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Abstract

We study the implications of multi-period loans for monetary and macroprudential policy, considering several realistic modifications – variable vs. fixed loan rates, non-negativity constraint on newly granted loans, and possibility for the collateral constraint to become slack – to an otherwise standard DSGE model with housing and financial intermediaries. Our general finding is that multiperiodicity affects the working of both policies, though in substantially different ways. We show that multi-period contracts make the monetary policy less effective, but only under fixed rate mortgages, and do not generate significant asymmetry to its transmission. In contrast, the effects of macroprudential policy do not depend much on the type of interest payments, but exhibit strong asymmetries, with tightening having stronger effects than easening, especially for short and medium maturities.

JEL: E44, E51, E52

Keywords: multi-period contracts, general equilibrium models, monetary policy, macroprudential policy

1 Introduction

Empirical evidence suggests that differences in the financial sector across countries have important implications for the transmission of monetary policy.[1] Recent contributions focusing on the structure of housing finance (see e.g. Campbell, 2013) highlight that there is a substantial heterogeneity among industrialized countries in terms of the characteristics of residential mortgage markets. Those differences affect the way a monetary policy action transmits to the economy. Giuliodori (2005), Assenmacher-Wesche and Gerlach (2008), and Calza et al. (2013) all stress that, among several institutional characteristics of national mortgage systems, having fixed or variable mortgage rates makes the largest difference for the effects of monetary policy on house prices and real variables (e.g. residential investment, consumption, and GDP). Moreover, those studies find that the monetary policy transmission is more efficient in those countries where variable-rate mortgages are prevalent.

If the evidence is strong for monetary policy, it is much less for macroprudential policy. Cardarelli et al. (2009) stress that the role of housing demand shocks in explaining the variability of consumption is stronger in those countries where the degree of mortgage market development is higher. In their paper, a high degree of market development is associated, among other things, with high loan-to-value ratios and longer loan maturity. Those two variables turn out to be non-negligible determinants of consumption variability.

On the theoretical ground, standard dynamic stochastic general equilibrium (DSGE) models with housing that followed the seminal contribution by Iacoviello (2005),[2] typically abstract from most of – if not all of – the above features of mortgages. In particular, the most common assumptions are that contracts last for one period, they are stipulated on the basis of a variable interest rate, and the collateral constraint faced by borrowers is always binding. As a consequence, these models cannot assess the implications that the mortgage market design might have for monetary and macroprudential policies.

In this paper we first evaluate the impact of having multi-period vs. one-period contracts on monetary and macroprudential policy in an otherwise standard DSGE model with housing and financial intermediaries. Second, we investigate whether or not fixed as opposed to variable rate mortgages can influence the nature of our results. Third, we analyze the possible interactions between loan

[1] Cecchetti (1999) and Ehrmann et al. (2003) examine the issue in a broader context than the one we are interested in.

[2] See, among others, Iacoviello and Neri (2010) or Gerali et al. (2010).

maturity and the fact that households' collateral constraint might be only occasionally binding. Finally, given that in a multi-period framework meeting the collateral constraint on total debt might require new loans to become sometimes negative – a possibility that is absent by definition in the one-period contract case – we analyze the effects of imposing the realistic constraint that borrowers cannot be forced to accelerate repayment of their debt (non-negativity constraint on new loans) and its interactions with loan maturity. Based on all of these departures we contribute in an original manner to the literature.

In fact, papers coping with multi-period mortgages (or long-term housing finance) do exist. A first group deals with different interesting issues, but abstracts from policy considerations. For example, Campbell and Cocco (2003) study how households should optimally choose between fixed-rate and adjustable-rate mortgages given the important welfare implications that choice implies. Hurst and Stafford (2004) and Li and Yao (2007) both focus on consumption smoothing, the former showing how homeowners use housing equity to smooth their consumption over time and the latter showing how changes in house prices affect consumption and welfare of young, middle-aged and old homeowners in a life-cycle model. Chambers et al. (2009a) and Chambers et al. (2009b) look at equilibrium homeownership rates. Garriga and Schlagenhauf (2009), Chatterjee and Eyigungor (2011), and Corbae and Quintin (2011) analyze equilibrium foreclosures. Finally, Kydland et al. (2012) develop a multi-period loans model in which loans taken out in a given period are only used to finance new homes constructed in the same period.[3] They show that their model better explains the U.S. residential investments dynamics than a model with one-period loans. Justiniano et al. (2013) highlight the asymmetry in the borrowing constraint that arises when mortgages are multi-period, and show that it helps to reproduce a sharp increase in the debt-to-housing ratio when house prices plummet.

On the policy side, theoretical contributions are all very recent and almost all of them focus on monetary policy and not on macroprudential policy. Benes and Lees (2010) investigate the implications of the existence of multi-period fixed-rate loans for the behaviour of a small open economy exposed to finance shocks and housing boom-bust cycles. Rubio (2011) studies how the proportion of fixed and variable rate mortgages affects business cycles and welfare in a DSGE model with housing. Calza et al. (2013) provide a rationale for their empirical findings by developing a DSGE model with two-period mortgage contracts, assuming

[3]This explains why loans in more standard models as Iacoviello (2005), where a loan taken out in a given period is collateralized by the next period housing stock, resemble home equity loan or refinancing while in Kydland et al. (2012) loans are closer to first mortgages.

that the existence of loans of different maturities reflects the distinction between variable rate and fixed rate contracts. Garriga et al. (2013) use the multi-period mortgage setup developed in Kydland et al. (2012) to analyze how monetary policy functions in such a context. Gelain et al. (2014a) use a version of the Kydland et al. (2012) framework to investigate whether a standard asset pricing model can account for the boom-bust patterns in U.S. data over the period 1995-2012. They find that the model with long-term mortgage debt and moving-average expectations does best in matching the data, relying on smaller housing preference shocks and more plausible LTV shocks. Gelain et al. (2014b) use the same framework, but in a general equilibrium context, to revisit the leaning-against-the-wind argument in a model where households' debt-to-income ratio dynamics is in line with the data thanks to the multi-period setup. All those papers conclude, among other things, that conducting monetary policy in an environment where mortgage contracts are taken out at fixed rates hampers the central bank's ability to stabilize the economy. Our findings in this respect are in line with theirs. Nevertheless, our analysis differs significantly from these contributions, mainly because we investigate the effects of the non-linearities brought into the model by our multi-period framework, and also discuss the implications for macroprudential policy.

Our framework is most similar to Calza et al. (2013), with three important differences. First, we generalize the framework from two-period contracts to m-period contracts. Second, we move away from the assumption that variable rate mortgages are one-period contracts and fixed rate mortgages are equivalent to long-term contracts. In this way the mortgage type and mortgage maturity become two distinct dimensions of our analysis. Third, and most importantly, we allow also the collateral constraint to take into account loans granted in the past and not yet repaid. This last feature is the one that introduces the possibility for new loans to become negative.

Our main findings and policy implications are as follows. We share with several papers the result that monetary policy is less effective under the assumption of multi-period loans. However, we show that it is true under fixed-rate contracts only, but not under variable rate ones, unless the size of monetary interventions is large so that the non-linearities embedded in our setup become relevant. This is an important finding that can be intuitively explained by the fact that in our framework the sequence of expected interest rates for a multi-period variable-rate loan equals the series of expected interest rates for rolled-over single period loans.[4] We also find that for monetary shocks of plausible size, multiperiod loans do not generate much asymmetry in monetary policy transmission.

The conclusions differ substantially for macroprudential policy. First, in this case there is not much difference between variable and fixed-rate contracts, at least when the central bank follows a standard Taylor-like rule that responds mainly to inflation. Second, because borrowers cannot be forced to accelerate repayment of their debt, macroprudential policy tightening becomes much less effective when maturity increases (and hence the non-negativity constraint on new loans becomes binding more frequently). Third, there is a lot of asymmetry produced by the plausible non-linearities that we consider in our model – contractionary policy has much stronger effects than expansionary policy, especially for shorter maturities. Fourth, because of these non-linearities, the marginal effects of expansionary policy are sharply declining with the size of intervention.

The rest of the paper is structured as follows. Sections 2 and 3 present the model and its calibration. Section 4 discusses the results. Section 5 concludes.

2 Model

We start from a standard medium-sized New Keynesian setup, extended to incorporate housing and credit frictions by building on Iacoviello (2005), and modified to allow for multi-period loans. A key feature of our extension, particularly relevant in a multi-period contract environment, is that the collateral constraint is not assumed to hold with equality every period. Instead, borrowers' total debt burden can occasionally exceed or fall below the value of collateralizable assets.

Our model economy is populated by two types of households, housing and capital producers, goods producers, and the government authorities. Below we sketch the optimization problems facing each class of agents, focusing particularly on those that make up the key ingredients of our extension.

2.1 Households

To introduce credit, we distinguish between two types of households that differ in their subjective discount rates. Those relatively patient are indexed by P and make natural lenders, while the impatient group, denoted by I, are natural

[4] This problem is treated differently by Garriga et al. (2013), who essentially consider first mortgages, so that the distinction between one and multi-period loans is always relevant, also with variable rates.

borrowers. The share of impatient households in population is ω. Within each group, a representative agent ι maximizes

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_i^t \left[\ln c_{i,t}(\iota) + A_\chi \frac{\chi_{i,t}(\iota)^{1-\sigma_\chi}}{1-\sigma_\chi} - \frac{n_{i,t}(\iota)^{1+\sigma_n}}{1+\sigma_n} \right] \right\} \tag{1}$$

for $i = \{I, P\}$ and $\beta_I < \beta_P$. In the formula above, c_t is consumption, χ_t denotes the housing stock and n_t is labor supply.

Patient households' maximization is subject to a standard budget constraint

$$\begin{aligned} P_t c_{P,t} + P_{\chi,t}(\chi_{P,t} - (1-\delta_\chi)\chi_{P,t-1}) + P_{k,t}(k_t - (1-\delta_k)k_{t-1}) + D_t = \\ = W_{P,t}(\iota) n_{P,t}(\iota) + R_{k,t} k_{t-1} + R_{t-1} D_{t-1} + \Pi_t + T_{P,t} + \Xi_{P,t}(\iota) \end{aligned} \tag{2}$$

where k_t denotes capital, $R_{k,t}$ is its rental rate, Π_t is profits from monopolistically competitive firms, $T_{i,t}$ is lump-sum net transfers, $P_{\chi,t}$ and $P_{k,t}$ denote housing and physical capital prices, $W_{i,t}$ is nominal wage, D_t stands for one-period deposits paying a risk-free rate R_t that is set by the central bank, and $\Xi_{i,t}$ is the payout from state-contingent securities traded between households of the same type and providing perfect insurance against household-specific labor income risk arising from wage stickiness.[5]

Impatient households do not accumulate physical capital nor hold any equity, and have access to m-period mortgage loans. In our baseline specification, mortgages are taken out at variable interest rates and with fixed principal payments, so that each period a borrower has to pay interest on the outstanding debt at the rate set at the beginning of the period, and repay the amount of principal due. Hence, her budget constraint can be written as

$$\begin{aligned} P_t c_{I,t} + P_{\chi,t}(\chi_{I,t} - (1-\delta_\chi)\chi_{I,t-1}) + (R_{\chi,t-1} - 1) \sum_{j=1}^{m} \frac{m-j+1}{m} L_{t-j} + \frac{1}{m} \sum_{j=1}^{m} L_{t-j} = \\ = W_{I,t}(\iota) n_{I,t}(\iota) + L_t + T_{I,t} + \Xi_{I,t}(\iota) \end{aligned} \tag{3}$$

or more compactly

$$P_t c_{I,t} + P_{\chi,t}(\chi_{I,t} - (1-\delta_\chi)\chi_{I,t-1}) + R_{\chi,t-1} S_{t-1} = W_{I,t}(\iota) n_{I,t}(\iota) + S_t + T_{I,t} + \Xi_{I,t}(\iota) \tag{4}$$

where $R_{\chi,t}$ is gross interest charged on loans by banks and S_t is end-of-period

[5] The presence of these securities allows us to save on notation and drop indexing other households' allocations with ι.

debt defined as

$$S_t = \sum_{j=1}^{m} \frac{m-j+1}{m} L_{t-j+1} \tag{5}$$

Additionally, impatient households' optimization is subject to a collateral constraint. Unless it implies $L_t < 0$, it is given by the following inequality

$$R_{\chi,t} S_t \leq \vartheta_t (1-\delta_\chi) \mathbb{E}_t \left\{ P_{\chi,t+1} \chi_{I,t} \right\} \tag{6}$$

where $\vartheta_t > 0$ denotes the target loan to value (LTV) ratio set by the macroprudential authority. Otherwise, since banks cannot force borrowers to accelerate repayment of outstanding debt, newly granted loans just dry up ($L_t = 0$), which minimizes the deviations of the observed LTV ratio from that recommened by the macroprudential authority. Note that, since the housing stock owned by households must be positive, the latter case can only arise with multi-period contracts, i.e. for $m > 1$. As a result, similarly to Justiniano et al. (2013), our modeling setup allows for increases in the observed LTV ratio above the levels implied by bank (or macroprudential) policies during the episodes of plummeting house prices or sharp tightening of lending standards. It also provides a mechanism making the effectiveness of macroprudential policy contingent on the state of the economy and on the scale of policy interventions.

Each household supplies differentiated labor in a monopolistically competitive fashion. Nominal wages are assumed to be sticky as in the Calvo scheme. More specifically, each period only a randomly selected fraction $1-\theta_w$ of households can reoptimize while the remaining wages are automatically indexed to the steady state inflation.

2.2 Firms

There are several types of firms in our model. Perfectly competitive final goods producers aggregate intermediate goods indexed by ν according to

$$y_t = \left[\int_0^1 y_t(\nu)^{\frac{1}{\mu}} d\nu \right]^{\mu} \tag{7}$$

Intermediate goods producing firms operate in a monopolistically competitive environment and use the following production function

$$y_t(\nu) = \varepsilon_{z,t} k_{t-1}(\nu)^{\alpha} n_t(\nu)^{1-\alpha} \tag{8}$$

where $\varepsilon_{z,t}$ is exogenous productivity and homogenous labor input is defined as

$$n_t(\nu) = [\omega n_{I,t}(\nu)]^{\gamma}[(1-\omega)n_{P,t}(\nu)]^{1-\gamma} \tag{9}$$

Intermediate firms are subject to nominal rigidities so that each period only a random fraction $1-\theta$ of them can reset their prices while the remaining ones adjust their prices to the steady state inflation. Since these firms are owned by patient households, they use their marginal utility to discount the future profits.

Finally, housing and capital production is undertaken by perfectly competitive firms owned by patient households. They purchase undepreciated housing and capital from the previous period and produce new stocks according to the following formulas

$$\chi_t = (1-\delta_\chi)\chi_{t-1} + \Big(1 - \Gamma_\chi\Big(\frac{i_{\chi,t}}{i_{\chi,t-1}}\Big)\Big) i_{\chi,t} \tag{10}$$

$$k_t = (1-\delta_k)k_{t-1} + \Big(1 - \Gamma_k\Big(\frac{i_{k,t}}{i_{k,t-1}}\Big)\Big) i_{k,t} \tag{11}$$

where $i_{\chi,t}$ and $i_{k,t}$ are final goods used for housing and capital investment while the adjustment costs functions are parametrized such that $\Gamma_j(1) = \Gamma_j'(1) = 0$ and $\Gamma_j''(1) = \kappa_j \geq 0$ for $j = \{\chi, k\}$.

2.3 Banks

Perfectly competitive banks owned by patient households collect deposits and use them to extend loans. Their problem is to maximize

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_P^t c_{P,t}^{-1} (R_{\chi,t-1}S_{t-1} - S_t + D_t - R_{t-1}D_{t-1}) \right\} \tag{12}$$

subject to

$$D_t = S_t \tag{13}$$

2.4 Government

The fiscal authority follows a passive policy, purchasing a constant fraction g_y of final goods and financing its expenditures with lump sum taxes levied on households such that the government budget is balanced every period

$$P_t g_t = g_y P_t y_t = \omega T_{I,t} + (1-\omega) T_{P,t} \tag{14}$$

where P_t is the price of final goods. The tax policy is such that the share of impatient households in the total tax burden is fixed at τ.

The monetary authority sets the policy rate according to the standard Taylor-like rule

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{y_t}{y}\right)^{\gamma_y}\right]^{1-\gamma_R} e^{\varepsilon_{R,t}} \tag{15}$$

where variables without time subscripts denote their steady state values and $\varepsilon_{R,t}$ is a monetary policy shock.

The macroprudential authority actions are modeled as an exogenous autoregressive process

$$\vartheta_t = (1-\gamma_\vartheta)\vartheta + \gamma_\vartheta \vartheta_{t-1} + \varepsilon_{\vartheta,t} \tag{16}$$

where $\varepsilon_{\vartheta,t}$ is a macroprudential policy shock.

2.5 Market clearing

The model is closed with a standard set of market clearing conditions. In particular, housing market clearing implies

$$\chi_t = \omega \chi_{I,t} + (1-\omega)\chi_{P,t} \tag{17}$$

and the aggregate resource constraint is

$$y_t = \omega c_{I,t} + (1-\omega)c_{P,t} + i_{k,t} + i_{\chi,t} + g_t \tag{18}$$

2.6 Fixed rate mortgages

Our baseline specification of loan contracts assumes that they are taken out at variable interest rates. In this case, the solution to banks' problem given by (12)-(13) is very simple as it implies that the interest charged on loans $R_{\chi,t}$ is equal to the policy rate R_t every period. Also, it follows from impatient households' budget constraint (4) that, unless the non-negativity constraint on loans is binding, there is no difference between single and multi-period loans. This is because impatient households' financial decisions can be described using only their debt S_t, without any need to refer to its maturity structure given by L_{t-j+1} for $j = 1, ..., m$.

However, as documented by Campbell (2013), in many countries (and in the US in particular), the vast majority of housing loans are long-term fixed-rate mortgages, with repayments made in equal installments every period. To incorporate this type of contract into our model, impatient households' budget constraint (3) needs to be modified to

$$P_t c_{I,t} + P_{\chi,t}(\chi_{I,t} - (1-\delta_\chi)\chi_{I,t-1}) + \frac{1}{m}\sum_{j=1}^{m}\tilde{R}_{\chi,t-j}L_{t-j} = \\ = W_{I,t}(\iota)\, n_{I,t}(\iota) + L_t + T_{I,t} + \Xi_{I,t}(\iota) \quad (19)$$

where $\tilde{R}_{\chi,t}$ denotes gross total interest cost of a loan. To ensure comparability with our baseline, the collateral constraint is specified as before, except that now the end-of-period debt is

$$S_t = \frac{1}{m}\mathbb{E}_t\left\{\sum_{j=1}^{m}\tilde{R}_{\chi,t-j+1}L_{t-j+1}\Upsilon_t^j\right\} \quad (20)$$

where the discounting terms, indexed by $j = 1, ..m$ and expressing all future instalments in present value terms, are defined as

$$\Upsilon_t^j = \sum_{i=1}^{m-j+1}\frac{1}{R_t ... R_{t+i-1}} \quad (21)$$

Hence, as in the variable-rate case, the left-hand side of the collateral constraint is the next period value of outstanding debt, defined as the expected present value of all future repayments due from time $t+1$ to the loan maturity date $t+m$. In particular, this form of the constraint ensures that the steady-state allocations do not depend on the mortgage type.

A modified objective of banks can be written as

$$\mathbb{E}_0\left\{\sum_{t=0}^{\infty}\beta_P^t c_{P,t}^{-1}\left(\frac{1}{m}\sum_{j=1}^{m}\tilde{R}_{\chi,t-j}L_{t-j} - L_t + D_t - R_{t-1}D_{t-1}\right)\right\} \quad (22)$$

It can be verified that if one abstracts away from uncertainty by considering the steady state equilibrium, the solution to banks' problem in the case of fixed-rate mortgage contracts implies

$$\tilde{R}_\chi = m\frac{R-1}{1-R^{-m}} \quad (23)$$

which is a standard annuity formula.

3 Calibration and solution

We calibrate the model to US data, measuring time in quarters. The assumed parameter values are reported in Table 1.

Following the standard practice, a subset of parameters are taken from the literature or calibrated to match the long-run averages observed in the data. Households' utility is parametrized such that it implies a moderate Frisch elasticity of labor supply and a substantially stronger smoothing motive in housing compared to consumption. The discount factor of patient households is set to obtain an annualized average real interest rate of slightly below 3%. Following Campbell and Hercowitz (2009), the relative impatience of borrowers is assigned at 0.5% quarterly. The steady state inflation rate is set to match the annual average of 2%. Physical capital is assumed to depreciate at 2% per quarter and its share in output is set to 0.3, both values being standard in the literature. The share of government purchases in output matches the long-run average of 16.5%. The steady-state LTV ratio, share of housing in utility and housing depreciation rate are calibrated to jointly match the following three long-run proportions: the debt-to-GDP ratio of 0.46, the share of residential investment in output of 4.5% and the housing-to-GDP ratio of 1.25.

While calibrating the parameters controlling the degree of heterogeneity between patient and impatient households, we follow Justiniano et al. (2013) and make sure that our choices are consistent with micro data evidence from the Survey of Consumer Finances (SCF). More specifically, we set the share of impatient households to equal the share of liquidity constrained consumers in this dataset of 61%. According to this source, a typical borrower works 8% more hours and her labor income is 36% lower compared to an average lender. We use these two statistics to pin down the share of impatient households in production and the degree of redistribution via the tax system. Such calibration also implies that the average total income of borrowers is about 40% of that of savers, which comes very close to 46% reported by the SCF.

The parameters controlling real and nominal rigidities, i.e. wage and price markups and stickiness, as well as investment adjustment costs are set at standard values assumed in the literature. Finally, the central bank rule is also parametrized in line with the original Taylor rule, except that we allow for some moderate interest rate smoothing. The degree of inertia in macroprudential policy is set at the same level as that for the monetary policy.

Due to non-linearities arising from inequality in the collateral constraint and the non-negativity restriction on newly granted loans, the model cannot be solved using standard perturbation techniques. To deal with this problem, we use the piecewise linear method developed by Guerrieri and Iacoviello (2014). This algorithm has the advantage of being applicable to models with a large number of state variables, and hence is particularly useful in our multi-period contract environment.

4 Results

We are now ready to show how multi-period loans work and how their presence affects the transmission of monetary and macroprudential policies. Our benchmark is the standard model with eternally binding collateral constraint and variable interest rate loans, i.e. equation (6) is assumed to hold as equality, which is a valid assumption for sufficiently small shocks. As we argued before, in this case it does not matter whether loans are single or multi-period. In particular, monetary and macroprudential policy affect the economy the same way. Our project could stop here with nothing. However, as we show below, the apparently minor but realistic deviations from this standard setup that we include in our model are sufficient to generate substantial differences between the working of single and multi-period contracts. In the remaining part of this section, we show what happens to the transmission of monetary and macroprudential policy shocks if we take into account the following features of the mortgage market:

1. banks cannot force borrowers to accelerate loan repayment,
2. the collateral constraint might be slack,
3. loans are taken out at fixed interest rates.

While considering multi-period loans, we set their maturity to 30 periods, i.e. 7.5 years, which is roughly the average effective length of mortgage loans in the US if one takes into account that some of them are prepaid (see e.g. Walentin, 2014). This is enough to generate sizable differences, but, naturally, longer maturities would make our arguments even stronger. The size of shocks is chosen each time so as to obtain a clear demonstration of our main points.

4.1 Non-negativity constraint on new loans

Our first departure from the standard setup is imposing a non-negativity constraint on new loans, implying that banks cannot demand faster debt repayment when the observed LTV ratio exceeds the limit set by the macroprudential authority. As explained before, this modification does not change anything in the single-period setting since the collateral value is always positive. However, once loans become multi-period, debt is no longer equivalent to the flow of loans. While the former still must be positive, the collateral constraint can imply a negative flow after sufficiently strong shocks. This feature of the standard model is highly unrealistic, since in the real world both the stock and the flow of new loans are always non-negative.

Figure 1 presents the impulse responses of GDP, inflation, debt and flow of new loans to a contractionary macroprudential policy shock, defined as a decrease in the target LTV ratio ϑ_t by 2 percentage points. For $m = 30$, this shock is strong enough to push new loans into a negative region in the benchmark model (dashed line falls below -100%). When the constraint on faster debt repayment is switched on (solid line), the fall of loans is limited by the floor of -100%. As a result, debt declines by less and so does output. This difference is sizable as the contraction in output is 36% smaller if the non-negativity constraint is taken into account. Hence, allowing for it can substantially weaken the effects of macroprudential policy tightening.

A similar picture emerges after a monetary policy shock. Figure 2 documents monetary transmission to an increase in the policy rate by 150 bps. In the unconstrained model, new loans become negative again. Adding the constraint puts a floor on new loans, hence limiting the decline in debt, GDP and inflation. As a result, the effects of monetary policy tightening become weaker.

Two things should be noted. First, as already explained, this constraint makes a difference only in a multi-period loan setting and this difference is increasing in the loan maturity m, an issue we examine in more detail later. Second, it works in an asymmetric way - it becomes binding only after sufficiently strong and contractionary shocks. The threshold size of shocks can be considered moderate in the case of macroprudential policy and high for monetary policy. Hence, we conclude that the combination of multi-period loans and the non-negativity constraint weakens the effects of macroprudential policy and introduces asymmetry into its transmission.

4.2 Occasionally binding collateral constraint

We next check how the slackness in the collateral constraint interacts with multi-period loans. As explained before, when the constraint is permanently binding and loans are taken at variable interest, their maturity does not affect policy transmission. However, in the real world this constraint should be rather thought of as not always binding - banks cannot force borrowers to take more loans just because the value of collateralizable assets increases. In particular, an increase in the target LTV ratio will boost lending when the constraint is tight and not necessarily so if its level before the intervention does not effectively limit impatient households' financial choices.

This effect is illustrated in Figure 3, which plots the responses to an easening of the LTV policy by 1 percentage point for variable rate multi-period contracts when occasional slackness in the collateral constraint is allowed (solid lines) or the constraint is assumed to hold with equality every period (dashed lines).[6] Clearly, for large enough shocks the collateral constraint stops binding, which weakens the policy transmission. The effects of policy changes also become asymmetric, since the constraint can become slack only for expansionary shocks. Similar observations can be made for sufficiently big expansionary monetary policy shocks (not shown).

It is worth noting that, for our calibration, the magnitude of shocks for which the possible slackness in the collateral constraint becomes relevant is smaller than in the case of the non-negativity constraint on new loans. Hence, in our model that takes into account both possibilities, a moderate (but not too small) policy expansion has smaller effects than a policy tightening. This is consistent with empirical evidence presented in Ravn and Sola (2004) who find that only moderate monetary tightening has real effects. Hence, our framework offers an explanation for this empirical finding that can be an alternative or complement to the standard downward nominal wage rigidity argument.

Given the focus of this paper, another interesting question is whether allowing for occasionally binding collateral constraints generates interesting interactions with loan maturity. In the baseline case of variable interest rate contracts, the answer to this question is negative, for reasons similar to those discussed before. More precisely, the collateral constraint imposes a limit on total debt which, if mortgages are taken out at variable rates, does not depend on the contract length. Hence, whether it becomes slack or not is not affected by the loan maturity.

4.3 Fixed interest rate contracts

In the next step we change the contract type from variable to fixed interest rates, making it more consistent with mortgage market design observed in some

[6]Note that our model is parametrized such that the collateral constraint is binding in the steady state, which is also the starting point for our simulations.

countries, including the US. To fix our attention, we abstract for a while from the possibility of hitting the non-negativity constraint or the collateral constraint becoming slack by setting the magnitude of shocks such that these additional features of our model are irrelevant.

We first apply a contractionary LTV shock and compare the impulse responses of variable (dashed lines) and fixed (solid lines) interest rates multi-period loans. As explained before, if the collateral constraint holds with equality and the interest rates are adjusted every period, the loan maturity does not matter, so our experiment can also be thought of as a comparison between single and multi-period loans under fixed interest rates.

As evidenced in Figure 4, this modification has hardly any effect. This is because the response of the interest rate to a macroprudential policy shock is very small, and hence the difference between a fixed and variable interest rate mortgage is insignificant. Naturally, this result comes from the fact that the central bank responds mainly to inflation, which changes very little in this scenario, and the difference between the two contract types would become bigger if we parametrized the Taylor rule such that it reacts mainly to output.

A different picture emerges when monetary policy shocks are analyzed (Figure 5). By construction, a monetary policy tightening implies an increase in the interest rate, which makes the cost of servicing the debt more expensive to impatient households, especially if mortgage interest payments are adjusted every period. In the case of fixed interest contracts, an increase in the policy rate affects only the cost of newly granted loans, making borrowers more immune to the tightening. As can be seen from the figure, the difference between fixed and variable rate mortgages is sizable and would be even larger if we assumed the average loan maturity of more than 7.5 years.

More generally, the presence of fixed-rate multi-period contracts will dampen (amplify) the credit market effects of shocks that spark an adjustment in the interest rate that goes in the opposite (same) direction than the response of loans. As an example, consider a standard housing preference shock, defined as a temporary increase in the weight of housing in household utility A_χ. In a model like the one presented in our paper, this shock leads to an increase in credit and expansion in economic activity, to which the central banks reacts by raising the short-term interest rate. Since, holding the Taylor rule parameters fixed, monetary policy is less powerful under fixed interest mortgages, housing preference shocks will have bigger effects on the economy compared to the case of variable-rate mortgages.

4.4 Strength and asymmetry in policy transmission

We have already noted that the frictions discussed above (i.e. non-negativity constraint on new loans, possibility of the collateral constraint becoming slack, and fixed interest rate contracts) can affect not only the effectiveness of monetary or macroprudential policy interventions, but also generate asymmetry in their transmission. We now look at this issue in more detail by focusing on how these three mortgage market features interact with loan maturity.

Figure 6 plots the peak and trough responses of output to negative and positive monetary policy shocks as function of loan maturity under different assumptions on the shock size and type of interest payments. The following observations can be made. First of all, no asymmetries arise for shocks of standard magnitude (25 bps). This is because such shocks are not big enough to make the collateral constraint slack or the non-negativity constraint binding even if loans are granted for as long as 25 years. If shocks are relatively large (50 bps), loans are taken out at variable rates and with moderate maturity, then an interest rate hike has slightly bigger effects on output than a decrase of the same magnitude. This happens because in the latter case impatient households, knowing that the monetary expansion is temporary, do not find it optimal to increase their borrowing to the extent made possible by an increase in the value of their collateral (housing), i.e. the collateral constraint becomes slack. When maturity is longer (at least 63 quarters in our case), this asymmetry gets reversed because the non-negativity constraint effectively imposes a floor on a decrease in debt and hence the effects of monetary policy tightening is reduced. Finally, for fixed interest rate contracts, the potency of monetary policy clearly decreases with loan maturity. This decrease is strong enough for the non-negativity constraint not to be an issue even for large monetary shocks and 25-year contracts, and for the collateral constraint to bind again for moderate maturities. As a result, the differences between the responses to positive and negative interest rate shocks of 50 bps disappear already for 14-quarter loans.

The asymmetries discussed above can be considered rather moderate. As can be seen in Figure 7, a much sharper picture emerges for macroprudential policy shocks. These shocks affect loans directly and hence make the non-linearities included in our framework more relevant. Even for moderate (1 pp) innovations to the LTV ratio the amplitude of output responses clearly differs between positive and negative shocks because of the collateral constraint becoming slack, and the non-negativity constraint kicking in for maturities of around 13 years. If macroprudential policy shocks are large (2 pp), this threshold maturity is halved and another discontinuity in the through response arises for higher maturities once the non-negativity constraint becomes binding not for one, but for two consecutive periods. As we already discussed, since LTV shocks do not lead to sizable interest rate adjustments, the dependance of peak and trough responses of output on loan maturity looks similar for fixed and variable rate contracts.

Summing up, the three mortgage market features that we focus on in this paper imply that average mortgage loan maturity clearly matters for the effects of monetary and macroprudential policy. However, as we have just demonstrated, this relationship is not simple: the economy's reaction to positive and negative shocks can be perfectly symmetric if their magnitude is small, close to symmetric for large interventions and long-term contracts, and strongly asymmetric for large shocks and intermediate average loan maturity.

5 Conclusions

In this paper we modify an otherwise standard DSGE model with housing and financial intermediaries in order to take into account typical characteristics of residential mortgage markets – those that empirical studies have found to be relevant in many dimensions and that are largely ignored in the theoretical literature. The aim of considering these modifications, which make our model more realistic, is to evaluate to what extent they affect the transmission mechanism of both monetary and macroprudential policy, the former already found to be affected on the empirical ground.

The main modification we focus on is the introduction of mutli-period loan contracts. With it we obtain our baseline model where contracts are stipulated with variable interest rates, households collateral constraint is assumed to be always binding, and new loans have the unrealistic feature that they might become negative for large enough shocks. Given this contrast with the evidence of our baseline model, we first impose the non-negativity constraint on new loans. Second, we allow for the possibility that the collateral constraint might be occasionally binding. Third, we relax the assumption of variable rates and introduce fixed rate loans to study how they might affect our results.

We confirm the conclusion from the empirical literature that monetary policy is less effective with fixed than with variable-rate mortgages. Further, we show that its transmission weakens in maturity in the former but not the latter case and that under a realistic calibration of monetary policy shocks there is not much asymmetry in the working of monetary policy. In contrast, if we consider macroprudential policy, there is not much difference between varibale and fixed-rate contracts. However, we find significant asymmetries in its transmission, especially for shorter maturities and sufficiently large (but realistic) interventions.

We believe that our results can be helpful to understand the implications of the observed cross-country heterogeneity in the mortgage market design for the monetary and macroprudential policy transmission mechanism. Importantly in the context of the current policy debate on the possibility to use macroprudential policy tools to stabilize the economy, we point out at some limits to their effectiveness in the presence of multi-period mortgage loans – a feature often neglected in the current macrofinancial modelling activity.

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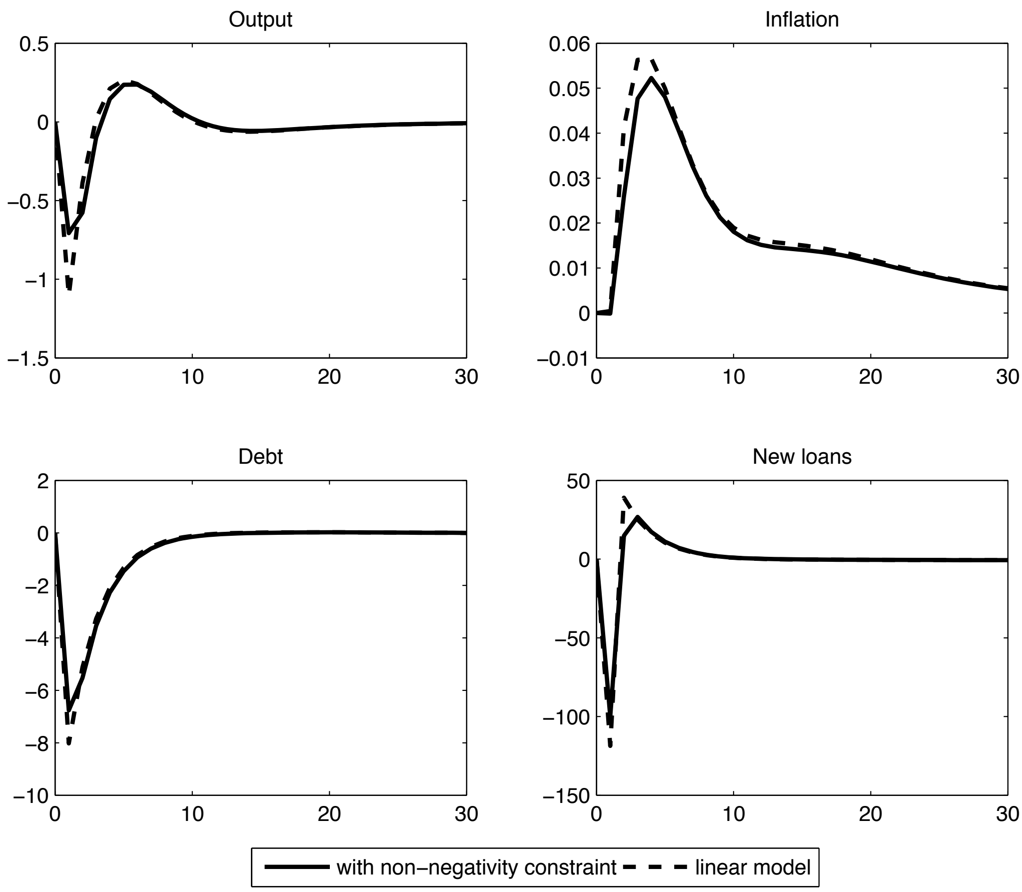
Tables and figures

Table 1: Calibration

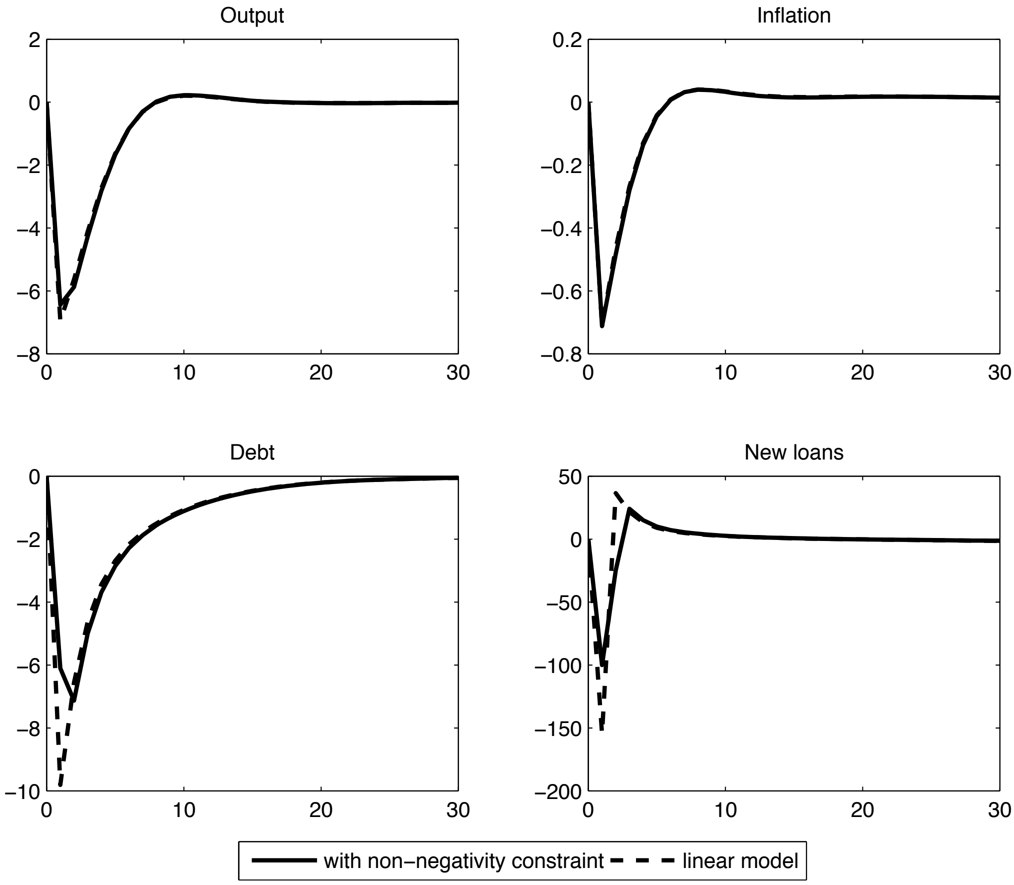
Parameter	Value	Description
β_P	0.993	Discount factor, patient HHs
β_I	0.988	Discount factor, impatient HHs
δ_χ	0.009	Housing stock depreciation rate
δ_k	0.02	Capital stock depreciation rate
ω	0.61	Share of impatient HHs in population
γ	0.5	Share of impatient HHs in production
A_χ	2500	Weight on housing in utility
σ_χ	5	Inverse of intertemporal elasticity of substitution in housing
σ_n	1	Inverse of Frisch elasticity of labor supply
μ_w	1.2	Steady state wage markup
θ_w	0.75	Calvo probability for wages
μ	1.2	Steady state product markup
θ	0.75	Calvo probability for prices
α	0.3	Output elasticity with respect to physical capital
κ_k	5	Capital investment adjustment cost
κ_χ	5	Housing investment adjustment cost
g_y	0.165	Share of government spending in output
τ	-0.165	Share of taxes levied on impatient HHs
ϑ	0.65	Steady state LTV ratio
γ_ϑ	0.8	LTV smoothing in macroprudential rule
π	1.005	Steady state inflation
γ_R	0.9	Interest rate smoothing in monetary policy rule
γ_π	1.5	Response to inflation in monetary policy rule
γ_y	0.5	Response to output in monetary policy rule

Figure 1: Reaction to macroprudential policy under non-negativity constraint



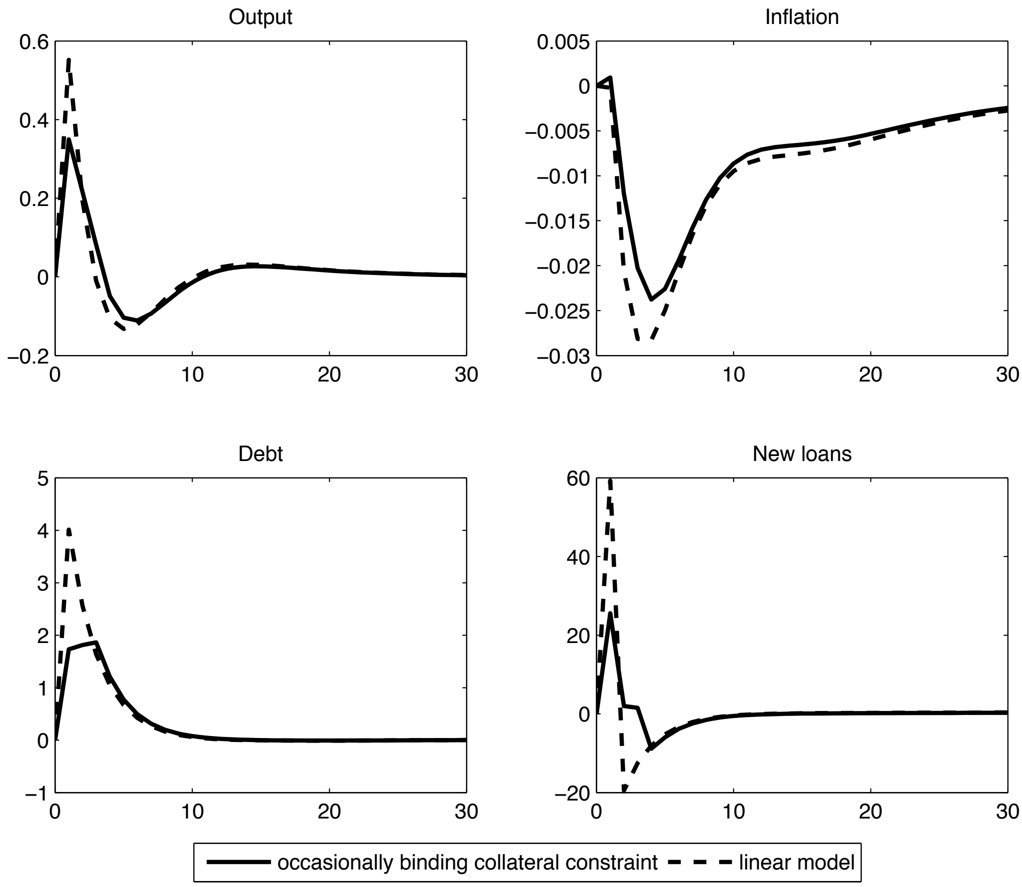
Note: Contractionary LTV shock (-2%) with (solid lines) and without (dashed lines) the non-negativity constraint taken into account. The loan maturity is 30 quarters. All responses are in percent deviations from the steady state.

Figure 2: Reaction to monetary policy under non-negativity constraint



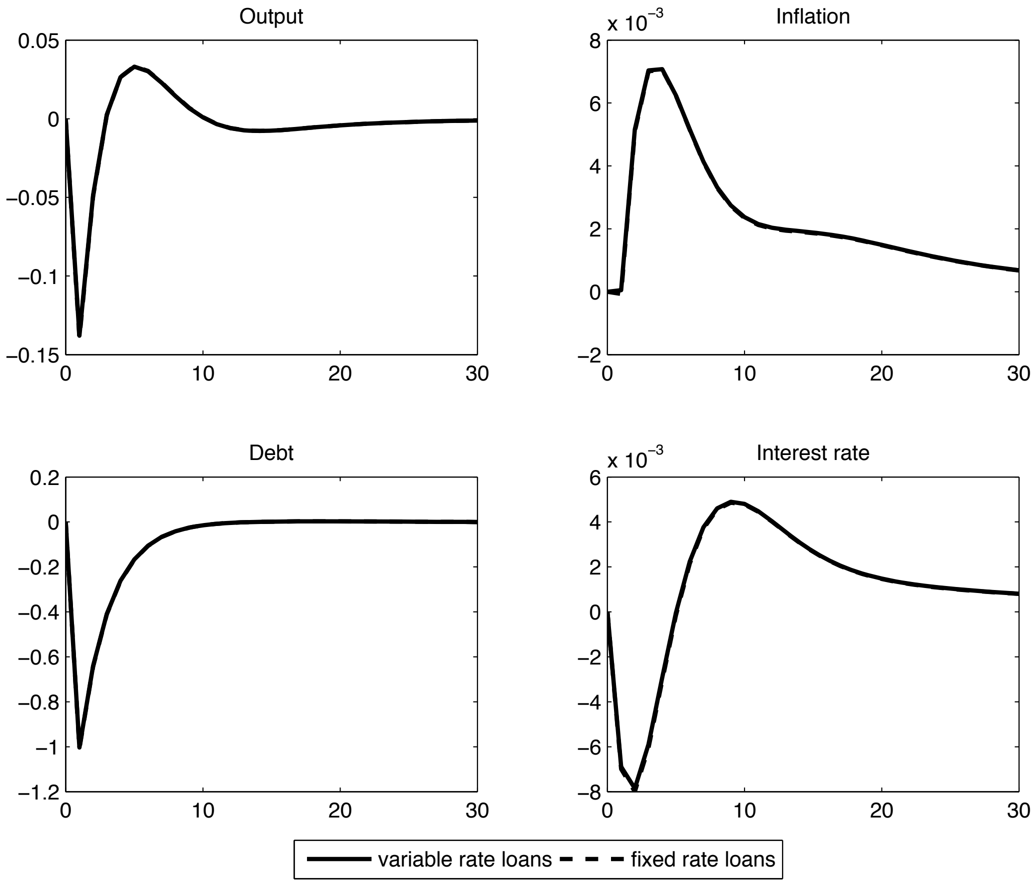
Note: Contractionary monetary policy shock (1.5%) with (solid lines) and without (dashed lines) the non-negativity constraint taken into account. The loan maturity is 30 quarters. All responses are in percent deviations from the steady state.

Figure 3: Reaction to macroprudential policy under occasionally binding collateral constraint



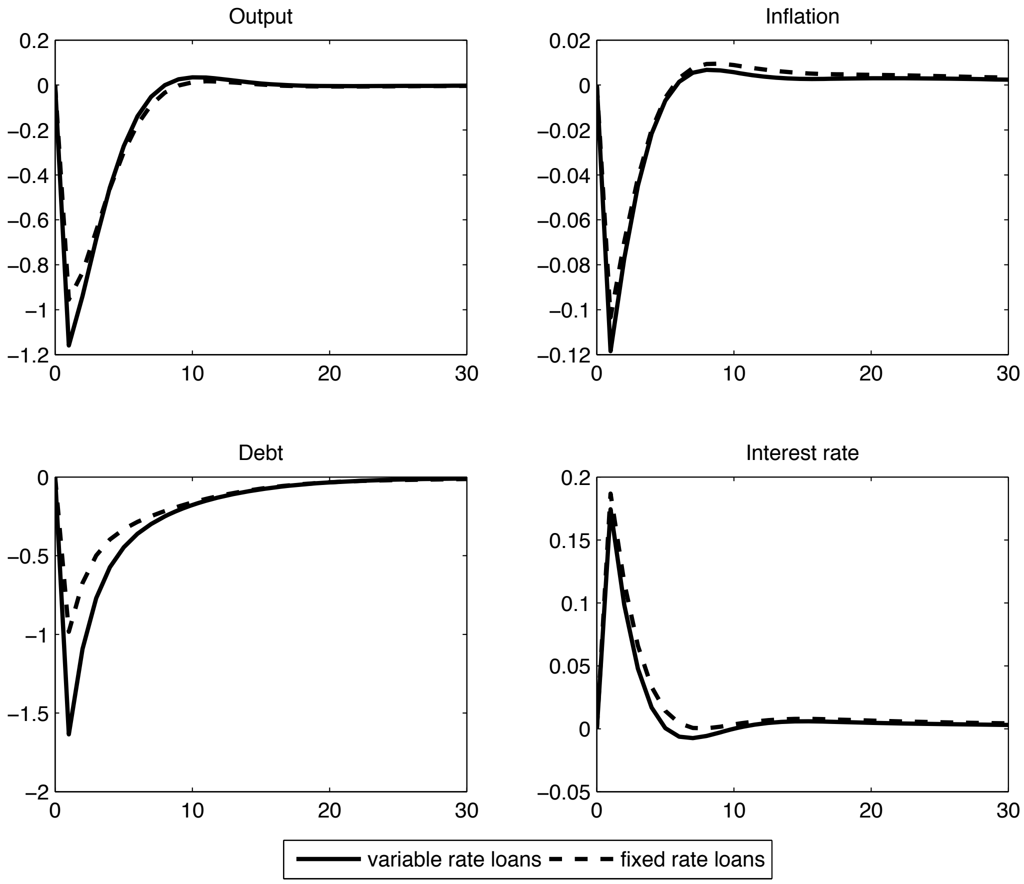
Note: Expansionary LTV shock (1%) with (solid lines) and without (dashed lines) occasionally binding collateral constraint taken into account. The loan maturity is 30 quarters. All responses are in percent deviations from the steady state.

Figure 4: Reaction to macroprudential policy under fixed rate loans



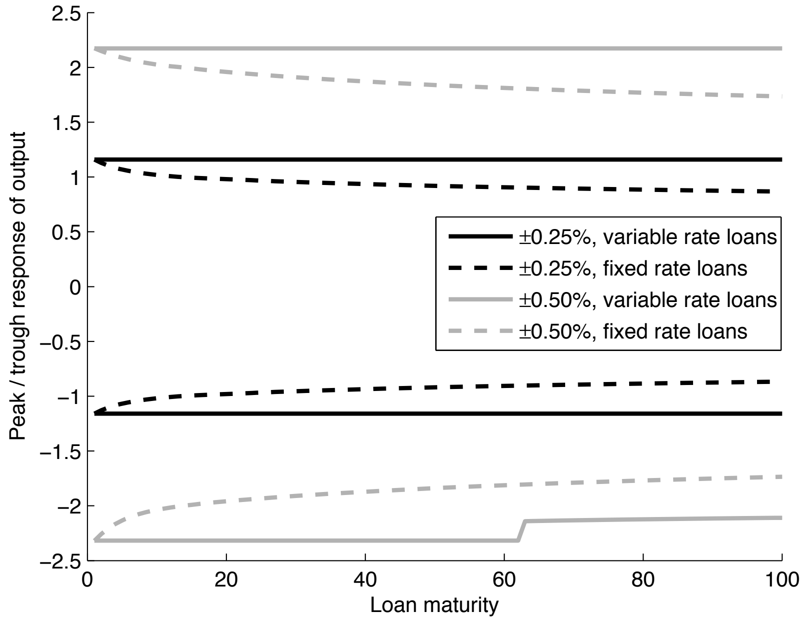
Note: Contractionary LTV shock (-0.25%) for variable (solid lines) and fixed (dashed lines) rate loans. The loan maturity is 30 quarters. All responses are in percent deviations from the steady state.

Figure 5: Reaction to monetary policy under fixed rate loans



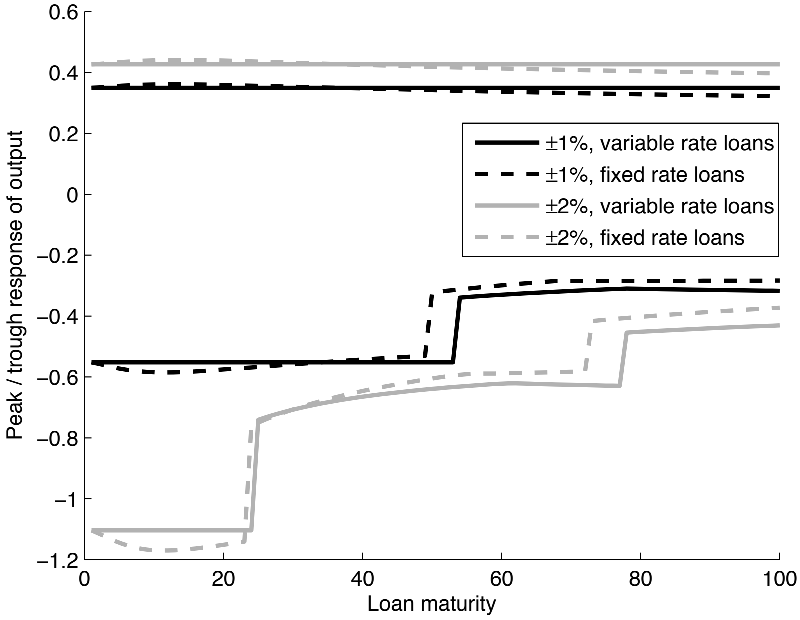
Note: Contractionary monetary policy shock (0.25%) for variable (solid lines) and fixed (dashed lines) rate loans. The loan maturity is 30 quarters. All responses are in percent deviations from the steady state.

Figure 6: Loan maturity and asymmetric transmission of monetary policy shocks



Note: Maximum responses of output to positive (lines below zero) and negative (lines above zero) interest rate shocks of different size (0.25% - black lines, 0.5% - grey lines) for variable (solid lines) and fixed (dashed lines) rate loans. All responses are in percent deviations from the steady state.

Figure 7: Loan maturity and asymmetric transmission of macroprudential policy shocks



Note: Maximum responses of output to positive (lines below zero) and negative (lines above zero) LTV shocks of different size (1% - black lines, 2% - grey lines) for variable (solid lines) and fixed (dashed lines) rate loans. All responses are in percent deviations from the steady state.

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