Monetary Policy and the Mortgage Market: a New-Keynesian Perspective*

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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) – matter for the transmission of monetary policy impulses, both conventional and unconventional. With adjustable-rate mortgages a conventional monetary policy shock implies a partial redistribution between savers and borrowers, a feature that is almost entirely absent under fixed-rate mortgages. Also, when households borrow at a fixed rate, unconventional monetary policy aimed at compressing term premia have an expansionary effect, similar to the one recorded under conventional policy shocks. The impact of monetary policy – both conventional and unconventional – is stronger when the share of borrowers or the level of households' mortgage debt are high.

Keywords: Mortgage market, long-term mortgages, quantitative easing, cash-flow channel.

JEL Class.: E44, E52, G21.

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1 Introduction

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 pre-crisis drag from historically high levels of debt and the subsequent deleveraging process; (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 insights 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 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.[1]

Second, 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 when the economy is solely hit by monetary policy shocks. Such results however cannot be generalized as they depend on the specific parameter values chosen. 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 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. All of the papers in this strand of literature however examine only the response of the economy to conventional short-term interest rate shocks, while they are silent on the impact of unconventional policies.

The transmission of unconventional policies, and more precisely quantitative easing (QE), is indeed explored in a third strand of literature. Vayanos and Vila (2009) introduces the idea that some in-

[1] 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.

vestors have preferences over specific maturities and thus purchases of securities by the central bank can lead to portfolio rebalancing and to a compression of risk premia. The idea of segmented markets is also present in more quantitative models such as Chen et al. (2012) and Alpanda and Kabaca (2015).

This work builds upon the findings of the above strands of literature, focussing on the transmission channels of conventional and unconventional monetary policies in a model with borrowers and savers. We therefore build a DSGE with ARMs and FRMs, starting from a simple New-Keynesian framework 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 term premium of new mortgages. Such shock is 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 monetary policy (ie. the one affecting the short term rate) there is a strong but temporary income effect for ARMs that is almost entirely offset by other general equilibrium effects; for FRMs the income effect is basically not existent. Second, quantitative easing policies have a positive impact on the economy, comparable to the one of conventional monetary policy shocks. Lastly, the reaction of aggregate variables such inflation and output to both conventional and unconventional policy shocks crucially depends on some features of the mortgage market. More precisely, the impact is stronger when the share of borrowers in the economy is high (due to their higher MPC) or 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 parameterization. Section 4 presents the results. Section 5 concludes.

2 The Model

On the demand side of the economy there is a household sector with patient and impatient agents; on the supply side there are intermediate-goods producers and retailers. Lastly, monetary policy closes the model via both a standard Taylor rule governing the short-term rate and an unconventional monetary policy shock, which directly affects 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 supply side of 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:

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

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

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

where $\Delta h_{P,t}$ is the net amount of housing purchased in the current period, q_t is the housing price, $w_{P,t} n_{P,t}$ is labor income, J_t^R are the profits from the intermediate-good production firm, owned by the patient household sector, and π_t is gross inflation. $l_{P,t}$ 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.

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:

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

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

$$c_{I,t} + q_t \Delta h_{I,t} + (r_{t-1} + \varphi) \frac{d_{I,t-1}}{\pi_t} \leq w_{I,t} n_{I,t} + l_{I,t},$$

and to a collateral constraint of the form:

$$d_{I,t} \leq m_I q_t h_{I,t}.$$

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 current value of the housing stock, weighted by a parameter m_I. Hence m_I can be easily interpreted as a loan-to-value (LTV) ratio.[2]

2.3 Mortgages

Before describing the rest of the model and discussing its parameterization, 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 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:

$$r_t = \begin{cases} (1-\nu_{P,t})\, r_{t-1} + \nu_{P,t} r_t^F & \text{if FRM} \\ r_t^{CB} & \text{if ARM} \end{cases} \tag{3}$$

where

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

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

If debt is an adjustable-rate mortgage (ARM), then the rate is equal to the short-term interest rate (r_t^{CB}), 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 the new flow of FRM debt, r_t^F, and the rate on the existing stock of 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. In what follows, we keep the ARM and FRM models separated and we do not allow for refinancing. Extending the model to include refinancing is straightforward and the results of a model with refinancing are reported in Appendix D.

2.3.1 Pricing of ARM mortgages

ARM contracts are equivalent to one period debt. To see this, replace $l_{I,t}$ and the definition of r_t in the budget constraint of the patient household using the law of motion of debt (2) and (3):

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

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

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

And similarly for the impatient. Hence, a model with ARMs leads to the very same dynamics of a model with 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 we assume that, in equilibrium, r_t^F is determined based on the term structure of the one-period risk-free interest rate. Let us start with the Euler equation for $d_{P,t}$:

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

where

$$r_t = \left(1 - \nu_{P,t}\right) r_{t-1} + \nu_{P,t} r_t^F.$$

Now, we assume that the expectation hypothesis holds, so that we can decompose the long-term rate into an expectation component and a term premium (see e.g. Cochrane 2001). In our case it implies that the following relationship holds (see Appendix B):

$$r_t^F = \sum_{j=0}^{\infty} \left(\frac{1-\varphi}{1+r^{CB}} \right)^j r_{t+j}^{CB} + TP_t$$

where the first term on the right-hand side is the expectation component and TP_t is the term premium.

It can be seen that this equation explicitely pins down r_t^F. 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.[3] Given that the model is solved via a first order approximation, the endogenous term premium is always a constant 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^{CB} being set by the central bank according to a Taylor-type rule:

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

Unconventional monetary policy is instead modelled as a shock directly hitting the term premium, which we assume to be entirely exogenous and equal to:

$$TP_t = \rho_{TP} TP_{t-1} + \varepsilon_t^F.$$

Hence, the shock ε_t^F acts as an exogenous deviation of the term premium, but it does not affect the path of future short-term policy rates, which is governed by the Taylor rule.[4] Indeed, the main

[3]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).

[4]Note, however, as previously explained, that strictly speaking there is no the term premium in the linearized version of the model. Note also the we implicitly assume that conventional monetary policy does not affect the term premium.

channel of transmission of QE policies is via a lowering of the term premium, due to the "duration extraction" activity of the central bank via asset purchases (see d'Amico et al. 2012).

Notice that the QE shock applies only to the model with FRM contracts. Indeed, an adjustable-rate mortgage has, by construction, a duration equal to 1 and so there is no term premium. Hence, QE in our model has no impact whatsoever on the ARM interest rate, as it coincides with the short term, risk free, interest rate and is thus entirely pinned down by the Taylor rule.[5]

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 Parameterization

The model is parameterized using as a reference Iacoviello (2005). We depart from the values used in that paper with respect to four parameters: the inverse of Frisch elasticity of labor supply, which we set at 1.5, and three parameters related to the mortgage market.[6] More precisely, we set the discount rate for the patients to 0.9943, which is coherent with the average 1 year Treasury rate in the US in the period 1997-2017 (equal to 2.33% in annual terms). Also, the duration of the mortgage is computed using the Macaulay duration formula. It can be shown (see Appendix C) that in steady state the duration of the mortgage is equal to

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

We recover a value of φ equal to 0.015 from setting the interest rate (in annual terms) equal to 5.59% (which was the average interest rate for 30 years FRM in the US in the period between 1997 and 2017) and a duration of 30 year mortgages in the US equivalent to about 8.9 years. In Section 4.3.1 we also perform some sensitivity analysis testing alternative values for mortgage duration. Lastly, we set the persistence of the unconventional monetary policy shock at 0.73, in line with the persistence of the conventional monetary policy shock. The value of parameters is reported in Table 1. The model is log-linearized around the non-stochastic steady state and solved using standard methods.

[5]In reality also ARM interest rates display some premia, which are mainly related to credit or liquidity risk. These premia can in turn be affected by unconventional monetary policy operations, but for the sake of simplicity in our model we do not allow for this possibility.

[6]The inverse of Frisch elasticity of labor supply in Iacoviello (2005) is set at 0.01, thus implying a strong response of labor supply to the real wage. We instead set this parameter halfway from two frequently chosen values in the literature, ie. 1 and 2.

Parameter	Value	Description
β_P	0.9943	discount factor patients
β_I	0.95	discount factor impatients
j	0.1	housing marginal utility
ϕ	1.5	inverse of Frisch elasticity of labor supply
m_I	0.55	loan-to-value ratio
ν_P	0.64	patient agents' wage share
φ	0.015	mortgage duration
Nominal rigidity parameters		
ξ_p	0.75	probability of a fixed price
ϵ_y	6	elasticity of substitution in the goods' market
Monetary policy parameters		
ρ_{CB}, ρ_{TP}	.73	shock persistence
ϕ_π	1.27	response to inflation
ϕ_y	.13	response to output

Table 1: Parameter values

4 Results

Having described the model and its parameterization, 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 introduce an unconventional policy aimed at targeting long-term interest rates. Lastly, we perform some sensitivity analysis to investigate the reaction of the economy to changes in parameters related to the mortgage market.

4.1 A conventional monetary policy shock

Does having fixed- or adjustable-rate mortgages affect the transmission of conventional monetary policy shocks? To answer such question we simulate a 25 bps decrease in the short-term monetary policy rate under the baseline parameterization 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 some log-linearized variables are reported in Figure 4.1.

A visual inspection of the IRFs under both types of mortgages seem to suggest that under FRMs the responses of output and inflation are somewhat attenuated compared to the ARM case. This result is in line with the literature (see eg. Rubio 2011). As will be shown in the sensitivity section, however, it crucially depends on the parameterization of the model. Also, aggregate responses mask significant differences in the asset positions of the agents in the two economies. To show this, we now turn to investigating the income channel of monetary policy, which in the model plays an important role. In order to compute the cash-flow effect, we construct the following variable:

$$CF_{z,t} = (r_{t-1} + \varphi)\,\frac{\bar{d}_z}{\pi_t}$$

which aims at capturing the impact on the budget constraint of the agent $z = \{P, I\}$ of an unexpected change in the mortgage rate. Note that to measure the income effect we keep the mortgage stock at its steady state, since we want to control for changes in the stock of debt that occur after the shock because of intertemporal substitution motives or general equilibrium effects. Then we compute the cash flow effect in terms of steady state consumption, $\frac{\Delta CF_{z,t}}{\bar{c}_z}$, where $\Delta CF_{z,t}$ represents the deviation of the variable from its steady state value. We can then decompose the response of consumption by explicitly setting apart the cash-flow effect from all other effects. Hence we decompose the response of consumption as follows:

$$\Delta c_{z,t}/\bar{c}_z \equiv \underbrace{\frac{\Delta CF_{z,t}}{\bar{c}_z}}_{\text{cash-flow effect}} + \underbrace{(\Delta c_{z,t}/\bar{c}_z - y_{z,t})}_{\text{other effects}}.$$

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 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. In the FRM case, the long term rate (r^F) does not move significantly, as the fall in the short-term rate is temporary and

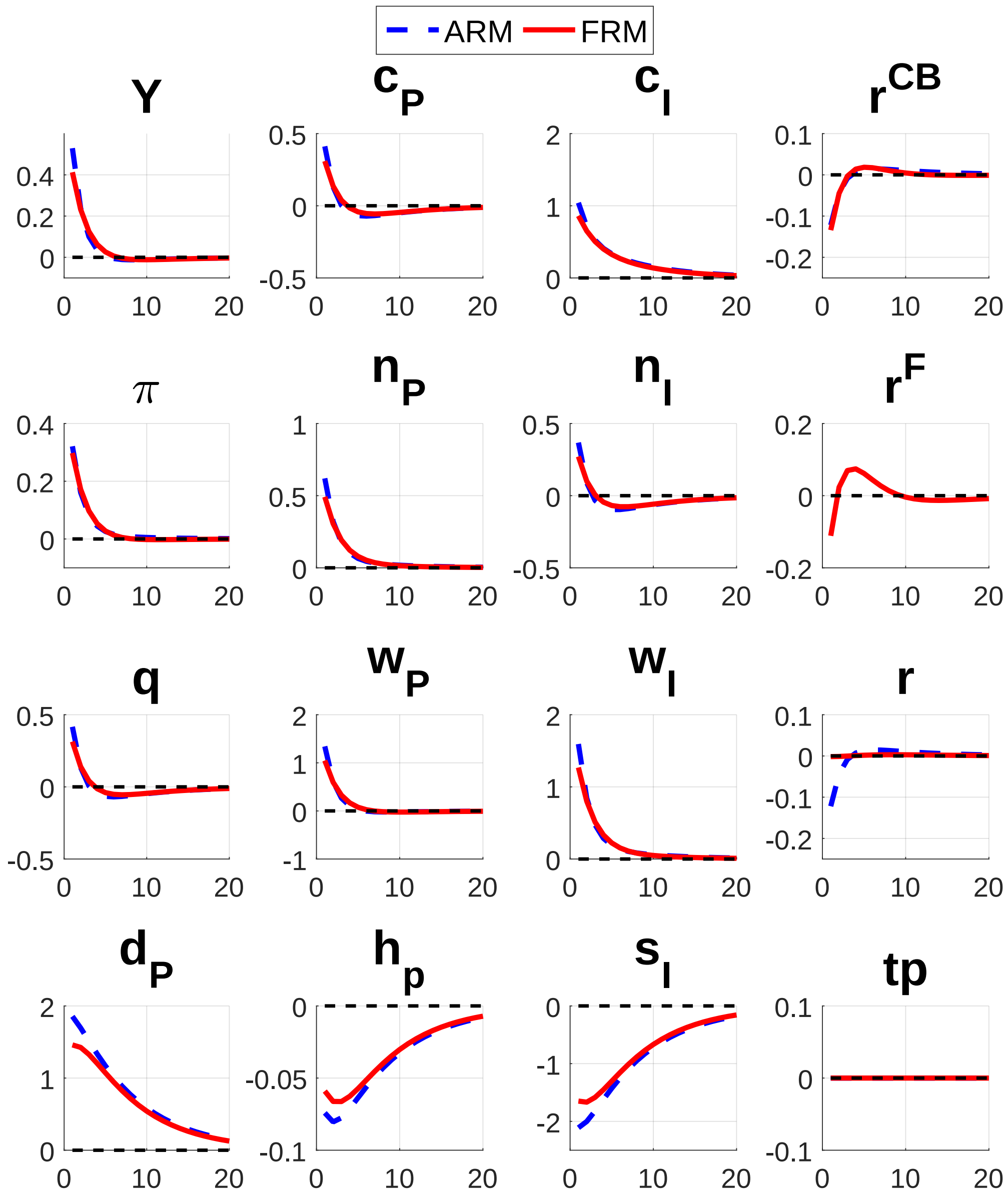

Figure 1: Conventional monetary policy shock

Note: the Figure depicts the IRFs of selected variables to a 25bp expansionary shock to the short-term interest rate. Values on the y-axis are percentage deviations from the steady state.

this only marginally affects the term structure.

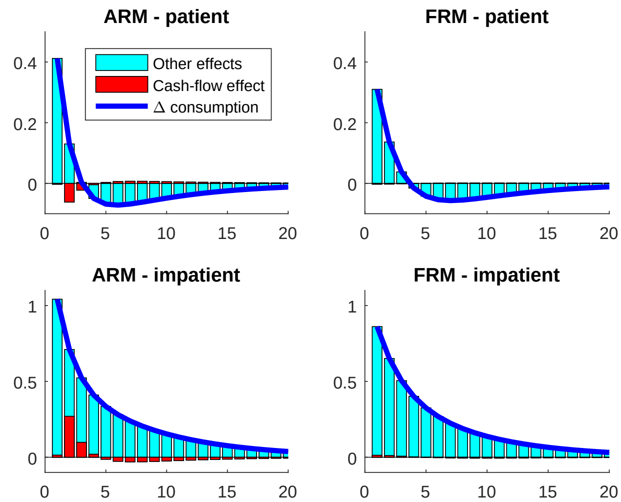

Figure 2: Decomposition of the consumption response to an expansionary conventional monetary policy shock

4.2 A QE shock

The next exercise consists of a QE shock, in order to study its transmission channels. In Figure 3 we plot the IRFs to a 25 bps expansionary QE shock, in the model with FRM, under two alternative assumptions on the short term rate. In the exercise, we model two scenarios: one in which the short term rate is fixed at its zero lower bound (ZLB) and the other one in which the short term rate is not constrained. In the case in which we are at the ZLB, the short-term rate is fixed 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.[7] In this way, the interest rate does not react to changes to output and inflation induced by the unconventional monetary policy shock. We also plot the results under an active Taylor rule, when the short term rate is not fixed.

The main finding of the exercise is that the cut of the long-term rate has an effect on the economy which is similar to the case of a cut in the short term interest rate. Notice that when the short term interest rate is not fixed at the ZLB, the reaction of the economy is significantly more muted. This

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

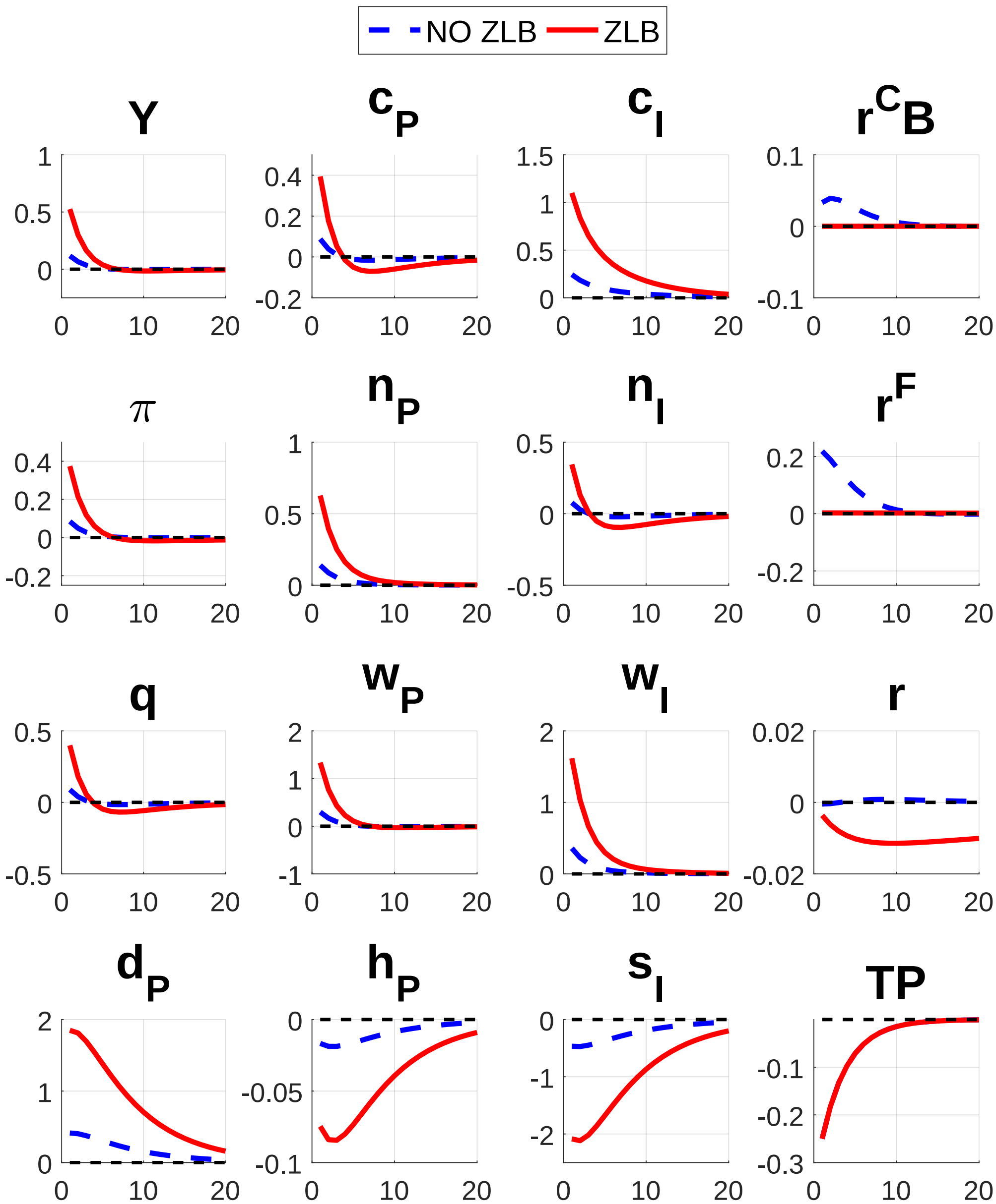

Figure 3: Unconventional monetary policy shock

Note: the Figure depicts the IRFs of selected variables to a 25bp expansionary shock to the term premium. Values on the y-axis are percentage deviations from the steady state.

is due to the fact that the QE shock produces an expansion in the economy; as a reaction to the expansion, the endogenous component of the Taylor rule prescribes a tightening of the short term rate, which curbs the reaction of output and inflation.

Also, note that the effect on consumption under the ZLB is quantitatively similar to the one obtained under a conventional monetary policy shock. Also in this case we can decompose the response of consumption into a cash flow vs other effects. This can be seen in Figure 4, where we report the decomposition between the direct cash flow effect on the budget constraint of the households and all the other effects in the ZLB case.

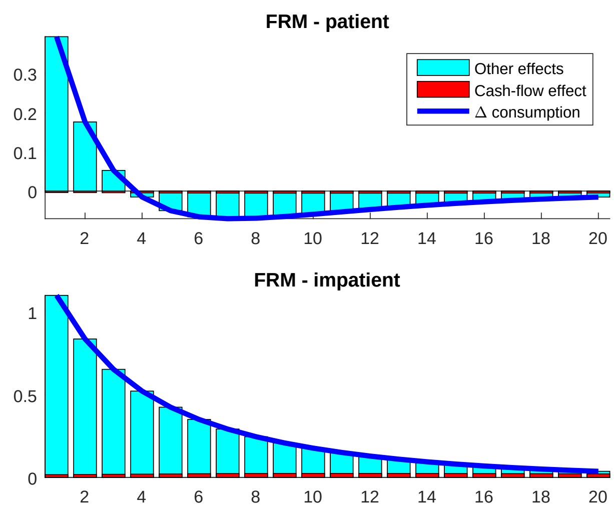

Figure 4: Decomposition of the consumption response to an unconventional monetary policy easing in the ZLB case

Most of the reaction of consumption is due to effects not related to the cash flow channel. The latter is very modest (although persistent) because the reduction in the long term rates affects the rate on new mortgages only and thus the rate on the stock for a long period of time.

To further assess the contribution of the cash-flow channel to the dynamics of consumption, we simulate the model for 1000 periods using respectively only conventional monetary policy shocks and QE shocks and compute the fraction of consumption variance attributable to the cash-flow effects. The results of the simulations are reported in Table 4.2. It can be noticed that, as expected, the cash-flow channel plays a marginal role under FRM contracts, as it does not exceed 0.04% of the variance of consumption of either patient or impatient agents, both under a conventional monetary policy shock and under a QE shock. The cash-flow effect is instead more relevant under ARMs as it accounts for about 2-3% of the variance of consumption of both agents under a series of conventional monetary policy shocks.

		Conventional MP	Quantitative Easing
ARM	patient	2.14%	-
	impatient	3.56%	-
FRM	patient	0.03%	0.03%
	impatient	0.04%	0.04%

Table 2: Contribution of the cash-flow effect to the variance of consumption.

4.3 Sensitivity analysis

We next turn to the analysis of how some features of the housing market may affect the impact and transmission of monetary policy shocks.

4.3.1 Share of lenders v. borrowers

The first exercise we perform is related to the implication of having more or less savers vs borrowers in the economy. Our baseline was an economy where 64% of the agents were savers and the rest were borrowers. One may wonder what happens when these shares vary. In Figure 5 we plot the response at the time of the shock of inflation and output to both a conventional monetary policy and to a QE shock. In other words, on the vertical axis we plot the IRF of either inflation or output at the time in which the shock materializes. On the horizontal axis we plot instead the share of lenders or patients in the economy, which we let vary from 35% to 95%. In the top panel, the IRFs to a conventional monetary policy shocks are reported, both in the case of ARM and FRM. It can be noticed that for both types of mortages, the aggregate response of the economy is more muted when the number of savers is larger. This can be explained by the fact that savers have a lower MPC compared to the borrowers. Hence, on aggregate, when the number of borrowers declines, so does the aggregate response of consumption (and hence of output and inflation). Also notice that for a low share of savers, the response under FRMs is stronger that the one under ARMs. On the other hand, the response under ARMs declines steadily but less abruptly than under FRMs.

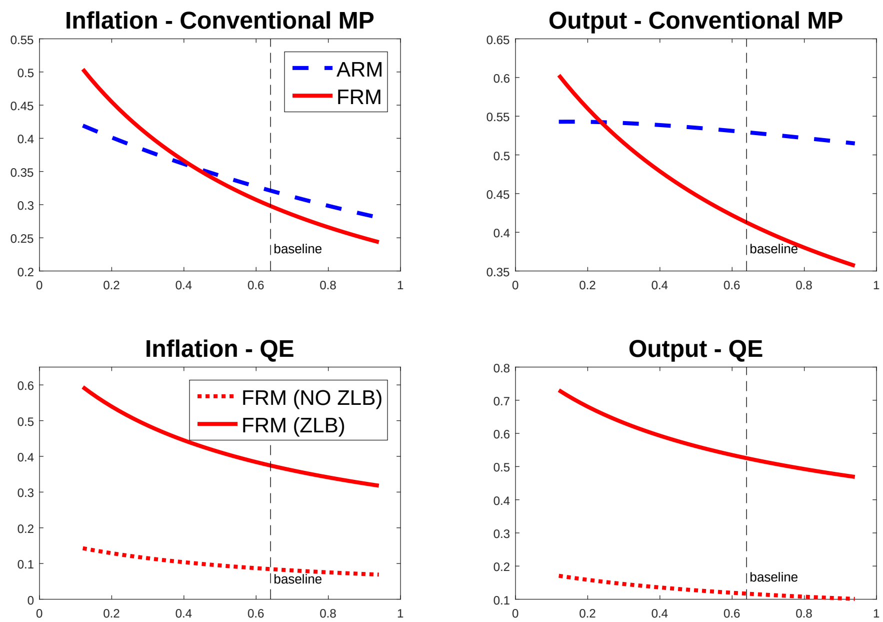

Figure 5: On impact IRFs of inflation and output for various shares of patients

Note: In the figure the response at time t of inflation and output to a conventional and unconventional monetary policy shock is reported. On the x-axis the share of patient agents is reported.

If we turn to the bottom panel, where the response to a QE shock is reported, we notice that also in this case the response of the economy is more muted when the share of savers is high. Also, notice that the response in the case of no zero lower bound is always significantly lower than the one recorded when the ZLB is active. Interestingly, the decline in the response of inflation and output when the share of patients increases is non-linear.

4.3.2 Level of debt

We now turn to considering what happens in economies that differ for the amount of debt borrowed or lend. In particular, we are interested in finding whether we can recover in our model the evidence in (Calza et al., 2013) according to which the response to monetary policy shocks is stronger when the level of debt is high. Hence, we simulate our model letting the parameter m_I, which measures the LTV ratio, vary from 20% to 80% of the current value of the housing stock of the borrower. The LTV ratio in our baseline case was instead set at 55%. The results of the exercise are simulated in Figure (6), where as in the previous section we plot the response on impact of output and inflation to both a conventional monetary policy shock and to a QE shock.

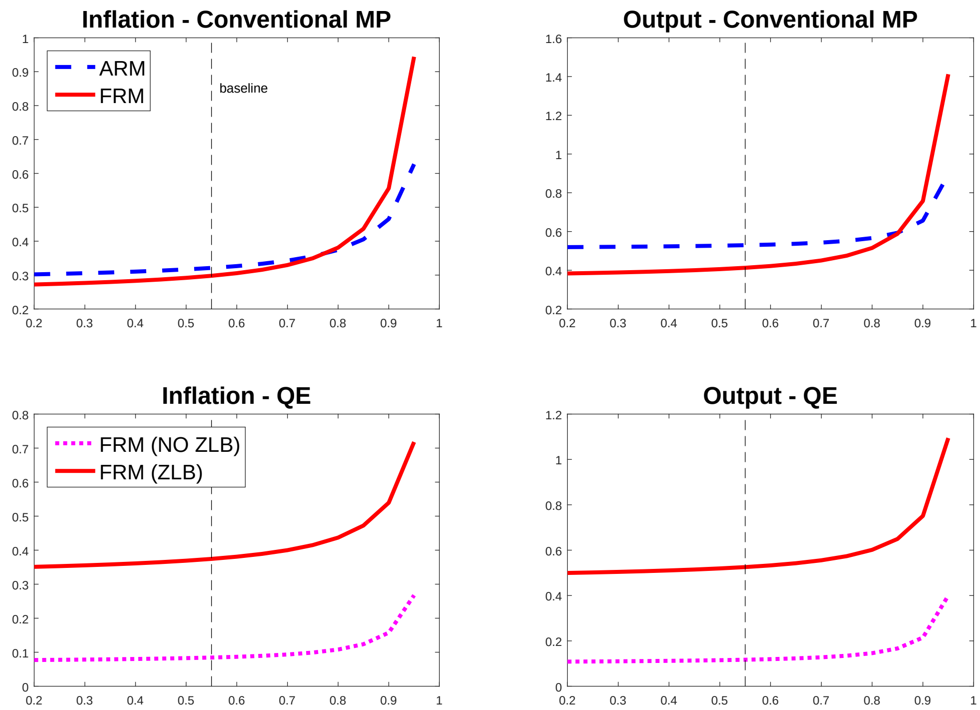

Figure 6: On impact IRFs of inflation and output for various LTV ratios

Note: In the figure the response at time t of inflation and output to a conventional and unconventional monetary policy shock is reported. On the x-axis the LTV ratio for impatient agents is reported.

As expected, we notice that under both types of shocks the response of the economy is stronger when the level of debt is high. The reason is mainly related to the fact that the intertemporal substitution channel becomes stronger with a higher level of debt. Notice also that under a conventional policy shock, the impact under ARMs is somewhat stronger for a LTV below 70%. For values above 80% the reaction under FRMs is stronger. Turning to the QE shock, it can be noticed that instead the amount of debt is relatively irrelevant for values of the LTV below 70%. Above this value, a sudden increase in the reaction of both output and inflation is recorded.

4.3.3 Mortage duration

As a last exercise, we perform some simulations concerning the duration of mortgages. More precisely, we depart from the parameterization in the main text, where mortgages have a residual maturity of 30 years and a duration of 8.9 years.

We therefore consider two alternative polar cases: we set φ vary from 0.0075 to 0.5. This implies, respectively, a duration of 12 years and of 2 years. At an annual interest rate of 5.59%, such figures imply that the maturity of the mortgage would be respectively 45 and of 1.25 years.

In Figure 7 the IRFs to an easing of the short-term policy rate and of the term premium are reported under various parameterizations of the duration parameter. The Figure can be read as follows: on the x axis there is φ, which measures the amount of the existing loan to be reimbursed in each period. Hence, moving from left to right, the duration of the mortgage shrinks, along with its residual maturity. It can be noted that apart from a spike around the longest maturities (ie. for values of φ close to zero) the reaction of both output and inflation is rather stable across FRM mortgageges with different duration.

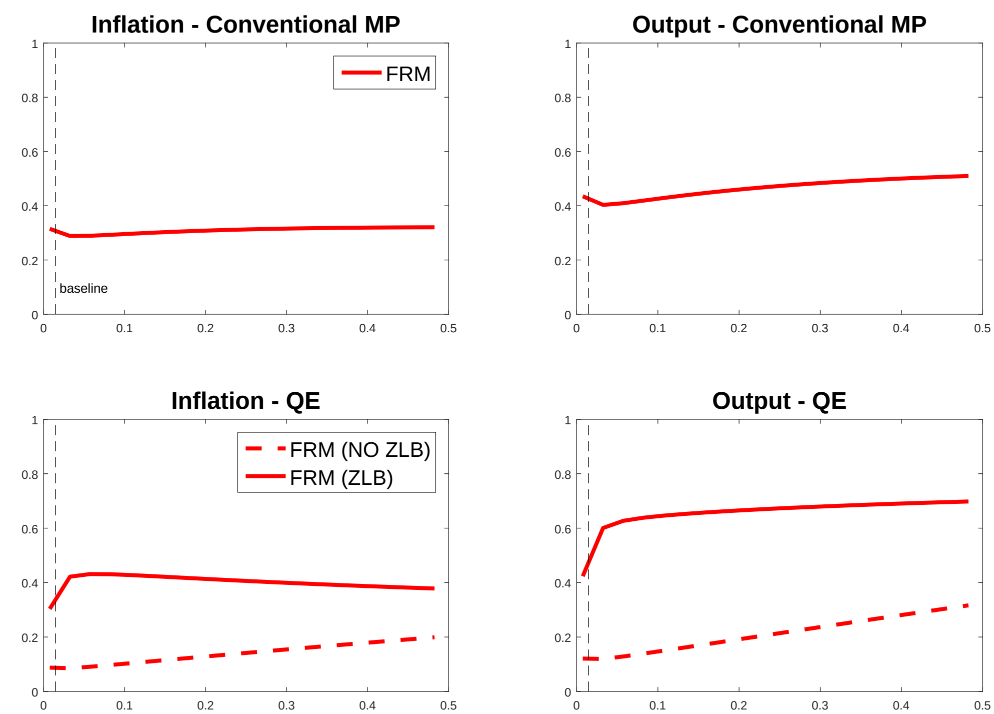

Figure 7: On impact IRFs of inflation and output for various durations

Note: In the figure the response at time t of inflation and output to a conventional and unconventional monetary policy shock is reported for various durations of the fixed rate mortgage. On the x-axis the parameter φ, measuring the principal component of the installment in each period is reported.

The reaction of these various economies diverges instead when considering an unconventional monetary policy shock in the no ZLB case. Indeed, the reaction of output and inflation on impact tends to converge to the one recorded in the ZLB case when the duration of the mortgage shortens.

5 Conclusions

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), but also the share of borrowers 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. Finally, the impact of monetary policy - both conventional and unconventional - is stronger when the share of borrowers or 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 meaningful financial sector that engages in maturity transformation or to include other types of monetary policy intervention, such as forward guidance. We leave this extension 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:

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

subject to:

$$\begin{aligned} & c_{P,t} + q_t \Delta h_{P,t} + l_{P,t} \leq w_{P,t} n_{P,t} + (r_{t-1} + \varphi) \frac{d_{P,t-1}}{\pi_t} + \frac{J_t^R}{\gamma_P} \\ & d_{P,t} = (1-\varphi) \frac{d_{P,t-1}}{\pi_t} + l_{P,t}. \end{aligned}$$

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

$$(\lambda_{P,t}) \qquad c_{P,t} + q_t \Delta h_{P,t} + d_{P,t} \leq w_{P,t} n_{P,t} + (1 + r_{t-1}) \frac{d_{P,t-1}}{\pi_t} + \frac{J_t^R}{\gamma_P}$$

Then first order conditions write:

$$\begin{aligned} c_{P,t} : &\qquad \frac{1}{c_{P,t}} = \lambda_{P,t} \\ h_{P,t} : &\qquad \lambda_{P,t} q_t = \frac{j}{h_{P,t}} + \beta^P E_t \left\{ \lambda_{P,t+1} q_{t+1} \right\} \\ n_{P,t} : &\qquad n_{P,t}^{\phi} = w_{P,t} \lambda_{P,t} \\ d_{P,t} : &\qquad \lambda_{P,t} = \beta^P E_t \left\{ \frac{\lambda_{P,t+1}}{\pi_{t+1}} (1 + r_t) \right\}. \end{aligned}$$

A.1.2 Impatient households

Impatient households maximize the stream of expected utility:

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

subject to:

$$
\begin{aligned}
\text{s.t. } & c_{I,t} + q_t \Delta h_{I,t} + (r_{t-1} + \varphi) \frac{d_{I,t-1}}{\pi_t} \le w_{I,t} n_{I,t} + l_{I,t} \\
& l_{I,t} + \frac{1-\varphi}{\pi_t} d_{I,t-1} \le m_I q_t h_{I,t} \\
& d_{I,t} = (1-\varphi) \frac{d_{I,t-1}}{\pi_t} + l_{I,t}
\end{aligned}
$$

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

$$
\begin{aligned}
(\lambda_{I,t}) \qquad & c_{I,t} + q_t \Delta h_{I,t} + (1 + r_{t-1}) \frac{d_{I,t-1}}{\pi_t} \le w_{I,t} n_{I,t} + d_{I,t} \\
(s_{I,t}) \qquad & d_{I,t} \le m_I q_t h_{I,t}
\end{aligned}
$$

Then first order conditions write:

$$
\begin{aligned}
c_{I,t} :& \frac{1}{c_{I,t}} = \lambda_{I,t} \\
h :& \lambda_{I,t} q_t = \frac{j}{h_{I.t}} + \beta^I E_t \left\{ \lambda_{I,t+1} q_{t+1} \right\} + s_{I,t} m_I q_t \\
n_{I,t} :& n_{I,t}^{\phi} = \lambda_{I,t} w_{I,t} \\
d_{I,t} :& s_{I,t} = \lambda_{I,t} - \beta^I E_t \left\{ \frac{\lambda_{I,t+1}}{\pi_{t+1}} (1 + r_t) \right\}.
\end{aligned}
$$

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:

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

where $n_P(i)$, $n_I(i)$ 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 and modelled *à la* Calvo. Retailers are assumed to be owned by savers, who thus obtain profits, distributed in a lump-sum fashion.

A.2.3 Aggregation and equilibrium

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

$$C_t = \gamma^P c_{P,t}(i) + \gamma^I c_{I,t}(i) \tag{4}$$

Equilibrium conditions are:

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

$$n_{P,t} = \gamma^P n_{P,t}(i) \tag{5}$$

$$n_{I,t} = \gamma^I n_{I,t}(i) \tag{6}$$

(ii) the housing market clearing

$$\bar{h}_t = \gamma^P h_{P,t}(i) + \gamma^I h_{I,t}(i) \tag{7}$$

(iii) the credit market clearing

$$\gamma^I d_{I,t} = \gamma^P d_{P,t} \tag{8}$$

(iv) and the resource constraint

$$Y_t = C_t. \tag{9}$$

B FRM rate pricing under the expectation hypothesis

Here we show how to recover the expectation component in the pricing of the FRM interest rate r_t^F. First of all, notice that the mortgage is a perpetuity with decaying coupons. More precisely, the original coupon is $\varphi + r_t^F$ and is geometrically decaying at the rate $1-\varphi$. Suppose now that $d_{t-1} = 0$ and that one unit of the mortgage is bought at time t and zero in all the subsequent periods. Then we will have that $l_t = 1$ and $l_j = 0$ for $j \neq t$. Then, by the expectation hypothesis, we get

$$\begin{aligned} 1 &= \frac{\varphi + r_t^F}{1 + r_t^{CB}} + E_t \left\{ \frac{\left(\varphi + r_t^F\right)(1-\varphi)}{\left(1 + r_t^{CB}\right)\left(1 + r_{t+1}^{CB}\right)} + \frac{\left(\varphi + r_t^F\right)(1-\varphi)^2}{\left(1 + r_t^{CB}\right)\left(1 + r_{t+1}^{CB}\right)\left(1 + r_{t+2}^{CB}\right)} + \dots \right\} \\ &= \left(\varphi + r_t^F\right) E_t \left\{ \sum_{j=0}^{\infty} \frac{(1-\varphi)^j}{\Pi_{k=0}^{j}\left(1 + r_{t+k}^{CB}\right)} \right\} \end{aligned}$$

or, more compactly:

$$\frac{1}{\varphi + r_t^F} = E_t \left\{ \sum_{j=0}^{\infty} \frac{(1-\varphi)^j}{\Pi_{k=0}^{j}\left(1 + r_{t+k}^{CB}\right)} \right\}.$$

Notice that in steady state:

$$\frac{1}{\varphi + r^F} = \sum_{j=0}^{\infty} \frac{(1-\varphi)^j}{\left(1 + r^{CB}\right)^{j+1}} = \frac{1}{1 + r^{CB}} \frac{1 + r^{CB}}{r^{CB} + \varphi}$$

which implies that

$$r^F = r^{CB}.$$

We can write the formula (B) recursively:

$$\frac{1}{\varphi + r_t^F} = \frac{1}{1 + r_t^{CB}} + \frac{1-\varphi}{1 + r_t^{CB}} E_t \left\{ \frac{1}{\varphi + r_{t+1}^F} \right\}$$

or more compactly:

$$\frac{1}{\varphi + r_t^F} = \frac{1}{1 + r_t^{CB}} \left[1 + E_t \left\{ \frac{1-\varphi}{\varphi + r_{t+1}^F} \right\} \right].$$

Alternatively, we can work with log returns, i.e. with their log-linearized version. In this case the above formula rewrites:

$$\hat{r}_t^F = \hat{r}_t^{CB} + \frac{1-\varphi}{1+r} E_t \hat{r}_{t+1}^F$$

or in levels (up to a constant):

$$r_t^F = r_t^{CB} + \beta_P \left(1-\varphi\right) E_t r_{t+1}^F$$

or

$$r_t^F = \sum_{j=0}^{\infty} \left(\frac{1-\varphi}{1+r^{CB}}\right)^j r_{t+j}^{CB}.$$

C Steady state mortgage duration

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

$$D = \frac{\sum_{i=1}^{\infty} i \left(\frac{1-\varphi}{1+r}\right)^{i-1}}{\sum_{i=1}^{\infty} \left(\frac{1-\varphi}{1+r}\right)^{i-1}} = \frac{r+\varphi}{1+r} \sum_{i=1}^{\infty} i \left(\frac{1-\varphi}{1+r}\right)^{i-1} \tag{10}$$

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

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

Hence:

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

and from (10):

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

D Model with refinancing

The FRM model can be easily extended to allow for the possibility of refinancing the mortgage. We model refinancing by assuming that impatient households can refinance a fraction χ_t of their residual

FRM loan $(1-\varphi)D_{I,t-1}$ in each period. This implies that the interest rate on fraction χ_t of the existing debt can be "updated" in each period to the interest rate applied in the current period to new loans r_t^F. Hence, the law of motion of the interest rate now writes

$$r_t = (1-\tilde{\nu}_t)\, r_{t-1} + \tilde{\nu}_t r_t^F$$

with

$$\tilde{\nu}_t = \frac{L_{I,t}}{D_{I,t}} + \chi_t \frac{(1-\varphi)D_{I,t-1}}{D_{I,t}}$$

or in real terms:

$$\tilde{\nu}_t = \frac{l_{I,t} + \chi_t(1-\varphi)d_{I,t-1}/\pi_t}{d_{I,t}},$$

where $\chi_t \frac{(1-\varphi)d_{I,t-1}/}{\pi_t d_{I,t}}$ is the fraction of existing debt that is refinanced. In order to pin down a value for χ_t, we also assume that refinancing is subject to adjustment costs, as in (Garriga et al., 2013), of the form:

$$AC_t = \kappa\,(\chi_t - \chi)^2\,,$$

where χ is the share of existing debt that is refinanced in steady state. Therefore the problem for the borrower in each period consists in choosing the share of existing debt to be refinanced (ie. χ_t) that minimizes the sum of the stream of future installments on the mortgage and adjustment costs:

$$\min_{\chi_t} E_t \sum_{j=t}^{\infty} \beta_I^{j-t} \lambda_{I,j}\,(\varphi + r_{j-t-1})\,\frac{d_{I,j-t-1}}{\pi_j} + AC_t. \tag{11}$$

This minimization implies that

$$\chi_t = \chi - \beta_I \frac{(1-\varphi)\, d_{I,t-1}}{2\kappa}\,\frac{\lambda_{I,t+1}}{\pi_{t+1}}\left(r_t^F - r_{t-1}\right).$$

where it can be seen that the borrower refinances more than at the steady state if the current interest rate on new loans is lower that the interest rate on the stock, ie. $r_t^F < r_{t-1}$. The refinancing share decreases otherwise. The lender takes the refinancing decision of the borrower as given.

Garriga et al. (2013) set the steady state fraction of debt refinanced in each period equal to 2% (hence $\chi = 0.02$) and set $\kappa = 12$, which implies high adjustment costs and a rather inelastic refinancing activity. Instead, in order to magnifiy the effects of refinancing, we simulate the economy assuming a steady state refinancing share equal to $\chi = 0.2$. This would (irrealistically) imply that 20% of the existing stock of loans would be refinanced in each quarter. We also set the adjustment cost parameter κ at a very low value (0.005), thus implying a cheap refinancing activity.

The results of the model with refinancing are reported in Figure (8), where the response of inflation and output, along with the share of refinanced outstanding debt is reported under the two competing hypotheses of an expansionary conventional monetary policy shock that lowers the short term interest rate by 100bp and of an expansionary QE shock that lowers the term premium by 25bp.

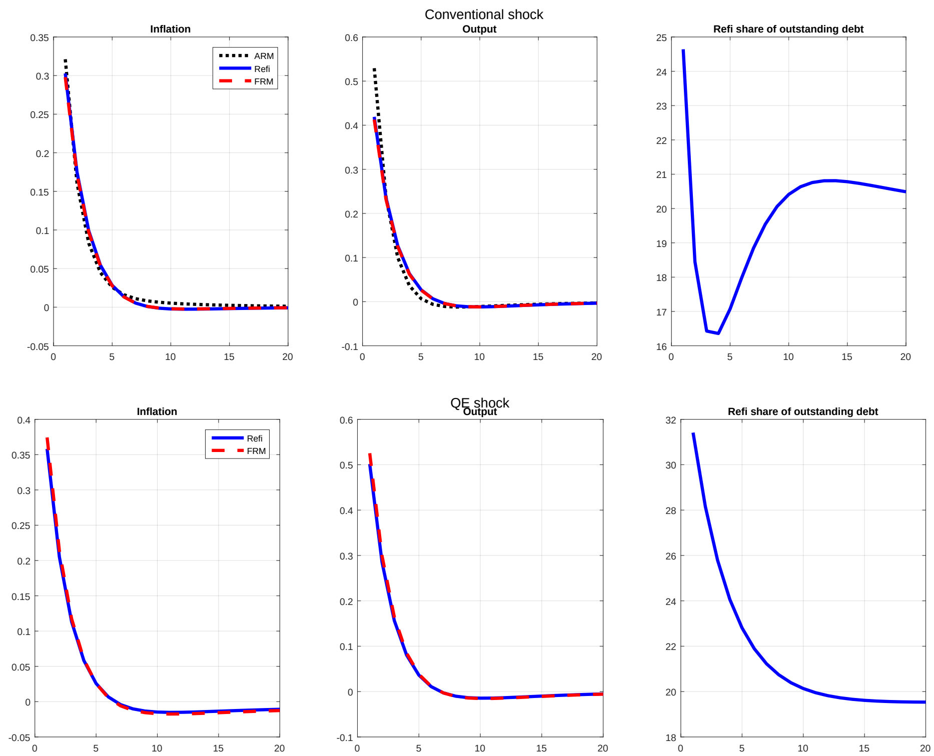

Figure 8: Model under ARM, FRM and refinancing
Note: in the figure the responses of inflation, output, and the refinancing share are plotted under a 25bp unexpected cut in the short term policy rate (upper panel) and under a 25bp unexpected cut in the term premium (lower panel).

For the conventional monetary policy shock we plot the IRFs of inflation and output under both the ARM and the two FRM cases: the one with no refinancing (red dashed line) and the one with refinancing (blue solid line). It can be observed that the dynamics of the model with refinancing is barely indistinguishable from the one of the FRM model with no refinancing. This notwithstanding the fact that the refinancing share varies significantly across the exercise, fluctuating from about 25% to 16% and then gradually converging at its 20% steady state level. For the QE shock instead we compare the response of inflation and output under the two competing hypoteses of refinancing and no refinancing. Also in this case, it can be observed that the reaction of the considered variables is barely distinguishable. If anything, the model with refinancing displays a more muted reaction in terms of inflation and output, although he refinancing shares almost doubles compared to its steady state value.