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MONETARY POLICY IN TIMES OF DEBT

by Mario Pietrunti * and Federico M. Signoretti*

Abstract

We model an economy with long-term mortgages and show that some characteristics of mortgage contracts – such as the type of interest rate (adjustable versus fixed) and the loan-to-value ratio – matter for the transmission of monetary policy impulses, both conventional and unconventional. A conventional monetary policy shock has a stronger impact on output and inflation with adjustable-rate mortgages, also reflecting the higher sensitivity of installments to changes in the short-term rate. When households borrow at a fixed rate, unconventional monetary policy can stimulate the economy mainly through a redistribution of income from savers to borrowers, who have a higher marginal propensity to consume. The impact of monetary policy – both conventional and unconventional – is stronger when the level of households' mortgage debt is high relative to housing wealth.

JEL Classification: E52, E58, G21.
Keywords: long-term mortgages, monetary policy, income channel.

Contents

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1 Introduction[1]

The interest on the relationship between the mortgage market and the transmission of monetary policy has flourished in recent years. Various reasons contributed to a renewed interest by scholars on the subject, namely: (i) the role of the mortgage market in the run-up of the 2008 crisis; (ii) the possible pre-crisis drag from historically high levels of debt; (iii) the unconventional reaction of monetary policy to the long-lasting crisis in most advanced economies. At the same time, the deepness of the crisis and the activation of non-standard policy tools by several central banks led to a rethinking of the most popular models and of the transmission mechanisms of monetary policy through the economy. So far the literature went a long way towards explaining the transmission of monetary policy measures. Our work draws new insight on the transmission of both conventional and unconventional monetary policy shocks via the mortgage market building on a number of conclusions of the most recent literature, briefly discussed in what follows.

First, one of the most relevant research questions recently tackled in the literature has been the impact of the standard intertemporal substitution channel, which has been put into question, while the empirical relevance of income or *cash-flow* effects has been more and more stressed. The income channel activates when changes in the monetary policy rate and the associated change in mortgage installments determine a redistribution of resources between agents - from borrowers to savers. Since borrowers and savers have typically different marginal propensities to consume (MPC), this channel may have aggregate effects on consumption and output. This claim has been tested in Cloyne et al. (2016), which compares the reaction to monetary policy shocks in two countries differing in the characteristics of their mortgage markets. More precisely, the authors compare the UK, where the majority of mortgages are ARMs and short-term, against the US, where mortgages are typically FRMs and long-term. The paper finds that in both countries indebted households react more to monetary policy shocks compared to non-indebted households. The reason lies in the higher marginal propensity to consume (MPC) of indebted households, which is in turn related to the existence of liquidity or borrowing constraints. Further, the authors find that the cash-flow (or income) effect is quantitatively more relevant than the standard intertemporal substitution effect. A similar result is found for the euro area in Ehrmann and Ziegelmeyer (2017) and in Sweden by Flodén et al. (2016). The latter

[1] We are grateful to Vincenzo Cuciniello, Giuseppe Ferrero, Stefano Neri, Andrea Ajello, Margarita Rubio, Marco Di Maggio for useful comments and fruitful discussions.The views expressed herein are those of the authors only and do not reflect those of Banca d'Italia or the Eurosystem.

paper, in particular, finds that the MPC out of change in interest expenses for highly indebted households under ARMs can even exceed one. Similarly, Di Maggio et al. (2016) investigate the effect of an expansionary monetary policy shock on ARM borrowers in the US, finding that the income shock induced by lower debt repayments leads to higher durable consumption and induces a faster debt repayment process (voluntary deleveraging). Further, the authors find some heterogeneity in MPC, given that in those US counties with a higher share of low income and underwater households and ARMs contracts, the consumption response to the interest rate cut is stronger.[2]

Second, the response of consumption and housing investment to monetary policy shocks is found to be stronger the higher the level of indebtedness of countries and households. Calza et al. (2013) make use of a panel VAR across different countries to study the impact of monetary policy shocks on housing, finding that the response is significantly different in countries with highly developed mortgage markets. Furthermore, private consumption reacts more when mortgage markets are more developed and where adjustable rate mortgages are predominant. Indeed, as discussed above, a stronger transmission of monetary policy impulses under ARM contracts is a fairly established fact in the literature, because of the existence of a cash-flow effect.

Third, in recent years several attempts have been made to introduce long-term mortgages in DSGE models in a meaningful way (see Rubio 2011, Brzoza-Brzezina et al. 2014 and Garriga et al. 2013). All of these papers study the response of the model economy to conventional monetary policy shocks under different institutional characteristics of the mortgage market. Rubio (2011) develops a model with both ARM and FRM contracts and shows that the cash-flow effect is present with ARM contracts only. On welfare grounds, it is shown that borrowers are better off with FRM while savers are better off with ARM under monetary policy shocks. Such results however cannot be generalized as they depend on the specific calibration of parameters. In the same vein, Brzoza-Brzezina et al. (2014) develops a model with ARM and FRM contracts of finite length. The key result of the paper is that FRM contracts reduce the effectiveness of monetary policy shocks. Further, when an occasionally binding

[2]There is a further strand of literature dealing with the theoretical underpinnings of overlooked channels of monetary policy transmission which focuses on heterogeneous agents models with incomplete markets. In this respect,Werning (2015) shows that the standard intertemporal substitution channel of monetary policy transmission is mainly a partial equilibrium channel and it is mainly relevant under complete markets. Under incomplete markets with idiosyncratic risk, instead, general equilibrium effects on income matter more. Such intuition is further developed in Luetticke (2015) and in Kaplan et al. (2016). Both papers investigate a setting with heterogeneous agents and show that the the direct, partial equilibrium, response to monetary policy shocks is less relevant than indirect effects, such as equilibrium changes in labor demand. On related grounds, Auclert (2016) shows that indirect effects matter because of redistribution between agents with different MPC.

collateral constraint is introduced in the model, it is found that the response under both types of contracts is not significantly influenced by the slackness of the constraint. In other words, the response is fairly symmetric. Lastly, Garriga et al. (2013) confirms the standard finding in the literature that stronger effects are obtained under ARM. Also, the size of the effect depends on the persistence of interest rate shocks: the higher the persistence, the stronger the influence on the whole term structure.

The flourishing of these different streams of literature nothwithstanding, none of the above discussed papers: a) quantifies the importance of income channel, b) analyzes the role of different starting levels of debt and, c) (more importantly) studies unconventional monetary policy. These three features are instead the focus of this work. We build a DSGE with ARMs and FRMs, starting from a simple New-Keynesian DSGE model with borrowers and savers and a collateral constraint à la Iacoviello (2005) and enriching it with long-term mortgages modeled as in Garriga et al. (2013). We depart from the existing literature by performing two types of analysis. First, we isolate the income effects arising from the response to monetary policy shocks from other, general equilibrium effects. Secondly, we introduce unconventional monetary policy as a shock to the long-term interest rate of new mortgages. Such shock can be interpreted as a shock to the term premium and therefore used to evalutate the effect on the economy of policies affecting the long -term rates, as obtained by asset purchase programmes.

We find the following results. First, for conventional policy (ie. policy affecting the short term rate) the stronger income effect for ARMs that is generally found in the literature is temporary and is almost entirely offset by other general equilibrium effects; for FRMs the income effect is basically not existent. Second, only FRM contracts are affected by unconventional policy. In this case, the contribution of the income channel is first-order for explaining the response of consumption: while the aggregate effect is quantitatively rather limited, the redistribution between borrowers and savers is significant (the income channel explains, on impact, between 65% and 70% of the response of consumption for both agents). Moreover, this effect is persistent because the reduction in long-term rates affects the rate on new mortgages, and thus the average rate on the stock of debt, for a long period of time. In other words, for FRMs the transmission channel of unconventional monetary policy is entirely different from the one related to standard monetary policy, as it is almost entirely driven by the income channel. Finally, conventional and unconventional monetary policies have a stronger impact when the level of households' debt is high.

The paper is structured as follows. Sections 2 and 3 describe the model, with an accurate description of mortgages and their pricing, and its calibration. Section 4 presents the results. Section 3 concludes.

2 The Model

On the demand side of the economy there is an household sector with patient and impatient agents; on the supply side there are intermediate-goods producers and retailers. Lastly, monetary policy completes the model via both a standard Taylor rule governing the short-term rate and unconventional monetary policy shocks, directly affecting long-term rates (see Section 2.4). In what follows we describe more in detail the demand side, given that the supply side is fairly standard. More details on the model can be found in Appendix A.

2.1 Patient households

Patient households represent a fraction γ_P of the total number of households in the economy and maximize the stream of intertemporal utility, given by the consumption good and housing, net of the disutility induced by labor. Hence, the patient household problem writes:

$$\max\ E_0 \left\{ \sum_{t=0}^{\infty} \beta_P^t \left[\log\left(c_{P,t} - \eta c_{P,t-1}\right) + j \log h_{P,t} - \frac{n_{P,t}^{1+\phi}}{1+\phi} \right] \right\} \tag{1}$$

subject to a budget constraint (written in real terms):

$$c_{P,t} + q_{h,t} \Delta h_t^P + l_{P,t} \leq w_{P,t} n_{P,t} + \left(r_{t-1} + \varphi\right) \frac{d_{P,t-1}}{\pi_t} + \frac{J_t^R}{\gamma_P}.$$

where Δh_t^P is the net amount of housing purchased in the current period, $q_{h,t}$ is the housing price, $w_{P,t} n_{P,t}$ is labor income and J_t^R are the profits from the intermediate-good production firm, owned by the patient household sector. $l_{P,t}$ is the new flow of loans, while the payment on the existing mortgage is made of an interest rate share $r_{t-1} d_{P,t-1}$ and a principal share, $\varphi d_{P,t-1}$, where φ is the fraction of debt expiring in the current period. Households are subject to internal habit formation in consumption, with η being the degree of habit persistence.[3]

[3]This is a fairly standard feature of most macroeconomic models that allows to get hump-shaped responses to shocks for

2.2 Impatient households

Impatient households represent a fraction γ_i of the total number of households. The key feature of these type of households is that they have a lower discount factor that the patient (ie. $\beta_i < \beta_p$) and thus in equilibrium they borrow in the credit market. The problem for the impatient writes:

$$\max\, E_0 \left\{ \sum_{t=0}^{\infty} \beta_I^t \left[\log \left(c_{I,t} - \eta c_{I,t-1} \right) + j \log h_{I,t} - \frac{n_{I,t}^{1+\phi}}{1+\phi} \right] \right\}$$

subject to a budget constraint (written in real terms):

$$c_{I,t} + q_{h,t} \Delta h_t^I + (r_{t-1} + \varphi) \frac{d_{I,t-1}}{\pi_t} \leq w_{I,t} n_{i,t} + l_{I,t}$$

and to a collateral constraint of the form:

$$d_{I,t} \leq m^I E_t \left\{ \frac{q_{t+1}^h h_{I,t} \pi_{t+1}}{1 + r_t} \right\}.$$

Such a constraint can be seen as an incentive compatibility constraint, requiring that the cost of repaying the stock of debt plus the interest share accumulated in period t is always lower that the expected value of the housing stock next period, weighted by a parameter m^I. Hence m^I can be easily interpreted as a loan-to-value (LTV) ratio.[4]

2.3 Mortgages

Before describing the rest of the model and discussing its calibration, it is worth to investigate more in detail the mechanics of the mortgage market.

Mortgage debt evolves symmetrically for patient and impatient households. Here we describe it from the point of view of the patient households. In each period a flow of new debt is issued: $l_{p,t}$. At the same time, an installment is received in each period, since a fraction φ of the stock of debt comes to maturity. Hence, in period t the patient household receives an installment made of a principal share, $\varphi d_{P,t-1}$, and of an interest share $r_{t-1} d_{P,t-1}$. The stock of debt (in real terms) in period t is equal

various macroeconomic variables and thus helps in bringing the model in line with the empirical evidence (Bouakez et al. 2005 and Del Negro et al. 2007).

[4] The standard microfoundation of such a constrain can be traced in Kiyotaki and Moore (1997).

to the sum of the unpaid debt plus the new flow:

$$d_{P,t} = (1-\varphi)\,\frac{d_{P,t-1}}{\pi_t} + l_{P,t}. \tag{2}$$

Hence, in absence of a new flow of debt, the stock of old debt gradually reduces (at a rate φ). The parameter φ can also be interpreted as a proxy for the length of the mortgage, as the duration of the mortgage is negatively related with φ (see *infra*).

The interest rate on the mortgage is computed as follows:

$$r_t = \begin{cases} (1-\nu_{P,t})\,r_{t-1} + \nu_{P,t} r_t^F & \text{if FRM} \\ r_t^{ib} & \text{if ARM} \end{cases}$$

where

$$\nu_{P,t} = \frac{l_{P,t}}{(1-\varphi)\,\frac{d_{P,t-1}}{\pi_t} + l_{P,t}}.$$

If debt is an adjustable-rate mortgage (ARM), then the rate is equal to the short-term, risk free, interest rate (r_t^{ib}), which is set by the central bank via a Taylor-type rule. If instead the mortgage is fixed-rate (FRM), then the interest rate is computed as a weighted average of the current rate on new FRM debt, r_t^F, and the rate on old debt, (r_{t-1}). Indeed $\nu_{P,t}$ is the fraction of new debt over total debt outstanding.

Hence, the only difference between ARMs and FRMs lies in the way the interest rate on the stock of mortgages is computed. This in turn has a stark implication for optimality conditions of agents in the economy. Indeed, under ARM contracts the interest rate paid on the stock of debt is entirely exogenous to borrowers and savers. On the contrary, in the case of FRM contracts, the interest rate paid on the stock of debt is a function of the ratio between the new flow of debt and the accumulated stock, ν_t. Hence, both patients' and impatients' Euler equations will include an extra-term reflecting the impact of the new flow of loans on the average interest rate paid on the stock (ie. $\partial r_t/\partial l_t$).

2.3.1 Pricing of ARM mortgages

ARM contracts are equivalent to one period debt. To see this, replace $l_{i,t}$ in the budget constraint of the patient household using the law of motion of debt (2):

$$c_{P,t}+q_{h,t}\Delta h_t^P+d_{P,t}\leq w_{P,t}n_{P,t}+\left(1+r_{t-1}\right)\frac{d_{P,t-1}}{\pi_t}.$$

Then the first order condition w.r.t. $d_{P,t}$ is a standard Euler equation:

$$\lambda_{P,t}=\beta^P E_t\frac{\lambda_{P,t+1}}{\pi_{t+1}}\left(1+r_t\right).$$

Since in ARM contracts $r_t=r_t^{ib}$, the ARM is tantamount to a one-period mortgage.

2.3.2 Pricing of FRM mortgages

The pricing of FRM contracts, instead, is quite different from ARM and one-period mortgages. Since FRM are long-term contracts, the interest rate on new mortgages r_t^F is equivalent to a long-term rate with duration φ. In what follows it will be shown that, in equilibrium, r_t^F is determined based on the term structure of one-period risk-free interest rate.

To see this, consider again the patient households' maximization problem (1), subject to the budget constraint and the equation for the mortgage rate rate, where $l_{P,t}$ and $\nu_{P,t}$ have been replaced in accordance with the equations above defined (with multipliers are reported in brackets):

$$\begin{aligned}
&(\lambda_{P,t}) && c_{P,t}+q_{h,t}\Delta h_t^P+d_{P,t}\leq w_{P,t}n_{P,t}+\left(1+r_{t-1}\right)\frac{d_{P,t-1}}{\pi_t}+\frac{J_t^R}{\gamma_P}\\
&(\lambda_{P,t}\mu_{P,t}) && r_t=r_{t-1}+\left[1-\frac{\left(1-\varphi\right)d_{P,t-1}}{\pi_t d_{P,t}}\right]\left(r_t^F-r_{t-1}\right).
\end{aligned}$$

Then first order conditions write:

$$\begin{aligned}
c_{P,t}: &\quad \frac{1}{c_{P,t}-\eta c_{P,t-1}}-\beta^P\eta E_t\left\{\frac{1}{c_{P,t+1}-\eta c_{P,t}}\right\}=\lambda_{P,t}\\
h_{P,t}: &\quad \lambda_{P,t}q_{h,t}=j\frac{\varepsilon_{j,t}^h}{h_{P,t}}+\beta^P E_t\left\{\lambda_{P,t+1}q_{h,t+1}\right\}\\
n_{P,t}: &\quad n_{P,t}^{\phi}=w_{P,t}\lambda_{P,t}\\
d_{P,t}: &\quad 1=\beta^P\left(1+r_t\right)E_t\left\{M_{P,t+1}\right\}+\tilde{\mu}_{P,t}\frac{\left(1-\varphi\right)d_{P,t-1}}{\pi_t d_{P,t}}\left(r_t^F-r_{t-1}\right)\\
&\quad -\left(1-\varphi\right)\beta^P E_t\left\{M_{P,t+1}\tilde{\mu}_{P,t+1}\left(r_{t+1}^F-r_t\right)\right\}\\
r_t: &\quad \tilde{\mu}_{P,t}=\beta^P E_t\left\{M_{P,t+1}\right\}+\left(1-\varphi\right)\beta^P E_t\left\{M_{P,t+1}\tilde{\mu}_{P,t+1}\right\}
\end{aligned}$$

where the last two equations are obtained by dividing by $\lambda_{P,t}$ and defining $\tilde{\mu}_{P,t}=\frac{\mu_{P,t}}{d_{P,t}}$ and

$E_t\left\{\frac{\lambda_{P,t+1}}{\lambda_{P,t}\pi_{t+1}}\right\} = E_t\left\{M_{P,t+1}\right\}$, with $E_t\left\{M_{P,t+1}\right\}$ being the stochastic discount factor.

As we are solving the model via first order approximation, we can ignore covariance terms and rewrite the two last equations as:

$$\begin{aligned} 1 &= \beta^P\left(1+r_t\right)E_t\left\{M_{P,t+1}\right\} + \tilde{\mu}_{P,t}\frac{\left(1-\varphi\right)d_{P,t-1}}{\pi_t d_{P,t}}\left(r_t^F - r_{t-1}\right) \\ &\quad -\left(1-\varphi\right)\beta^P E_t\left\{M_{P,t+1}\right\}E_t\left\{\tilde{\mu}_{P,t+1}\right\}E_t\left\{\left(r_{t+1}^F - r_t\right)\right\} \end{aligned}$$

$$\tilde{\mu}_{P,t} = \beta^P E_t\left\{M_{P,t+1}\right\} + \left(1-\varphi\right)\beta^P E_t\left\{M_{P,t+1}\right\}E_t\left\{\tilde{\mu}_{P,t+1}\right\}.$$

In order to close the model, we need a pricing equation. We assume that patient households have access to a one period bond with interest rate r_t^{ib}. The Euler equation for this bond pins down the stochastic discount factor (SDF):

$$\frac{1}{1+r_t^{ib}} = \beta^P E_t\left\{M_{P,t+1}\right\}.$$

We can now replace the SDF in the first order conditions, thus getting:

$$\begin{aligned} 1 &= \frac{1+r_t}{1+r_t^{ib}} + \tilde{\mu}_{P,t}\frac{\left(1-\varphi\right)d_{P,t-1}}{\pi_t d_{P,t}}\left(r_t^F - r_{t-1}\right) \\ &\quad -\frac{1-\varphi}{1+r_t^{ib}}E_t\left\{\tilde{\mu}_{P,t+1}\right\}E_t\left\{\left(r_{t+1}^F - r_t\right)\right\} \end{aligned}$$

$$\tilde{\mu}_{P,t} = \frac{1}{1+r_t^{ib}} + \frac{1-\varphi}{1+r_t^{ib}}E_t\left\{\tilde{\mu}_{P,t+1}\right\}.$$

Recursively solving the last equation, it can easily be shown that $\tilde{\mu}_{P,t}$ is the expectation of the infinite sum of future short term policy rates, discounted by φ:

$$\tilde{\mu}_{P,t} = \Sigma_{k=0}^{\infty}E_t\left\{\frac{\left(1-\varphi\right)^k}{\Pi_{j=0}^k\left(1+r_{t+j}^{ib}\right)}\right\}.$$

Hence $\tilde{\mu}_{P,t}$ conveys information on the expected path of future policy rates. Now we substitute for r_t in the Euler equation for $d_{P,t}$:

$$
\begin{aligned}
1 \quad = \quad & \frac{1+\frac{(1-\varphi)d_{P,t-1}}{\pi_t d_{P,t}}r_{t-1}+\left[1-\frac{(1-\varphi)d_{P,t-1}}{\pi_t d_{P,t}}\right]r_t^F}{1+r_t^{ib}}+ \\
& +\tilde{\mu}_{P,t}\frac{(1-\varphi)\,d_{P,t-1}}{\pi_t d_{P,t}}\left(r_t^F-r_{t-1}\right)- \\
& -\frac{1-\varphi}{1+r_t^{ib}}E_t\left\{\tilde{\mu}_{P,t+1}\right\}E_t\left\{r_{t+1}^F\right\}-\frac{(1-\varphi)\,d_{P,t-1}}{\pi_t d_{P,t}}r_{t-1}-\left[1-\frac{(1-\varphi)\,d_{P,t-1}}{\pi_t d_{P,t}}\right]r_t^F.
\end{aligned}
$$

It can be seen that this equation implicity pins down r_t^F as a function of d_t and of future policy rates.

All of the above mainly reflects a simple intuition: when choosing a long-term, fixed rate, mortgage, the borrower is locking in its future payments. Therefore, in equilibrium, the interest rate on FRMs will reflect the expectations of borrowers and savers concerning the future path of the short term interest rate, plus a term premium, determined by the covariance between consumption in each period and the installment.[5] Given that the model is solved via a first order approximation, the term premium is always zero and therefore the nominal rate on FRM mortgages will fully reflect the expectation on the evolution of the short-term rate.

2.4 Monetary Policy and rest of the model

Conventional monetary policy is modelled in a standard way, with the short-term nominal interest rate r_t^{ib} being set by the central bank according to a Taylor-type rule:

$$
r_t^{ib}=\rho_{ib}r_{t-1}^{ib}+(1-\rho_{ib})\left[\bar{r}^{ib}+\phi_\pi\left(\pi_t-\bar{\pi}\right)+\phi_y\left(y_t-y_{t-1}\right)\right]+\varepsilon_t^{ib}.
$$

Unconventional monetary policy is instead modelled as a shock directly hitting the rate on new long-term mortgages, r_t^F:

$$
r_t^{F,unc}=r_t^F+\varepsilon_t^F.
$$

Hence, the shock ε_t^F acts as an exogenous deviation of the long-term rate, r^f, from the value consistent with the term structure (i.e. the expectation over the path of short term rates) and can therefore be loosely interpreted as an exogenous variation in the term premium.[6] In practical terms,

[5] In our model other components such as credit and liquidity premia are equal to zero, given the absence of frictions that give rise to them. For a model with a credit premium see Ajello and Tanaka (2017).

[6] Note, however, as previously explained, that strictly speaking there is no the term premium in the linearized version of the model.

the shock is simulated by replacing r_t^F with $r_t^{F,unc}$ in the definition of the mortgage interest rate r_t. Thus, this shock does not affect the path of future short-term policy rates and consequently does not significantly affect the intertemporal substitution of agents. On the other hand, as we will show in the results, it determines significant income effects, by generating strong and persistent redistribution of resources between agents.

The rest of the model is fairly standard and is reported in Appendix A.2. There is a productive sector that uses the labor of both households to produce an intermediate good which is bought by retailers. Price rigidities in the goods market are modeled à la Rotemberg.

3 Calibration

The model is calibrated using as a reference Gerali et al. (2010) and Iacoviello and Neri (2010). As for parameters related to the mortgage market, we make use of the 2014 wave of the Survey of Income and Wealth (SHIW), a biannual survey conducted by the Bank of Italy on about 8,000 Italian households.[7] We set the discount factor for the patients to 0.992, which is coherent with the average ARM rate in Italy in 2014 equal to 3.3% in annual terms (source: SHIW). The discount factor for the impatients is set at 0.95 as in Iacoviello (2005). The loan-to-value ratio, μ_i, is set at 36.6%, which is the average of the ratio of outstanding mortgages over housing value observed in Italy in 2014 (source: SHIW). Lastly, the duration of the mortgage is computed using the Macaulay duration formula. It can be shown (see Appendix B) that in steady state the duration of the mortgage is equal to

$$D = \frac{1+r}{r+\varphi}.$$

Hence, for an interest rate equal to 3.3% and an average duration of mortgages in Italy equivalent to about 16 years (source: SHIW), we recover a value of φ of 0.0076. In Appendix C we also perform some robustness checks using alternative values for mortgage duration.

The value of calibrated parameters is reported in Table 1.

[7] See `http://www.bancaditalia.it/statistiche/tematiche/indagini-famiglie-imprese/bilanci-famiglie/index.html`.

Parameter	Value	Description
β_p	0.992	discount factor patients
β_i	0.95	discount factor impatients
j	0.1	Housing marginal utility
η	0.75	degree of habit formation
ϕ	1.5	inverse of Frisch elasticity of labor supply
μ_i	0.366	loan-to-value ratio
α	.25	capital share
ν_p	.63	patient agents' wage share
φ	0.0076	Mortgage duration
Nominal rigidity parameters		
κ_p	233	degree of price stickiness
ϵ_y	6	elasticity of substitution in the goods' market
Taylor rule parameters		
ρ_r	.3	response to past interest rate
ϕ_π	1.44	response to inflation
ϕ_y	.52	response to output

Table 1: Calibration values

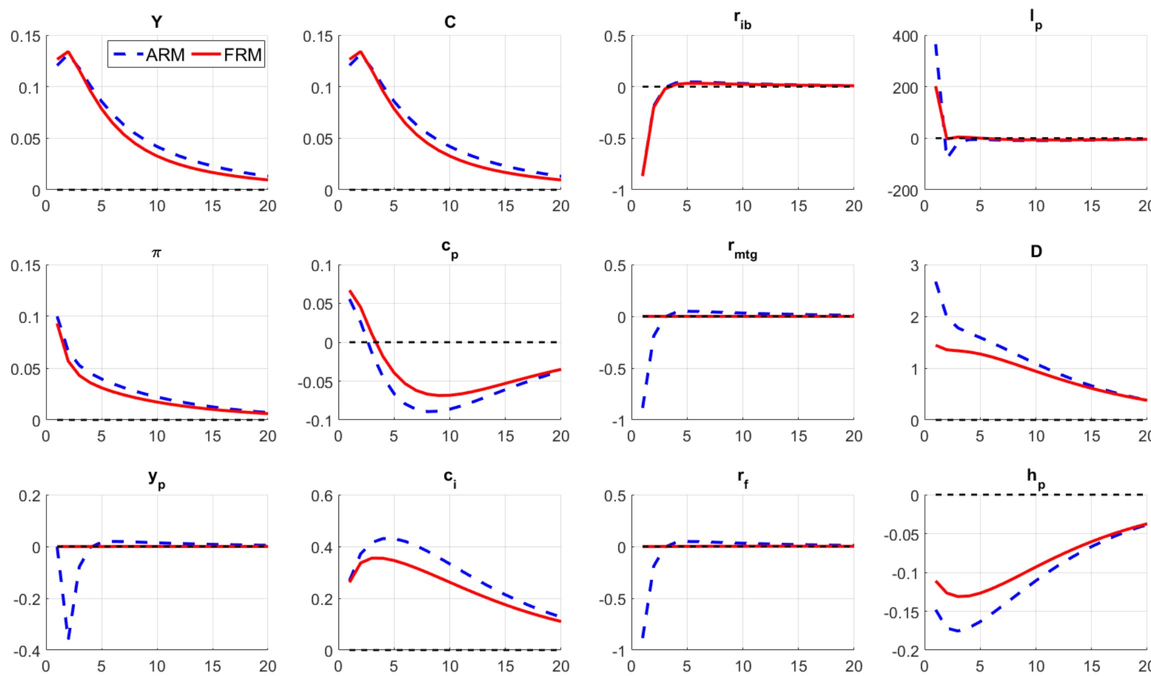
4 Results

In this section we perform three exercises. First, we investigate the impact of an unexpected monetary policy interest rate cut in an economy where mortgages are long term. Second, we investigate whether the response of the economy varies with the level of household debt, in relation to housing wealth, a proxy of the state of the financial cycle. Lastly, we introduce unconventional policies aimed at targeting long-term interest rates.

4.1 A conventional monetary policy shock

Does having FRM or ARM mortgages affect the transmission of conventional monetary policy shocks? To answer such question we simulate a 100 bps decrease in the short-term monetary policy rate under the baseline calibration in two distinct economies: one where mortgage contracts are ARM and one in which contracts are FRM. In the case of ARM, as previously shown, the response of the economy is the one that could be observed under a one period mortgage. The IRFs of the log-linearized variables are reported in Figure 1.

Figure 1: Conventional monetary policy shock



The main results of the exercise are the following. First, under FRMs the responses of output and inflation are somewhat attenuated compared to the ARM case. This result - in line with the literature (see eg. Rubio 2011) - masks however significant differences in the asset positions of the agents in the two scenarios. Indeed, the differences between FRM and ARM are not tremendous in aggregate terms but become very relevant when considering the dynamics of patients' and impatients' consumption. And this is directly related to the income channel of monetary policy, which in the model plays an important role. In order to compute the income, or cash-flow, effect, we construct the following variable:

$$Inc_{p,t} = (r_{t-1} + \varphi) \frac{\bar{d}}{\pi_t}$$

which aims at capturing the impact on the budget constraint of an unexpected change in the mortgage rate. Note that to measure the income effect we keep the level of mortgage at its steady state, as in periods after the shock the agent may decide to alter its stock of debt because of intertemporal substitution motives or general equilibrium effects. Then we compute its deviation in terms of steady state consumption:

$$y_{p,t} = \frac{\Delta Inc_{p,t}}{\bar{c}_p}.$$

It can be seen in Figure 1 that the direct effect from the change in the interest rate for the patient (blue dashed line) is negative under ARM, while it is almost non existent in the case of FRMs, since it is only related to the marginal change in inflation.

Furthermore, we decompose the response of consumption by disentangling the direct interest rate effect and all the indirect general equilibrium effects. Hence we decompose the response of consumption as follows:

$$\Delta c_{p,t}/\bar{c}_p \equiv \underbrace{\Delta Inc_{p,t}/\bar{c}_p}_{\text{rate effect}} + \underbrace{\left(\Delta c_{p,t} - \Delta Inc_{p,t}\right)/\bar{c}_p}_{\text{indirect effects}}$$

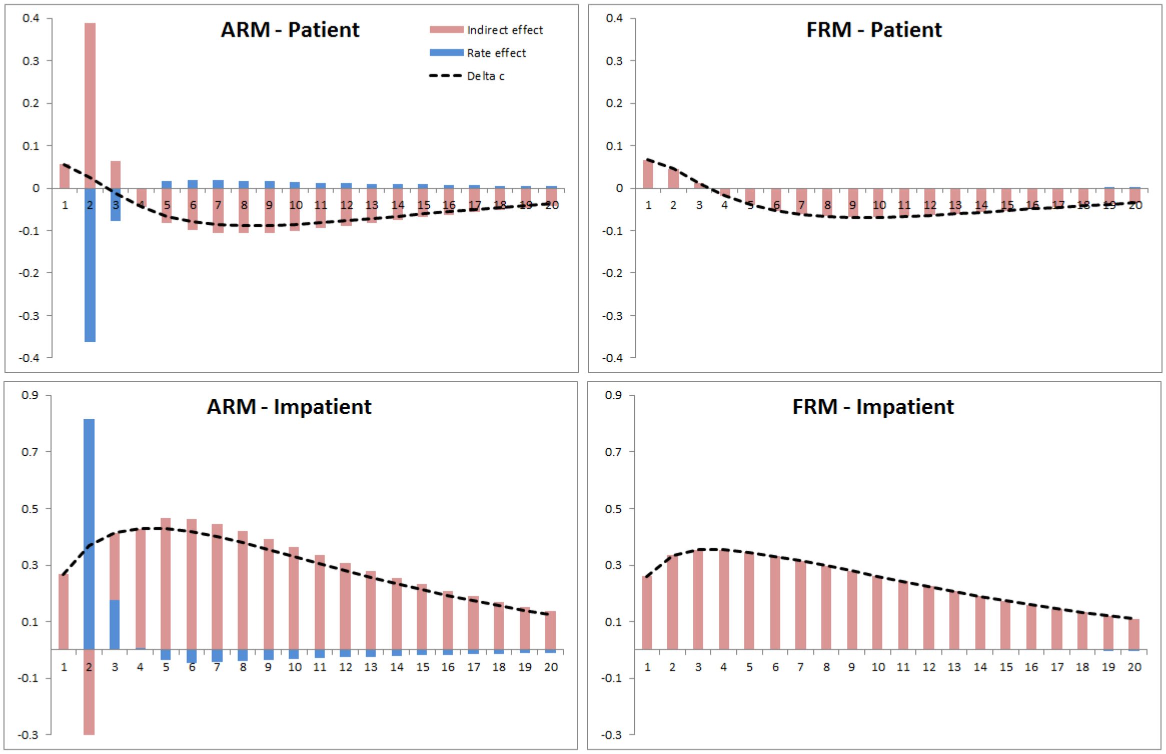
where Δx_t represents the deviation of a given variable from its steady state value.

Figure 2 shows the decomposition of the log-linear deviation from the steady state of consumption for both agents under the two contracts. First, it has to be noticed that the rate (or income or cash-flow) effect is material only in the case of ARMs, as expected. The effect is however short-lived and is affected only by the changes in the nominal interest rate, which changes by much in the ARM case and almost does not move in the FRM case. Inflation has a really small contribution to the income effect. The long term rate (r^f) does not move significantly in the FRM case, as the fall in the short-term rate is temporary and this only marginally affects the term structure.

4.2 The relevance of households' debt

So far we have shown that the existence of long-term mortgages (ie. FRMs) implies a different response to the same interest rate shock, due to the stickiness of the long term rate, which in turn shuts

Figure 2: Decomposition of the monetary policy shock



down the cash flow channel. A further question is then whether the level of debt influences such reaction. Such question is of particular relevance in the light of the literature on financial cycles.[8] In other words, we are interested in understanding whether having an economy with a high or a low level of households' mortgage debt matters for monetary policy transmission. Hence, we compare the response of the model to a conventional monetary policy shock in a low debt environment, modeled as an economy where the loan-to-value (LTV) ratio for the impatients is set at 20%, lower than the baseline calibration, and a highly indebted economy, where the LTV is set at 80%. The IRFs to the same monetary policy shock as in the previous section is reported in Figures 3 and 4.

In Figure 3 we plot output and inflation. Two results starkly emerge. First, the economy with a high level of debt reacts significantly more to the monetary policy stimulus compared to the low debt economy. A 100 bps cut in the short term interest rate induces an increase on impact of about 0.12% for output and of 0.09% on inflation, whereas in the highly indebted economy such values jump at about 0.20% for output and between 0.14% and 0.19% for inflation. Hence, the effectiveness

[8]For a discussion on the financial cycle see *ex multis* Drehmann et al. (2012).

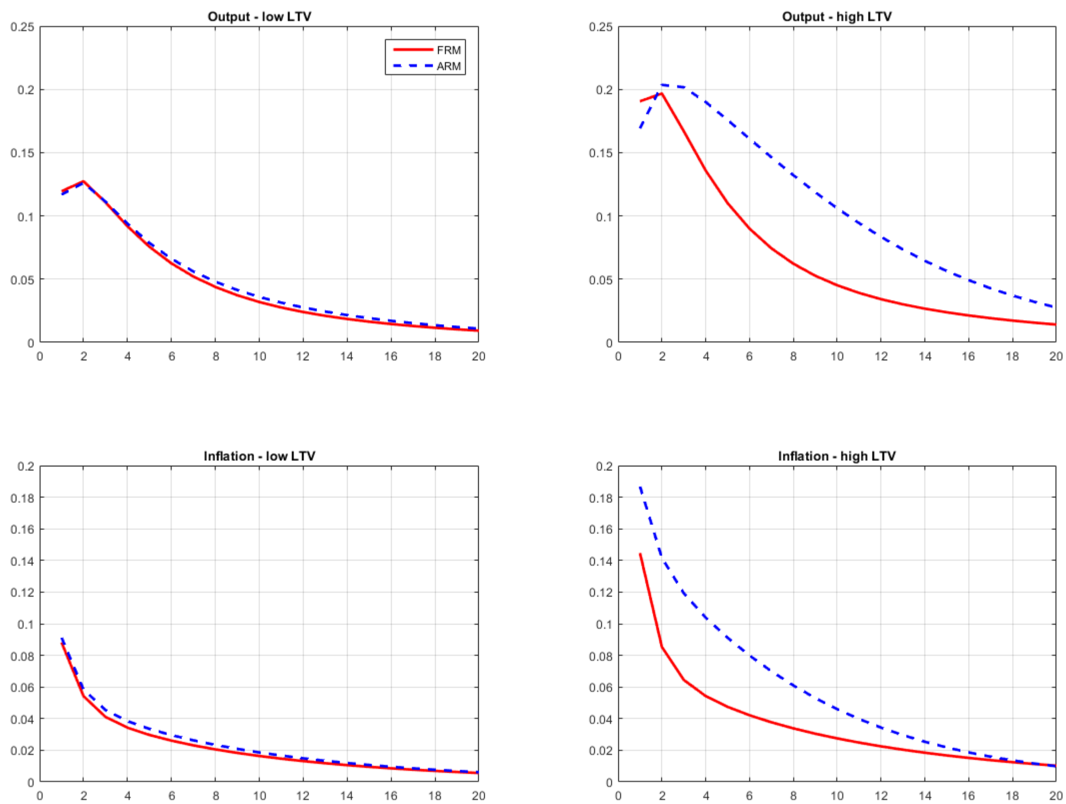


Figure 3: Conventional monetary policy shock under different debt levels

of monetary policy seems crucially linked to the level of households' indebtness, which in our setup is used to capture different phases of the the financial cycle.

Secondly, the differences between the response under ARM and FRM contracts matter more when the economy has a high starting level of debt as an economy with ARM contracts reacts significantly more to monetary policy shocks. Most importantly, the response is different not only on impact, but it stays also in the subsequent periods.

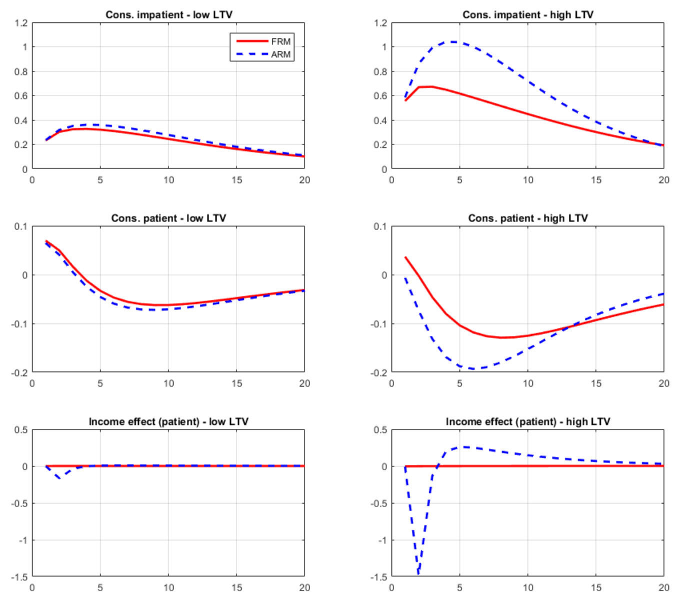


Figure 4: Conventional monetary policy shock under different debt levels

The reason for this is quite consequential: we have shown in Section 4.1 that the income channel is what explains a large part of the difference between ARM and FRM. Clearly, such effect is stronger the higher the initial level of the debt. In Figure 4 indeed we plot the consumption response under these two calibrations, along with the income effect ($y_{p,t}$) for the patient household. It can be noticed that such effect is almost negligible in the case of ARMs under a low debt scenario, while it is about ten times higher in the high debt environment.

4.3 Unconventional monetary policy and mortgage debt

As a last exercise, we investigate the effect of an unconventional monetary policy and its transmission channels. In Figure 5 we plot the IRFs to a 100 bps unconventional policy shock, in the model with FRM, under the two alternative calibrations for the LTV. In the exercise, we fix the short-term policy rate to its steady-state level, in order to simulate a situation in which the central bank commits to keep short-term policies rates unchanged while undertaking unconventional operations.[9] In this way, the interest rate does not react to changes to output and inflation induced by the unconventional monetary policy shock.

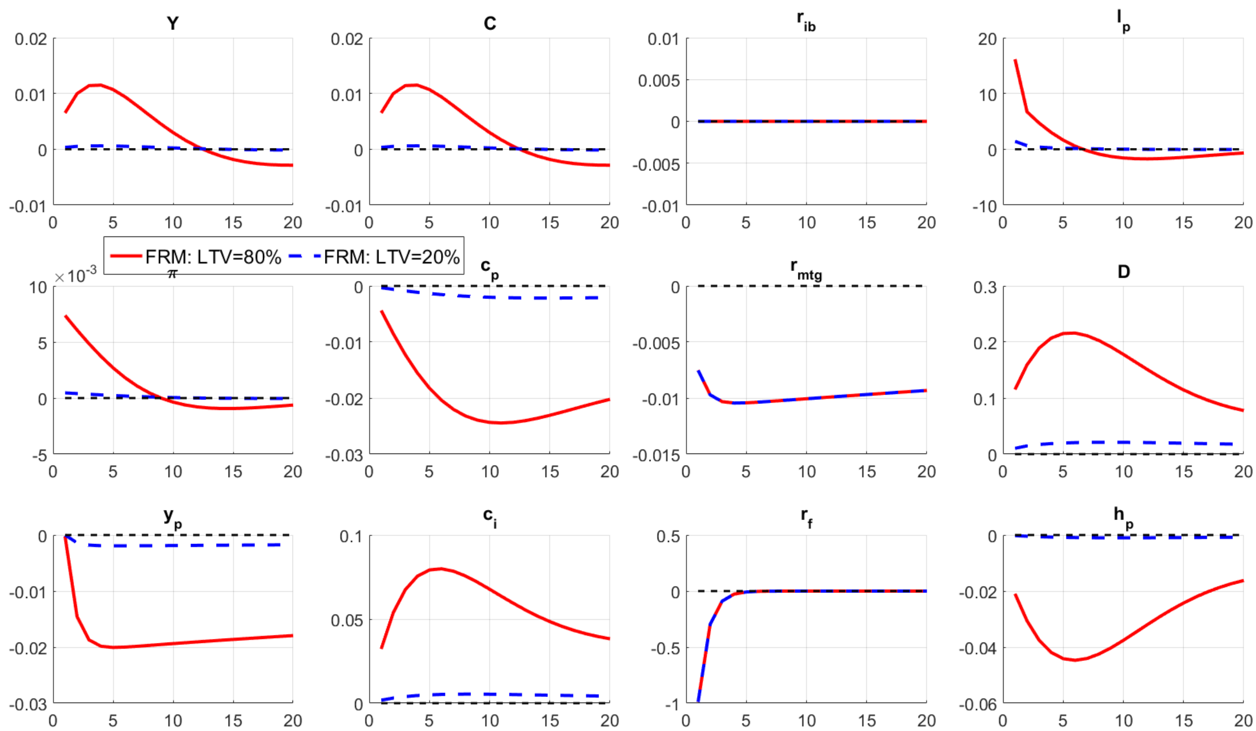


Figure 5: Unconventional monetary policy easing under different debt levels

The main finding of the exercise is that cutting the long-term rate has an effect on the economy whose magnitude is significantly reinforced when the level of debt is high. The response of output is

[9]Technically, we do this assuming that the degree of persistence of the AR(1) parameter in the Taylor rule is close to 1.

smaller compared to a conventional monetary policy shock: in a highly indebted economy a 100 bps reduction in the long-term rate is associated with a 1 basis point increase in output and to a 0.7 basis point increase in inflation.

Also, note that the effect on consumption is radically different compared to a conventional monetary policy shock. Indeed, in a standard monetary policy shock the consumption of both patient and impatient households moves in the same direction on impact - ie. it increases in the case of an easing shock. Quite on the contrary, the effect of an unconventional shock implies a reaction of consumption in opposite directions for borrowers and savers. This is indeed due to the fact that the shock mainly transmits via the income effect, which - in the case of an easing shock - tends to benefit impatients and make patients worse off. Hence, on aggregate the response of consumption will depend on the relative size of the two cohorts. Interestingly, in the case of a shock to the long-term rate, there is a cash flow effect. This is in contrast with the case of a short term rate shock under FRM mortgages, where the income effect is almost non-existent. This can be seen in Figure 6, where we report the decomposition between the direct rate effect on the budget constraint of the households and the indirect, general equilibrium, effects.

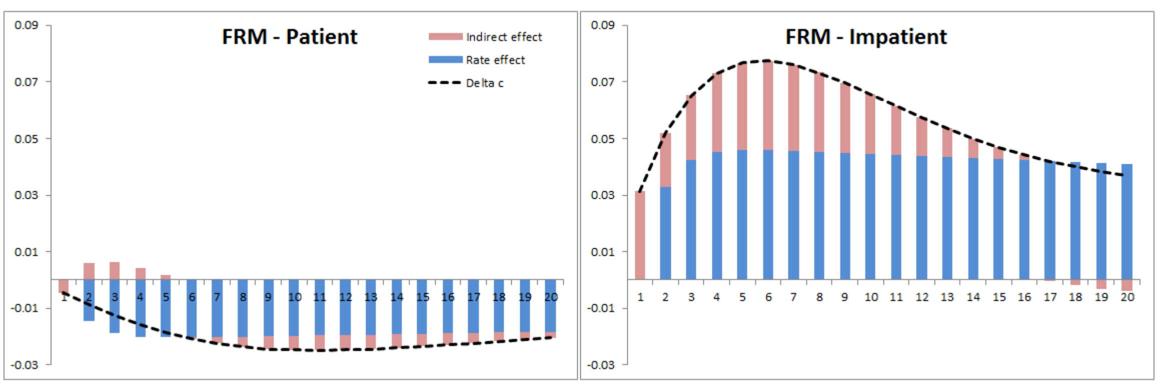


Figure 6: Decomposition of the consumption response to an unconventional monetary policy easing

Most of the reaction of consumption is due to this income effect. Moreover, such effect is persistent because the reduction in the long term rates affects the rate on new mortgages and thus the rate on the stock for a long period of time.

5 Conclusions and future research

In this paper we modeled an economy with long-term mortgages and show that some characteristics of mortgage contracts, mainly the type of interest rate (adjustable v. fixed), and the level of debt in the economy, matter for the transmission of monetary policy impulses, both conventional and unconventional.

We find that conventional monetary policy has a stronger impact on output and inflation under adjustable-rate mortgages compared with fixed-rate ones. This is due to the sensitivity of ARM installments to a change in the short-term interest rate, which determines a redistribution of wealth between savers and borrowers, given their different marginal propensities to consume. Second, when households borrow with FRMs, unconventional policies can provide a stimulus to the economy while keeping the short-term rate unchanged. Also in this case a relevant role is played by a redistribution of income between agents with different propensities to consume (borrowers and savers), which is persistent over time. Finally, the impact of monetary policy - both conventional and unconventional - is stronger when the level of debt in the economy is high.

This paper represents only a first step towards a more accurate investigation of the relationship between long-term debt and monetary policy. In our research agenda, we aim at enriching the model in order to incorporate a zero-lower bound on the short term rate as well as a meaningful financial sector that engages in maturity transformation. We leave these extensions to further research.

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A Households' problems and rest of the model

A.1 Households

Here we report more in detail the problem faced by patient and impatient households.

A.1.1 Patient households

Patient households maximize the stream of expected utility:

$$\max\ E_0 \left\{ \sum_{t=0}^{\infty} \beta_P^t \left[\log\left(c_{P,t} - \eta c_{P,t-1}\right) + j\varepsilon_{j,t}^h \log h_{P,t} - \frac{n_{P,t}^{1+\phi}}{1+\phi} \right] \right\}$$

subject to:

$$\begin{aligned}
&c_{P,t} + q_{h,t}\Delta h_t^P + l_{P,t} \leq w_{P,t} n_{P,t} + \left(r_{t-1} + \varphi\right) \frac{d_{P,t-1}}{\pi_t} + \frac{J_t^R}{\gamma_P} \\
&d_{P,t} = (1-\varphi) \frac{d_{P,t-1}}{\pi_t} + l_{P,t} \\
&\nu_{P,t} = \frac{l_{P,t}}{(1-\varphi) \frac{d_{P,t-1}}{\pi_t} + l_{P,t}} \\
&r_{t=} \left(1 - \nu_{P,t}\right) r_{t-1} + \nu_{P,t} r_t^F .
\end{aligned}$$

Replacing $l_{P,t}$ and $\nu_{P,t}$, the constraints write:

$$\begin{aligned}
&(\lambda_{P,t}) \qquad c_{P,t} + q_{h,t}\Delta h_t^P + d_{P,t} \leq w_{P,t} n_{P,t} + \left(1 + r_{t-1}\right) \frac{d_{P,t-1}}{\pi_t} + \frac{J_t^R}{\gamma_P} \\
&(\lambda_{P,t}\mu_{P,t}) \qquad r_t = r_{t-1} + \left[1 - \frac{(1-\varphi)\, d_{P,t-1}}{\pi_t d_{P,t}}\right] \left(r_t^F - r_{t-1}\right)
\end{aligned}$$

Then first order conditions write:

$$
\begin{aligned}
c_{P,t}: \quad & \frac{1}{c_{P,t}-\eta c_{P,t-1}} - \beta^P \eta E_t \left\{ \frac{1}{c_{P,t+1}-\eta c_{P,t}} \right\} = \lambda_{P,t} \\
h_{P,t}: \quad & \lambda_{P,t} q_{h,t} = j \frac{\varepsilon^h_{j,t}}{h_{P,t}} + \beta^P E_t \left\{ \lambda_{P,t+1} q_{h,t+1} \right\} \\
n_{P,t}: \quad & n^{\phi}_{P,t} = w_{P,t} \lambda_{P,t} \\
d_{P,t}: \quad & \lambda_{P,t} = \beta^P E_t \left\{ \frac{\lambda_{P,t+1}}{\pi_{t+1}} \left(1+r_t\right) \right\} + \lambda_{P,t} \mu_{P,t} \frac{(1-\varphi)\, d_{P,t-1}}{\pi_t d^2_{P,t}} \left(r^F_t - r_{t-1}\right) \\
& -\beta^P E_t \left\{ \frac{\lambda_{P,t+1} \mu_{P,t+1} (1-\varphi)}{\pi_{t+1} d_{P,t+1}} \left(r^F_{t+1} - r_t\right) \right\} \\
r_t: \quad & \lambda_{P,t} \mu_{P,t} = \beta^P E_t \left\{ \frac{\lambda_{P,t+1}}{\pi_{t+1}} \right\} d_{P,t} + \beta^P E_t \left\{ \frac{\lambda_{P,t+1} \mu_{P,t+1}}{\pi_{t+1}} \frac{(1-\varphi)\, d_{P,t}}{d_{P,t+1}} \right\}
\end{aligned}
$$

where $\mu_{P,t} = 0\, \forall t$ if ARM.

A.1.2 Impatient households

Impatient households maximize the stream of expected utility:

$$
\max\ E_0 \left\{ \sum_{t=0}^{\infty} \beta^t_I \left[\log\left(c_{I,t} - \eta c_{I,t-1}\right) + j \log h_{I,t} - \frac{n^{1+\phi}_{I,t}}{1+\phi} \right] \right\}
$$

subject to:

$$
\begin{aligned}
\text{s.t. } & c_{I,t} + q_{h,t} \Delta h^I_t + \left(r_{t-1} + \varphi\right) \frac{d_{I,t-1}}{\pi_t} \leq w_{I,t} n_{i,t} + l_{I,t} \\
& l_{I,t} + \frac{1-\varphi}{\pi_t} d_{I,t-1} \leq m^I E_t \left\{ \frac{q^h_{t+1} \pi_{t+1} h_{I,t}}{1+r_t} \right\} \\
& d_{I,t} = (1-\varphi) \frac{d_{I,t-1}}{\pi_t} + l_{I,t} \\
& \nu_{I,t} = \frac{l_{I,t}}{(1-\varphi) \frac{d_{I,t-1}}{\pi_t} + l_{I,t}} \\
& r_t = r_{t-1} + \nu_{I,t} \left(r^{ib}_t - r_{t-1}\right)
\end{aligned}
$$

Replacing $l_{I,t}$ and $\nu_{I,t}$, the constraints write:

$$
\begin{aligned}
(\lambda_{I,t}) \qquad & c_{I,t} + q_{h,t}\Delta h_t^I + (1+r_{t-1})\frac{d_{I,t-1}}{\pi_t} \leq w_{I,t}n_{I,t} + d_{I,t} \\
(\lambda_{I,t}\mu_{I,t}) \qquad & r_t = r_{t-1} + \left[1 - \frac{(1-\varphi)\, d_{I,t-1}}{\pi_t d_{I,t}}\right]\left(r_t^F - r_{t-1}\right) \\
(s_{I,t}) \qquad & d_{I,t} \leq m^I E_t\left\{\frac{q_{t+1}^h \pi_{t+1} h_{I,t}}{1+r_t}\right\}
\end{aligned}
$$

Then first order conditions write:

$$
\begin{aligned}
c_{I,t} :& \frac{1}{c_{I,t} - \eta c_{i,t-1}} - \beta^I \eta E_t\left\{\frac{1}{c_{I,t+1} - \eta c_{I,t}}\right\} = \lambda_{I,t} \\
h :& \lambda_{I,t} q_{h,t} = j\frac{1}{h_{I.t}} + \beta^I E_t\left\{\lambda_{I,t+1} q_{h,t+1}\right\} + s_{I,t} m^I E_t\left\{\frac{q_{t+1}^h \pi_{t+1}}{1+r_t}\right\} \\
n_{I,t} :& n_{I,t}^{\phi} = \lambda_{I,t} w_{I,t} \\
d_{I,t} :& s_{I,t} = \lambda_{I,t} - \beta^I E_t\left\{\frac{\lambda_{I,t+1}}{\pi_{t+1}}(1+r_t)\right\} + \lambda_{I,t}\mu_{I,t}\frac{(1-\varphi)\, d_{I,t-1}}{\pi_t d_{I,t}^2}\left(r_t^F - r_{t-1}\right) - \\
& - \beta^I E_t\left\{\frac{\lambda_{I,t+1}\mu_{I,t+1}(1-\varphi)}{\pi_{t+1} d_{I,t+1}}\left(r_{t+1}^F - r_t\right)\right\}
\end{aligned}
$$

$$
\begin{aligned}
r_t :& \lambda_{I,t}\mu_{I,t} = -\beta^I E_t\left\{\frac{\lambda_{I,t+1}}{\pi_{t+1}}\right\} d_{I,t} + \beta^I E_t\left\{\frac{\lambda_{I,t+1}\mu_{I,t+1}}{\pi_{t+1}}\frac{(1-\varphi)\, d_{I,t}}{d_{I,t+1}}\right\} - \\
& - s_{I,t} m^I E_t\left\{\frac{q_{t+1}^h \pi_{t+1} h_{I,t}}{(1+r_t)^2}\right\}
\end{aligned}
$$

where $\mu_{I,t} = 0\, \forall t$ if ARM.

A.2 Rest of the model

A.2.1 Intermediate-good producers

A continuum of firms of mass one carries out physical production of an intermediate good in a regime of perfect competition. Formally, an intermediate-good producer i produces the wholesale good $Y_t^W(i)$ using differentiated labor from both patients and impatients, according to the technology:

$$
Y_t^w(i) = A_t^E\left(n_t^{P,d}(i)\right)^{\nu}\left(n_t^{I,d}(i)\right)^{1-\nu}
$$

where $n^{P,d}(i)$, $n^{I,d}(i)$ are patients' and impatients' labor demand, A_t^E is a productivity shock to the neutral technology that evolves according an $AR(1)$ process.

The parameter ν, which determines the relative productivity of the two types of agents, also contributes to pin down the relative wage – and thus income – share. Thus ν can be interpreted as a measure of the relative economic size of Savers.

A.2.2 Retailers

A continuum of retailers of mass one buy intermediate goods, differentiate them at no cost, and sell their unique variety, $Y_t(j)$, to households. The market power enjoyed by retailers allows them to set prices at a mark-up over wholesale price. We also assume that price setting is sticky, as retailers suffer a quadratic cost for changing their prices, parameterized by κ_p and proportional to nominal aggregate output, as in (Rotemberg, 1982). Retailers are assumed to be owned by savers, who thus obtain profits, distributed in a lump-sum fashion.

households' stochastic discount factor $\Lambda_{0,t}^P$ because we assume – as mentioned before – that retail firms are owned by this type of agents.

A.2.3 Aggregation and equilibrium

In order to write equilibrium conditions, it is useful to define aggregate consumption C_t and aggregate borrowing and lending as, respectively:

$$C_t = \gamma^P c_t^P(i) + \gamma^I c_t^I(i) \tag{3}$$

$$B_t = \gamma^I b_t^I \tag{4}$$

$$D_t = \gamma^P d_t^P\ . \tag{5}$$

Equilibrium conditions are:

(i) the labor market clearing, for patients and impatients, respectively:

$$n_t^{P,d} = \gamma^P n_t^P(i) \tag{6}$$

$$n_t^{I,d} = \gamma^I n_t^I(i) \tag{7}$$

(ii) the housing market clearing

$$\bar{h}_t = \gamma^P h_t^P(i) + \gamma^I h_t^I(i) \tag{8}$$

(iii) the credit market clearing

$$B_t = D_t \tag{9}$$

(iv) and the resource constraint

$$Y_t \left[1 - \frac{\kappa_p}{2}\left(\frac{\pi_t}{\bar{\pi}} - 1\right)^2\right] = C_t. \tag{10}$$

B Calibration of mortgage duration

From the Macaulay duration formula, in steady state we have:

$$D = \frac{\sum_{i=1}^{\infty} i\left(\frac{1-\varphi}{1+r}\right)^{i-1}}{\sum_{i=1}^{\infty}\left(\frac{1-\varphi}{1+r}\right)^{i-1}} = \frac{r+\varphi}{1+r}\sum_{i=1}^{\infty} i\left(\frac{1-\varphi}{1+r}\right)^{i-1}$$

Define for simplicity$x \equiv \frac{1-\varphi}{1+r}$. It can be shown that $S = \sum_{i=1}^{\infty} i\left(\frac{1-\varphi}{1+r}\right)^{i-1} = \sum_{i=1}^{\infty} ix^{i-1} = 1 + 2x + 3x^2 + ...$ is a converging series. Compute, indeed, $xS = \sum_{i=1}^{\infty} ix^i = x + 2x^2 + 3x^3 + ...$ Then

$$S - xS = 1 + x + x^2 + ... = \sum_{i=1}^{\infty} x^{i-1} = \frac{1}{1-x}$$

then

$$S = \frac{1}{(1-x)^2} = \left(\frac{1+r}{r+\varphi}\right)^2$$

hence

$$D = \frac{r+\varphi}{1+r}\left(\frac{1+r}{r+\varphi}\right)^2 = \frac{1+r}{r+\varphi}$$

C Robustness analysis on mortgage duration

In this section we perform some robustness analysis concerning the duration of mortgages. More precisely, we depart from the calibration in the main text, where mortgages have a residual maturity of about 22 years and a duration of 16 years.

We therefore consider two alternative polar cases: a residual mortgage length of 5 and 40 years. At an annual interest rate of 3.3%, such figures imply a duration of respectively 5 and 23 years, and a value of φ of 0.0456 and 0.0029.

In Figure 7 the IRFs to a easing of the short-term policy rate are reported under various calibrations of the duration parameter. It can be noted that the reaction of most variables is fairly similar. Mortgage rates react more when duration is shorter, due to the fact that as duration tends to zero, mortgages become of the adjustable-rate type.

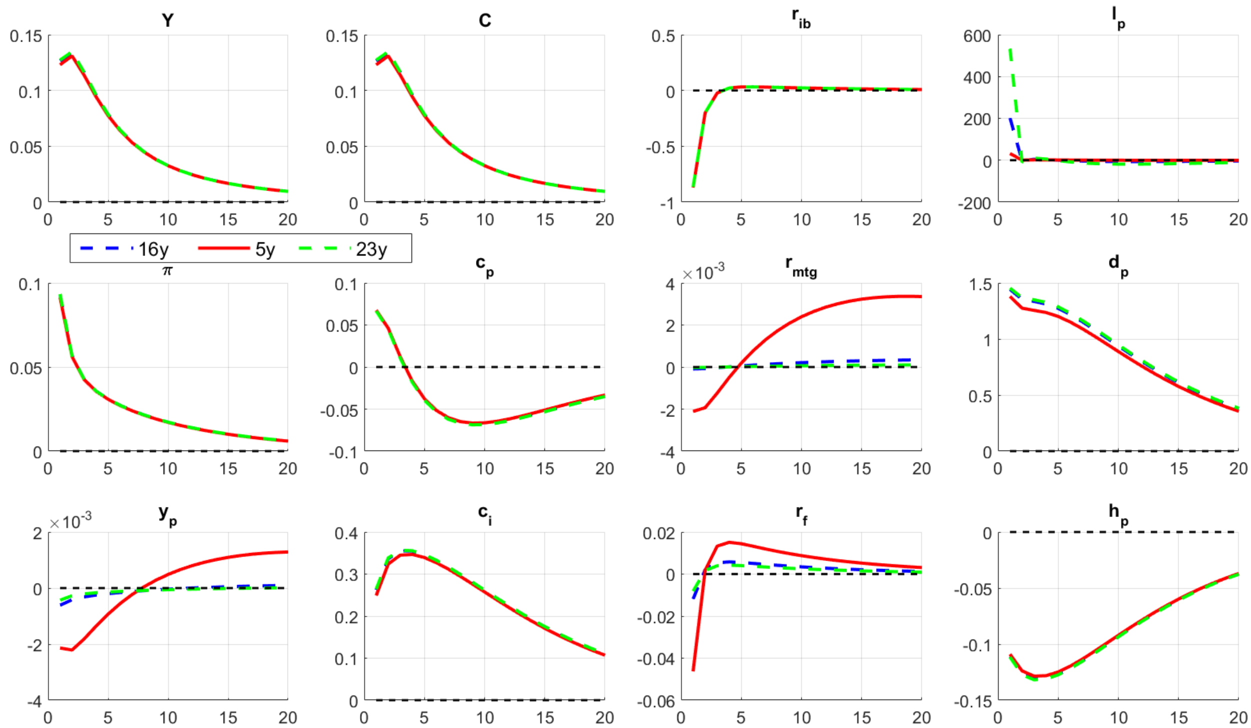

Figure 7: Conventional monetary policy shock with mortgages of various durations
Note: in this picture the response of various variables to a standard 1% monetary policy easing shock are reported under three parameterizations of FRMs duration. The blue dashed line represents an economy with FRMs with 16 years duration. The red solid line represents an economy with FRMs of 5 years duration. The green dashed line represents an economy with FRMs of 23 years duration.

The reaction of the three economies diverges instead when considering an unconventional monetary policy shock, as can be grasped in Figure 8. Indeed, the reaction of all the considered variables tends to weaken with longer durations. This is due to the different strenght of income effect in the various cases, which in turn is affected by the reaction of the FRM rate.

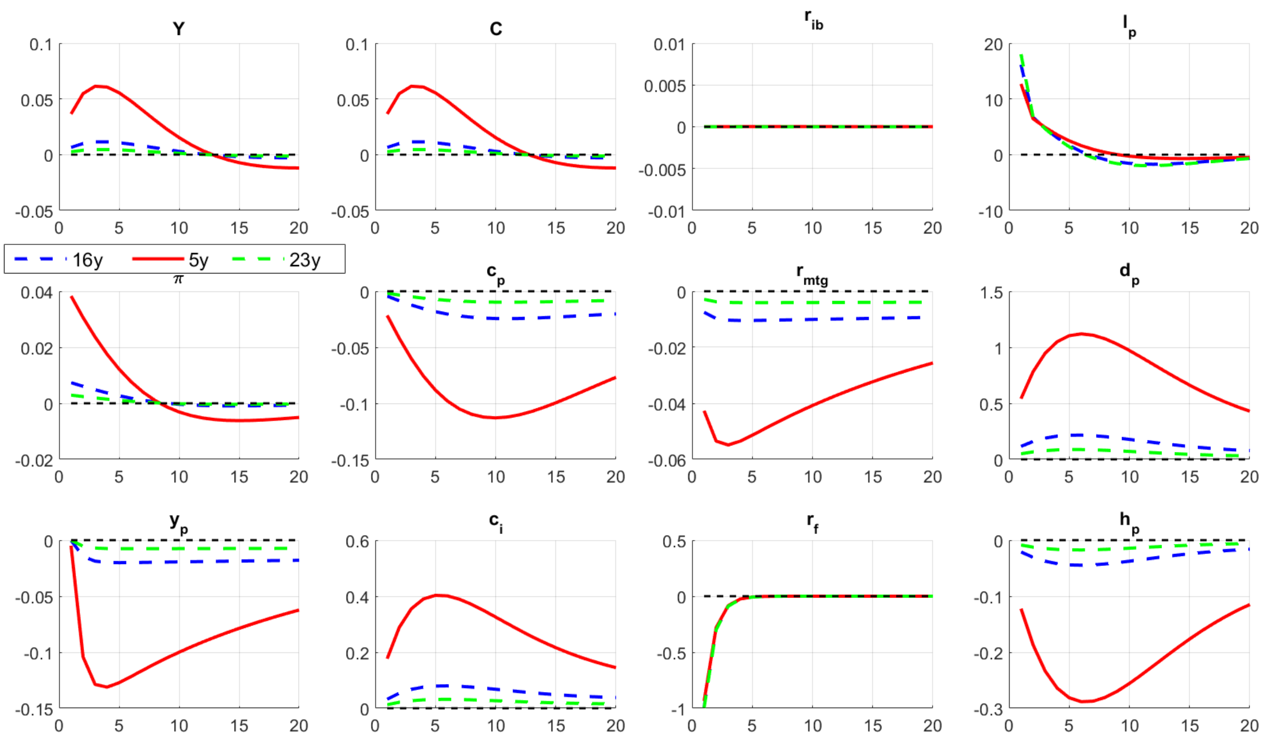

Figure 8: Unconventional monetary policy shock with mortgages of various durations
Note: in this picture the response of various variables to a 1% unconventional monetary policy easing shock are reported under three parameterizations of FRMs duration. The blue dashed line represents an economy with FRMs with 16 years duration. The red solid line represents an economy with FRMs of 5 years duration. The green dashed line represents an economy with FRMs of 23 years duration. In all three cases the LTV is set at 80%.

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