. gamma	0.01	10^5	0.06	0.05	0.08
σ_j	Inv. gamma	0.01	0.25	0.01	0.00	0.02
σ_{mE}	Inv. gamma	0.01	10^5	1.00	0.72	1.27
σ_{mI}	Inv. gamma	0.01	10^5	36.2	30.4	41.2
σ_d	Inv. gamma	0.01	10^5	0.11	0.09	0.12
σ_{bh}	Inv. gamma	0.01	10^5	3.77	2.63	4.89
σ_{be}	Inv. gamma	0.01	10^5	5.55	4.30	6.78
σ_{qk}	Inv. gamma	0.01	10^5	0.05	0.04	0.05
σ_y	Inv. gamma	0.01	10^5	1.09	0.78	1.38
σ_l	Inv. gamma	0.01	10^5	0.10	0.02	0.18
σ_{kb}	Inv. gamma	0.01	10^5	0.47	0.41	0.53
σ_{rb}	Inv. gamma	0.01	10^5	0.62	0.51	0.73

Note: Results based on 2 chains, each with 12,000,000 draws Metropolis algorithm.

Figure A1: Prior and posterior distribution of estimated parameters



Note: Estimation was carried out using Dynare version 4.4.3 with chains of 12 million draws. Prior and posterior distribution for other estimated structural parameters are available from the authors.

B The Model

Hereby we describe the key features of the model borrowing largely from Gerali et al. (2010) for the common sections.

B.1 Households and entrepreneurs

In the economy there are two groups of households, patient and impatient, and entrepreneurs. Each of these group has unit mass. The only difference between these agents is that patient's discount factor (β_P) is higher than impatient's (β_I) and entrepreneurs' (β_E).

B.1.1 Patient households

The representative patient household maximize the expected utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta_P^t \left[\epsilon_t^z (1 - \alpha^P) \log(c_t^P(i) - \alpha^P c_{t-1}^P) + \epsilon_t^h \log h_t^P(i) - \frac{(l_t^P)^{1+\phi}}{1+\phi} \right] \quad (3)$$

which is a function of current individual consumption $c_t^P(i)$, lagged aggregate consumption c_{t-1}^P , housing services $h_t^P(i)$ and hours worked $l_t^P(i)$. The parameter α^P measures the degree of habit formation in consumption; ϵ_t^h captures exogenous shocks to the demand for housing while ϵ_t^z is an intertemporal shock to preferences. These shocks have an AR(1) representation with *i.i.d* normal innovations. Household optimizes subject to the following budget constraint (in real terms) :

$$\begin{aligned} \text{s.t. } & c_t^P(i) + q_t^h \Delta h_t^P(i) + d_t^P(i) + M_t a_t \\ & \leq w_t^P l_t^P(i) + \frac{(1 + r_{t-1}^d) d_{t-1}^P(i)}{\pi_t} + T_t^P + \frac{M_{t-1}}{\pi_t} a_{t-1} (1 + r_{t-1}^f) \Phi_{t-1} \end{aligned} \quad (4)$$

The flow of expenses includes current consumption, accumulative of housing services, deposits at domestic banking system d_t^P and purchase of foreign bonds a_t . Resources are composed of wage earnings $W_t^P l_t^P$, gross interest income on last period domestic $\frac{(1+r_{t-1}^d)d_{t-1}^P(i)}{\pi_t}$ (gross inflation rate π_t) and foreign bonds $\frac{M_{t-1}}{\pi_t} a_{t-1} (1 + r_{t-1}^f) \Phi_{t-1}$, where M_t denotes real exchange rate. And a number of lump-sum transfers T_t^P including labor union membership net fee, dividends from the retail firms J_t^R , the banking sector dividends $(1 - \omega^b) \frac{J_{t-1}^b}{\pi_t}$ and government net transfers $Tr_t^{G,b}$.

Finally, Φ_t denotes the external risk premiums over r^f , and we assume it follows the process below:

$$\begin{aligned}\Phi_t &= \exp\left(-\tilde{\phi}_a(A_t - \bar{A}) - \tilde{\phi}_s(R_t^f - R_t - (R^f - R^{ss})) + \tilde{\Phi}_t\right) \\ \text{where } A_t &= \frac{a_t(i)P_{F,t}^f S_t}{d_t^P(i)P_t} = \frac{a_t(i)M_t}{d_t^P(i)}\end{aligned}\quad (5)$$

B.1.2 Impatient households

Impatient households do not hold deposits and do not own retail firms, but receive dividends from labor unions and subsidies on mortgage interest payments. The representative impatient household maximizes the expected utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta_I^t \left[\epsilon_t^z (1 - \alpha^I) \log(c_t^I(i) - \alpha^I c_{t-1}^I) + \epsilon_t^h \log h_t^I(i) - \frac{(l_t^I)^{1+\phi}}{1+\phi} \right] \quad (6)$$

which depends on consumption $c_t^I(i)$, housing services $h_t^I(i)$ and hours worked $l_t^I(i)$. Similarly, the parameter α^I measures the degree of habit formation in consumption. Household maximizes subject to the following (real term) budget constraints:

$$c_t^I(i) + q_t^h \Delta h_t^I(i) + ((1 + r_{t-1}^{bH}(1 - \tau_t^h)) \frac{b_{t-1}^I(i)}{\pi_t} \leq w_t^I l_t^I(i) + b_t^{bH}(i) + T_t^I \quad (7)$$

Impatient household's expenses include consumption, accumulation of housing services and reimbursement, less mortgage interest deductability, of past borrowing have to be financed with the wage income and new borrowing net union fees (T_t^I).

In addition, impatient households face a borrowing constraint: they carry over the unamortized share (ρ^A) of last period debt (b_{t-1}^I) and borrow to finance new housing investment. But they can only borrow up to a certain fraction of the value of their collateralizable new housing investment at period t .

$$\begin{aligned}b_t^I(i) &\leq (1 - \rho_t^A) \frac{b_{t-1}^I(i)}{\pi_t} + m_t q_t \Delta h_t^I \\ \text{where } \Delta h_t^I &= h_t^I - (1 - \delta_h) h_{t-1}^I\end{aligned}\quad (8)$$

where m_t is the stochastic loan-to-value (LTV) for mortgages. The assumption on households' discount factors is such that, absent uncertainty, the borrowing constraint of the impatient is binding in a neighborhood of the steady state. As in Iacoviello (2005) and Gerali et al. (2010), we assume that the size of shocks in the model is "small enough" so to remain

in such a neighborhood, and we can thus solve the model imposing that the borrowing constraint always binds.

We assume that the LTV follows the stochastic AR(1) process, where η_t^m is an *i.i.d.* zero mean normal random variable with standard deviation equal to σ_m and $\bar{m}$ is the (calibrated) steady-state value.

$$m_t = (1 - \rho_m)\bar{m} + \rho_m m_{t-1} + \eta_t^m \quad (9)$$

Similarly, ρ^A is the stochastic amortization plan for mortgages. It follows a AR(1) process, with η_t^A is an *i.i.d.* zero mean normal random variable with standard deviation equal to σ_A and $\bar{\rho}^A$ is the (calibrated) steady-state value.

$$\rho_t^A = (1 - \rho_a)\bar{\rho}^A + \rho_a \rho_{t-1}^A + \eta_t^A \quad (10)$$

At a macro-level, the value of m_t and ρ^A determine that amount of credit that banks make available to each type of households, for a given value of their housing stock and amortization plan.

B.1.3 Entrepreneurs

There is an infinity of entrepreneurs of unit mass. Each one i only cares about his own consumption $c^E(i)$ and maximizes the following utility function:

$$E_0 \sum_{t=1}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E) \quad (11)$$

where a^E , similarly to households, measures the degree of consumption habits. Entrepreneur's β_E is assumed to be strictly lower than β_P , implying that entrepreneurs are, in equilibrium, net borrowers. In order to maximize lifetime consumption, entrepreneurs choose the option stock of physical capital $k_t^E(i)$, the degree of capacity of utilization $u_t(i)$, the desired amount of labor input $l_t^E(i)$ and borrowing $b_t^E(i)$. Labor and effective capital are combined to produce an intermediate output $y_t^E(i)$ according to the following production function:

$$y_t^E(i) = a_t^E (k_{t-1}^E(i) u_t(I))^{\alpha_E} l_t^E(i)^{1-\alpha_E} \quad (12)$$

where a_t^E is an exogenous AR(1) process for total factor productivity. Labor of the two types of households are combined in the production function in a Cobb-Douglas fashion as in Iacoviello and Neri (2008).

The intermediate good is sold in a competitive market at wholesale price P_t^w . Entrepreneurs can borrow ($b_t^E(i)$, in real terms) from the banks.

$$\begin{aligned} c_t^E(i) + W_t l_t^E(i) &+ \frac{(1 + i_{t-1}^{bE})b_{t-1}^E(i)}{\pi_t} + q_t^k k_t^E(i) + \phi(u_t(i))k_{t-1}^E(i) \\ &= \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1 - \delta)k_{t-1}^E(i) \end{aligned} \quad (13)$$

W_t is the aggregate wage index, q_t^k is the price of one unit of physical capital in terms of consumption; $\phi(u_t(i))k_{t-1}^E(i)$ is the real cost of setting a level $u_t(i)$ of utilization rate, with $\phi(u_t) = \zeta_1(u_t - 1) + \frac{\zeta_2}{2}(u_t - 1)^2$; $1/x_t$ is the price in terms of the consumption good of the wholesale good produced by each entrepreneur.

Similarly to the mortgage borrowers, we assume that the amount of resources that banks are willing to lend to entrepreneurs is constrained by the value of their collateral, which is given by their holding of physical capital. The borrowing constraint is thus

$$(1 + r_t^{bE})b_t^E(i) \leq m_t^E E_t(q_{t+1}^k \pi_{t+1}(1 - \delta)k_t^E(i)) \quad (14)$$

where m_t^E is the entrepreneurs' loan-to-value ratio, which follows a stochastic process.

B.1.4 Loan and deposit demand

Following Gerali et al. (2010) we assume that units of deposit and loan contracts bought by households and entrepreneurs are a composition CES basket of slightly differentiated products - each supplied by a branch of a bank - j - with elasticity of substitution equal to ϵ_t^d , ϵ_t^{bH} , and ϵ_t^{bE} , respectively. As in the standard Dixit-Stiglitz framework for goods markets, in the credit market agents have to purchase deposit (loan) contracts from each single bank in order to save (borrow) one unit of resources.

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Moreover, it is assumed that elasticity of substitution in the banking industry is stochastic. This allows one to study how exogenous shocks hitting the banking sector transmit to the real economy. ϵ_t^{bH} and ϵ_t^{bE} (ϵ_t^d) affect the value of the markups (markdowns) that banks charge when setting interest rates and, thus, the value of the spread between the policy rate and the retail loan (deposit) rates. Innovations to the loan (deposit) markup (markdown) can thus be interpreted as innovations to bank spreads arising independently of monetary policy allowing us to analyze their effects on the real economy.

Given the Dixit-Stiglitz framework, demand for an individual bank's loans and deposits depends on the interest rates charged by the bank - relative to the average rates in the economy. The demand function for household i seeking an amount of borrowing equal to $b_t^H(i)$ can be derived from minimizing the due total repayment:

$$\min_{b_t^H(i,j)} \int_0^1 r_t^{bH}(j) b_t^I(i, j) dj$$

subject to

$$\left(\int_0^1 b_t^H(i, j)^{\frac{\epsilon_t^{bH}-1}{\epsilon_t^{bH}}} dj \right)^{\frac{\epsilon_t^{bH}}{\epsilon_t^{bH}-1}} \geq b_t^I(i) \quad (15)$$

Aggregating first order conditions across all impatient households, aggregate impatient households' demand for loans at bank j is obtained as:

$$b_t^H(j) = \left(\frac{r_t^{bH}(j)}{r_t^{bH}} \right)^{-\epsilon_t^{bH}} b_t^I \quad (16)$$

where $b_t^I \equiv \gamma^I b_t^I(i)$ indicates aggregate demand for household loans in real terms (γ^s , $s \in [P, I, E]$ indicates the measure of each subset of each subset of agents) and r_t^{bH} is the average interest rates on loans to households, defined as:

$$r_t^{bH} = \left[\int_0^1 r_t^{bH}(j)^{1-\epsilon_t^{bH}} dj \right]^{\frac{1}{1-\epsilon_t^{bH}}} \quad (17)$$

Demand for entrepreneurs' loans is obtained analogously, while demand for deposits at bank j of impatient household i , seeking an overall amount of (real) savings $d_t^P(i)$, is obtained by maximizing the revenue of total savings

$$\max_{d_t^P(i,j)} \int_0^1 r_t^d(i) d_t^P(i, j) dj$$

subject to

$$\left(\int_0^1 d_t^P(i, j)^{\frac{\epsilon_t^d - 1}{\epsilon_t^d}} dj \right)^{\frac{\epsilon_t^d}{\epsilon_t^d - 1}} \geq d_t^P(i) \quad (18)$$

and is given by (aggregating across households):

$$d_t^P(j) = \left(\frac{r_t^d(j)}{r_t^d} \right)^{-\epsilon_t^d} d_t^I \quad (19)$$

where $d_t \equiv \gamma^P d_t^P$ and r_t^d is the aggregate (average) deposit rate, defined as:

$$r_t^d = \left[\int_0^1 r_t^d(j)^{1-\epsilon_t^d} dj \right]^{\frac{1}{1-\epsilon_t^d}} \quad (20)$$

B.1.5 Labor market

We assume there are two unions, one for patients households and the other for the impatient ones. Each union sets nominal wages for workers to its labor type by maximizing a weighted average of its members' utility, subject to a constant elasticity (ϵ_t^l) demand schedule and to quadratic adjustment costs (premultiplied by a coefficient κ_w), with indexation ι_w to a weighted average of lagged and steady-state inflation. The unions charge their member with lump-sum fees to cover the adjustment costs with equal split. In a symmetric equilibrium, the labor choice for each single household in the economy will be given by the ensuing (non-linear) wage-Phillips curve. Moreover, there are perfectly competitive "labor packers" who buy the differentiated labor services from unions, transform them into an homogeneous composite labor input and sell it, in turn, to intermediate-good-producing firms. These assumptions imply a demand for each kind of differentiated labor service $l_t(n)$ equal to :

$$l_t(n) = \left(\frac{W_t(n)}{W_t} \right)^{-\epsilon_t^l} l_t \quad (21)$$

where W_t is the aggregate wage in the economy. The stochastic elasticity of labor demand implies a time-varying markup process. In the adjustment cost function for nominal wages, the parameter denotes the parameters measuring the size of these costs, while measures the degree of indexation to past prices.

B.2 International trade and current account

B.2.1 Household intra-temporal consumption decisions

Each period households decide how much of the domestically and foreign produced goods to purchase, let $j = p, i, e$:

$$\max c_t^j = \left((1 - \omega)^{1/\eta} (c_{H,t}^j)^{(\eta-1)/\eta} + \omega^{1/\eta} (c_{F,t}^j)^{(\eta-1)/\eta} \right)^{\eta/(\eta-1)} \quad (22)$$

$$\text{s.t. } P_{H,t} c_{H,t}^j(i) + P_{F,t} c_{F,t}^j(i) = 1 \quad (23)$$

Where, c_t^j denotes consumption bundle at time t , $c_{H,t}^j$ is the consumption of home produced goods and $c_{F,t}^j$ refers to the purchase of goods produced in the foreign economy, i.e. import. $P_{H,T}$ is the price of home produced goods and $P_{F,T}$ is the price of foreign produced goods, both denominated in domestic currency. Define:

$$P_t = \left((1 - \omega) P_{H,t}^{1-\eta} + \omega P_{F,t}^{1-\eta} \right)^{1/(1-\eta)} \quad (24)$$

B.2.2 Import

We assume imported goods $c_{F,t}$ is produced by competitive foreign firms which convert foreign outputs one-for-one into $c_{F,t}$, and the price is set to the marginal cost:

$$\begin{aligned} P_{F,t} &= S_t P_{F,t}^f (1 - \phi^f + \phi^f (1 + r_t^f)) \\ p_{F,t} \equiv \frac{P_{F,t}}{P_{H,t}} &= p_t M_t (1 - \phi^f + \phi^f (1 + r_t^f)) \end{aligned} \quad (25)$$

We normalize all the prices by $P_{H,t}$, note:

$$\begin{aligned} \pi_t \equiv \frac{P_t}{P_{t-1}} &= \frac{p_t}{p_{t-1}} \frac{P_{H,t}}{P_{H,t-1}} \\ &= \pi_{home,t} \left[\frac{(1 - \omega) + \omega p_{F,t}^{1-\eta}}{(1 - \omega) + \omega p_{F,t-1}^{1-\eta}} \right]^{-1/1-\eta} \end{aligned} \quad (26)$$

where, $\pi_{home,t} = \frac{P_{H,t}}{P_{H,t-1}}$

B.2.3 Export

We assume demand for export, X_t , equals to the following:

$$\begin{aligned} X_t &= \left(\frac{P_{x,t}^f}{P_{F,t}^f} \right)^{-\eta^f} Y_t^f \\ &= p_{x,t}^{-\eta^f} Y_t^f \end{aligned} \quad (27)$$

Where, $\frac{P_{x,t}^f}{P_{F,t}^f} \equiv p_t^x$ denotes the term of trade (TOT) and Y_t^f foreign output which we assume is exogenous, $P_{F,t}^f$ price of foreign (produced) goods in foreign currency and $P_{x,t}^f$ is the price of export goods (home produced) in foreign currency.

Equating price and marginal cost:

$$\begin{aligned} S_t P_{x,t}^f &= P_{H,t}(\mu^x(1+r_d) + 1 - \mu^x) \\ \frac{P_t}{P_{H,t}} \frac{S_t P_{F,t}^f}{P_t} \frac{P_{x,t}^f}{P_{F,t}^f} &= \mu^x(1+r_d) + 1 - \mu^x \\ p_t M_t p_t^x &= \mu^x(1+r_d) + 1 - \mu^x \end{aligned} \quad (28)$$

B.2.4 Current account

Equating international demand and supply of money:

$$\begin{aligned} &S_t a_t P_{F,t}^f + \text{expenses on imports} \\ &= \text{receipts from export} + S_{t-1}(1+r_{t-1}^f)\Phi_{t-1}a_{t-1}P_{F,t-1}^f \end{aligned} \quad (29)$$

$$\text{expenses on imports} = S_t P_{F,t}^f (1 - \phi^f + \phi^f(1+r_t^f)) \omega \left(\frac{p_t}{p_{F,t}} \right)^\eta C_t \quad (30)$$

$$\text{receipts from exports} = S_t P_{x,t}^f X_t \quad (31)$$

Implies:

$$\begin{aligned} &S_t a_t P_{F,t}^f + S_t P_{F,t}^f (1 - \phi^f + \phi^f(1+r_t^f)) \omega \left(\frac{p_t}{p_{F,t}} \right)^\eta C_t \\ &= S_t P_{x,t}^f X_t + S_{t-1}(1+r_{t-1}^f)\Phi_{t-1}a_{t-1}P_{F,t-1}^f \end{aligned} \quad (32)$$

$\Rightarrow$

$$\begin{aligned} \frac{S_t a_t P_{F,t}^f}{P_t} + \frac{S_t P_{F,t}^f}{P_t} (1 - \phi^f + \phi^f (1 + r_t^f)) \omega \left(\frac{p_t}{p_{F,t}} \right)^\eta C_t \\ = \frac{S_t P_{x,t}^f X_t}{P_t} + \frac{S_t (1 + r_{t-1}^f) \Phi_{t-1} a_{t-1} P_{F,t-1}^f}{P_t} \end{aligned} \quad (33)$$

$\Rightarrow$

$$\begin{aligned} a_t M_t + M_t (1 - \phi^f + \phi^f (1 + r_t^f)) \omega \left(\frac{p_t}{p_{F,t}} \right)^\eta C_t \\ = M_t p_{x,t} X_t + \frac{M_{t-1}}{\pi_t} a_{t-1} (1 + r_{t-1}^f) \Phi_{t-1} \end{aligned} \quad (34)$$

B.3 Banks

The banks intermediate funds between savers and borrowers. The set up of the banking sector largely follows from Angelini et al. (2014), thus we defer readers to the original paper for a more detailed description. However, we describe the key elements of the banking sector so that it provides a coherent picture of the model.

Banks enjoy monopoly powers in intermediation activity, which allows them to adjust rates on loans and deposits in response to shocks in the economy. This feature allows us to study how different degrees of interest rate pass-through affect the transmission of shocks in particular monetary policy. The second key feature of the banks is that they have to obey a balance sheet identity: $B_t = D_t + K_t^b$ suggesting that banks can finance their loans B_t using either deposits D_t or bank capital (equity) K_t^b . Moreover, there is an (exogenously given) “optimal” risk weighted capital-assets ratio for banks, which can be ¹³ intuitively viewed as a binding risk-weighted capital requirements for the banks. This implies bank capital and risk weights will have a key role in determining the credit supply conditions in the model. In addition, banks accumulated capital out of retained earnings, which implies a feedback loop between the real and the financial side of the economy. As macroeconomic conditions deteriorate, bank profits are negatively hit, and this weakens the ability of banks to raise new capital; depending on the nature of the shock that hit the economy, banks might respond to the ensuing weakening of their financial position (i.e. increasing leverage) by reducing the amount of loans they are willing to issue, thereby exacerbating the original contraction.

¹³Technically, as deposits and capital are perfect substitutes, this “targeted” bank capital requirements provides a way to pin down the choices by the bank.

In the model, each bank $j \in [0, 1]$ composes three parts: two “retail” branches and one “wholesale” unit. The two retail branches are responsible for loan issuance and deposit taking, while the wholesale unit manages the capital position of the group, in addition, raises wholesale loans and wholesale deposits in the interbank market.

B.3.1 Wholesale branch

The wholesale bank combines bank capital (K_t^b) and wholesale deposits (D_t) on the liability side and issues wholesale loans (B_t) on the asset side. However, banks are subject to a quadratic cost whenever the risk weighted capital (B_t^{RW}) to assets ratio (K_t^b/B_t^{RW}) deviates from a target: ν^b .

Bank capital is accumulated each period out of retained earnings according to:

$$K_t^{b,n}(j) = (1 - \delta^b)K_{t-1}^{b,n}(j) + \omega^b J_{t-1}^{b,n}(j) \quad (35)$$

where, $K_t^{b,n}(j)$ is bank j 's equity in nominal terms, $\omega^b J_{t-1}^{b,n}(j)$ are overall profits made by the three branches of bank j in nominal terms, $(1 - \omega^b)$ summarizes the dividend policy of the bank, and δ^b measures resources used in managing bank capital and conducting the overall banking intermediation activity.

The dividend policy is assumed to exogenously fixed, the problem for wholesale bank is thus to choose loans $B_t^i(j)$ ($i = E, H$) and deposits $D_t(j)$ so as to maximize profits, subject to a balance sheet constraint:

$$\begin{aligned} \max \quad & E_0 \sum_{t=1}^{\infty} \lambda_{0,t}^p \left[(1 + R_t^{b,H})B_t^H(j) + (1 + R_t^{b,E})B_t^E(j) - (1 + R_t^d)D_t(j) \right. \\ & \left. - K_t^b(j) - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b(j)}{B_t^{RW}(j)} - \nu^b \right)^2 K_t^b(j) \right] \\ \text{s.t.} \quad & B_t(j) = B_t^H + B_t^E = D_t(j) + K_t^b(j) \end{aligned} \quad (36)$$

where $R_t^{b,i}$ - the net wholesale loan rates for $i = H, E$ and R_t^d - the net deposit are taken as given. And $B_t^{RW} = RW^H B_t^H + RW^E B_t^E$

The first order conditions yield a condition linking the spread between wholesale rates on loans and deposits the degree of leverage $b_t(j)/K_t^b(j)$ for bank j , i.e.

$$R_t^{b,i} = R_t^d - \kappa_{Kb} \left(\frac{K_t^b(j)}{B_t^{RW}(j)} - \nu^b \right) \left(\frac{K_t}{B_t^{RW}(j)} \right)^2 RW^i \quad (37)$$

In order to close the model, it is assumed that banks can invest any excess fund they have in a deposit facility at the central bank remunerated at rate r_t , thus $R_t^d \equiv r_t$ in the interbank market implying:

$$R_t^{b,i} = r_t - \kappa_{Kb} \left(\frac{K_t^b}{B_t^{RW}} - \nu^b \right) \left(\frac{K_t}{B_t^{RW}} \right)^2 RW^i \quad (38)$$

Moreover, the above equation can be rearranged to highlight the spread between (whole-sale) loan and deposit rates:

$$S_t^W \equiv R_t^b - r_t = -\kappa_{Kb} \left(\frac{K_t^b}{B_t^{RW}} - \nu^b \right) \left(\frac{K_t}{B_t^{RW}} \right)^2 RW^i \quad (39)$$

B.3.2 Retail banking

Retail banks operate under a monopolistic competition regime where they set lending and deposit rates.

Loan branch: Retail loan branches obtain wholesale loans $B_t^i(j)$ from the wholesale unit at the rate $R_t^{b,i}$ for $i = H, E$, differentiate them at no cost and resell them to households and firms applying two distinct mark-ups. The problem for retail loan banks is to choose $r_t^{bH}(j), r_t^{bE}(j)$ to maximize

$$\begin{aligned} \max \quad & E_0 \sum_{t=1}^{\infty} \lambda_{0,t}^p \left[r_t^{b,H}(j) b_t^H(j) + r_t^{b,E} b_t^E(j) - R_t^{b,H} B_t^H(j) - R_t^{b,E} B_t^E(j) \right. \\ & \left. - \frac{\kappa_{bH}}{2} \left(\frac{r_t^{bH}}{r_{t-1}^{bH}} - 1 \right)^2 r_t^{bH} b_t^H - \frac{\kappa_{bE}}{2} \left(\frac{r_t^{bE}}{r_{t-1}^{bE}} - 1 \right)^2 r_t^{bE} b_t^E \right] \\ \text{s.t.} \quad & b_t^H(j) = \left(\frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} \right)^{-\epsilon_t^{bH}} b_t^H \quad \text{and} \quad b_t^E(j) = \left(\frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} \right)^{-\epsilon_t^{bE}} b_t^E \end{aligned} \quad (40)$$

where $b_t^H(j) + b_t^E(j) = B_t(j)$. Moreover, it can be shown that the spread between the loan and the policy rate:

$$S_t^{b,i} \equiv r_t^{b,i} - r_t = \frac{\epsilon_t^{bi}}{\epsilon_t^{bi} - 1} S_t^W + \frac{1}{\epsilon_t^{bi} - 1} r_t \quad (41)$$

Deposit branch: Retail deposit branches collect deposits $d_t(j)$ from households and then pass the raised funds to the wholesale unit, which pays them at rate r_t . The problem for

the deposit branch is to choose the retail deposit rate $r_t^d(j)$, applying a monopolistically competitive mark-down to the policy rate r_t , and maximize:

$$\begin{aligned} \max \quad & E_0 \sum_{t=1}^{\infty} \lambda_{0,t}^p \left[r_t D_t(j) - r_t^d d_t(j) - \frac{\kappa_d}{2} \left(\frac{r_t^d}{r_{t-1}^d} - 1 \right)^2 r_t^d D_t \right] \\ \text{s.t.} \quad & d_t(j) = \left(\frac{r_t^d(j)}{r_t^d} \right)^{-\epsilon_t^d} D_t \end{aligned} \quad (42)$$

with $d_t(j) = D_t(j)$.

Finally, profits of bank j are the sum of earnings from the wholesale unit and the retail branches. After deleting the intra-group transactions, their expression is:

$$J_t^b(j) = r_t^{bH}(j) b_t^H(j) + r_t^{bE}(j) b_t^E(j) - r_t^d(j) d_t(j) - \frac{\kappa_{Kb}}{2} \left(\frac{K_t^b(j)}{B_t^{RW}} - \nu^b \right)^2 K_t^b(j) - Adj_t^B(j) \quad (43)$$

where $Adj_t^B(j)$ indicates adjustment costs for changing interest rates on loans and deposits.

B.4 Retailers

Retailers also enjoy monopoly power but subject to a quadratic price adjustment costs when revising prices. More specifically, they buy intermediate goods from entrepreneurs at the wholesale price P_t^W and differentiate the goods at no cost. Each retailer then sales their unique variety at a mark-up over the wholesale price. The retail prices are further assumed to be indexed to a combination of past and steady-state inflation, with relative weights parametrized by ς . In a symmetric equilibrium, the Phillips curve is given by the retailers' problem first-order condition:

$$1 - \epsilon_t^y + \frac{\epsilon_t^y}{x_t} - \kappa_p (\pi_{t-1} - \pi_{t-1}^\varsigma \pi^{1-\varsigma}) \pi_t + \beta_P E_t \left[\frac{c_t^P - a^P c_{t-1}^P}{c_{t+1}^P - a^P c_t^P} \kappa_p (\pi_{t+1} - \pi_t^{\iota_P} \pi^{1-\iota_P}) \pi_{t+1} \frac{y_{t+1}}{y_t} \right] = 0 \quad (44)$$

where, $x_t = P_t/P_t^W$ is the gross markup earned by retailers.

B.5 Capital goods producers

At beginning of each period, we assume each capital good producer purchases an amount $i_t(j)$ of final good from retailers and stock of old undepreciated capital $(1 - \delta)k_{t-1}$ from entrepreneurs (at a nominal price P_t^K). Old capital can be converted one-to-one into new capital, while the transformation of the final good is subject to quadratic adjustment costs. The capital goods producers is a convenient modeling device which generate a market price

for capital. The amount of new capital that capital goods producers can produce is given by:

$$k_t(j) = (1 - \delta)k_{t-1}(j) + \left[1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_t^{qk} i_t(j)}{i_{t-1}(j)} - 1 \right)^2 \right] i_t(j) \quad (45)$$

where κ_t is the parameter measuring the cost for adjusting investment and ϵ_t^{qk} is a shock to productivity of investment goods. The new capital stock is then sold back to entrepreneurs at the end of period at the nominal price P_t^k . Market for new capital is assumed to be perfectly competitive, and it can be shown that capital goods producers profit maximization delivers a dynamic equation for the real price of capital $q_t^k = P_t^k/P_t$ similar to Christiano and others (2005) and Smets and Wouters (2003).

B.6 Monetary policy

The monetary authority follows a Taylor rule of the type:

$$(1 + r_t) = (1 + r)^{(1-\Phi_R)}(1 + r_{t-1})^{\Phi_R} \left(\frac{\pi_t}{\pi} \right)^{\Phi_\pi(1-\Phi_\pi)} \left(\frac{Y_t}{Y_{t-1}} \right)^{\Phi_y(1-\Phi_y)} \epsilon_t^R \quad (46)$$

where Φ_π and Φ_y are weights assigned to inflation and output stabilization, respectively, r is the steady-state nominal interest rate and ϵ_t^R is an exogenous shock to monetary policy.

B.7 Government

We assume government subsidizes the impatient households such that a certain percent of the (mortgage) debt interest payment is “financed” by the government. In addition, the government consumes and makes transfers to households. The spending is financed by a tax on patient households’ profit. The government does not issue debt, hence the budget is balanced using the transfers each period. More specifically, the following additional equations are introduced into the model:

We assume government consumption is proportional (g_y) to the annual output:

$$G = g_y(Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3})/4 \quad (47)$$

Government budget balance is respected:

$$G + \text{transfers} + \tau_t^h * r_{t-1}^{bH} b_{t-1}^I = \tau^J J_R \quad (48)$$

where, τ^h is the tax deductibility on mortgage interest payment. Finally, transfers are divided

according to wage share:

$$\begin{aligned}\text{transfer to patient} &= transfer * \left(\frac{w^p l^p}{w^p l^p + w^i l^i} \right) \\ \text{transfer to impatient} &= transfer * \left(\frac{w^i l^i}{w^p l^p + w^i l^i} \right)\end{aligned}\tag{49}$$

B.8 Aggregation and market clearing

Equilibrium in the goods market is expressed by the resource constraint

$$Y_t = C_t^{dom} + q_t^k [K_t - (1 - \delta)K_{t-1}] + G_t + X_t + adj_t\tag{50}$$

where $C_t^{dom} \equiv c_t^{dom,P} + c_t^{dom,I} + c_t^{dom,E}$ denotes aggregate consumption of domestic goods. Equilibrium in the housing market is given by:

$$\bar{h} = \gamma^P h_t^P(i) + \gamma^I h_t^I(i)\tag{51}$$

where $\bar{h}$ denotes the exogenous fixed housing supply.

C Data and Sources

Real GDP: Gross domestic product, constant prices, seasonally adjusted. Source: Statistics Sweden

Real consumption: Household consumption expenditure, constant prices, seasonally adjusted. Source: Statistics Sweden

Real investment: Gross fixed capital formation, constant prices, seasonally adjusted. Source: Statistics Sweden

Interest rate on mortgages: Monetary financial institution mortgage lending rates on new agreements during the period to households on all contracts. Source: Sveriges Riskbank

Banking lending rate to firms: Monetary financial institution lending rates at the end of each period to non-financial corporations for loans with fixed periods. Source: Sveriges Riskbank

Deposit rate: Banks' deposit rates at the end of each period on all accounts. Source: Sveriges Riskbank

Repo rate: Source: Sveriges Riskbank

Real loans to households: Lending to households by mortgage lenders (1996Q1-2001Q3) and loans to households from Swedish MFI with housing collateral (2001Q4-2014Q4). Source: Sveriges Riskbank

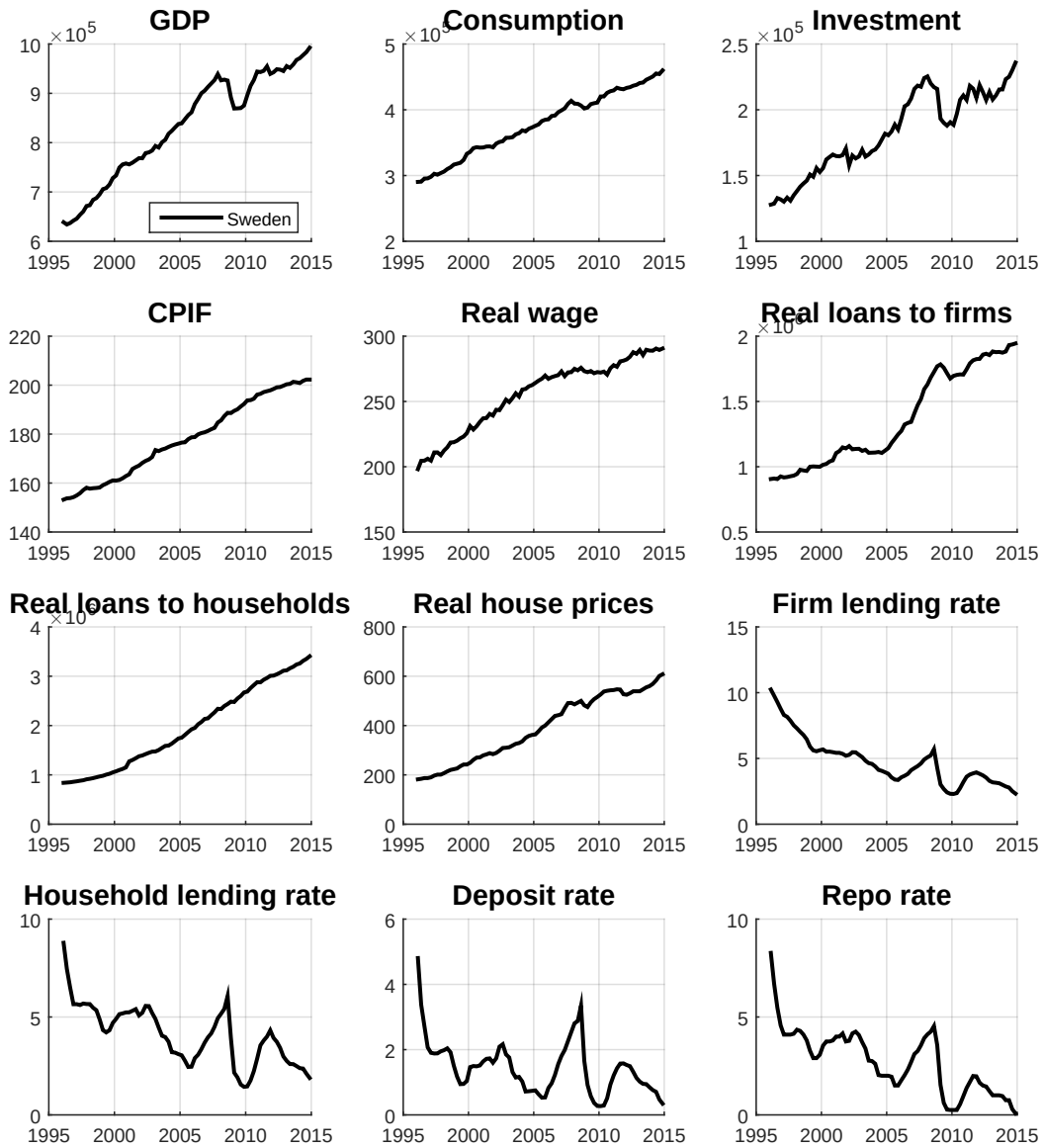
Real loans to firms: Lending to non-financial corporations by Swedish MFI. Source: Statistics Sweden

Real wages: Hourly labor cost index. Source: Statistics Sweden

Inflation: CPIF inflation. Source: Statistics Sweden

Real house prices: Source: Sveriges Riskbank

Raw data



Sources: Sveriges Riksbank and Statistics Sweden.

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