Macroprudential and Monetary Policies Interactions in a DSGE Model for Sweden

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Abstract

We analyse the effects and the interactions of macroprudential and monetary policies with an estimated dynamic stochastic general equilibrium (DSGE) model tailored to Sweden. Households are constrained by a loan-to-value ratio and mortgages are amortized. Government grants mortgage interest payment deductions. Lending rates are affected by mortgage risk weights. We find that to curb the household debt-to-income ratio demand-side macroprudential measures are more effective and less costly in terms of foregone consumption than monetary policy. A tighter macroprudential stance is also welfare improving, by promoting lower consumption volatility in response to shock, especially when combining different instruments, whose sequence of implementation is key.

Keywords: Macroprudential Policies; Monetary Policy; Collateral Constraints.

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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 and reserves a role to monetary policy only in extraordinary times and after a fully-fledged cost-benefit analysis (IMF, 2015). Macroprudential policy is regarded as the first line of defense against the rise of systemic financial vulnerabilities because monetary policy is considered too blunt a tool. Monetary policy remains assigned to macroeconomic stability, often via an inflation targeting approach, yet, since macroprudential policies are still unproven, risks to financial stability cannot be ruled out with certainty from the considerations behind monetary policy decisions (Bernanke, 2015). Indeed, it cannot be excluded, on rare occasions, that monetary policy itself could pose a threat to financial stability that cannot be addressed with macroprudential instruments, with any “leaning against the wind” being justified only by a thorough cost-benefit analysis (Svensson, 2015). Current thinking is that macroprudential tools, if deployed in a timely manner, can effectively contain vulnerabilities, although their effects, especially on welfare need further study (Claessens, 2014). Coordination between these 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, making it important to understand the potential of macroprudential polices in curbing such risks. Swedish banks have a large exposure to mortgages, at some 400 per cent of GDP, increasing the potential for mounting vulnerabilities in the housing market and household balance sheets to undermine the resilience of the financial system. Nonetheless, the potential stability benefits of macro-prudential policies from moderating household debt have to be assessed taking into account the welfare costs on the economy. Monetary policy effectiveness in halting such dynamics in housing markets are also examined, although there seems to be no scope for monetary policy to “lean against the wind” as low inflation expectations have prompted the Riksbank to focus on the fight against the low inflation to protect the credibility of the inflation targeting framework and hence its effectiveness in promoting macroeconomic stability.

This paper contributes to the literature in two ways. First, it compares in a fully-fledged general equilibrium model the costs and benefits of macro-prudential and monetary policies in reducing household debt, 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, loan-to-value (LTV) ratios, amortization requirements and tax deductibility of mortgage interest payments and of a supply-side measure, mortgage risk weight. This is motivated by the circumstance that in the case of Sweden there may be room for tightening the macroprudential stance via the demand-side instruments, with the potential for higher benefits than supply-side macro-prudential measures which have already been tightened in recent years (Chen, 2014). To achieve this goal we modify the dynamic stochastic general equilibrium (DSGE) model of (Gerali et al., 2010) to make it suitable for a small open economy, introducing also additional macroprudential measures and estimating it with Swedish data. Second, we study the welfare implications of these
policies shedding 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 2015Q2 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, a strong household demand fostered by historically low interest rates, rising incomes and wealth, and population growth especially in the main cities. The record high share of households expecting further house prices increases could support further borrowing.

[Figure 1 about here]

[Figure 2 about here]

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 the interest rate costs (21 percent above SEK 100,000) from taxes due.

[Figure 3 about here]

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

[Figure 4 about here]

[Figure 5 about here]
Mortgage contracts in Sweden often run for 30-50 years, but it is not common practice to have a fixed amortization schedule. In practice, the rate of amortization varies, and Riksbank analysis\(^1\) suggests that just 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 recently, the attitude towards amortization has improved, with 69 percent of all households with new loans amortizing their mortgage in 2014. Amortization was more common for more leveraged loans, as 85 percent of households with LTV above 70 percent amortized their mortgage, but only 40 per cent for loans with LTV between 50 and 70 percent. 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.

Moreover, an amortization of mortgage debt faster than that stipulated in the contract can be costly in Sweden. Given the sheer size of household debt, an increase in amortization rate corresponds to a significant cost for the households. In addition, households need to pay for the interest rate differential compensation 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,\(^3\) subsequently.

\[
\text{Interest rate differential compensation} = \\
(mortgage interest rate - (ask rate for a government bond with the same fixed period +1percentage point)) \times \text{outstanding debt} \times \text{remaining period}
\]

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 per cent were at variable rate. This preference for variable rate contracts

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\(^1\) See Deputy Governor Cecilia Skingsley’s speech, (Skingsley, 2007)

\(^2\) In the 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. However, this should not be confused with the maturity of the loan. Repayment period in this case refers to the maturity implied by the amortizations and not the maturity specified in the loan agreement. (Sveriges Riskbank, 2014)

\(^3\) The formula was modified in 2014 replacing government bond with covered bond.
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 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 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 authorities have rolled out Basel III measures ahead of schedule, including with the introduction in 2013 of a capital conservation buffer at 2.5 percent, in 2014 of minimum risk weights of 25 percent for mortgages, in 2015 of a systemic risk buffer at 3 percent, of a 2 percent capital surcharge for the four systemically important banks and of a countercyclical risk buffer at 1 percent.\footnote{The countercyclical capital buffer is to be raised to 1.5 percent in June 2016.} Macroprudential measures on the credit demand side have been taken to a more limited extent. In 2010 the Financial Supervisory Authority (FSA) established a 85 percent cap for the LTV ratio. The measure 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 LTV ratio to reach about 72 percent in 2010, but still with about 50 percent of the new borrowers in 2014 with an LTV ratio just below the cap. However, in a context of double digit growth rates for house prices, house purchasers could increase their DTI ratio while still meeting the 85 percent LTV cap. This would imply a continuing vulnerability to a prolonged recession compounded by a housing market decline due to the ensuing wealth effects and debt deleveraging.

3 The Model

To analyze the costs and benefits of macro-prudential and monetary policies in reducing household debt we use a dynamic stochastic general equilibrium (DSGE) model with financial frictions and an imperfectly competitive banking sector modifying the Gerali et al. (2010) model. We modify the model along two dimensions. First, we tailor the model to Sweden’s characteristics by dividing the world in a small open economy and in 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 a mortgage risk weight.

The home economy is affected by the foreign economy while the reverse is not true. Final consumption goods are traded, and home savers can invest in foreign bonds. The home economy is populated by two types of households, patient and impatient and by entrepreneurs. Households consume, work and accumulate housing (in fixed supply),\footnote{This assumption may not be that implausible given the housing stock per capita has remained largely unchanged since 1990s in Sweden.} while
entrepreneurs produce a homogenous intermediate good using capital bought from capital-good producers and labor supplied by households. Agents (households and entrepreneurs) have different degree of impatience, hence different discount factors of future utility. The heterogeneity in agents’ discount factors provides a simple way to generate financial flows in the equilibrium: patient households (savers) purchase a positive amount 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.

We model the LTV ratio by allowing impatient households to borrow up to a fraction of new housing investment each period. We model the amortization requirement assuming that the impatient households have to repay a fixed fraction of the loan principal each period. The interaction between mortgage amortization, and new housing investment generates a wedge between the average LTV for the mortgage stock and the LTV on new mortgages, since every period the repayment of the loan principal makes the average LTV on outstanding mortgages lower than the that of new mortgages. In addition, we model the tax deductibility of mortgage interest payments by having the borrowers receive, from the government, a deduction on their mortgage interest payments which is proportional to the size of the mortgage and mortgage interest rates. 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 transfer from/to the households to ensure this balance is respected each period.

The financial flows are channeled through an imperfectly competitive banking sector. Banks supply deposits and loans to the agents, and set interest rates on both deposit and loan in order to maximize profits. The amount of loans issued by each intermediary can be financed through the amount of deposits that they raise and through 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 are forced to converge back to the requirement by adjusting the rates.

Households supply their differentiated labor services through unions which set wages to 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 sectors which produce final and intermediate goods: a monopolistically competitive retail sector and a capital-good producing sector. Retailers buy the intermediate goods from entrepreneurs at a price which includes a markup over the purchasing cost and that is subject to further adjustment costs. As in Gerali et al. (2010), physical capital good producers are used as a modeling device to 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

4.1 Data

We use a Bayesian approach and choose prior distributions for the parameters which are added to the likelihood function; the 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, repo rates, real loans to households, real loans to firms, wage inflation, CPIF inflation, and real house prices. The sample period runs from 1996Q1 to 2014Q4. We remove the trend from the variables using the HP filter. We estimate the parameters that are difficult to calibrate, or the ones that we have very little information about, and calibrate those determining the steady state in order to obtain reasonable values for some key steady-state values and ratios.

4.2 Calibrated parameters and prior distributions

Calibration. Table 1 reports the values of the calibrated parameters. We calibrate the model to resemble the Swedish economy, in doing so 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 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 households’ utility function is calibrated at 0.2 following Gerali et al. (2010).

For the loan-to-value (LTV) ratios, we set \( m_i \) at 0.85 in line with the current LTV requirements 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 Swedish monetary financial institutions lending data. We calibrate the amortization periods for the 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 15 percent and set \( \epsilon_t \) at 5. In the goods market, a value of 6 for \( \epsilon_y \) in steady state delivers a markup of 20 percent. We calibrate the elasticity of substitution of deposits \( \epsilon_d \) 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 weight for mortgages to 25 percent according to the existing risk weights requirement for mortgages, and 50 percent for corporate loans. 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.

\(^6\)See Appendix B for a description of the data.
consistent with the Swedish bank’s high risk weighted capital ratios.

**Prior distributions.** Tables 3 and 4 list our priors. These are guided by previous literature, in particular Adolfson et al. (2008), Lindé et al. (2009), and Gerali et al. (2010). When 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 $\rho_R$, $\Phi_\pi$ and $\Phi_y$ to 0.8, 1.7, and 0.13 respectively. For the LTV, we set the prior mean on $\rho_{mi}$ to 0.75 suggesting it take some time for any announced LTV to be implemented.

### 4.3 Posterior estimates

Tables 3 and 4 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 8 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.

As for the monetary policy rule, we find a relatively large degree of interest rate inertia, consistent with Adolfson et al. (2008), but our estimates suggest a higher responsiveness of monetary policy to inflation and output (i.e. higher estimated $\Phi_\pi$ and $\Phi_y$). One explanation could be that the Riksbank has changed its reaction function, becoming more aggressive, during the crisis, as Adolfson et al. (2008) estimated model focuses only on the pre-crisis sample. Regarding nominal rigidities, we find that wage stickiness is much more significant than price stickiness. This may reflect the fact that the wages are in general only re-negotiated every three years, and the goal of wage bargaining is to preserve a constant rate of wage change in Sweden. Concerning the parameters measuring the degree of stickiness in bank rates, we find that deposit rates adjust more rapidly than the rates on loans to changes in policy rates. This is not surprising given Swedish households can easily switch their deposits into other financial instruments, thereby banks tend to adjust deposit rates frequently to meet the needs. Finally, we found mortgage rates adjust faster compared with lending rate to firms, reflecting the high share of variable rate mortgage contracts in Sweden Angelini et al. (2014).
5 Model Properties

To illustrate the broad properties of the estimated model, we study the dynamics of the model with impulse responses, focusing on the impact of a contractionary monetary policy shock. We also analyze how the impact of the shock varies with different levels of macroprudential requirements, because the model features the additional following mechanisms besides the traditional interest rate channel which affects the transmission of the 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 to borrow 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 over the unpaid mortgage principal forward. The introduction of amortization requirements overcomes the difference between the way the economy works and the main models in the literature (e.g. Gerali et al. (2010)) that assume that at the beginning of every period the households repay the mortgage debt in full 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 of an increase in monetary policy rates on the macroeconomy, while dampening the impact on household debt.

- The banking sector dampens the response of retail rates to a monetary policy shock owing to the stickiness of bank lending rates. This mitigates the reduction in lending, consumption and investment following a monetary tightening as in Gerali et al. (2010). Moreover, the bank capital constraint introduces a further wedge between the bank lending and deposit rates and monetary policy rates.

Figure 9 shows the impacts on output, inflation, and household debt-to-income ratio of a 100 basis point exogenous rise in monetary policy rate. In the benchmark model, 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 stylized facts in business cycle theory.

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 same amount implying that the bank interest rate
spread decreases. The response of bank capital is initially negative, reflecting the decrease in bank margins and thus profit, but it subsequently increases as spread rises. 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 degrees of macroprudential policy intensity. 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.\(^7\)

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 the amortization rates are currently very low implies it can take years for any newly introduced LTV requirements to “work their way through” the mortgage stock implying a long time to reach the new steady state. Thus, we will 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 mortgage amounts. Moreover, falling house prices reduce collateral values, reinforcing the impact of the initial tightening of the LTV cap. In

\(^{7}\)It 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.
what follows, we consider a scenario in which LTV cap is reduced by 5 percentage points to 80 percent.

*Over the short run.* Borrowers’ consumption falls by about 0.2 percent one year after the LTV is lowered. Savers’ consumption falls too, although by less, as the fall in the stock of mortgages lowers bank profitability, hence the deposit rates offered to the savers 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. All together, the tightening of LTV cap has a contractionary effect on the economy lowering consumption by 0.02 percent one year after the shock, and GDP would continue to decline by 0.1 percent three years after the shock.

*In the new steady state.* Borrowers’ debt declines by about 10 percent, in part because house prices fall about 1.5 percent. The relatively modest fall in house prices, in part, reflects 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). However, borrower’s consumption 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. The result is driven by the falling bank profits, 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.

[Figure 10 about here]

### 6.2 Amortization requirements

With the introduction of amortization requirements, a portion of the mortgage principal must be repaid each period, by an amount dependent on the amortization plan on 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 ‘unpaid’ initial debt principal plus a stream of ‘unpaid’ new loans. Thus, by specifying a faster amortization plan, household debt is reduced.

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

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 over to the next periods, 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 11 illustrates the impact of tightening of amortization requirements equivalent to a 5-year reduction in maturity to 45 years.

*Over the short run.* The impact on consumption partly depends on the balance between: a larger amortization repayment which would tighten household’s cash flow constraint, and a lower debt—hence lower future interest payments—which would relax household’s resource 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 partly is driven by the endogenous responses from the monetary authority that has lowered the repo rate quite significantly by almost 1 percentage point. The very accommodative monetary conditions implies that the 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 slowing down the de-leveraging and helping to manage 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 debt-to-income ratio falling by the similar amount, and house prices reduced 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 lower 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.

6.3 Tax deductibility of mortgage interest

A reduction in mortgage interest payment deductibility increases the cost of servicing a mortgage to household’s thereby tightening budget constraints—income effect. Moreover, this would make a debt financed housing purchase more costly relative to the price of consumption goods, as the cost of servicing a unit of debt increases with the reduction in mortgage interest deductibility—substitution effect. Figure 12 illustrates the impacts on household debt, debt-to-income ratio, consumption, and borrowers’ housing stock following a 5 percentage points reduction of mortgage tax deductibility to 25 percent.

*Over the short run.* The negative income effects stemming from tighter budget constraints would lower borrower’s demand for housing, in turn household debt would fall. However, borrower’s consumption increases in the short run for two reasons: first, consumption becomes cheaper relative to housing, thus borrowers would optimally decide to consume more and to lower demand for housing (for a given level of utility), and second, the baseline case assumes 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, however, they also benefit from
the higher transfers leading to higher consumption. The overall impact is slightly higher aggregate consumption, output and inflation. House prices would fall by about 0.6 percent in the near term.

In the new steady state. Borrower’s household debt is lowered by about 2.2 percent, similar to the DTI ratio. Their consumption will be higher by about 0.1 percent, with a 2 percent lower holding of housing stock. Savers’ consumption also increases in this case by about 0.1 percent, as explained above, driven by higher transfers. The latter would be sufficient to offset the decline in bank profit which would lead to a decline in consumption.

Importantly, the impact on consumption depends on how the government utilizes the savings that came from a reduction in tax deductibility. Figure 13 compares the baseline scenario where we assumed the saving arisen from the 5 percentage point reduction in mortgage tax deductibility is fully re-distributed back to the two types of households with an assumption that these additional revenues are not redistributed. The figure illustrates that the re-distribution of the savings clearly helps to mitigate the negative impact on consumption.

[Figure 12 about here]
[Figure 13 about here]

6.4 Mortgage risk weights

An increase in mortgage risk weights implies, ceteris paribus, a higher bank capital requirement that is proportional to banks’ mortgage exposure. Thus, an increase in mortgage risk weights implies that banks will need to accumulate more capital through profits, requiring them to increase the profit margin, hence lending rates, for a given level of loan and deposit demand. A higher borrowing rate then leads to a reduction in mortgage demand thus lowering household debt. However, given that adjusting mortgage rate is subject to a cost the pass-through can be slow. Meanwhile, the households anticipate the rise in mortgage rates in the future by adjusting their demand and monetary policy acts immediately to cushion such shock. In the long run, higher bank capital requirement simply leads to less credit to both the firms and households, reducing output and aggregate consumption. Figure 14 illustrates a 5 percentage points increase in mortgage risk weights to 30 percent.

Over the short run. Borrower’s consumption would decline by a marginal amount of 0.02 percent 2 years after the shock, dragging down the aggregate consumption by just over 0.01 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 will only be reduced by about 0.2 percent, with similar decline in house prices and DTI ratio. However, both saver’s and borrower’s
consumption will decline, implying a 0.5 percent permanently lower aggregate consumption. This result is largely driven by the fact that banks need to reduce credit supply to both households and firms. A lower firm lending affects the investment, capital stock thus output. The simulation suggests output would be 0.6 percent lower in the new steady state.

[Figure 14 about here]

7 Welfare optimal macroprudential policies

Are borrowers better off if policy makers tighten macroprudential policies reducing the probability of a crisis down the road? More generally, is the society better off? The results from the previous section indicate that tightening macroprudential policies can reduce household indebtedness with small negative impacts on consumption, partly owing to the fact that households with lower debt would have more resources available to consume. However, this does not necessarily indicate that households are better off; in particular, in the steady states that are associated with stricter macroprudential requirements borrowers in general own less housing. 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 consumption, housing accumulation as well as labor supply for all the agents in the economy. Moreover, a welfare function would also consider the distribution of housing stock, as households’ utility functions are non-linear in housing stocks.

With a welfare function, we can search for the macroprudential policy settings that would maximize welfare. For this purpose, we perform a second-order approximation to the model’s equilibrium conditions and to welfare, and simulate the model subject to the stochastic shocks at the posterior mean of the model’s parameters, and report the mean of welfare following Schmitt-Groh´e and Uribe (2007) and Quinta and Rabanal (2014). 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:

\[
W = W_{\text{saver}} + W_{\text{borrower}} + W_{\text{entrepreneur}}
\]

\[
W^i_t = U^i_t + \beta W^i_{t+1} \quad i = \text{saver, borrower, entrepreneur}
\]

Where \(W^i_t\) is the welfare of the \(i^{th}\) type of borrowers, \(U^i_t\) 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 the welfare over a range of LTV requirements. There are two countervailing forces to determine a 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 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, reducing consumption, in response to adverse shocks. In turn, this leads to higher output losses.

We find that the welfare improvements become very small after the LTV cap reaches 60 percent, but welfare continues to improve as LTV caps tightens. This is in part due to the fact that the LTV cap only apply to new mortgages, which represent only 8 percent of the mortgage stock. Thus the impact from a stricter LTV cap is small on the aggregate credit.

Amortization requirement. Next, we examine the welfare over a range of amortization requirements which apply to the existing mortgage stock. Higher amortization requirements imply for households a larger mortgage principal payment in every period, which is proportional to the size of the mortgage stock. We find a highly non-linear relationship between the 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 outweighs the costs from larger repayments in every period that lead to lower housing investment and consumption. The relationship reaches a “local” maximum around an amortization requirement of 60 years, then welfare starts to decline until amortization requirement reaches 30. After that, it becomes optimal to further tighten amortization requirements with very high marginal improvements.

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 interests on the existing mortgage stock, thereby inducing them to borrow less and shift their preferences towards consumption as discussed in the previous section. We find that welfare would decrease by lowering deductibility. This suggests in our baseline calibration the benefit of lowering deductibility which would lead to a reduction in household debt is lower compared with the costs.

Risk weights on mortgages. Finally, we analyze banks and supply-side measures investigating whether higher risk weights on mortgages improve welfare as banks with stronger capital buffer 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. However, higher mortgage risk weight would imply less mortgage credit flow to the households reducing borrower’s demand for housing, which may reduce welfare. We find that welfare improves as risk weights on mortgages increase, with the marginal improvements significantly diminishing when risk weight is over 40 percent.
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 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 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 importantly, our results suggest that policymaker can achieve higher welfare using a combination of the two measures.

   [Figure 19 about here]

   [Figure 20 about here]

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 about here]

   [Figure 22 about here]

8 Conclusion

Our paper takes a general equilibrium approach to study with a DSGE model the effects and the interactions of macroprudential and monetary policies to address financial stability risks in an economy like 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, a potential alternative, has a higher cost in terms of foregone consumption that raises questions about the net benefits delivered in normal circumstances.

Overall we assess that a further tightening of macroprudential policies in Sweden amidst high and rising household debt and housing prices can significantly reduce households’ debt-to-income ratios, while decreasing consumption and output by a small amount and leading to a modestly lower housing stock for the borrowing households. 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 mortgage falls below 80 percent. Third, only a mix of the macroprudential measures studied delivers the maximum level of welfare. Importantly, we find that tighter macroprudential policies lead to a more muted response of the economy to a banking system shock. 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.

Further development of the modeling framework would be needed to take into account the distribution of LTV ratios, and to introduce a housing construction sector. Moreover, it would be interesting to introduce an additional DTI requirement and study its interaction with the existing LTV constraint.
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<td>Entrepreneurs’ discount factor</td>
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<td>Annualized bank rate on loans to entrepreneurs</td>
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<td>$g/y$</td>
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<td>Share of loans to households over total loans</td>
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<td>$4 \times r^d$</td>
<td>Annualized bank rate on deposits (percent)</td>
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Note: Results based on 2 chains, each with 12,000,000 draws Metropolis algorithm.
Table 4: Prior and posterior distribution of the structural parameters II

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Note: Results based on 2 chains, each with 12,000,000 draws Metropolis algorithm.
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.
Figure 3: Tax incentives for home ownership, 2013.

![Tax incentives for home ownership, 2013.](image)

Sources: European Commission and authors’ calculation.
Note: Composite tax index range: 0 (Low) 3 (High)

Figure 4: Housing stock to population

![Housing stock to population](image)

Sources: Statistics Sweden and authors’ calculation.
Note: Ratio of dwellings to population in thousand
Figure 5: Interest rate fixation periods for Swedish mortgages

Sources: European Commission and authors’ calculation.

Figure 6: Spread between mortgage interest rates over 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.
Figure 7: Swedish household indebtedness and housing price expectations

Sources: NIER and authors’ calculation.
**Figure 8:** 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.
Figure 9: 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.
**Figure 10:** Impacts from a permanent df reduction in LTV: 85 → 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).

**Figure 11:** Impacts from a permanent change in amortization requirement: 50 → 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 = 45 years) compared with the baseline (Amortization = 50 years).
**Figure 12:** Impacts from a reduction in mortgage tax deductibility: 30 → 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).

**Figure 13:** Households’ consumption responses from a reduction in mortgage tax deductibility: 30 → 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.
Figure 14: Impacts from a increase in mortgage risk weights: 25 → 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).
Figure 15: Welfare: loan-to-value ratio

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

Figure 16: Welfare: amortization

The figure depicts welfare over a range of amortization requirements.
Figure 17: Welfare: tax deductibility on mortgage interest repayments

The figure depicts welfare over a range of tax deductibility.

Figure 18: Welfare: mortgage risk weights

The figure depicts welfare over a range of mortgage risk weights.
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.
Figure 21: Welfare: interaction between mortgage tax deductibility and LTV

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.

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

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.
Appendices

A The Model

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

A.1 Households and entrepreneurs

In the economy there are two groups of households, patient and inpatient, and entrepreneurs. Each of these groups has unit mass. The only difference between these agents is that patient’s discount factor (\(\beta_P\)) is higher than inpatient’s (\(\beta_I\)) and entrepreneurs’ (\(\beta_E\)).

A.1.1 Patient households

The representative patient household maximizes the expected utility:

\[
\max E_0 \sum_{t=0}^{\infty} \beta_t^P \left[ \epsilon^P_t (1 - \alpha^P) log(c^P_t(i) - \alpha^P c^P_{t-1}) + \epsilon^h_t logh^P_t(i) - \frac{(\Pi^P_t)^{1+\phi}}{1 + \phi} \right]
\]  

which is a function of current individual consumption \(c^P_t(i)\), lagged aggregate consumption \(c^P_{t-1}\), housing services \(h^P_t(i)\) and hours worked \(l^P_t(i)\). The parameter \(\alpha^P\) measures the degree of habit formation in consumption; \(\epsilon^h_t\) captures exogenous shocks to the demand for housing while \(\epsilon^z_t\) 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):

\[
s.t. \quad c^P_t(i) + q^h_t \Delta h^P_t(i) + d^P_t(i) + M_t a_t \leq w^P_t l^P_t(i) + (1 + r^d_{t-1}) d^P_{t-1}(i) + T^P_t + \frac{M_{t-1}}{\pi_t} a_{t-1}(1 + r^f_{t-1}) \Phi_{t-1} (1 + r^f_{t-1}) \Phi_{t-1}
\]  

The flow of expenses includes current consumption, accumulative of housing services, deposits at domestic banking system \(d^P_t\) and purchase of foreign bonds \(a_t\). Resources are composed of wage earnings \(W^P_t l^P_t\), gross interest income on last period domestic \(\frac{(1 + r^d_{t-1}) d^P_{t-1}(i)}{\pi_t}\) (gross inflation rate \(\pi_t\)) and foreign bonds \(\frac{M_{t-1}}{\pi_t} a_{t-1}(1 + r^f_{t-1}) \Phi_{t-1}\), where \(M_t\) denotes real exchange rate. And a number of lump-sum transfers \(T^P_t\) including labor union membership net fee, dividends from the retail firms \(J^R_t\), the banking sector dividends \((1 - \omega^b) \frac{J^b_{t-1}}{\pi_t}\) and government net transfers \(T r^G_{t}\).

Finally, \(\Phi_t\) denotes the external risk premiums over \(r^f\), and we assume it follows the
process below:

\[ \Phi_t = \exp \left( -\tilde{\phi}_a(A_t - \bar{A}) - \tilde{\phi}_s(R^f_t - R_t - (R^f - R^{ss})) + \tilde{\Phi}_t \right) \]

where

\[ A_t = \frac{a_t(i)P_{Et}S_t}{d_t^p(i)P_t} = \frac{a_t(i)M_t}{d_t^p(i)} \tag{5} \]

### A.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:

\[ \max E_0 \sum_{t=0}^{\infty} \beta_t \left[ \epsilon_t (1 - \alpha^I) \log(c^I_t(i) - \alpha^I c^I_{t-1}) + \epsilon_t^h \log h^I_t(i) - \frac{(l^I_t)^{1+\phi}}{1 + \phi} \right] \tag{6} \]

which depends on consumption \( c^I_t(i) \), housing services \( h^I_t(i) \) and hours worked \( l^I_t(i) \). Similarly, the parameter \( a^I \) measures the degree of habit formation in consumption. Household maximizes subject to the following (real term) budget constraints:

\[ c^I_t(i) + q^h_t \Delta h^I_t(i) + \left( (1 + r^H_{t-1}(1 - \tau^h)) \frac{b^I_{t-1}(i)}{\pi_t} \right) \leq w_t^I l^I_t(i) + b^{Ht}_t(i) + T_t^I \tag{7} \]

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 un-amortized share \( (\rho^A) \) of last period debt \( b^I_{t-1} \) 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 \( t \).

\[ b^I_t(i) \leq (1 - \rho^A_t) \frac{b^I_{t-1}(i)}{\pi_t} + m_t q_t \Delta h^I_t \]

where \( \Delta h^I_t = h^I_t - (1 - \delta_h)h^I_{t-1} \)

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 \( \eta_t^m \) is an i.i.d. zero mean normal random variable with standard deviation equal to \( \sigma_m \) and \( \bar{m} \) is the (calibrated) steady-state value.

\[ m_t = (1 - \rho_m)\bar{m} + \rho_m m_{t-1} + \eta_t^m \tag{9} \]
Similarly, $\rho^A$ is the stochastic amortization plan for mortgages. It follows a AR(1) process, with $\eta^A_t$ is an i.i.d. zero mean normal random variable with standard deviation equal to $\sigma_A$ and $\bar{\rho}^A$ is the (calibrated) steady-state value.

$$\rho^A_t = (1 - \rho_a)\bar{\rho}^A + \rho_a\rho^A_{t-1} + \eta^A_t$$  \hspace{1cm} (10)

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

### A.1.3 Entrepreneurs

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

$$E_0 \sum_{t=1}^{\infty} \beta_t^E \log(c^E_t(i) - a^E c^E_{t-1})$$  \hspace{1cm} (11)

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

$$y^E_t(i) = a^E_t (k^E_{t-1}(i)u_t(I))^{\alpha^E_t} l^E_t(i)^{1-\alpha^E_t}$$  \hspace{1cm} (12)

where $a^E_t$ 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 $P^w_t$. Entrepreneurs can borrow ($b^E_t(i)$, in real terms) from the banks.

$$c^E_t(i) + W_t l^E_t(i) = \frac{(1 + \gamma^E_t) b^E_{t-1}(i)}{\pi_t} + q^k_t k^E_t(i) + \phi(u_t(i)) k^E_{t-1}(i)$$

$$= \frac{y^E_t(i)}{x_t} + b^E_t(i) + q^k_t (1 - \delta) k^E_{t-1}(i)$$  \hspace{1cm} (13)

$W_t$ is the aggregate wage index, $q^k_t$ is the price of one unit of physical capital in terms of consumption; $\phi(u_t(i)) k^E_{t-1}(i)$ 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

\[(1 + r_t^{BE})b_t^E(i) \leq m_t^E E_t(q_{t+1}^k \pi_{t+1}(1 - \delta)k_t^E(i))\]  

(14)

where \(m_t^E\) is the entrepreneurs’ loan-to-value ratio, which follows a stochastic process.

**A.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 \(\epsilon_t^d\), \(\epsilon_t^{bH}\), and \(\epsilon_t^{bE}\), 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. \(\epsilon_t^{bH}\) and \(\epsilon_t^{bE}\) (\(\epsilon_t^d\)) 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:

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

subject to

\[
\left( \int_0^1 b_t^H(i,j)\frac{\phi_t^{bH}}{\phi_t^{bH-1}} dj \right)^\frac{\phi_t^{bH}}{\phi_t^{bH-1}} \geq b_t^H(i) \]  

(15)

Aggregating first order conditions across all impatient households, aggregate impatient households’ demand for loans at bank \(j\) is obtained as:
\[
b_t^H(j) = \left( \frac{r_t^{bH}(j)}{r_t^{bH}} \right)^{-\epsilon_t^H} b_t^I
\] (16)

where \( b_t^I \equiv \gamma^I b_t^I(i) \) indicates aggregate demand for household loans in real terms (\( \gamma^s, s \in [P, I, E] \) 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:

\[
r_t^{bH} = \left[ \int_0^1 r_t^{bH}(j)^{1-\epsilon_t^{bH}} dj \right]^{\frac{1}{1-\epsilon_t^{bH}}}
\] (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 \( d_P^t(i) \), is obtained by maximizing the revenue of total savings

\[
\max_{d_P^t(i,j)} \int_0^1 r_t^d(i) d_P^t(i,j) dj
\]

subject to

\[
\left( \int_0^1 d_P^t(i,j) \frac{\epsilon_t^{d-1}}{\epsilon_t^d} dj \right)^{\frac{\epsilon_t^d}{\epsilon_t^{d-1}}} \geq d_P^t(i)
\] (18)

and is given by (aggregating across households):

\[
d_P^t(j) = \left( \frac{r_t^d(j)}{r_t^d} \right)^{-\epsilon_t^d} d_t^I
\] (19)

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

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

A.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 (\( \epsilon_t^l \)) demand schedule and to quadratic adjustment costs (premultiplied by a coefficient \( \kappa_w \)), with indexation \( \iota_w \) 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:

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

(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.

**A.2 International trade and current account**

**A.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)}

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

(22)

(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)}

(24)

**A.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:

$$P_{F,t} = S_t P_{F,t}^f (1 - \phi_f + \phi_f (1 + r_t^f))

p_{F,t} = P_{F,t} P_{H,t}^{-1} = p_t M_t (1 - \phi_f + \phi_f (1 + r_t^f))

(25)

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

$$\pi_t = \frac{P_t}{P_{t-1}^{1-\eta}} = \frac{p_t}{p_{t-1}^{1-\eta}} \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}

(26)
where, $\pi_{\text{home},t} = \frac{P_{H,t}}{P_{H,t-1}}$

### A.2.3 Export

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

$$X_t = \left( \frac{P_{F,t}}{P_{F,t}} \right)^{-\eta_f} Y_t^f$$

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

Equating price and marginal cost:

$$S_t P_{F,t} = P_{H,t} (\mu x (1 + r_d) + 1 - \mu x)$$

$$\frac{P_t}{P_{H,t}} \frac{S_t P_{F,t}}{P_{F,t}} = \mu x (1 + r_d) + 1 - \mu x$$

$$p_t M_t p^x_t = \mu x (1 + r_d) + 1 - \mu x$$

### A.2.4 Current account

Equating international demand and supply of money:

$$S_t a_t P_{F,t} + \text{expenses on imports}$$

$$= \text{receipts from export} + S_{t-1} (1 + r_{t-1}) a_{t-1} P_{F,t-1}$$

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

$$\text{receipts from exports} = S_t P_{x,t} X_t$$

Implies:

$$S_t a_t P_{F,t} + S_t P_{F,t} (1 - \phi^f + \phi^f (1 + r_t^f)) \omega \left( \frac{p_t}{p_{F,t}} \right)^\eta C_t$$

$$= S_t P_{x,t} X_t + S_{t-1} (1 + r_{t-1}) a_{t-1} P_{F,t-1}$$
⇒

\[
\frac{S_t a_t P_{F,t}^f}{P_t} + \frac{S_t P_{F,t}^f}{P_t} (1 - \phi^f + \phi^f (1 + r_{t}^f)) \omega \left( \frac{p_t}{p_{F,t}} \right)^\eta C_t
\]

\[
= \frac{S_t P_{x,t}^f X_t}{P_t} + \frac{S_t (1 + r_{t-1}^f) \Phi_{t-1} a_{t-1} P_{F,t-1}^f}{P_t}
\]

(33)

⇒

\[
a_t M_t + M_t (1 - \phi^f + \phi^f (1 + r_{t}^f)) \omega \left( \frac{p_t}{p_{F,t}} \right)^\eta C_t
\]

\[
= M_t p_{x,t} X_t + \frac{M_{t-1}}{\pi_t} a_{t-1} (1 + r_{t-1}^f) \Phi_{t-1}
\]

(34)

A.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 \(^8\) 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 weaken 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.

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.

\(^8\)Technically, as deposits and capital are perfect substitutes, this “targeted” bank capital requirements provides a way to pin down the choices by the bank.
A.3.1 Wholesale branch

The wholesale bank combines bank capital ($K_b$) 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 ($B_{RW}$) to assets ratio ($\frac{K_b}{B_{RW}}$) deviates from a target: $\nu^b$.

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

$$K_{b,n}^b(j) = (1 - \delta^b)K_{b,n}^b(j) + \omega^bJ_{b,n}^b(j)$$  \hspace{1cm} (35)

where, $K_{b,n}^b(j)$ is bank j’s equity in nominal terms, $\omega^bJ_{b,n}^b(j)$ 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 $\delta^b$ 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:

$$\max \sum_{t=1}^\infty \lambda^b_{0,t} \left[ (1 + R_{t,E}B_t^E(j)) + (1 + R_{t,H}B_t^H(j)) - (1 + R_{t,d}D_t(j) - K_b(j) - \kappa K_b^2 \frac{K_b}{B_{RW}} - \nu^b) \right]$$

s.t. $B_t(j) = B_t^H + B_t^E = D_t(j) + K_t(j)$  \hspace{1cm} (36)

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

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.

$$R_{t,i}^b = R_{t,d}^d - \kappa K_b \left( \frac{K_t^b(j)}{B_{RW}^i(j)} - \nu^b \right) \left( \frac{K_t}{B_{RW}^i(j)} \right)^2$$  \hspace{1cm} (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 $R_{t,d}^d \equiv r_t$ in the interbank market implying:

$$R_{t,i}^b = r_t - \kappa K_b \left( \frac{K_t^b(j)}{B_{RW}^i(j)} - \nu^b \right) \left( \frac{K_t}{B_{RW}^i(j)} \right)^2$$  \hspace{1cm} (38)

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

\[ S_t^{\text{W}} = R_t^b - r_t = -\kappa K_b \left( \frac{K_t^b}{B_t^{\text{RW}}} - \nu^b \right) \left( \frac{K_t}{B_t^{\text{RW}}} \right)^2 RW^i \]  

(39)

A.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 \( R_t^i \) 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

\[
\max E_0 \sum_{t=1}^{\infty} \lambda_{0,t}^p \left[ r_t^{bH}(j)b_t^H(j) + r_t^{bE}(j)b_t^E(j) - R_t^{bH} B_t^H(j) - R_t^{bE} B_t^E(j) \right. \\
- \frac{\kappa_{bH}}{2} \left( \frac{r_t^{bH}}{r_{t-1}^{bH}} - 1 \right)^2 r_t^{bH} b_t^H - \frac{\kappa_{bE}}{2} \left( \frac{r_t^{bE}}{r_{t-1}^{bE}} - 1 \right)^2 r_t^{bE} b_t^E \]  

\[
\text{s.t. } b_t^H(j) = \left( \frac{r_t^{bH}(j)}{r_{t-1}^{bH}(j)} \right)^{-\epsilon_t^{bH}} b_t^H \quad \text{and} \quad b_t^E(j) = \left( \frac{r_t^{bE}(j)}{r_{t-1}^{bE}(j)} \right)^{-\epsilon_t^{bE}} b_t^E \]  

(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:

\[ S_t^{b,i} = r_t^{b,i} - r_t = \frac{e_t^{b,i}}{\epsilon_t^{b,i} - 1} S_t^{\text{W}} + \frac{1}{\epsilon_t^{b,i} - 1} r_t \]  

(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:

\[
\max E_0 \sum_{t=1}^{\infty} \lambda_{0,t}^p \left[ r_tD_t(j) - r_t^d d_t(j) - \frac{\kappa_{d}}{2} \left( \frac{r_t^d}{r_{t-1}^d} - 1 \right)^2 r_t^d D_t \right] \\
\text{s.t. } d_t(j) = \left( \frac{r_t^d(j)}{r_{t-1}^d} \right)^{-\epsilon_t^d} D_t \]  

(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:

\[ J_t^b(j) = r_t^{bH}(j)b_t^H(j) + r_t^{bE}(j)b_t^E(j) - r_t^d(j)d_t(j) - \frac{\kappa_{K_b}}{2} \left( \frac{K_t^b(j)}{B_t^{\text{RW}}} - \nu^b \right)^2 K_t^b(j) - \text{Adj}_t^B(j) \]  

(43)
where $Adj_t^R(j)$ indicates adjustment costs for changing interest rates on loans and deposits.

### A.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 $\varsigma$. In a symmetric equilibrium, the Phillips curve is given by the retails' problem first-order condition:

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

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

### A.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:

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

where $\kappa_t$ is the parameter measuring the cost for adjusting investment and $\epsilon^q_k$ 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).

### A.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 $\Phi_\pi$ and $\Phi_y$ are weights assigned to inflation and output stabilization, respectively, $r$ is the steady-state nominal interest rate and $\epsilon_t^R$ is an exogenous shock to monetary policy.
A.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:

\[
G = g_y(Y_t + Y_{t-1} + Y_{t-2} + Y_{t-3})/4
\]  

(47)

Government budget balance is respected:

\[
G + \text{transfers} + \tau^h t_{t-1} b_{t-1}^I = \tau^I J_R
\]  

(48)

where, \(\tau^h\) is the tax deductibility on mortgage interest payment. Finally, transfers are divided according to wage share:

\[
\text{transfer to patient} = \text{transfer} \times \left( \frac{w_p w_p + w_i w_i}{w_p w_p + w_i w_i} \right)
\]

\[
\text{transfer to impatient} = \text{transfer} \times \left( \frac{w_p w_p + w_i w_i}{w_p w_p + w_i w_i} \right)
\]

(49)

A.8 Aggregation and market clearing

Equilibrium in the goods market is expressed by the resource constraint

\[
Y_t = C_{t}^{\text{dom}} + q_t^k [K_t - (1 - \delta)K_{t-1}] + G_t + X_t + \text{adj}_t
\]  

(50)

where \(C_{t}^{\text{dom}} \equiv c_{t}^{\text{dom,P}} + c_{t}^{\text{dom,I}} + c_{t}^{\text{dom,E}}\) denotes aggregate consumption of domestic goods. Equilibrium in the housing market is given by:

\[
\bar{h} = \gamma^P h_t^P(i) + \gamma^I h_t^I(i)
\]

(51)

where \(\bar{h}\) denotes the exogenous fixed housing supply.
B 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.
References


Svensson, L. (2015). Cost-benefit analysis of leaning against the wind: are costs larger also with less effective macroprudential policy? *memo.*