JMP

Giovanni Sciacovelli

July 29, 2024

Abstract

1 Introduction

To be written.

Related literature This study contributes to the literature studying how the efficacy of monetary policy is influenced by housing market characteristics, showing both empirically and theoretically that the interaction between MPCs and ARMs is an important amplifier of policy transmission. From an empirical standpoint, the significance of housing institutions for monetary policy transmission has been investigated by studies such as Slacalek, Tristani and Violante (2020), Cloyne, Ferreira and Surico (2020), Flodén et al. (2021), Battistini et al. (2022), and Corsetti, Duarte and Mann (2022). The findings in Di Maggio et al. (2017) are particularly relevant for this study: in the United States, interest rate transmission is more pronounced in areas with a higher proportion of ARMs and among lower-income households. Caspi, Eshel and Segev (2024) exploit an exogenous variation in the exposure to ARM due to a regulatory shift in Israel and unveil a similar pattern: households with a higher share of ARM mortgages decrease their consumption after a monetary policy tightening, with this effect being predominant across lower-income households.[1] For the Euro Area, similar findings are documented in Pica (2022) and Almgren et al. (2022). Pica (2022) shows stronger monetary policy transmission in those Euro Area countries where ARMs are more widespread, while Almgren et al. (2022) find that the impact of monetary policy shocks is correlated with the proportion of hand-to-mouth households in the economy. This paper contributes to this literature by showing that, in the Euro Area, higher shares of hand-to-mouth households and ARMs not only independently increase monetary policy transmission, but also interact to amplify this effect, making transmission particularly pronounced when both variables are elevated.

From a theoretical standpoint, monetary policy transmission through housing and mortgage markets has been explored extensively. Important contributions include Iacoviello (2005), Calza, Monacelli and Stracca (2013), Hedlund et al. (2016), Garriga, Kydland and Šustek (2017, 2021), and Greenwald (2018). Among these contributions, Corsetti, Duarte and Mann (2022) and Pica (2022) develop representative-agent open-economy

[1] Note that mortgage features in Israel are such that households have a fraction of their overall mortgage debt with is subject to adjustable rates. For such a reason, the authors refer to households with a *higher share of ARM mortgages*.

New-Keynesian models to show that, within the Euro Area, stronger transmission takes place where homeownership rates and ARM shares are higher. This paper contributes to this literature by developing an heterogeneous-agent model that allows to explore the role of MPCs for transmission through mortgages. The model shows that the ability of ARMs to amplify transmission depends on the level of the MPC in the economy, being particularly effective when MPCs are high.

The model developed in this paper builds on literature that incorporates heterogeneous agents into housing models, such as Beraja et al. (2019), Wong (2020), McKay and Wieland (2021), Eichenbaum, Rebelo and Wong (2022), and Berger et al. (2023).[2] In particular, the household block of the model used in this paper is based on Wong (2020), with two important distinctions. First, given the prominent role of ARMs in the Euro Area, the model incorporates this mortgage feature and disregards the refinancing option, much more widespread in the United States. Second, while Wong (2020) develops and OLG model due to the core role of life-cycle considerations her analysis, this paper employs a more standard infinitely-lived framework.

2 Empirics

The goal of my empirical exercises is to study the relative importance of MPCs and ARMs for monetary policy transmission across Euro Area countries. To achieve this goal, I implement three different exercises.

First, I conduct a cross-country analysis to examine the correlation between the strength of monetary policy pass-through and the share of hand-to-mouth households and of ARMs across Euro Area countries.[3] This analysis uses data from the Eurosystem's Household Finance and Consumption Survey (HFCS), which offers harmonized data from several European economies.[4] Following the approach in Almgren et al. (2022) and Pica (2022),

[2]Other important studies with heterogeneous agents investigating housing and mortgage institutions, albeit with lower emphasis on monetary policy transmission, are: Kaplan, Mitman and Violante (2020), Berger et al. (2018), and Guerrieri, Lorenzoni and Prato (2020).

[3]I use the share of hand-to-mouth households in an economy, constructed following the work by Kaplan, Violante and Weidner (2014), as a proxy for its MPC.

[4]The HFCS is conducted by the ECB, national central banks of the Eurosystem and national statistical agencies. The survey collects household-level data on household finances and consumption, similarly to

whose results I reproduce and extend, I first estimate the strength of monetary policy transmission in each Euro Area country independently, and then compute its correlation with the share of hand-to-mouth households and of ARMs.

After obtaining suggestive evidence of the importance of hand-to-mouth households and of ARMs for transmission from the first exercise, I use HFCS data to advance my investigation with a second exercise. In this analysis, I explore the correlation between the strength of monetary policy transmission and the share of hand-to-mouth households and of ARMs within a panel framework. By exploiting the varying exposures of countries to monetary policy shocks based on their levels of these two variables, I gather additional insights into their relationship with the strength of monetary transmission.

Finally, I complement these two exercises with one additional analysis. Relying on Italian data, for which time-series data on the share of hand-to-mouth households and ARMs are available, I perform a standard time-series analysis on the additional effect of a monetary policy shocks depending on the levels of ARMs and hand-to-mouth shares. Although this analysis lacks the cross-country perspective of the initial exercises, it enables me to leverage the variation in these variables within Italy to investigate the heterogeneous effects of a monetary policy shock depending on the two variables of interest.

The following sections will provide a detailed discussion of each exercise. Importantly, despite employing different methodologies, the evidence from the three exercises are consistent with each other, highlighting the significant role of ARMs, hand-to-mouth households, and their interaction in increasing monetary policy transmission across Euro Area countries.

2.1 Cross-country analysis

My main analysis employs data from the following Euro Area countries: Austria, Belgium, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.[5]

---

the Survey of Consumer Finances conducted by the Federal Reserve Board for families in the United States. Four waves of the survey have been carried out with an approximate triennial frequency: in 2010, in 2014, in 2017 and in 2021.

[5]These represent ten of the eleven early adopters of the Euro. Finland, the eleventh early adopter, is excluded from the main analysis due to the lack of data availability for its share of ARMs in HFCS.

The sample covers the period 1999Q1-2019Q4, ending before the beginning of the Covid-19 pandemic. For each country in the sample, my goal is to estimate the strength of monetary policy pass-through across Euro Area countries. To do so, I estimate the response of consumption to monetary policy shocks using the local projections method introduced by Jordà (2005). In particular, for each country c, I estimate the following regression:

$$y^c_{t+h} = \alpha^{h,c} + \beta^{h,c}\epsilon^{MP}_t + \sum_{j=1}^{p} \Gamma^{h,c}_j X_{t-j} + u^c_{t+h}, \qquad h = 0, \ldots, H \tag{1}$$

where y^c is the logarithm of consumption in country c, ϵ^{MP} is the monetary policy shock (I use the series constructed by Jarociński and Karadi; 2020), and X is a set of lagged control variables. The coefficients of interest are $\beta^{h,c}$, which capture the effect of a monetary policy shock on consumption in each country at different horizons.[6] In the baseline regressions I set the number of lags $p = 3$ and the horizon of the impulse responses to $H = 12$ quarters. The variables included as lagged controls are the left-hand-side variable, the monetary policy shock, GDP and CPI in country c, and Euro Area GDP, CPI and short-term interest rate.[7]

Figure 1 shows the maximum effect of a monetary policy shock on consumption over a 12-month period, which I use as a proxy for the strength of monetary policy transmission in each country in the sample. In line with previous findings in the literature, the figure shows that transmission is very heterogeneous in the Euro Area (e.g. Corsetti et al.; 2022; Almgren et al.; 2022; Pica; 2022).

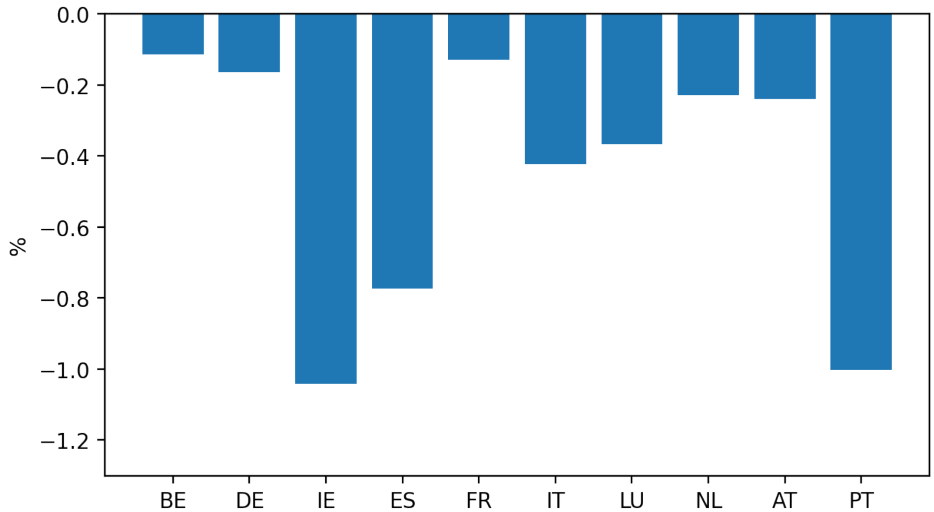
Since I want to investigate the correlation between the strength of monetary policy pass-through with the share of hand-to-mouth households and of ARMs, I proceed by constructing these variables using data from the HFCS.[8] The share of ARMs in an economy is computed as the fraction of outstanding mortgages with an adjustable-rate, while the share of hand-to-mouth households is constructed using the methodology pioneered by Kaplan, Violante and Weidner (2014). Intuitively, households are hand-to-mouth when their liquid balances are low relatively to their monthly incomes. Letting y_t denote monthly income, m_i denote liquid wealth and $\underline{m}_i$ denote a credit limit for household i, a household

[6]Appendix B.14 shows the impulse response functions of this coefficient for each Euro Area country in the sample.

[7]Appendix A details the sources of the data used in the analysis.

[8]My baseline analysis relies on data from the second wave of the survey. Appendix XXX shows that my results do not depend on the choice of the survey wave.

Figure 1: Maximum effect of a recessionary monetary policy shock on consumption



Notes: Responses to a one standard deviation shock. Each bar represents the maximum response of consumption within a 12-quarter period from the shock estimated using equation (1).

is categorized as being hand-to-mouth if:

$$\begin{cases} 0 \leq m_i \leq \frac{y_i}{2} & \text{if } m_i \geq 0 \\ m_i \leq \frac{y_i}{2} - \underline{m_i} & \text{if } m_i \leq 0. \end{cases} \tag{2}$$

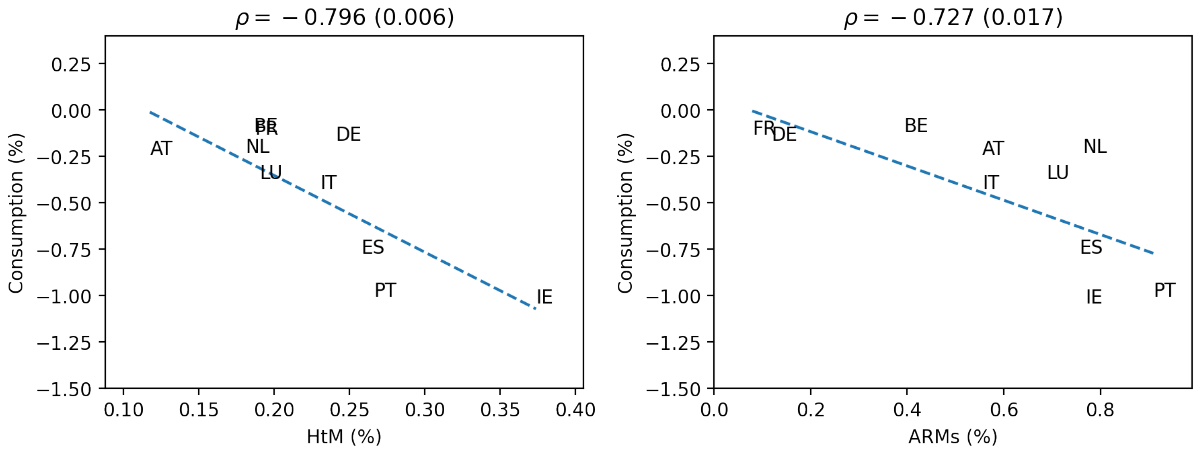
According to this definition, households are hand-to-mouth if their liquid balances are either less than half their monthly income or, in case of negative liquid balances due to credit card debt, less than half their income net of credit card debt repayment. ASK LAURA

Figure 2 shows the correlation between the maximum response of consumption to a monetary policy shock, my proxy for the strength of monetary policy transmission, and the shares of hand-to-mouth households and of ARMs.[9] In line with previous findings by Almgren et al. (2022) and Pica (2022), I find a strong correlation between the peak response of consumption and the two variables of interest. The correlation coefficients are large in magnitude (−0.796 and −0.727 for hand-to-mouth and ARMs, respectively) and have p-values below 5%.[10]

[9] Appendix XXX shows that the results are robust to considering the average effect of a monetary policy shock rather than its maximum effect.

[10] Appendix XXX shows that these results are robust to several alternative specifications as well as definitions of shares of ARMs.

Figure 2: Correlation between the response of consumption and HtM and ARMs shares



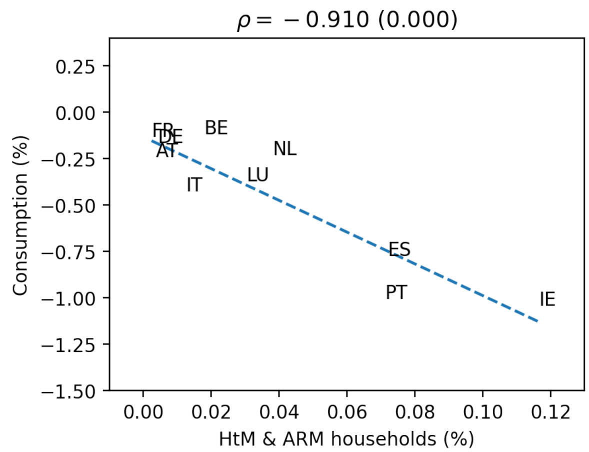
Notes: The y-axes show the peak response of consumption to a one standard deviation recessionary monetary policy shock estimated using equation (1). The x-axis of the left panel is the share of households classified as hand-to-mouth households in the HFCS according to equation (2); the x-axis of the right panel is the share of outstanding ARMs in each country in the HFCS. On top of each chart I show ρ, the correlation coefficient, together with its p-value in parenthesis.

Additionally, figure 3 displays the correlation between the peak response of consumption with the fraction of households in each country that are both hand-to-mouth and have an adjustable rate on their mortgage. This correlation is even stronger than the ones in figure 2, suggesting that monetary policy is particularly effective in those economies with high shares of liquidity constrained households who are also subject to rapidly adjusting rates on their mortgages.

2.2 Panel local projections (Explain better what the exercise does/estimates)

In my second exercise, I leverage the varying exposures of countries to monetary policy shocks, determined by their shares of hand-to-mouth households and ARMs, to estimate the effects of these two variables, as well as their interaction, on the strength of monetary transmission. Instead of estimating the effect of a monetary policy shock on each country individually, I set up my dataset as a panel and directly estimate the impact of hand-to-mouth households and ARMs on the strength of transmission. I again use data covering the period 1999Q1 to 2019Q4. Using the local projections method introduced by Jordà

Figure 3: Correlation between the response of consumption and shares of HtM households with ARMs



Notes: The y-axis shows the peak response of consumption to a one standard deviation recessionary monetary policy shock estimated using equation (1). The x-axis is the share of households classified as hand-to-mouth households according to equation (2) who have an adjustable-rate mortgage in the HFCS. On top of the chart I show ρ, the correlation coefficient, together with its p-value in parenthesis.

(2005), adapted for panel analysis, I estimate the following fixed-effects regression:

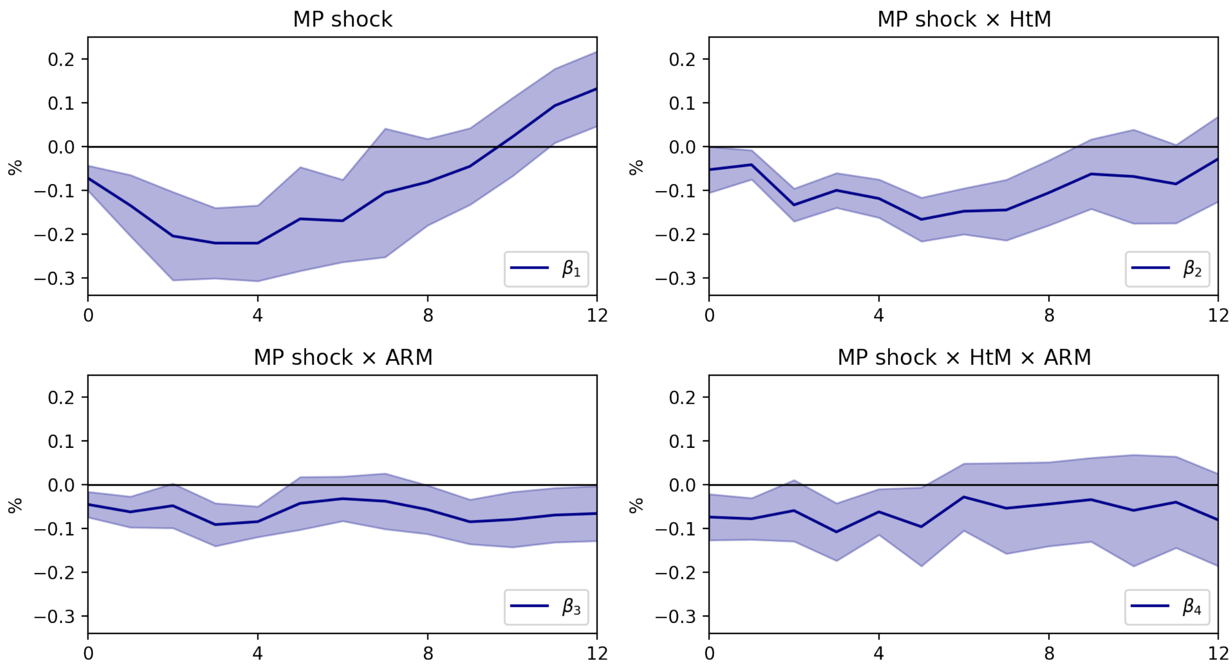
$$\begin{aligned} y^c_{t+h} =& \beta^h_0 + \beta^h_1 \epsilon^{MP}_t + \beta^h_2 \epsilon^{MP}_t HtM^c + \beta^h_3 \epsilon^{MP}_t ARM^c + \\ &+ \beta^h_4 \epsilon^{MP}_t HtM^c ARM^c + \Gamma^h X^{h,c} + u^c_{t+h}, \qquad h = 0, \ldots, H \end{aligned} \tag{3}$$

where y^c is the logarithm of consumption in country c, ϵ^{MP} is the monetary policy shock by Jarociński and Karadi (2020), ARM^c is the share of ARMs in country c in the second wave of the HFCS, HtM^c is the share of hand-to-mouth households in country c in the second wave of the HFCS, and X is a set of contemporaneous and lagged control variables.[11] The horizon of the impulse responses is set to $H = 12$ quarters. X includes the variables interacted with the monetary policy shock, two lags of the left-hand-side variable, two lags of the monetary policy shock, two lags of GDP and CPI in country c, and two lags of Euro Area GDP, CPI and short-term interest rate.

The coefficients of interest in this exercise are: β_1, which captures the effect of a monetary policy shock on the dependent variable when HtM and ARM are at their average values; β_2, which captures the additional effects of a monetary policy shock when HtM is one standard deviation higher than its average while ARM is at its average; β_3, which

[11] The variables HtM^c and ARM^c are standardized.

Figure 4: Response of consumption to a monetary policy shock

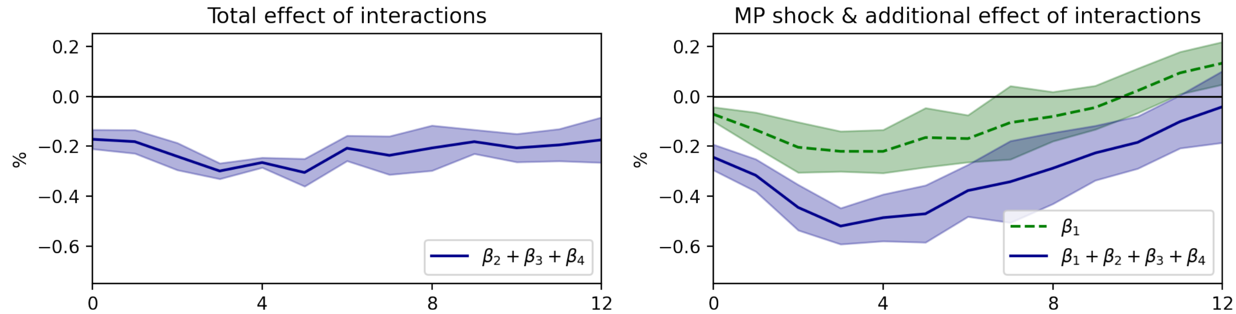


Notes: The dark blue lines in each panel show the evolution, over a 12-quarter horizon, of coefficients β_1 to β_4 estimated using equation (3). The shaded blue areas represent 90% confidence intervals.

captures the additional effects when ARM is one standard deviation higher than its average while HtM is at its average; and β_4, which is particularly interesting since it reflects the effects of the interaction between HtM and ARM, capturing the additional impact of the shock when both HtM and ARM are one standard deviation above their averages.

Figure 4 shows the impulse response function of the variables of interest estimated through the panel local projection model of equation (3). The top left panel shows that a one standard deviation recessionary monetary policy shock is associated with a statistically significant drop in consumption of up to ≈ -0.22 percentage points when HtM and ARM are at their averages. The top right panel shows the additional effect of a monetary policy shock when HtM is one standard deviation higher than its average, while the bottom right left shows the additional effect of a monetary policy shock when ARM is one standard deviation higher than its average. In both cases, there is a statistically significant additional drop in consumption when these variables are above their means. Comparing the magnitudes of the two effects, the impact of HtM appears to be larger. Finally, the bottom right panel displays the effect the interaction between HtM and ARM on the ef-

Figure 5: Total effect of interactions



Notes: The left panel shows the total additional effect of a recessionary one standard deviation monetary policy shock on consumption when HtM and ARM are one standard deviation above their averages (sum of coefficients β_2 to β_4 in equation (3)). The right panel compares the effect of the monetary policy shock when HtM and ARM are at their average (dashed green line) with the effect when HtM and ARM are one standard deviation above their averages (blue line). The shaded blue and green areas represent 90% confidence intervals.

fectiveness of monetary policy pass-through. When both HtM and ARM are one standard deviation above their means, a recessionary monetary policy shock is associated with an even larger drop in consumption, with a magnitude similar to that of the effect of high ARM (coefficient β_3, bottom left panel) which is statistically significant for approximately 6 quarters.[12]

To gather more insights on the effects of higher HtM and ARM on monetary policy transmission, figure 5 shows the total effect of the variables interacted with the monetary policy shock (coefficients β_2 to β_4) and compares it with the effect of the shock when HtM and ARM are at their averages. The panels show that the interactions are statistically significant and quantitatively important: when both HtM and ARM are one standard deviation above their means, the effect of a monetary policy shock approximately doubles (the maximum effect goes from ≈ -0.22 to ≈ -0.52).

[12] Appendix B.2 shows that the results presented in this section are robust to a set of alternative specifications.

2.3 Evidence using Italian data

In my third and last exercise, I focus my analysis on one individual country, Italy, and investigate how the impact of a monetary policy shock differs depending on the levels of hand-to-mouth households and ARMs.[13] Due to the limited availability of the HtM time series, this analysis relies on a short time frame relative to the previous one: the sample covers the period from 2007Q1 to 2019Q4. I again use local projections (Jordà; 2005) and estimate the following regression:

$$\begin{aligned} y_{t+h} = &\beta_0^h + \beta_1^h \epsilon_t^{MP} + \beta_2^h \epsilon_t^{MP} HtM_{t-1} + \beta_3^h \epsilon_t^{MP} ARM_{t-1} + \\ &+ \beta_4^h \epsilon_t^{MP} HtM_{t-1} ARM_{t-1} + \Gamma^h X^h + u_{t+h}, \qquad h = 0, \ldots, H \end{aligned} \tag{4}$$

where y is the logarithm of output in Italy, ϵ^{MP} is the monetary policy shock by Jarociński and Karadi (2020), HtM and ARM are the shares of hand-to-mouth households and ARMs, respectively, while X is a set of contemporaneous and lagged control variables.[14,15] The horizon of the impulse responses is set to $H = 12$ quarters. X includes the variables interacted with the monetary policy shock, two lags of the left-hand-side variable, two lags of the monetary policy shock, two lags of Italian GDP, CPI, overall mortgage rate and ARM rate, and two lags of Euro Area GDP, CPI and short-term interest rate.[16,17]

Similarly to my previous exercise, the coefficients of interest in this analysis are: β_1, which captures the effect of a monetary policy shock on the dependent variable when HtM and ARM are at their average values; β_2, which captures the additional effects of a monetary policy shock when HtM is one standard deviation higher than its average while ARM is at its average; β_3, which captures the additional effects when ARM is one standard deviation higher than its average while HtM is at its average; and β_4, which captures the effects of the interaction between HtM and ARM, measuring the additional

[13] The time series for the share of hand-to-mouth households was provided by the authors of Slacalek, Tristani and Violante (2020), who could reconstruct it based on the exercises they implement in their analysis. The time series for the share of outstanding ARMs was provided by economists at the Bank of Italy. I am grateful to both for sharing their me.

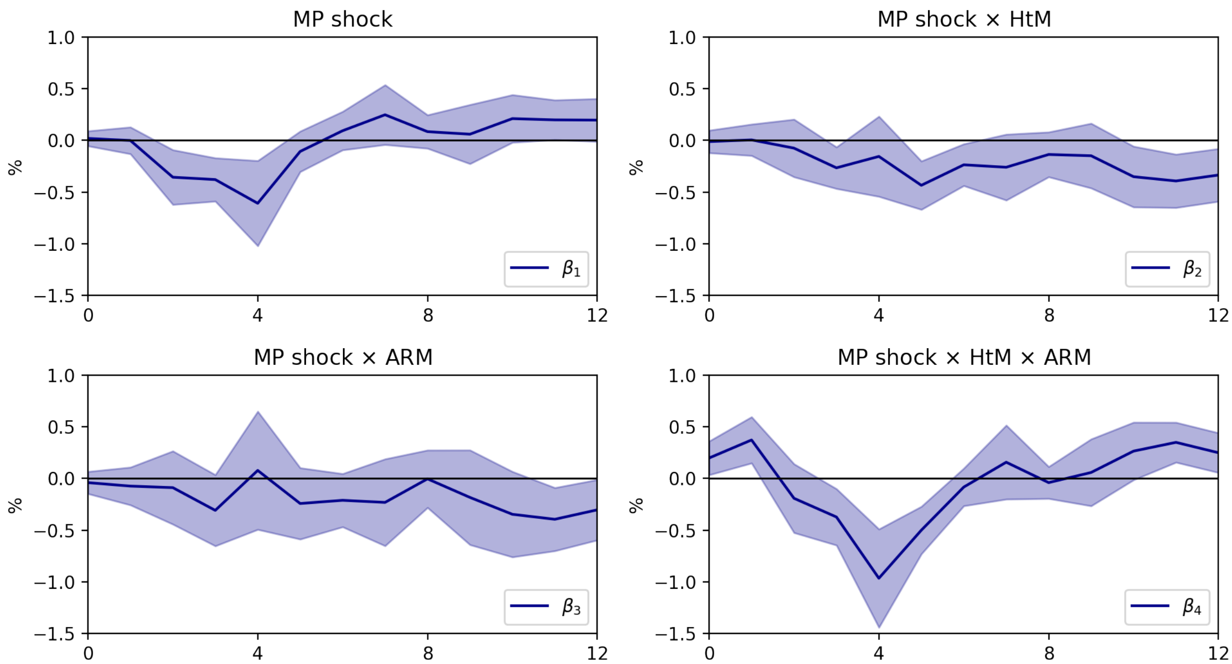
[14] Note that the time subscripts on ARM and HtM imply that the regression estimates the differential effect of a monetary policy shock depending on the hand-to-mouth and ARM shares in the quarter *prior* to the shock.

[15] The variables ARM and HtM are standardized.

[16] Appendix XXX contains a detailed description of the variables used in the analysis.

[17] See appendix B.3 for results obtained using alternative specifications.

Figure 6: Italy – Response of consumption to a monetary policy shock

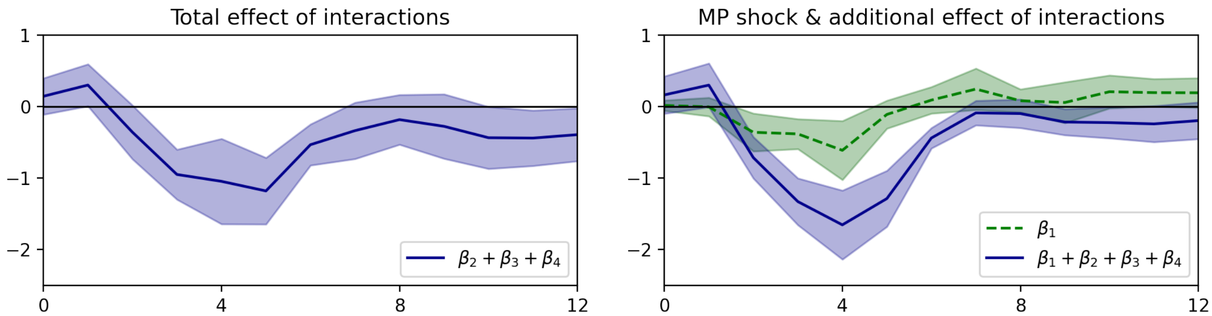


Notes: The dark blue lines in each panel show the evolution, over a 12-quarter horizon, of coefficients β_1 to β_4 estimated using equation (3). The shaded blue areas represent 90% confidence intervals.

impact of the shock when both HtM and ARM are one standard deviation above their averages.

Figure 6 shows the impulse response functions of variables β_1 to β_4 in the local projection model of equation (4). Qualitatively, the Italian results are in line with those estimated for the Euro Area displayed in figure 4. The top left panel shows that a one standard deviation recessionary monetary policy shock is associated with a statistically significant drop in consumption of up to ≈ -0.61 percentage points when HtM and ARM are at their averages. The top right panel shows that, when HtM is one standard deviation higher than its average, the effect of a monetary policy shock tends to be larger: the coefficients are negative, with a peak of ≈ -0.44, and they are often statistically significant. The bottom left panel shows the additional effect of a monetary policy shock when ARM is one standard deviation higher than its average. The coefficients are negative, signalling that ARMs tend to strengthen monetary policy transmission but, differently from figure 4, they are not statistically significant. Finally, the bottom right panel shows that, when both HtM and ARM are one standard deviation above their means, a recessionary mon-

Figure 7: Italy – Total effect of interactions



Notes: The left panel shows the total additional effect of a recessionary one standard deviation monetary policy shock on consumption when HtM and ARM are one standard deviation above their averages (sum of coefficients β_2 to β_4 in equation (3)). The right panel compares the effect of the monetary policy shock when HtM and ARM are at their average (dashed green line) with the effect when HtM and ARM are one standard deviation above their averages (blue line). The shaded blue and green areas represent 90% confidence intervals.

etary policy shock is more effective, with a statistically significant peak effect of ≈ -0.97. It is interesting to note that ARMs, despite not being statistically significant in Italy, are important when combined with a higher share of hand-to-mouth households to increase monetary policy pass-through confirming the interesting complementary between these variables found in the panel exercise of equation (3).[18]

To obtain an overall picture of the effects of a monetary policy shock depending on the levels of HtM and ARM, figure 7 shows the total effect of the variables interacted with the monetary policy shock (coefficients β_2 to β_4) and compares it with the effect of the shock when HtM and ARM are at their averages. When HtM and ARM are higher, monetary policy transmission is stronger: the peak effect is ≈ -1.65 versus a peak effect of ≈ -0.61 when these variables are at their mean values.

2.4 Empirical analysis: Summary of key findings

The empirical results presented in this section contribute to the existing literature on the effects of monetary policy across Euro Area countries, particularly in relation to the role

[18] Appendix B.3 shows that the results presented in this section are robust to a set of alternative specifications.

of the share of hand-to-mouth households and ARMs. Previous studies have typically examined the impact of these variables independently (e.g., Corsetti et al.; 2022; Almgren et al.; 2022; Pica; 2022). However, my analysis reveals that it is important to consider their combined effects on the strength of monetary transmission. As shown in sections 2.2 and 2.3, the shares of hand-to-mouth households and ARMs not only amplify transmission in isolation, but also interact in a complementary manner. This interaction significantly increases monetary policy pass-through, making it particularly strong when both variables are elevated. This finding highlights that, in order to fully understand the mechanism through which monetary policy transmits through mortgages, it is important to account for the joint impact of these variables.

3 Model

This section describes the model I developed to understand the mechanisms through which MPCs and ARMs interact in the transmission of monetary policy. The model combines a standard HANK framework, as outlined in Auclert, Rognlie and Straub (2023), with a household block that incorporates housing and mortgage decisions, following the approach of Wong (2020). This structure allows for heterogeneity in both MPCs and ARMs, allowing the investigation of how each of these, as well as their interaction, influences monetary policy transmission.

The main intuition of the model is as follows. Households experience idiosyncratic productivity shocks, leading to income heterogeneity that affects both their MPC and their mortgage choices: poorer households have higher MPCs and tend to opt for mortgages with higher loan-to-value ratios. When a monetary policy shock occurs, the mortgage payments of households with ARMs are immediately impacted due to the swift pass-through of short-term interest rates to mortgage rates, affecting their available resources for consumption. While wealthier households, whose mortgage payments constitute a small fraction of their overall income, will hardly change their consumption choices, poorer households, who have higher MPCs, will need to make significant adjustments. Therefore, the impact of a monetary policy shock through the mortgage channel is stronger the higher the fraction of households with ARMs, since they are the ones who experience changes in mortgage payments, and the greater the prevalence of high MPC households, since they are the ones making larger consumption adjustments.

The model is primary used to interpret the empirical evidence presented in the previous section and to quantify how variations in MPCs and ARMs across Euro Area countries contribute to the differences in monetary policy transmission they experience. In addition, I use the model to study the welfare consequences of a monetary policy shock depending on the MPC and ARM levels in an economy. This analysis helps to shed light on the recent policy measures implemented by the Spanish government to help less affluent families after the post-Covid rate hike by the ECB.[19]

This section is organized as follows. First, I describe each of the model blocks in turn. Second, I present the model calibration. Third, I discuss the performance of the model in matching some important untargeted moments.

3.1 Model blocks

I start the model description with the households block, where I follow the approach of Wong (2020). This is the most involved part of the model, as it involves households making both discrete and continuous choices. Subsequently, I introduce the additional blocks required to close the model in general equilibrium. These components are largely standard, and I follow the framework in Auclert, Rognlie and Straub (2023).

Preferences Time is discrete and the economy is populated by a unit mass of infinitely lived households indexed by i. Households discount the future at rate β. The momentary utility of a household is given by:

$$u(c,h,n) = \frac{\left(c^{\alpha}h^{1-\alpha}\right)^{1-\sigma} - 1}{1-\sigma} - \psi \frac{n^{1+\phi}}{1+\phi} \tag{5}$$

where $\sigma > 0$. c and h denote flexible consumption and the stock of housing, respectively, while n represents hours worked. This specification assumes that the service from housing is equal to its stock, in line with Eichenbaum, Rebelo and Wong (2022). Households cannot freely adjust their housing stock, but may always freely adjust the other consumption good.

[19]The description of the measures adopted by the Spanish government can be found here.

Housing stock Households enter each period with a stock of housing inherited from the previous period. The law of motion for the housing stock is

$$h' = (1 - \delta)h, \tag{6}$$

which dictates that the stock that households inherit is $(1 - \delta)h$, where h is the previous period's housing stock and δ is the rate of depreciation.

Each period, households must choose whether to change their house or remain in their current one. In either case, their updated housing stock h' will be the relevant one for the period's utility. If households decide to change, they have to sell the house they inherited. Revenues from the sale are $(1 - f)p(1 - \delta)h$, where p is the price of a unit of housing stock and f is a proportional adjustment cost which captures the loss that households incur when they decide to change their house.[20] Households then purchase a new house h' at price p.

In aggregate, the overall amount of housing available is in fixed supply $\bar{H}$, so that movements in house prices are determined by changes in the demand for housing coming from the households block of the economy.

Income process Households are subject to idiosyncratic uncertainty. In particular, income of household i at time t is

$$y_{i,t} = w_t e_{i,t} n_{i,t} \tag{7}$$

where w_t is the real wage in the economy at time t, $n_{i,t}$ are hours worked by the household in the period, and $e_{i,t}$ is the household's current productivity. Following standard practice in the literature (e.g., Guerrieri and Lorenzoni; 2017; Auclert, Rognlie and Straub; 2020, 2023), I assume that $e_{i,t}$ behaves according to the following AR(1) process:

$$\log e_i' = \rho_e \log e_i + \epsilon_i \tag{8}$$

where $|\rho_e| < 1$ and ϵ_i is an idiosyncratic shock drawn from a normal distribution with standard deviation σ_e. Accordingly, at each point in time, households will vary in their

[20]This is a standard feature of housing models (see, e.g., Kaplan and Violante; 2014; Kaplan et al.; 2018; Berger et al.; 2018; Wong; 2020; Eichenbaum et al.; 2022) which captures the closing fees and costs that are associated with the sale of a house. In addition, adjustment costs lead households to change their house infrequently, which is a realistic feature of the model.

productivity level $e_{i,t}$. This feature of the model, together with the presence of a borrowing constraint, implies that households will have different MPCs. Since the aim of this study is to analyze how the effectiveness of ARMs depends on MPCs, this is a crucial feature of the model.

Risk-free assets Households can invest in one-period ahead risk-free assets. A household's position in these assets is denoted by a'. These assets pay interest rate r. I introduce incomplete markets in the economy by constraining households to save in these assets, that is, $a' \geq 0$.

Mortgages Households may take out loans with their house as collateral. These loans are modelled as a proportional repayment plan: each period, household pay back a fixed proportion of the remaining balance, μ. Accordingly, a household that inherits a mortgage level b will see their mortgage balances evolve according to:

$$b' = (1 - \mu)b. \tag{9}$$

Households can open a mortgage only to finance part of their housing purchase:

$$b' \in [0, \lambda p h'] \tag{10}$$

where λ is a pre-specified loan-to-value cap, p is the price of a housing unit and h' is the level of the housing stock a household wants to purchase. Hence, households cannot use the mortgage as a saving device (the mortgage amount needs to be positive) and can borrow up to a fraction λ of the value of the house they wish to buy.

The total payment for a household entering the period with a mortgage level b is calculated as $(r^b + \mu)b$, where

$$r^b = r + \Delta^b \tag{11}$$

represents the mortgage interest rate, comprising the risk-free rate r and a constant spread Δ^b. After a monetary shock, only households with an ARM will experience changes in their mortgage payments due to adjustments in r^b. In contrast, households with a FRM will see no change in r^b due to the fixed nature of their mortgage contracts, ensuring their monthly payments remain stable. Within the economy, γ represents the fraction of households with an ARM, while $(1-\gamma)$ represents the fraction with a FRM.

The total amount of mortgage debt at time t is given by $B = \int b^i(e,h,b,a)di$. At each point in time, households collectively pay financial intermediaries an amount equal to $r^b B$ and borrow additional resources through mortgages equal to $\Delta B = B' - B$. Therefore,

$$\Omega = \Delta B - r^b B \tag{12}$$

represents the net new resources available to households through the mortgage markets.

Value functions The vector of household states is $\{e,h,b,a\}$, which captures the productivity level e, the housing stock h, the mortgage balance b and the liquid balance a that a household enters the period with. At each point in time, households need to make a discrete choice and decide whether to buy a new house and possibly open a new mortgage, or staying in their current home. The value functions associated with these two choices, buying or staying, are denoted by $V^{buy}(e,h,b,a)$ and $V^{stay}(e,h,b,a)$, respectively. The overall value function is

$$V(e,h,b,a) = \max\{V^{buy}(e,h,b,a), V^{stay}(e,h,b,a)\}. \tag{13}$$

A common problem in models with discrete choices is that, due to the presence of the *max* operator, there can be kinks in the value function and discontinuities in the agents' optimal policy functions for continuous variables. As a consequence, it is not possible to make use of derivatives in the solution algorithm, which creates significant complications when solving these models.[21] To overcome these problems, I follow the methodology in Iskhakov et al. (2017), Bardóczy (2022) and Beraja and Zorzi (2024), and rewrite the overall value function as:

$$V(e,h,b,a) = \max\{V^{buy}(e,h,b,a) + \sigma_\epsilon \epsilon_b, V^{stay}(e,h,b,a) + \sigma_\epsilon \epsilon_s\} \tag{14}$$

where ϵ_b and ϵ_s are independent and identically distributed (iid) taste shocks drawn from a type 1 extreme value (Gumbel) distribution with scale parameter σ_ϵ.[22] The computational value of the taste shocks is to smooth out the value function around the discrete

[21] In particular, this implies that the endogenous grid-point method (EGM) developed by Carroll (2006) cannot be applied.

[22] These are linearly additive taste shocks à la McFadden (1973).

choice, allowing the use of derivatives in the solution algorithm. In addition, the use of taste shocks allows the model to better capture the fact that, in reality, the probability of choosing to buy a new house changes smoothly: without them, the model would imply a discontinuous change in these probabilities as soon as $V^{buy}(e,h,b,a)$ exceeds $V^{stay}(e,h,b,a)$.

The assumption on the distribution of the taste shocks implies that the probability that a household chooses to change their housing stock as a function of their state $\{e,h,b,a\}$ is given by the multinominal logit form:

$$P(b|e,h,b,a) = \frac{exp\left(\frac{V^{buy}(e,h,b,a)}{\sigma_\epsilon}\right)}{exp\left(\frac{V^{buy}(e,h,b,a)}{\sigma_\epsilon}\right) + exp\left(\frac{V^{stay}(e,h,b,a)}{\sigma_\epsilon}\right)} \tag{15}$$

and the value function is given by:

$$V(e,h,b,a) = \sigma_\epsilon \log\left(exp\left(\frac{V^{buy}(e,h,b,a)}{\sigma_\epsilon}\right) + exp\left(\frac{V^{stay}(e,h,b,a)}{\sigma_\epsilon}\right)\right). \tag{16}$$

Finally, I will introduce the value functions associated with the two discrete choices. Households that decide to purchase a new house, the *buyers*, have decisions that are characterized by the following value function:

$$\begin{aligned} V^{buy}(e,h,b,a) = \max_{c,h',b',a'} u(c,h') + \beta \mathbb{E}\left[V(e',h',b',a')|e\right] \\ \text{s.t. } c + a' + ph' - b' \leq y + (1+r)a - (1+r^b)b + p(1-f)(1-\delta)h - \tau \\ b' \in [0, \lambda ph'] \\ a' \geq 0 \end{aligned} \tag{17}$$

where $u(c,h')$ is specified in equation (5), y in equation (7), and τ represents lump-sum taxes that households pay to the government. According to this definition, households that choose to buy a new house make four continuous choices: the size of their consumption basket c, the size of their new house h', the size of their new mortgage debt b' used to cover part of the housing cost ph', and the amount of resources to save in the form of liquid assets a'. Importantly, before buying a new house and opening a new mortgage, household have to close any outstanding mortgage debt they still owe, making an overall payment equal to $(1+r^b)b$, and need to sell any house they already own, making a revenue equal to $p(1-f)(1-\delta)h$.

Stayers, those households that decide to remain in their current home, have decisions that are characterized by the following value function:

$$
\begin{aligned}
V^{stay}(e,h,b,a) = \max_{c,a'} u(c,h') + \beta \mathbb{E}\left[V(e',h',b',a')|e\right] \\
\text{s.t. } c + a' \leq y + (1+r)a - M - \tau \\
M = (r^b + \mu)b \\
h' = (1-\delta)h \\
b' = (1-\mu)b \\
a' \geq 0
\end{aligned}
\tag{18}
$$

where $u(c,h')$ is specified in equation (5), y in equation (7), and τ represents lump-sum taxes that households pay to the government. In this case, households face a standard consumption-saving problem where part of their resources are used to cover mortgage payments M. These payments contribute to the reduction of their mortgage debt in line with the dynamics of equation (9).

This section concludes the description of the households block, the most complex part of the model. The following paragraphs detail the additional blocks I introduce to close the model in general equilibrium.

Labor market The economy is characterized by sticky wages, which I introduce following the setup in Auclert, Rognlie and Straub (2023).[23,24] Each household i is assumed to provide their hours of work, n_i, to a continuum of unions indexed by k. Each union k aggregates efficient hours into a union-specific task, $N_{k,t} = \int e_{i,t} n_{i,k,t}$, where $n_{i,k,t}$ are the hours that household i provides to union k. Union-specific tasks are then aggregated into employment services, N_t, through a CES aggregator with elasticity of substitution ϵ:

$$
N_t = \left(\int_k N_{k,t}^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}. \tag{19}
$$

Employment services are then sold to firms at the nominal wage W_t. The union sets the wage as to maximize the average utility of its members subject to an extra additive

[23]Earlier contributions using a similar framework are Erceg, Henderson and Levin (2000) and Schmitt-Grohé and Uribe (2005).

[24]Sticky wages have been shown to have better properties within the context of heterogeneous-agent models relative to sticky prices by Auclert, Bardóczy and Rognlie (2023).

quadratic disutility term: $\frac{\xi}{2}\int_{\kappa}\left(\frac{W_{\kappa,t}}{W_{\kappa,t-1}}-1\right)^2$.[25] The union allocates hours demanded by firms equally across its members, so that all households end up working the same amount of hours. This setting then implies the following Wage New Keynesian Phillips Curve:

$$\pi_t^W = \kappa\left(\frac{v'(N_t)}{\frac{\epsilon}{\epsilon-1}w_t(u_c'(C_t, H_t, N_t))} - 1\right) + \beta\pi_{t+1}^W, \tag{20}$$

where $\pi_t^W = \frac{W_t}{W_{t-1}} - 1$ and $\kappa = \frac{\epsilon}{\xi}$. Intuitively, equation (20) implies that the union will set higher nominal wages W_t whenever the marginal cost from an additional hour of work exceeds its marginal benefit.

Final goods producers Perfectly competitive producers operate a simple linear production technology:

$$Y_t = L_t, \tag{21}$$

where Y_t is aggregate output and L_t is aggregate employment. The optimization problem of the firm implies:

$$P_t = W_t \tag{22}$$

where P_t is the final goods price. This condition implies

$$\pi_t = \frac{P_t}{P_{t-1}} - 1 = \frac{W_t}{W_{t-1}} - 1 = \pi_t^W, \tag{23}$$

so that goods price inflation and wage inflation are equal, with sticky wages translating into sticky prices.

Government The government sets tax revenues T_t to be collected from households (i.e., $T_t = \int \tau^i di$).[26] Accordingly, outstanding debt at the end of each period is

$$D_t = (1 + r_{t-1})D_{t-1} - T_t \tag{24}$$

where D_t is real government debt. I assume that the government follows a tax rule to keep its debt constant over time:

$$T_t = r_{t-1}D_{t-1} \tag{25}$$

[25]Note that these are standard Rotemberg (1982) adjustment costs.

[26]Note that I disregard public spending in my analysis.

which states that the government collects tax revenues to cover its interest payments and any public expenditure, keeping the outstanding amount of debt at the end of the period unchanged.

Monetary policy The monetary authority sets the nominal interest rate, i_t, following a standard Taylor rule that targets price-index inflation[27]

$$i_t = r^* + \phi_\pi \pi_t + \epsilon_t^m \tag{26}$$

where r^* denotes the zero-inflation real rate, $\pi_t = \frac{P_t}{P_{t-1}} - 1$ and ϵ_t^m is the monetary policy shock. Given this rule for the nominal interest rate, the real interest rate is defined by the the Fisher equation

$$1 + r_t = \frac{1 + i_t}{1 + \pi_{t+1}}. \tag{27}$$

Combining equations (26) and (27), it follows that the real rate in this economy will be equal to:

$$1 + r_t = \frac{1 + r^* + \phi_\pi \pi_t}{1 + \mathbb{E}_t \pi_{t+1}}. \tag{28}$$

Equilibrium Given an initial wealth distribution $\mathcal{D}_{-1}(a, e)$, an initial nominal wage W_{-1}, idiosyncratic states e, a monetary policy rule defined in equation (26), an initial government debt D_{-1}, and a tax rule for T_t in equation (25) that satisfies the intertemporal government budget constraint in (24), a general equilibrium is a path for prices and aggregates, $\{P_t, W_t, \pi_t, \pi_t^W, r_t, i_t, p_t\}$ and $\{Y_t, N_t, C_t, H_t, D_t, B_t, T_t\}$, policies for households

$$\{c_t^i(e,h,b,a), a_t^i(e,h,b,a), h_t^i(e,h,b,a), b_t^i(e,h,b,a)\}_{i \in \{buy, stay\}}$$

and distributions $\mathcal{D}_t(a, e)$, such that households optimize, unions optimize, firms optimize, fiscal and monetary authorities follow their rules, and assets, labor, housing and

[27]Note that I assume the central bank does not respond directly to changes in output, in line with the inflation-targeting regime adopted by the ECB.

goods markets clear:[28]

$$A_t = \int a_t^i(e,h,b,a)di = D_t \tag{29}$$

$$N_t = \int e_t^i n_t^i(e,h,b,a)di = L_t \tag{30}$$

$$H_t = \int h_t^i(e,h,b,a)di = \bar{H}_t \tag{31}$$

$$Y_t = C_t + p_t\delta\bar{H}_t + p_t f(1-\delta)\int^{i\in buy} h_t di - \Omega_t. \tag{32}$$

3.2 Calibration

The model is calibrated to a reference country: Spain. This country is chosen to facilitate comparability with other similar Euro Area studies, such as Corsetti, Duarte and Mann (2022) and Pica (2022), which use Spain as their reference economy. I use European data sources, which provide information on the Spanish economy, to calibrate most parameters of the model. Nonetheless, a few parameters have not been estimated for Spain nor for any other European economy. For these parameters, which I discuss below, I rely on US estimates.

Two parameters are particularly critical in the analysis, since they control the MPC and the share of households with ARMs: β and γ. Since my goal is to study the role that MPCs and ARMs play in the transmission of monetary policy, I first calibrate these parameters for the Spanish economy, and then conduct counterfactual exercises modifying β and γ. These exercises allow me to investigate how variations in MPCs and ARMs affect monetary pass-through.

Households The model is calibrated to a quarterly frequency. The coefficient of risk aversion σ, and the coefficient capturing the inverse Frisch elasticity ϕ, are both set to 2, standard values in the literature (see, e.g., McKay, Nakamura and Steinsson; 2016). The parameter ψ, which captures the coefficient on disutility from labor, is set to 0.789 to normalize aggregate steady-state output to 1.

The discount rate β is set to match the average liquid asset holdings net of mortgage

[28] See appendix C.1 for a derivation of the goods markets clearing condition.

Table 1: Parameter Values

Parameter	Explanation	Value	Target/Source
Households			
β	Discount factor	0.972	Net assets/GDP=0.53
σ	Inverse EIS	2	Standard value
ϕ	Inverse Frisch	2	Standard value
ψ	Labor disutility coefficient	0.789	$Y^{ss} = 1$
α	Consumption share	0.901	H/C ratio=5.96
r	Short-term interest rate	1.05%	Mean Eonia rate 2003-2018
ρ_e	Persistence, productivity	0.967	McKay, Nakamura and Steinsson (2016)
σ_e^2	Variance, productivity	0.033	McKay, Nakamura and Steinsson (2016)
σ_ε	Scale parameter	0.1	Beraja and Zorzi (2024)
$\underline{a}$	Borrowing constraint	0	McKay, Nakamura and Steinsson (2016)
Housing			
γ	ARM share	75.6%	ECB HFCS
Δ^b	Mortgage rate spread	1.95%	Mean mortgage rate 2003-2018
f	Adjustment cost	0.1	OECD (2012)
λ	Mortgage borrowing limit	0.85	Pica (2022)
δ	Yearly housing depreciation	2%	BEA estimate (Fraumeni; 1997)
μ	Mortgage repayment speed	0.015	Mortgage maturity $T = 25$ years
$\bar{H}$	Housing stock	5.62	$p^{ss} = 1$
Unions			
ϵ	Steady-state wage markup	11	Auclert et al. (2021)
κ	Slope of Phillips curve	0.1	Auclert et al. (2021)
Policy			
ϕ_π	Taylor rule coefficient	1.5	Standard value

Notes: See text for a discussion on the sources and targets.

debt to annual GDP ratio over 2012–2018 of 0.53.[29] The parameter α, controlling for the

[29] The time period 2012-2018 is the one available in the ECB Distributional Wealth Accounts (DWA), the source of data for this calibration. To compute liquid assets, I match the categories in Guerrieri and Lorenzoni (2017) and McKay, Nakamura and Steinsson (2016), which provide a definition of liquid assets for the US, in the DWA. In particular, I sum the following entries: Deposits, Debt Securities, Listed Shares, and Investment Fund Shares. The entry Mortgage Debt accounts for mortgages in the calculation of net assets.

non-durable share in the utility function, is calibrated to match the average housing stock to annual consumption ratio over 2012–2018 of 5.96.[30] These targets yield $\beta = 0.972$ and $\alpha = 0.901$.

The short-term interest rate, r, is set to the average annual short-term rate in the Euro Area (Eonia) during the 2003-2018 period: 1.05%. Following standard practice in the literature (see, e.g., McKay, Nakamura and Steinsson; 2016; Wong; 2020), the borrowing constraint on these assets is set to 0, so that households are only allowed to borrow though mortgages.

The persistence and variance of the productivity process described in equation (7), ρ_e and σ_e^2, have not been estimated for Spain. Accordingly, they are calibrated following McKay, Nakamura and Steinsson (2016), which rely on US estimates by Floden and Lindé (2001). The autoregressive coefficient ρ_e is set to 0.967, matching the evidence in Floden and Lindé (2001). With regards to the variance of the process, the evidence in Floden and Lindé (2001) would imply $\sigma_e^2 = 0.017$. Nonetheless, McKay, Nakamura and Steinsson (2016) discuss how such a value would imply too little volatility in earnings relative to the more recent empirical evidence in Guvenen, Ozkan and Song (2014), and therefore consider the calibration with $\sigma_e^2 = 0.033$. Since additional evidence as shown that earning volatility is much larger than previous annual estimates would imply (Ganong et al.; 2024), I use this higher value in my calibration. The process is discretized into five states using the Rouwenhorst method.

The scale parameter σ_ε in equation (14) is chosen based on the analysis in Beraja and Zorzi (2024): given the evidence in Bachmann et al. (2021), which is particularly important within my context since it relies on European data, $\sigma_\varepsilon = 0.1$ is deemed to be a reasonable value for this parameter.

Housing The share of households with an ARM is taken from the HFCS, where it stands at 75.6% for Spain. In order to implement counterfactual exercises targeting other Euro Area countries, this number is adjusted to reflect the share of ARMs that these countries have in the HFCS.

[30]The entry Housing Wealth in the DWA accounts for the end-of-period housing stock used to compute the H/C ratio.

The spread between the risk-free rate r and the mortgage rate r^b, Δ^b, is set to match the average annual mortgage rate in Spain over the period 2003-2018. Since the average is equal to 3%, the spread is set to 1.95%. The rate of depreciation of the housing stock, δ, is set to an annual value of 2%, in the middle of the estimates of the Bureau of Economic Analysis (Fraumeni; 1997). The parameter governing the speed of mortgage repayment, μ, is set to 0.015 to match the typical duration of a Spanish mortgage, where the average mortgage maturity is 25 years (van Hoenselaar et al.; 2021). Appendix C.2 provides additional details on the procedure followed to calibrate this parameter.

In line with the evidence provided in OECD (2012), the parameter f controlling the fraction of transaction fees associated with the sale of housing is calibrated to 10% for Spain. This is larger than the estimate of 5% which is commonly used in the literature (see, e.g., Berger et al.; 2018; Wong; 2020; Diaz and Luengo-Prado; 2010), accounting for the larger transaction costs that characterize housing sales across European economies.

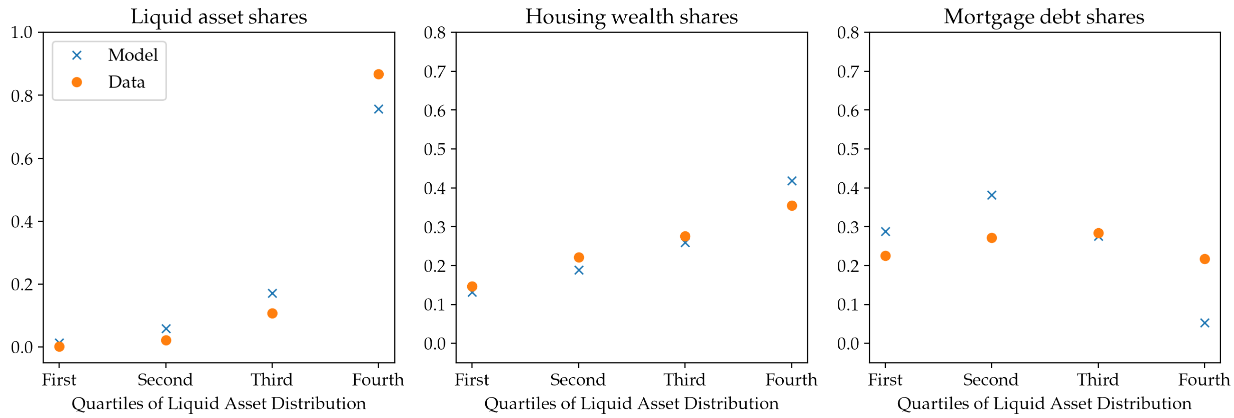
The parameter governing the maximum loan-to-value ratio, λ, is set to match the evidence in Pica (2022). This parameter is calibrated to 0.85, slightly higher than its standard value of 0.8 (see, e.g., Berger, Guerrieri, Lorenzoni and Vavra; 2018; McKay and Wieland; 2021), in line with the empirical LTVs across Euro Area countries. The fixed supply of housing stock, $\bar{H}$, is set to normalize the the steady-state price of housing to 1.

Firms and policy The parameters controlling unions and policy behaviours are taken from Auclert et al. (2021), and are standard ones used in the literature. In particular, the elasticity of substitution parameter ϵ in equation (19) is chosen to match a steady-state markup of 11. The parameter κ accounting for the slope of the Phillips curve is set to 0.1. Finally, the Taylor rule coefficient ϕ_π in equation (26) is set to 1.5.

3.3 Model fit

This section shows that the model is able to match important untargeted moments in the data. Figure 8 compares the distribution of assets and mortgage debt in the model and in the HFCS data. The model successfully replicates the upward trends in the distribution of liquid assets and housing wealth. Notably, the fourth quartile of the liquid asset distribution owns the vast majority of assets (approximately 80% in both the model and the data)

Figure 8: Distributions of assets and debt: Model vs data



Notes: In each panel, households are ranked based on their position in the liquid asset distribution. Each dot represents the average value of the variable of interest within a specific quartile in the model (in blue) and in the HFCS data for Spain (in orange).

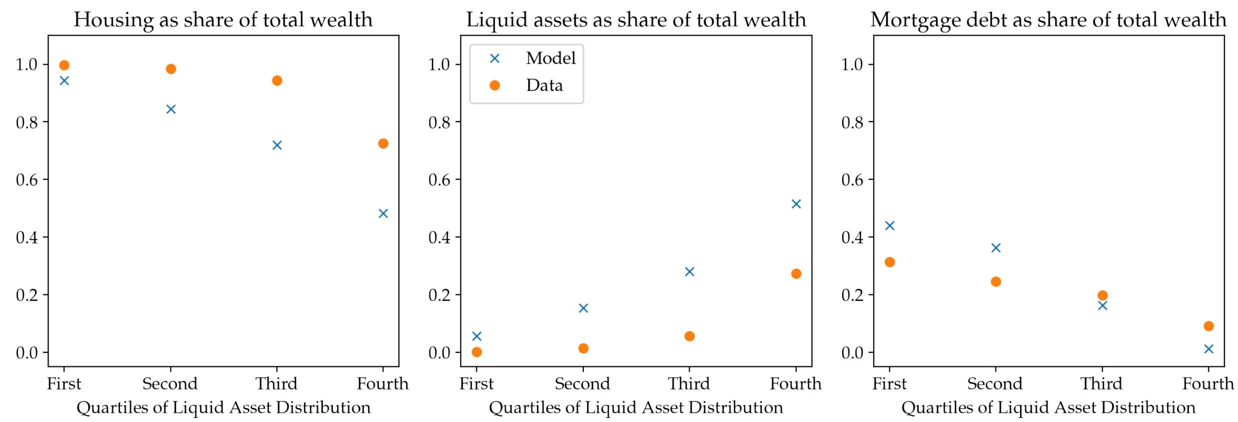
and holds the largest share of housing wealth (around 40% in both cases). Additionally, the model captures the hump-shaped profile of the mortgage debt distribution. Despite underestimating the fraction of debt held by the top quartile, it closely tracks the share of mortgage debt among the lower quartiles. This is particularly relevant for this study, as these households exhibit the highest MPCs in the economy.

Figure 9 shows the composition of total wealth. Both in the model and in the data, households in the lower asset quartiles have most of their wealth invested in housing, whereas households in higher quartiles hold a greater share of liquid assets. Additionally, the model is able to replicate the decreasing pattern of the ratio between mortgage debt and total wealth along the liquid asset distribution.

Overall, both in the data and in the model, lower income households primarily accumulate wealth in the form of housing and carry substantial mortgage debt relative to their assets.[31] This indicates that fluctuations in mortgage conditions are especially significant for this cohort of households, which is characterized by high MPCs.

[31] Appendix C.3 provides a description of the policy functions for the *buyers*, shedding light to the mechanism through which lower income households end up having large debt positions in the model.

Figure 9: Composition of total wealth: Model vs data



Notes: In each panel, households are ranked based on their position in the liquid asset distribution. Each dot represents the average value of the variable of interest within a specific quartile in the model (in blue) and in the HFCS data for Spain (in orange).

4 Results

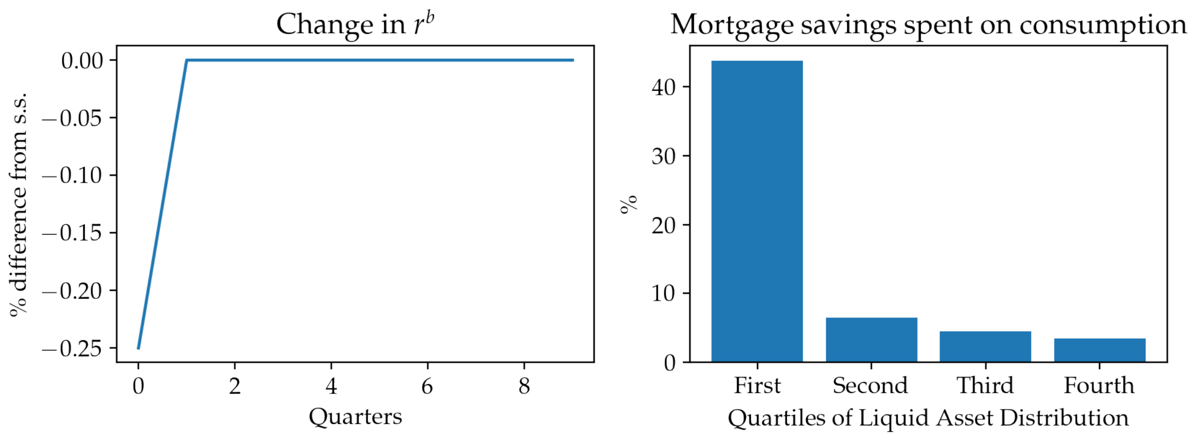
In this section, I use the model to examine how MPCs and ARMs affect the transmission of monetary policy through mortgages and to interpret the empirical findings from section 2.

The analysis is divided into two parts. First, I conduct partial equilibrium exercises to isolate the impact that MPCs and ARMs have on transmission. By controlling for the endogenous responses of consumption and house prices, this analysis shows the mechanism through which MPCs and ARMs shape household consumption behavior following changes in monetary policy. After having understood this mechanism, I reintroduce the endogenous responses of prices and present the general equilibrium results.

4.1 The interaction between MPCs and ARMs

I conduct four partial equilibrium exercises to analyze the mechanism through which MPCs and ARMs shape the transmission of monetary policy through mortgages. To isolate the mortgage channel of transmission, the first three exercises analyze shocks to the mortgage rate r^b alone. After having established how the mortgage channel operates,

Figure 10: Transmission of mortgage rate shock to consumption by asset quartile



Notes: The left panel shows the dynamics of the mortgage rate. In the right panel, households are ranked based on their position in the liquid asset distribution. Each bar shows the average fraction of mortgage savings, arising from the one-time reduction in r^b, that is spent on consumption.

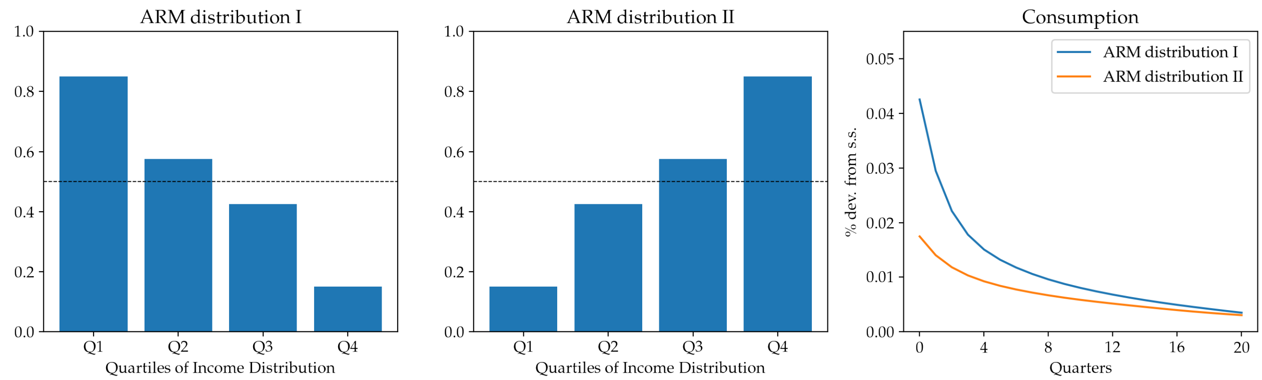
the fourth exercise analyzes a complete monetary policy shock, where both r and r^b are affected.

4.1.1 The role of the MPC

To examine how MPCs influence the transmission of monetary policy through mortgage markets, I conduct a partial equilibrium exercise investigating how different households respond to changes in mortgage interest rates depending on their MPC.

This analysis assumes that all households in the Spanish economy have ARMs ($\gamma = 1$) and that the economy is shocked with a one-time reduction in the mortgage interest rate r^b. As shown in the left panel of figure 10, the shock is calibrated so that the mortgage rate decreases by 25 b.p. on impact. This reduction results in a one-time decrease in mortgage payments for all households with positive mortgage balances. The right panel of figure 10 illustrates the fraction of these savings that is allocated to consumption across different quartiles of the liquid asset distribution. Households in the lowest quartile, which have higher MPCs, promptly use their mortgage savings to increase non-durable consumption. In contrast, wealthier households, which already have sufficient resources to meet their consumption needs, spend a much smaller fraction of their savings on consumption.

Figure 11: Transmission of mortgage rate shock depending on the ARM distribution



Notes: The left and middle panels show the fraction of households with ARMs in different income quartiles. The horizontal dashed line indicates the overall ARM share in the two simulations. The right panel shows the response of consumption to a reduction in the mortgage rate r^b. The mortgage rate shock is calibrated to lead to a 25 b.p. reduction in r^b on impact, and it follows an AR(1) process with persistence 0.5.

This exercise highlights the crucial role of MPCs in the transmission mechanism through mortgages: the impact of lower mortgage rates on consumption depends on the MPC of the households benefiting from these rate reductions. Hence, even with a high fraction of ARMs in the economy, mortgages may not be a relevant vehicle of monetary transmission if they are held by low MPC households.

4.1.2 The distribution of ARMs

Building on the previous exercise, I explore how the distribution of ARMs within the economy affects the strength of transmission. Using the model calibrated to the Spanish economy, I assess how consumption responds to a reduction in the mortgage rate under two different ARM distributions. Figure 11 illustrates these two distributions. While both simulations have the same economy-wide MPC level and ARM share, *distribution I* features a higher concentration of ARMs among low-income households (who have high MPCs), whereas *distribution II* has the opposite pattern. The right panel of figure 11 shows that skewing the ARM distribution towards lower-income households results in a consumption response to a 25 b.p. fall in the mortgage rate that is approximately 2.4 times larger.

This result aligns with the previous analysis, which showed that mortgage transmission is stronger when the affected households have high MPCs. Accordingly, a distribution where a greater fraction of ARMs are held by lower-income households leads to higher transmission.

4.1.3 MPC and ARM interaction

To gain additional insight on the relationship between MPCs and ARMs in the transmission of monetary policy through mortgages, I compare two economies that differ in both MPC levels and ARM shares. The first economy is Spain, the standard representative country for this study. The second economy is Austria, which I choose for its low MPC, since it exhibits the lowest hand-to-mouth ratio among Euro Area countries (see figure 2).

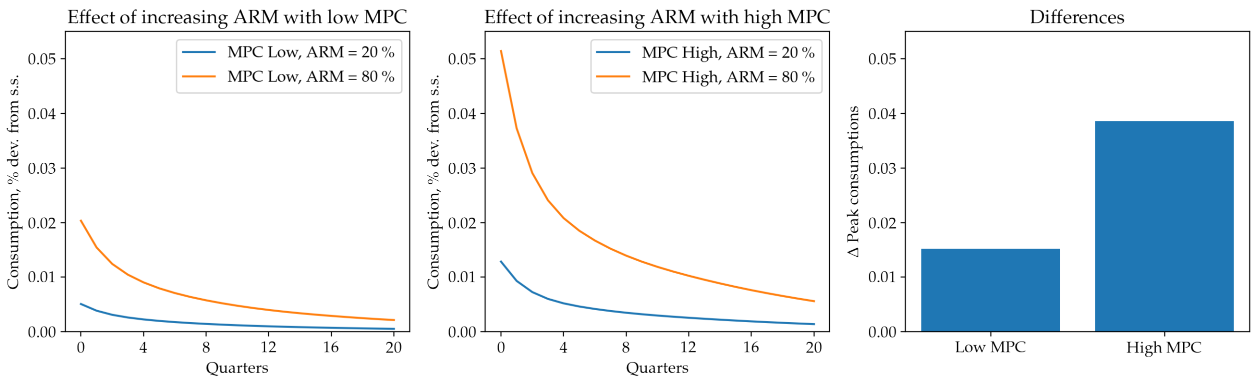
In this comparison, the Austrian economy is calibrated to replicate the Spanish economy in all respects except for its MPC. Specifically, I adjust the Austrian economy's MPC so that the ratio MPC^{ES}/MPC^{AT} matches the empirical ratio $HtM^{ES}/HtM^{AT} \approx 2$.[32] Both economies are subjected to a 25 b.p. reduction in the mortgage rate.

Figure 12 presents the results of this exercise. The left and middle panels show the effects of increasing the ARM share in both economies. In each case, a higher fraction of households affected by the mortgage rate change leads to a stronger response in consumption. However, the right panel shows that the magnitude of this increase varies depending on the MPC level: as ARM shares rise from 20% to 80%, the increase in consumption is significantly larger in the economy with the higher MPC.

Consistent with the empirical analysis in section 2, this exercise shows that not only higher MPCs and ARMs increase monetary policy transmission independently, but their interaction also matters. The intuition for this result follows from the previous analysis: while higher ARM shares increase the fraction of households directly affected by lower mortgage rates, higher MPCs lead to greater consumption adjustments following the shock.

[32]use the ratio of hand-to-mouth shares from the HFCS data to calibrate the counterfactual MPC, as direct MPC data is unavailable. In the model, the counterfactual MPC is obtained by calibrating the economy to match the liquid asset to GDP ratio that is consistent with the target MPC level.

Figure 12: Transmission of mortgage rate shock: MPC and ARM interaction



Notes: The left and middle panels show the consumption response, in percentage deviations from its steady-state value, to a mortgage rate shock in the low and high MPC economies, respectively. The blue line shows the response when the share of ARMs in the economy is 20%, while the orange line shows the response when the share is 80%. The right panel displays the difference in the peak response of consumption when the share of ARMs decreases from 20% to 80%. The mortgage rate shock is calibrated to lead to a 25 b.p. reduction in r^b on impact, and it follows an AR(1) process with persistence 0.5.

4.1.4 A complete monetary policy experiment

My final partial equilibrium exercise examines the impact of a complete monetary policy shock on consumption in the two economies previously considered: Spain (high MPC) and Austria (low MPC). A complete monetary policy shock affects the real interest rate r, which in turn influences the mortgage rate r^b in line its definition in equation (11). Unlike the previous exercises, this analysis incorporates the effects on consumption due both to changes in the return on liquid balances and to changes on the mortgage rate.

The results are summarized in table 2, where *Low MPC* and *High MPC* refer to Austria and Spain, respectively, and *Low ARM* and *High ARM* denote economy-wide ARM shares of 20% and 80%, respectively. For each combination, the table presents the peak consumption response. The results are consistent with previous analyses: increasing the MPC or ARM share enhances transmission. Importantly, raising the ARM share from 20% to 80% results in a peak consumption increase of magnitude 0.016% (a 44% increase from its previous value) in the low-MPC economy and 0.039% (a 75% increase from its previous value) in the high-MPC economy, highlighting the role of the interaction between ARMs and MPCs.

Table 2: Effects of a monetary policy shock on peak consumption in PE

	Low MPC	High MPC	Δ MPC
Low ARM	0.036%	0.052%	0.016%
High ARM	0.052%	0.091%	0.039%
Δ ARM	0.016%	0.039%	0.054%

Notes: High MPC refers to the reference Spanish economy, while *Low MPC* refers to the counterfactual Austrian economy. *Low ARM* and *High ARM* refer to ARM shares of 20% and 80%, respectively. Each entry represents the peak consumption response after a monetary policy shock. The entries in the Δ *MPC* column and Δ *ARM* row show the differences in peak consumption. The shock leads to a 25 b.p. reduction in r on impact and follows an AR(1) process with persistence 0.5.

Summary The partial equilibrium exercises show how MPCs and ARMs interact in the transmission of monetary policy through mortgages. MPCs are crucial because they determine how sensitive consumption is to changes in available resources, while ARMs dictate the proportion of households directly affected by changes in mortgage rates. Effective transmission through the mortgage channel requires both a high ARM share, so that a significant fraction of households experiences the shock, and high MPCs, so that the consumption response is pronounced. Accordingly, higher transmission is observed with increased MPCs for a given ARM share or a higher ARM share for a given MPC. Notably, transmission is particularly strong when both MPCs and ARMs are high, consistent with the empirical evidence on their interaction discussed in section 2.

4.2 Monetary policy experiments

After establishing the mechanism through which MPCs and ARMs interact in the transmission of monetary policy through mortgages, this section shifts to a quantitative general equilibrium analysis, where prices adjust endogenously to monetary policy shocks. I first show that the interaction between MPCs and ARMs remains significant in general equilibrium, and then use the model to evaluate the extent to which differences in transmission across Euro Area countries are due to differences in their MPCs and ARMs. In all of the following exercises, the monetary policy shock ϵ^m in equation (26) is calibrated so that the

Table 3: Effects of a monetary policy shock on peak consumption in GE

	Low MPC	High MPC	Δ MPC
Low ARM	0.64%	0.64%	0.00%
High ARM	0.72%	0.79%	0.07%
Δ ARM	0.07%	0.15%	0.15%

Notes: High MPC refers to the reference Spanish economy, while *Low MPC* refers to the counterfactual Austrian economy. *Low ARM* and *High ARM* refer to ARM shares of 20% and 80%, respectively. Each entry represents the peak consumption response after a monetary policy shock. The entries in the Δ *MPC* column and Δ *ARM* row show the differences in peak consumption. As detailed in section 4.2, the shock leads to a reduction in ϵ^m of $\approx$ 100 b.p. on impact and follows an AR(1) process with persistence 0.5.

peak drop of consumption in the model matches the peak drop in the Spanish data.[33]

4.2.1 A complete monetary policy experiment in GE

As a primary analysis, I replicate the monetary policy experiment from Section 4.1.4 in a general equilibrium setting to verify that the interaction between MPCs and ARMs continues to be significant for monetary policy transmission. The results of this experiment are presented in table 3. In general equilibrium, the consumption response is larger due to the endogenous movements of prices and quantities. Importantly, the table shows that the interaction between MPCs and ARMs remains a significant amplifier of transmission: increasing the ARM share from 20% to 80% leads to a peak consumption increase of magnitude 0.07% (a 11% increase from its previous value) in the low MPC economy (Austria) and 0.15% (a 23% increase from its previous value) in the high MPC economy (Spain).

4.2.2 Model-data comparison

To assess the extent to which differences in monetary policy transmission across Euro Area countries are due to differences in their MPCs and ARMs, I proceed in the following manner. Starting with the benchmark calibration for Spain, I adjust the parameters

[33] This implies a 112 b.p. reduction of ϵ^m on impact. The shock is assumed to follow an AR(1) process with persistence 0.5.

Table 4: MPC and ARM contributions to overall transmission

	Difference			Contribution		
	Data	Model	% Explained	ARM	MPC	Interaction
AT	0.533	0.087	16%	29%	34%	37%
BE	0.659	0.097	15%	80%	0%	20%
DE	0.609	0.154	25%	96%	1%	2%
FR	0.642	0.152	24%	88%	−5%	17%
IE	-0.269	-0.030	11%	13%	74%	13%
IT	0.351	0.060	17%	81%	4%	15%
LU	0.405	0.035	9%	45%	40%	15%
NL	0.544	0.025	5%	−7%	110%	−3%
PT	-0.229	-0.056	24%	93%	3%	4%
Total	0.471	0.077	16%	57%	29%	14%

Notes: For each country, the table shows the difference in percentage points in peak response to a monetary policy shock relative to Spain. This difference is computed both in the data (second column) and in the model (third column), together with the fraction of the difference captured by the model (fourth column). The last three columns display the fraction of the model-implied difference in response between each country and Spain which is due to differences in ARMs, MPCs, and their interaction. The last row (*Total*) displays averages across countries.

β and γ to generate counterfactual consumption responses for economies with different MPC levels and ARM shares. For each Euro Area country c, I modify β so that the ratio MPC^{ES}/MPC^{c} matches the empirical ratio HtM^{ES}/HtM^{c}, and calibrate γ to match the empirical ARM share in that country. By comparing these counterfactual responses, I quantify how much of the variation in monetary policy transmission across Euro Area countries is due to differences in MPCs and ARMs.[34]

Table 4 displays the results of this analysis. The *Difference* section includes three columns for each country: the empirical peak consumption response relative to Spain (*Data*), the model-implied peak consumption response relative to Spain (*Model*), and the percentage of the empirical difference explained by the model (*% Explained*). Additionally, the *Contri-*

[34]This section shows my baseline results, where MPCs and ARMs are treated as independent of each other. Appendix C.4 shows additional results obtained by introducing an exogenous correlation between MPCs and ARMs.

bution section breaks down the contributions of differences in ARMs, MPCs, and their interaction to explain the model-implied differences in consumption responses across countries relative to Spain. This decomposition is achieved by separately adjusting ARMs and MPCs and computing the counterfactual consumption responses, thereby isolating the impact of each factor on the overall consumption response.[35]

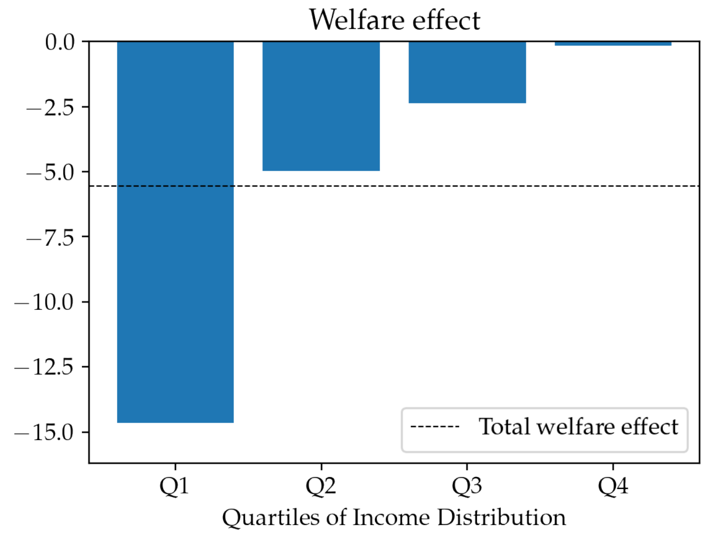
The model is able to explain between 5% and 25% of the differences in response across Euro Area economies, with an average of 16%. Of this, differences in ARMs explain an average of 57% of the model-implied differences in consumption responses, varying from -7% to 96%. This contribution is particularly pronounced in economies with significant differences in ARMs but smaller differences in MPCs compared to Spain, such as Germany and Portugal. Differences in MPCs explain 29% of the variation on average, with notable impacts in the Netherlands and Ireland, where differences in MPCs are more substantial than differences in ARMs relative to Spain. Finally, interactions between ARMs and MPCs contribute to 14% of the explained differences.

The Netherlands presents an interesting case to illustrate the importance of accounting for differences in MPCs when assessing transmission through mortgage. Despite having a higher share of ARMs than Spain, the Netherlands has a lower MPC. Consequently, a counterfactual economy with Dutch MPC and Spanish ARMs shows a smaller consumption response than an economy with Dutch ARMs and MPC. This discrepancy, which results in a negative ARM contribution of -7%, indicates that without adjusting for the lower MPC, we would incorrectly overestimate transmission in the Dutch economy. When the model incorporates the lower MPC, it more accurately reflects the empirical data, predicting lower transmission in the Netherlands than in Spain.[36]

[35] As an explanatory example, the difference between Spain and Austria in their peak consumption responses is 0.533 in the data and 0.087 in the model, implying that the model explains 16% of the empirical difference. Starting from the response in the Austrian economy, a counterfactual economy with the Austrian MPC and Spanish ARM would have a difference in peak response with Spain of 0.025 (29% of the overall model-implied difference of 0.087). Similarly, a counterfactual economy with the Austrian ARMs and Spanish MPC would have a difference in peak response with Spain of 0.03 (34% of the overall model-implied difference of 0.087).

[36] France is the only case with a negative MPC contribution. France has the lowest ARM share across the countries considered, equal to 7.9%. As a consequence, the MPC contribution exercise compares two economies where monetary transmission takes place only through standard channels, since ARM transmission is essentially not place. Among these two economies, the one with the higher MPC has slightly smaller transmission (see Auclert, Rognlie and Straub; 2023; Bilbiie; 2024, for a discussion on the conditions for

Figure 13: Welfare consequences of a recessionary monetary policy shock



Notes: The chart shows the welfare effect of a recessionary monetary policy shock on households in different quartiles of the income distribution. The welfare effect is computed as the present value of the change in utility that households experience over a 12-quarter period following the shock. The shock follows an AR(1) process with persistence 0.5 and is calibrated to lead to an increase in ϵ^m of ≈ 100 b.p. on impact. The shock is exactly the one considered in section 4.1.4, with the only exception that it is recessionary instead of expansionary.

4.3 Welfare effects and Spanish policy measures

The model developed in this paper provides insights into the welfare consequences of recessionary monetary policy shocks, specifically through their impact on mortgage payments. Figure 13 illustrates these consequences for different income quartiles in the Spanish economy. In line with the previous analysis, households in the lowest income quartile experience the greatest welfare loss: due to their limited resources, they must reduce consumption more sharply following an increase in mortgage payments.

This analysis helps interpret recent policy measures implemented in the Spain economy. In response to inflationary pressures following the Covid-19 pandemic, the European Central Bank raised interest rates, leading to significant increases in monthly mortgage payments for households with ARMs (see International Monetary Fund; 2024, for an evaluation of mortgage service cost changes across Euro Area economies after monetary

amplifications in HANK models).

policy hikes). To alleviate the burden on lower-income households, the Spanish government has reduced the applicable ARM interest rate from Euribor + 0.25% to Euribor - 0.10% for these families.[37] Given the welfare consequences of a recessionary shock presented in figure 13, this policy appears well-targeted, as it mitigates the impact of higher rates on those who are most adversely affected by them.

5 Conclusion

[37]See here for a detailed explanation of the measures.

References

Almgren, M., Gallegos, J.-E., Kramer, J. and Lima, R. (2022). Monetary Policy and Liquidity Constraints: Evidence from the Euro Area, *American Economic Journal: Macroeconomics* **14**(4): 309–340.

Auclert, A., Bardóczy, B. and Rognlie, M. (2023). MPCs, MPEs, and Multipliers: A Trilemma for New Keynesian Models, *Review of Economics and Statistics* **105**(3): 700–712.

Auclert, A., Bardóczy, B., Rognlie, M. and Straub, L. (2021). Using the Sequence-Space Jacobian to Solve and Estimate Heterogeneous-Agent Models, *Econometrica* **89**(5): 2375–2408.

Auclert, A., Rognlie, M. and Straub, L. (2020). Micro Jumps, Macro Humps: Monetary Policy and Business Cycles in an Estimated HANK Model, *Working Paper* .

Auclert, A., Rognlie, M. and Straub, L. (2023). The Intertemporal Keynesian Cross, *Journal of Political Economy* **Forthcoming**.

Bachmann, R., Born, B., Goldfayn-Frank, O., Kocharkov, G., Luetticke, R. and Weber, M. (2021). A Temporary VAT Cut as Unconventional Fiscal Policy, *NBER Working Papers 29442, National Bureau of Economic Research, Inc* .

Bardóczy, B. (2022). Spousal Insurance and the Amplification of Business Cycles, *Working Paper* .

Battistini, N., Falagiarda, M., Hackmann, A. and Roma, M. (2022). Navigating the Housing Channel of Monetary Policy across Euro Area Regions, *ECB Working Paper, European Central Bank, Frankfurt* (2022/2752).

Beraja, M., Fuster, A., Hurst, E. and Vavra, J. (2019). Regional Heterogeneity and the Refinancing Channel of Monetary Policy, *The Quarterly Journal of Economics* **134**(1): 109–183.

Beraja, M. and Zorzi, N. (2024). Durables and Size-Dependence in the Marginal Propensity to Spend, *Working Paper* .

Berger, D., Guerrieri, V., Lorenzoni, G. and Vavra, J. (2018). House Prices and Consumer Spending, *Review of Economic Studies* **85**(3): 1502–1542.

Berger, D., Milbradt, K., Tourre, F. and Vavra, J. (2023). Refinancing Frictions, Mortgage Pricing and Redistribution, *Working Paper* .

Bilbiie, F. O. (2024). Monetary Policy and Heterogeneity: An Analytical Framework, *Review of Economic Studies (Forthcoming)* .

Calza, A., Monacelli, T. and Stracca, L. (2013). Housing Finance and Monetary Policy, *Journal of the European Economic Association* **11**(1): 101–122.

Carroll, C. (2006). The Method of Endogenous Gridpoints for Solving Dynamic Stochastic Optimization Problems, *Economics Letters* **91**(3): 312–320.

Caspi, I., Eshel, N. and Segev, N. (2024). The Mortgage Cash-Flow Channel: How Rising Interest Rates Impact Household Consumption, *Working Paper* .

Cloyne, J., Ferreira, C. and Surico, P. (2020). Monetary Policy when Households have Debt: New Evidence on the Transmission Mechanism, *The Review of Economic Studies* **87**(1): 102–129.

Corsetti, G., Duarte, J. B. and Mann, S. (2022). One Money, Many Markets, *Journal of the European Economic Association* **20**(1): 513–548.

Di Maggio, M., Kermani, A., Keys, B. J., Piskorski, T., Ramcharan, R., Seru, A. and Yao, V. (2017). Interest Rate Pass-Through: Mortgage Rates, Household Consumption, and Voluntary Deleveraging, *American Economic Review* **107**(11): 3550–3588.

Diaz, A. and Luengo-Prado, M. J. (2010). The Wealth Distribution with Durable Goods, *International Economic Review* **51**(1): 143—170.

Eichenbaum, M., Rebelo, S. and Wong, A. (2022). State Dependent Effects of Monetary Policy: the Refinancing Channel, *American Economic Review* **112**(3): 721–761.

Erceg, C. J., Henderson, D. W. and Levin, A. T. (2000). Optimal monetary policy with staggered wage and price contracts, *Journal of Monetary Economics* **46**(2): 281–313.

Floden, M. and Lindé, J. (2001). Idiosyncratic Risk in the United States and Sweden: Is There a Role for Government Insurance?, *Review of Economic Dynamics* **4**(2): 406–437.

Flodén, M., Kilström, M., Sigurdsson, J. and Vestman, R. (2021). Household Debt and Monetary Policy: Revealing the Cash-Flow Channel, *The Economic Journal* **131**(636): 1742–1771.

Fraumeni, B. M. (1997). The Measurement of Depreciation in the U.S. National Income and Product Accounts, *Survey of Current Business* **77**: 7–23.

Ganong, P., Noel, P., Patterson, C., Vavra, J. and Weinberg, A. (2024). Earnings Instability, *Working Paper* .

Garriga, C., Kydland, F. E. and Šustek, R. (2017). Mortgages and Monetary Policy, *The Review of Financial Studies* **30**(10): 3337–3375.

Garriga, C., Kydland, F. E. and Šustek, R. (2021). MoNK: Mortgages in a New-Keynesian model, *Journal of Economic Dynamics and Control* **123**: 104059.

Greenwald, D. L. (2018). The Mortgage Credit Channel of Macroeconomic Tranmission, *Working Paper* .

Guerrieri, V. and Lorenzoni, G. (2017). Credit Crises, Precautionary Savings, and the Liquidity Trap, *Quarterly Journal of Economics* **132**(2): 1427–1467.

Guerrieri, V., Lorenzoni, G. and Prato, M. (2020). Slow Household Deleveraging, *Journal of the European Economic Association* **18**(6): 2755–2775.

Guvenen, F., Ozkan, S. and Song, J. (2014). The Nature of Countercyclical Income Risk, *Journal of Political Economy* **122**(3): 621–60.

Hedlund, A., Karahan, F., Mitman, K. and Ozkan, S. (2016). Monetary Policy, Heterogeneity, and the Housing Channel, *Working Paper* .

Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle, *American Economic Review* **95**(3): 739– 764.

International Monetary Fund (2024). Chapter 2: Feeling the Pinch?, *World Economic Outlook (April 2024)* .

Iskhakov, F., Jørgensen, T. H., Rust, J. and Schjerning, B. (2017). The endogenous grid method for discrete-continuous dynamic choice models with (or without) taste shocks, *Quantitative Economics* **8**(2): 317–365.

Jarociński, M. and Karadi, P. (2020). Deconstructing Monetary Policy Surprises—The Role of Information Shocks, *American Economic Journal: Macroeconomics* **12**(2): 1–43.

Jordà, O. (2005). Estimation and Inference of Impulse Responses by Local Projections, *American Economic Review* **95**(1): 161–182.

Kaplan, G., Mitman, K. and Violante, G. L. (2020). The Housing Boom and Bust: Model Meets Evidence, *Journal of Political Economy* **128**(9).

Kaplan, G., Moll, B. and Violante, G. L. (2018). Monetary Policy According to HANK, *American Economic Review* **108**(3): 697–743.

Kaplan, G. and Violante, G. (2014). A Model of the Consumption Response to Fiscal Stimulus Payments, *Econometrica* **82**(4): 1199–1239.

Kaplan, G., Violante, G. L. and Weidner, J. (2014). The Wealthy Hand-to-Mouth, *Brookings Papers on Economic Activity* (1): 77–138.

McFadden, D. (1973). Conditional Logit Analysis of Qualitative Choice Behavior, *Institute of Urban and Regional Development, University of California* .

McKay, A., Nakamura, E. and Steinsson, J. (2016). The Power of Forward Guidance, *American Economic Review* **106**(10): 3133–3158.

McKay, A. and Wieland, J. F. (2021). Lumpy Durable Consumption Demand and the Limited Ammunition of Monetary Policy, *Econometrica* **89**(6): 2717–2749.

OECD (2012). OECD Economic Surveys: European Union 2012, *OECD Economic Surveys: European Union 2012, OECD Publishing, Paris* .

Pica, S. (2022). Housing Markets and the Heterogeneous Effects of Monetary Policy Across the Euro Area, *Working Paper* .

Rotemberg, J. J. (1982). Monopolistic Price Adjustment and Aggregate Output, *The Review of Economic Studies* **49**(4): 517–531.

Schmitt-Grohé, S. and Uribe, M. (2005). Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model, *NBER Macroeconomics Annual* **20**: 383–425.

Slacalek, J., Tristani, O. and Violante, G. L. (2020). Household balance sheet channels of monetary policy: A back of the envelope calculation for the euro area, *Journal of Economic Dynamics and Control* **115**: 103879.

van Hoenselaar, F., Cournède, B., Pace, F. D. and Ziemann, V. (2021). Mortgage Finance Across OECD Countries, *OECD Economics Department Working Paper No. 1693, OECD Publishing, Paris* .

Wong, A. (2020). Refinancing and the Transmission of Monetary Policy to Consumption, *Working Paper* .

A Data sources

The following are the sources of the data used in the analyses.

Gross Domestic Product: *Gross Domestic Product at Market Prices*, chain linked volumes, seasonally and calendar adjusted, quarterly frequency. Source: Eurostat, table NAMQ 10 GDP.

Consumption: *Final Consumption Expenditure of Households and NPISH at Market Prices*, chain linked volumes, seasonally and calendar adjusted, quarterly frequency. Source: Eurostat, table NAMQ 10 GDP.

Consumer Price Index: *All-items HICP*, monthly frequency averaged to convert into quarterly frequency. Source: Eurostat, table PRC HICP MIDX.

Short-term interest rate: *Euro Area day-to-day rate*, quarterly frequency. Source: Eurostat, table IRT ST Q.

Share of ARM households: Entry DL1110 ("Outstanding balance of HMR mortgage") filtered using entry DL1110ai ("Has adjustable interest rate HMR mortgage"). Source: ECB Household Finance and Consumption Survey (HFCS), waves one, two and three

Share of hand-to-mouth households: This variable is constructed following the procedure detailed in Almgren et al. (2022). Source: ECB Household Finance and Consumption Survey (HFCS), waves one, two and three

Outstanding amount of ARMs - Italy: *Consistenze di prestiti per l'acquisto di abitazioni famiglie consumatrici a tasso variabile*, quarterly frequency. Source: Bank of Italy.

Share of hand-to-mouth households - Italy, time series: Provided by the ECB on the basis of the series constructed for the analysis in Slacalek, Tristani and Violante (2020), quarterly frequency.

Mortgage interest rate - Italy: *Cost of borrowing for households for house purchase*, monthly frequency averaged to convert into quarterly frequency. Source: ECB SDW, MIR dataset.

ARM interest rate - Italy: *Tassi d'interesse armonizzati - prestiti per acquisto abitazioni - variabile entro 1 anno*, monthly frequency averaged to convert into quarterly frequency. Source: Bank of Italy, Statistical Database.

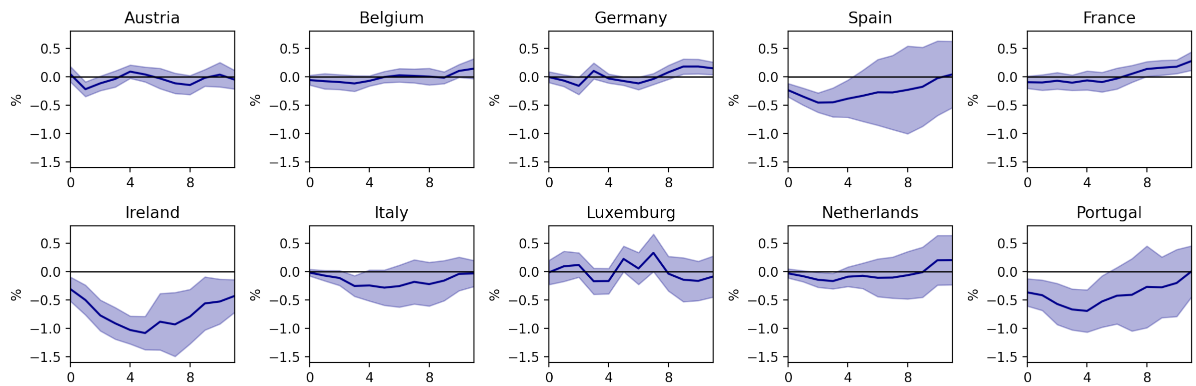
Monetary policy shocks: Monetary policy shocks by Jarociński and Karadi (2020), series updated until October 2022, monthly frequency summed up to convert into quarterly frequency. Source: Marek Jarocinski's website: https://marekjarocinski.github.io.

B Empirics – Additional figures

B.1 Euro Area impulse response functions

These sections shows IRFs. In line with Pica and Almgrend we see large differences.

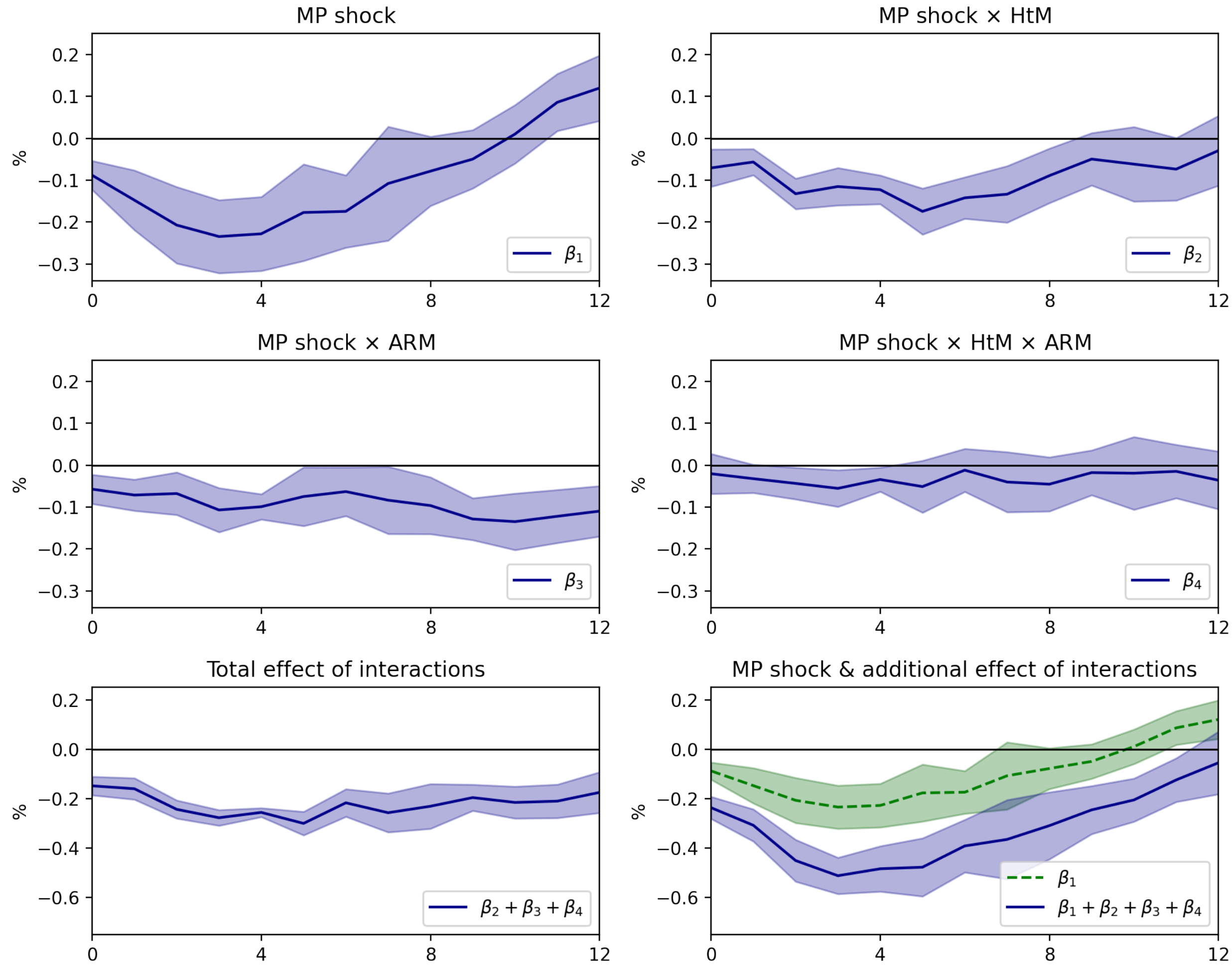
Figure B.14: IRFs of consumption to a recessionary monetary policy shock



Notes: Responses to a one standard deviation recessionary monetary policy shock. The shaded blue areas are 90% confidence intervals.

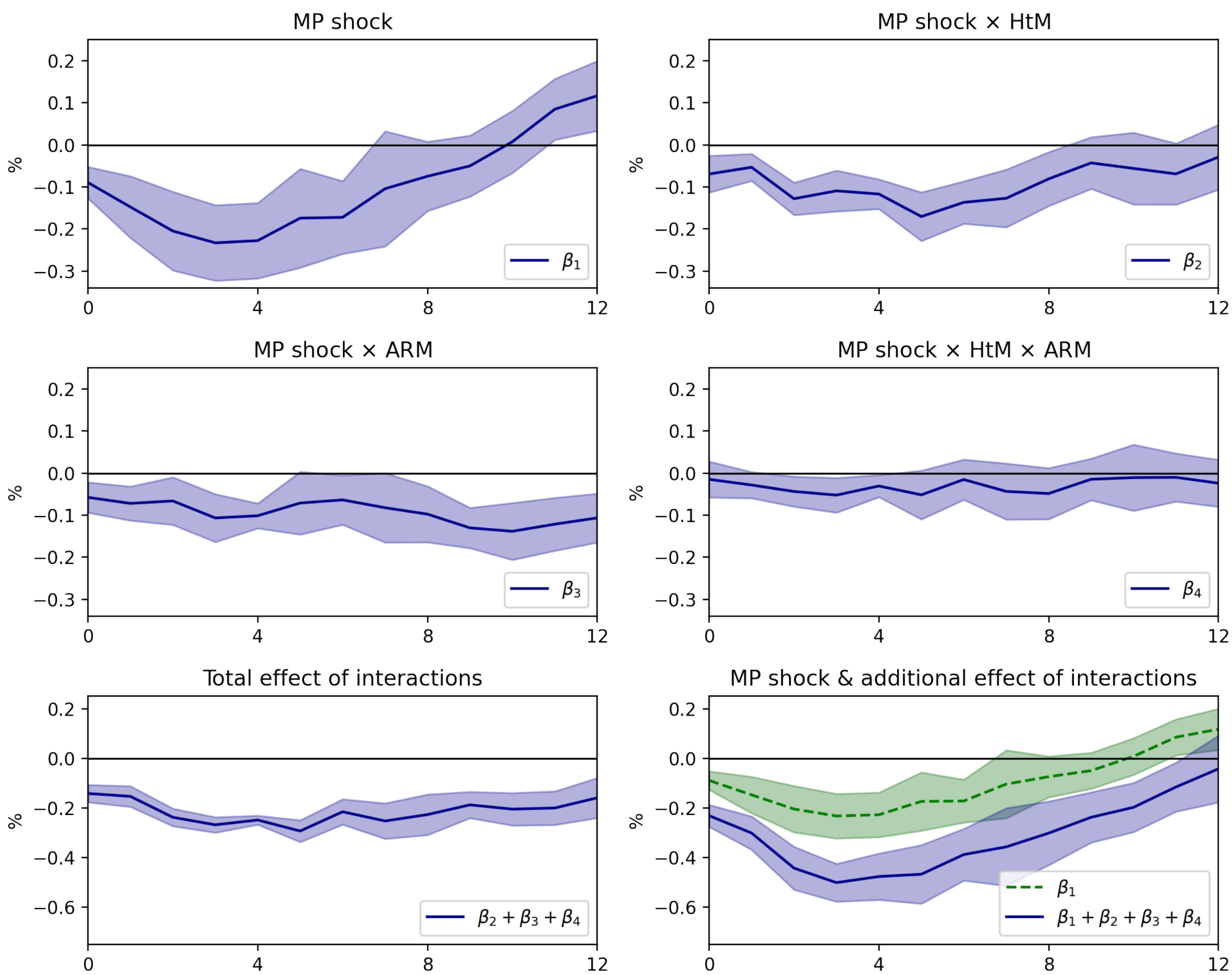
B.2 Panel local projections –Robustness

Figure B.15: Correlation between the response of consumption and HtM and ARMs shares



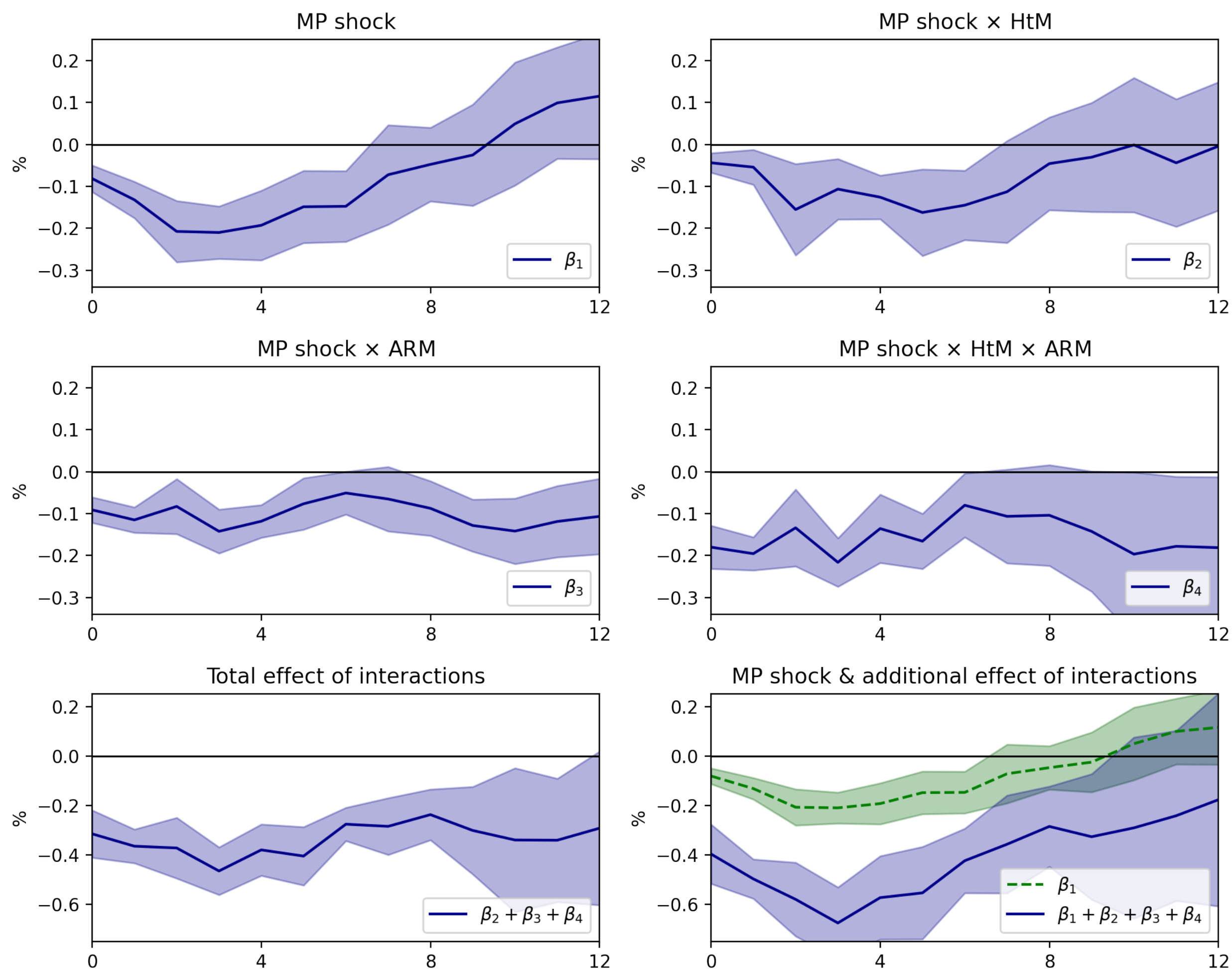
Notes:

Figure B.16: Correlation between the response of consumption and HtM and ARMs shares



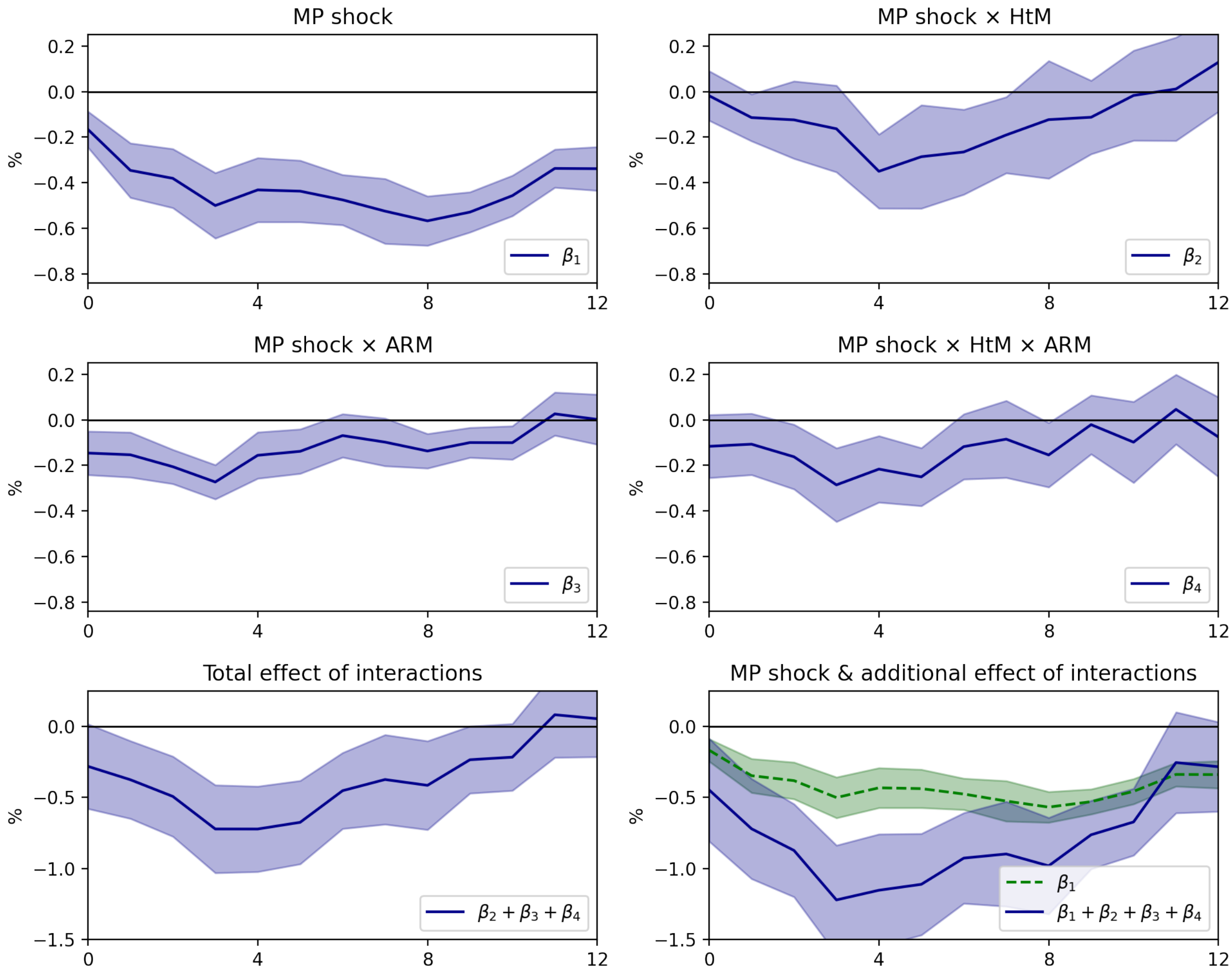
Notes:

Figure B.17: Correlation between the response of consumption and HtM and ARMs shares



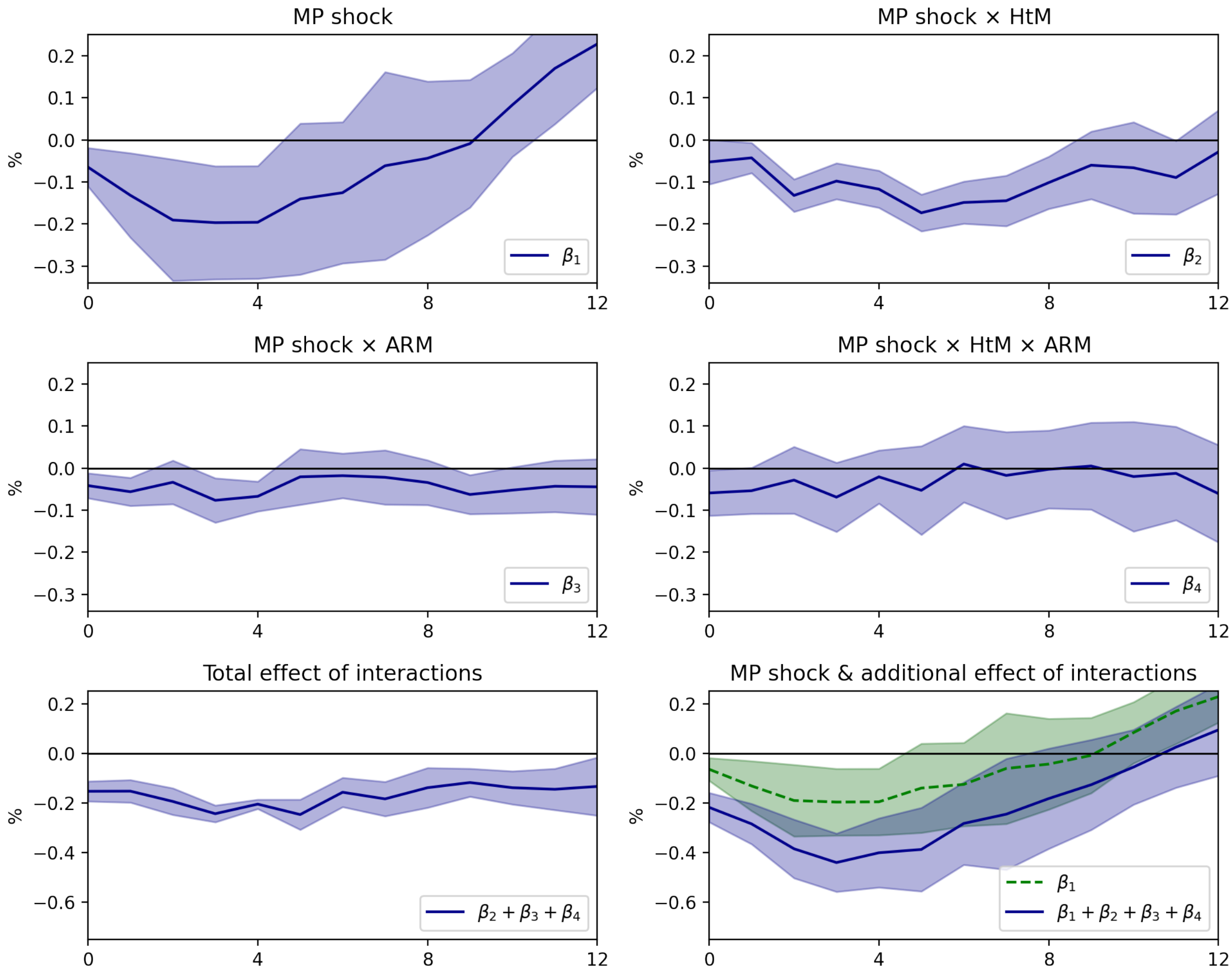
Notes:

Figure B.18: Correlation between the response of consumption and HtM and ARMs shares



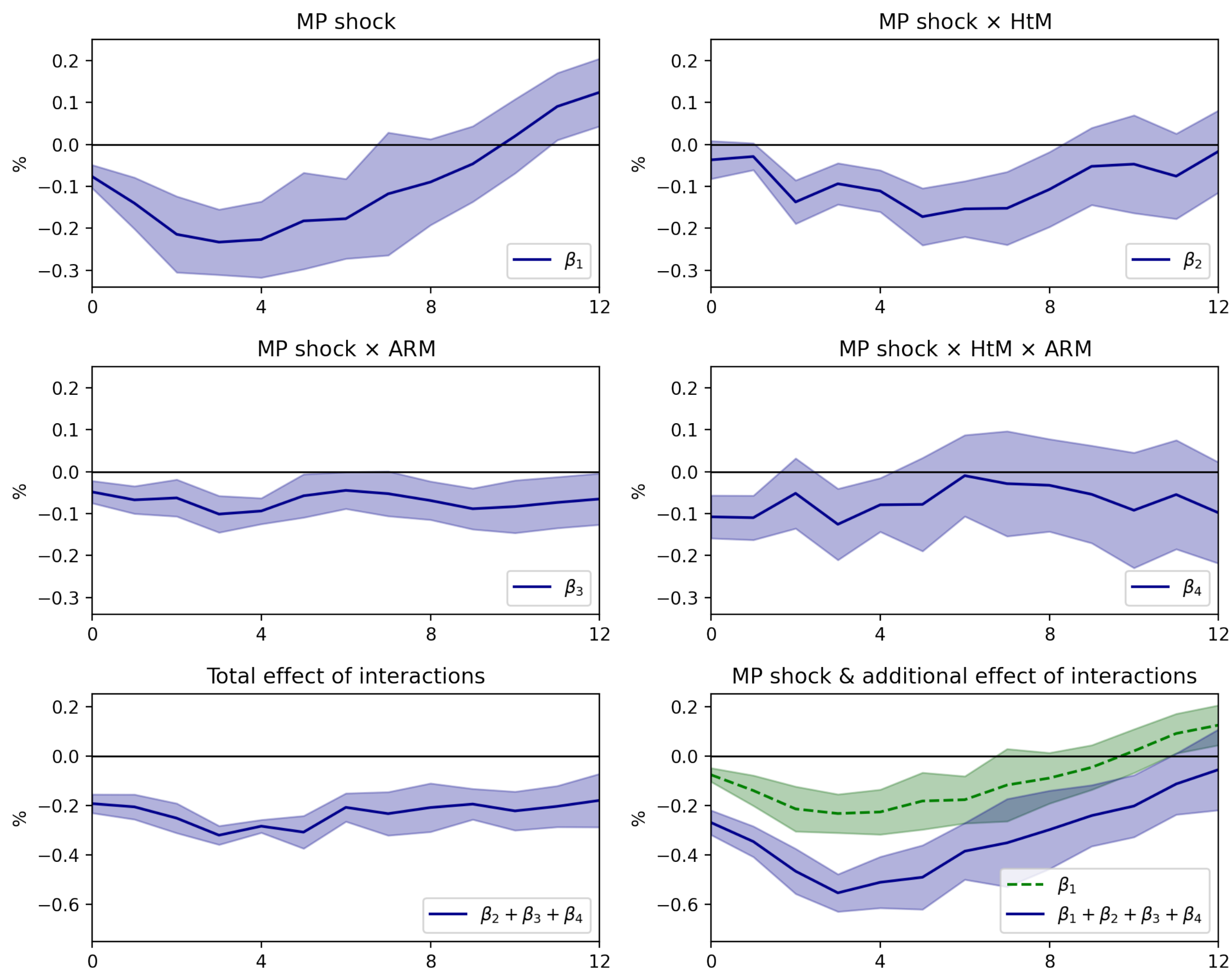
Notes:

Figure B.19: Correlation between the response of consumption and HtM and ARMs shares



Notes:

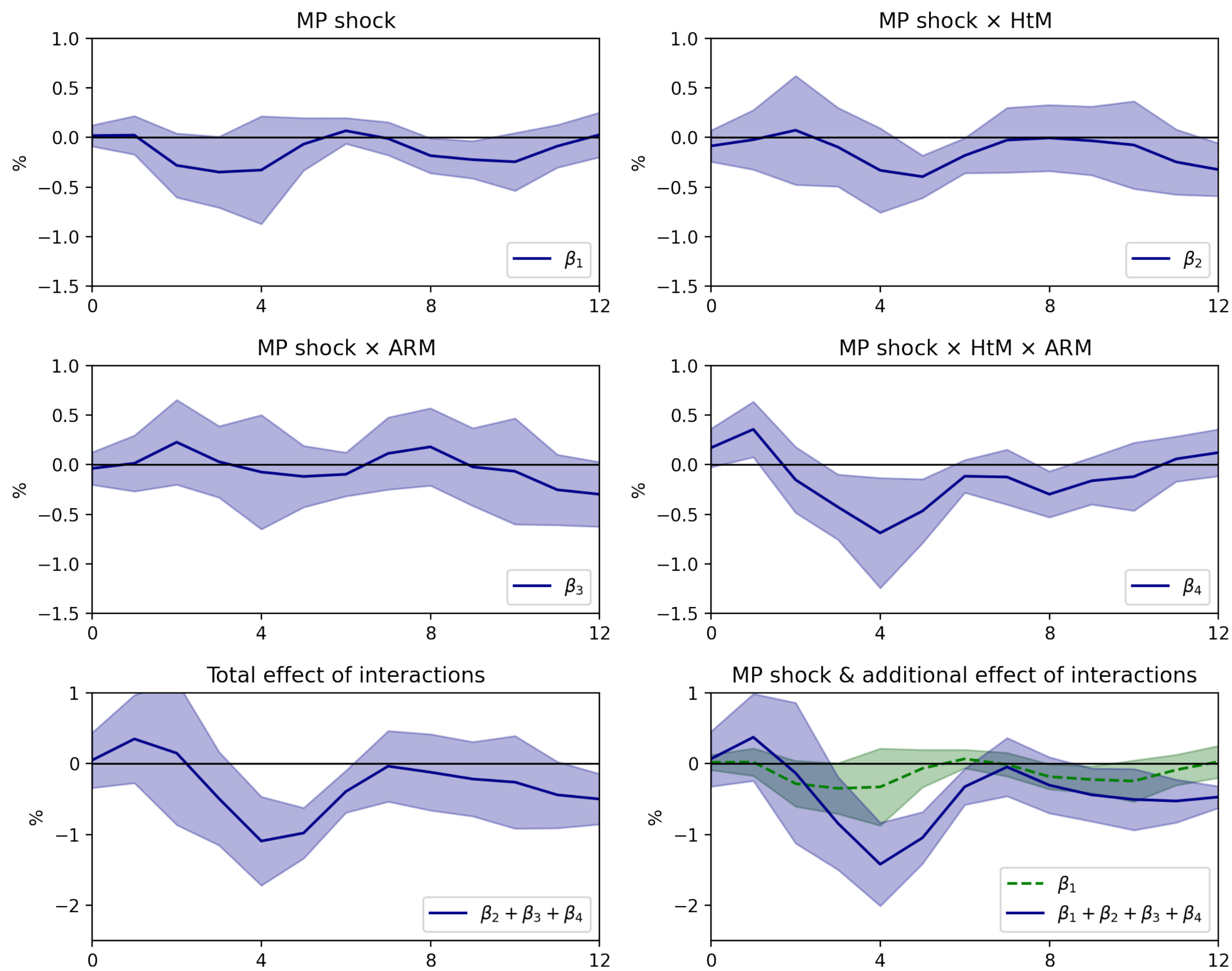
Figure B.20: Correlation between the response of consumption and HtM and ARMs shares



Notes:

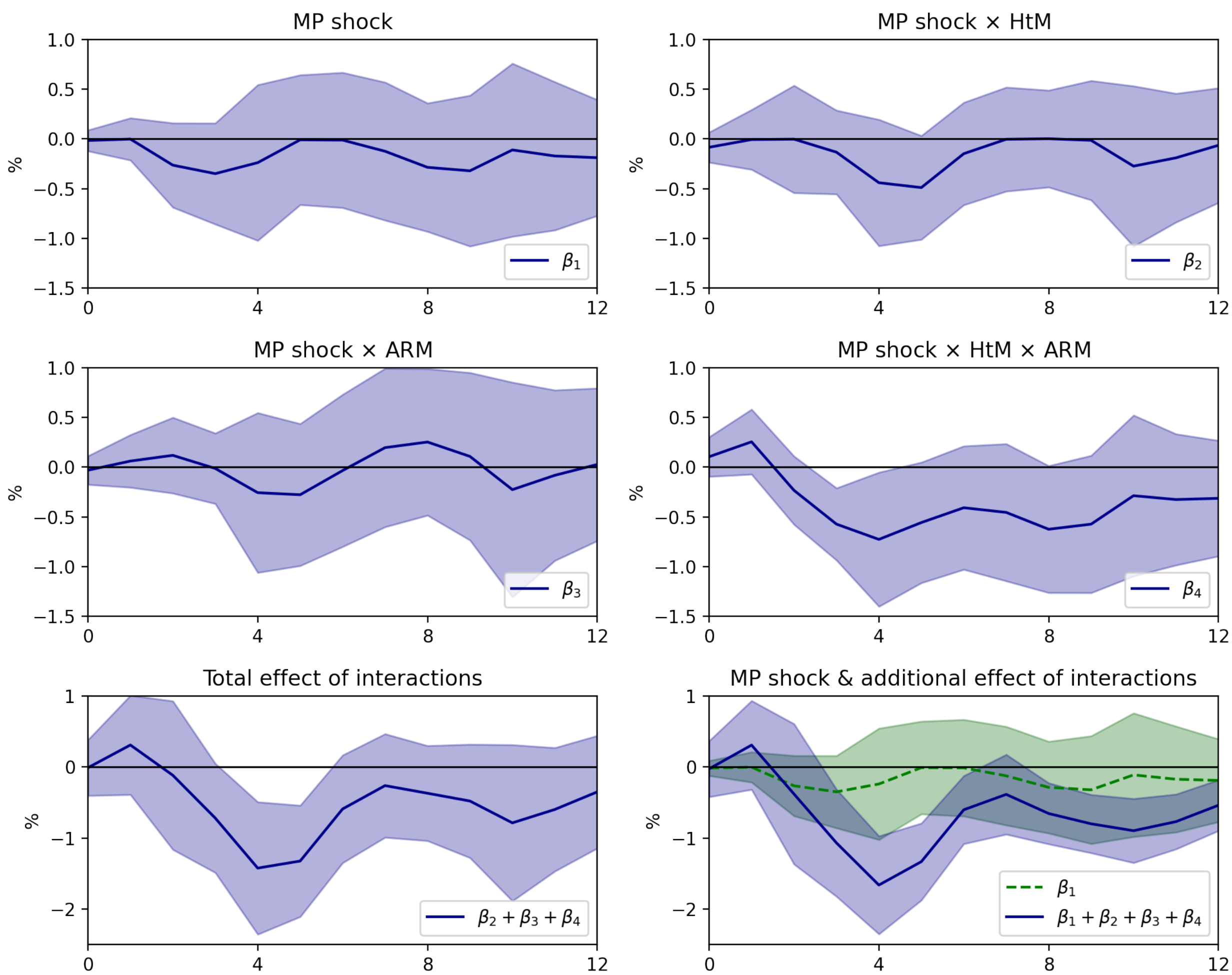
B.3 Italian local projections - Robustness

Figure B.21: Correlation between the response of consumption and HtM and ARMs shares



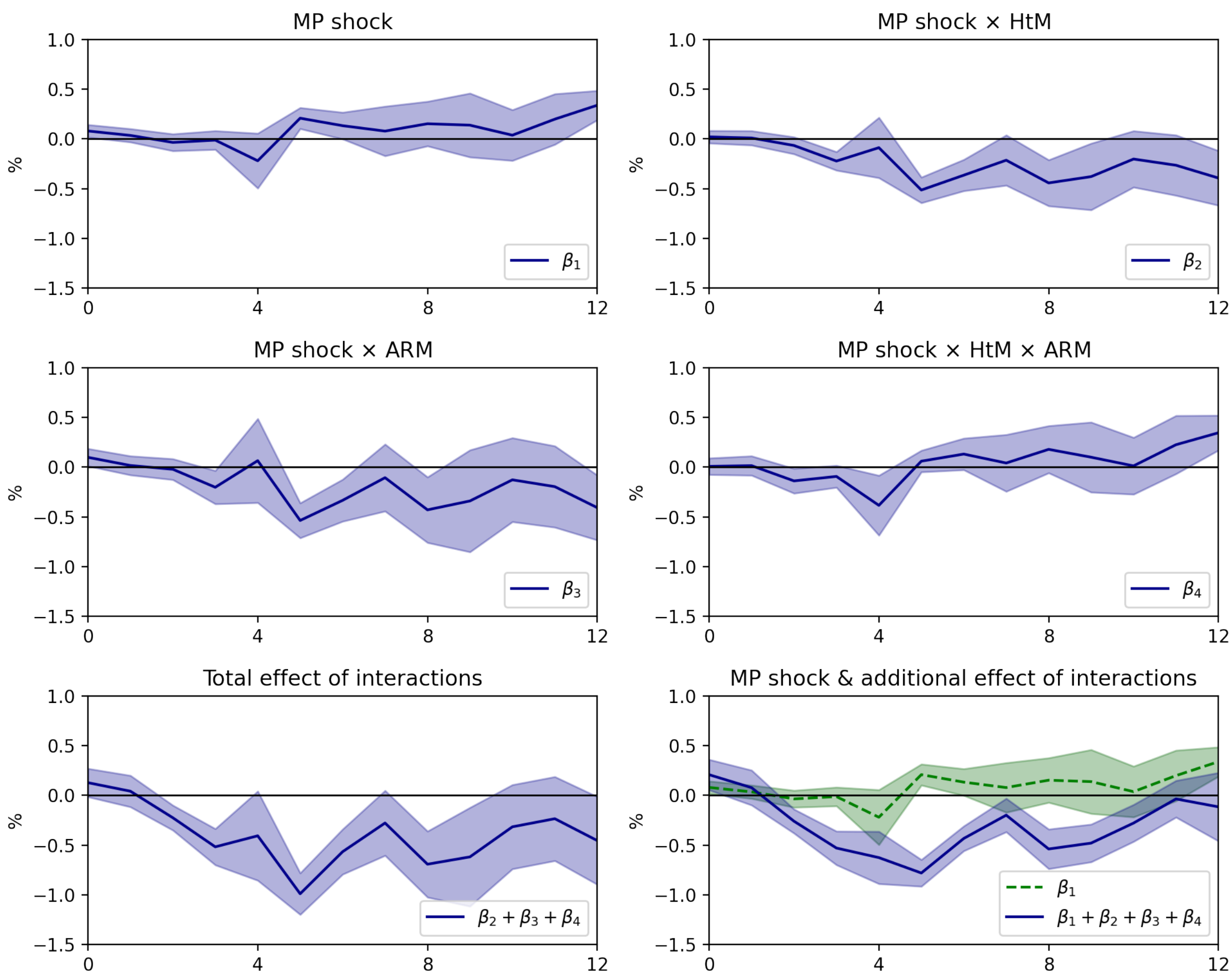
Notes:

Figure B.22: Correlation between the response of consumption and HtM and ARMs shares



Notes:

Figure B.23: Correlation between the response of consumption and HtM and ARMs shares



Notes:

C Model - Derivations and additional material

C.1 Derivation of goods market clearing condition

Households face two budget constraints, depending on whether they choose to be buyers or stayers. The two budget constraints are:

$$c + a' + ph' - b' = wen + (1+r)a - (1+r^b)b + p(1-f)(1-\delta)h - \tau$$
$$c + a' = wen + (1+r)a - (r^b + \mu)b - \tau.$$

Let:

$$C_t = \int c^i di$$
$$A_t = \int a_t^i di$$
$$B_t = \int b_t^i di$$
$$B_t^{buy} = \int^{i \in buy} b_t^i di$$
$$B_t^{stay} = \int^{i \in stay} b_t^i di$$
$$H_t = \int h_t^i di$$
$$H_t^{buy} = \int^{i \in buy} h_t^i di$$
$$H_t^{stay} = \int^{i \in stay} h_t^i di$$
$$N_t = \int e_t^i n_t^i(e,h,b,a) di$$

Aggregating the two constraints, I obtain:

$$\begin{aligned} C_t + A_t + pH_t^{buy} - B_t^{buy} =& w_t N_t + (1+r_t)A_{t-1} - (1+r_t^b)B_{t-1}^{buy} - (r_t^b + \mu)B_{t-1}^{stay} + \\ & p_t(1-f)(1-\delta)H_t^{buy} - T_t \end{aligned} \tag{33}$$

which can be re-arranged as:

$$\begin{aligned} C_t + A_t + pH_t^{buy} - B_t^{buy} =& w_t N_t + (1+r_t)A_{t-1} - r_t^b B_t - B_{t-1}^{buy} - \mu B_{t-1}^{stay} + \\ & p_t(1-f)(1-\delta)H_t^{buy} - T_t \end{aligned} \tag{34}$$

The production function (21) and the labor market condition (equation (30)) imply that $N_t = Y_t$, while firm optimality (22) implies that $w_t = 1$. Moreover, and the asset market condition (29) states that $A_t = D_t$. Substituting these conditions, equation (34) becomes:

$$\begin{aligned} C_t + D_t + pH_t^{buy} - B_t^{buy} =& w_t Y_t + (1 + r_t) D_{t-1} - r_t^b B_t - B_{t-1}^{buy} - \mu B_{t-1}^{stay} + \\ & p_t(1 - f)(1 - \delta) H_t^{buy} - T_t \end{aligned} \tag{35}$$

Imposing the government budget constraint (24) and the tax rule (25), equation (36) becomes:[38]

$$C_t + pH_t^{buy} - B_t^{buy} = Y_t - r_t^b B_t - B_{t-1}^{buy} - \mu B_{t-1}^{stay} + p_t(1 - f)(1 - \delta) H_t^{buy} \tag{36}$$

which can be re-arranged as:

$$C_t + pH_t^{buy} = Y_t - r_t^b B_t + (B_t^{buy} - B_{t-1}^{buy}) - \mu B_{t-1}^{stay} + p_t(1 - f)(1 - \delta) H_t^{buy}. \tag{37}$$

Noting that equation (9) implies, for *stayers*, $\mu B_{t-1}^{stay} = B_{t-1}^{stay} - B_t^{stay}$, equation (37) becomes:

$$C_t + pH_t^{buy} = Y_t - r_t^b B_t + (B_t^{buy} - B_{t-1}^{buy}) + (B_t^{stay} - B_{t-1}^{stay}) + p_t(1 - f)(1 - \delta) H_t^{buy} \tag{38}$$

which can be re-written as:

$$C_t + pH_t^{buy} = Y_t \underbrace{- r_t^b B_t + (B_t - B_{t-1})}_{\Omega_t} + p_t(1 - f)(1 - \delta) H_t^{buy} \tag{39}$$

Adding and subtracting pH_t^{stay}, and noting that equation (6) implies $pH_t^{stay} = (p(1 - \delta) H_{t-1}^{stay})$ equation (40) becomes:

$$C_t + pH_t = Y_t + \Omega_t - p_t f (1 - \delta) H_t^{buy} + p_t (1 - \delta) H_t \tag{40}$$

which, imposing housing market clearing (31), can be simplified into:

$$C_t + \delta p \bar{H} = Y_t + \Omega_t - p_t f (1 - \delta) H_t^{buy}, \tag{41}$$

the goods market clearing condition (32).

C.2 Calibration of μ

The parameter governing the speed of mortgage repayment is calibrated to match the duration of a typical Spanish mortgage. In particular, given the maturity of a mortgage

[38] Note that I am using the fact that $G_t = 0$.

equal to T and mortgage interest rate r^b, the duration formula is given by:

$$Duration = \frac{\sum_{t=1}^{T} tPV_t}{\sum_{t=1}^{T} PV_t} = \frac{\sum_{t=1}^{T} tPV_t}{P} \tag{42}$$

where t is the time until a mortgage payment will be made and PV_t is the present value of that mortgage payment. P represents the present value of all future mortgage payments, which is the principal. Since mortgage payments M are computed such that:

$$P = \sum_{t=0}^{T} \frac{M}{(1+r^b)^t} \tag{43}$$

it follows that:

$$M = \frac{r^b P(1+r^b)^T}{(1+r^b)^T - 1}. \tag{44}$$

Applying this definition of M, it follows that equation (42) can be re-written as:

$$Duration = \sum_{t=1}^{T} \frac{t}{(t+r^b)^t} \frac{r^b(1+r^b)^T}{(1+r^b)^T - 1}. \tag{45}$$

Given the mortgage repayment structure in the model, where $M^{model} = (r^b + \mu)b$, it follows that $M_t^{model} = (r^b + \mu)(1-\mu)^{t-1}P$, where P is the principal amount of the mortgage. Accordingly, the duration in the model will be:

$$Duration^{model} = \frac{\sum_{t=1}^{T} \frac{t(r^b+\mu)(1-\mu)^{t-1}P}{(1+r^b)^t}}{P} = \frac{1+r^b}{1+\mu}. \tag{46}$$

Accordingly, it follows that in order for $Duration = Duration^{model}$, it has to be the case that:

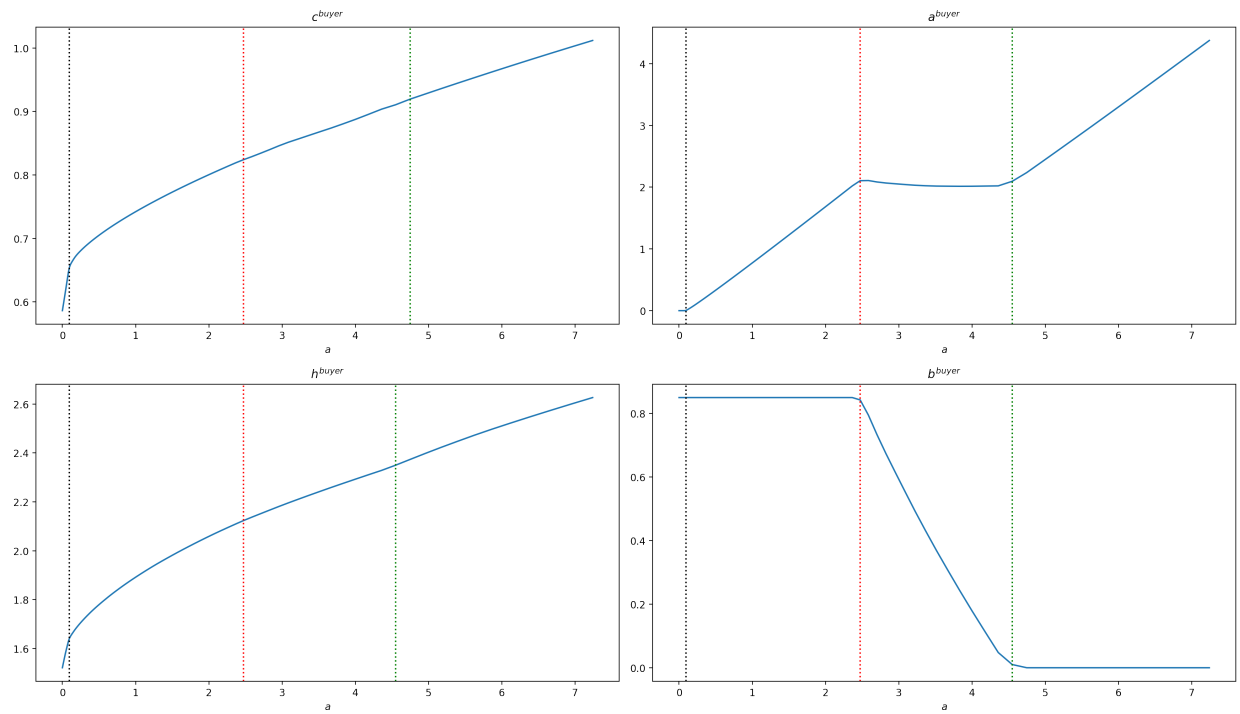
$$\mu = (1+r^b)\left(\sum_{t=1}^{T} \frac{r^b t(1+r^b)^T}{((1+r^b)^T - 1)(1+r^b)}\right)^{-1} - r^b. \tag{47}$$

Given my targets of $T = 25$ years and $r^b = 3\%$, and quarterly calibration, it follows that $\mu = 0.015$.

C.3 Policy functions

This appendix describes the policy functions that characterize the optimal behaviour of the *buyers*, those households who choose to adjust their housing stock. It is of interest to study their policy functions since they solve a particularly involved problem.

Figure C.24: Policy functions for *buyers*, households adjusting their housing stock



Notes: The x-axis is the state variable a, representing the liquid balances a household enters the period with. The policy functions are those of a representative household that enters the period with average productivity shock e and low mortgage debt bph.

Figure C.24 shows the policy functions for the four continuous choices that *buyers* make: consumption c, liquid balances a, housing stock h, and loan-to-value ratio b. The functions displayed are those of a representative household that starts the period with average income and low mortgage debt. Three vertical lines divide each chart into four areas, each characterized by a different behaviour.

The first area is the one on the left of the black vertical dotted line. This represents the area where households are at their liquid balance constraint, implying that they are not on their Euler equation. This can be seen in the policy function for a, which shows that households choose to not save any resources ($a = 0$). In this region, households have so little resources that they cannot afford their desired consumption bundle. For this reason, any additional resource they get is used to increase durable and non-durable consumption (the policy functions for c and h area particularly steep in this region), and they borrow as much as possible through mortgages (b is at the LTV constraint).

The second area is the one between the black and red lines. In this area households are on their Euler equation and have more resources than those they need to satisfy their consumption needs. Therefore, households need to choose whether to save these resources in the form of liquid balances a, or to reduce their mortgage uptake b. The figure shows that households decide to keep b at the LTV constraint and save in liquid assets a. This is the optimal behaviour due to the presence of two forces in the model. First, due to idiosyncratic uncertainty, households find it optimal to keep positive liquid savings in case of negative productivity shocks. Second, due to the presence of adjustment costs, households understand that mortgages can be accessed infrequently. Hence, when opening a mortgage with low resources, it is optimal to borrow more than what would be strictly necessary for house purchase, saving part of these resources for future needs.

The third area is the one between the red and green lines. In this area households reach the satisfactory amount of liquid savings that are necessary to face adverse productivity shocks, and decide to use their additional resources to reduce the amount they borrow through mortgages, decreasing future mortgage payments.

The fourth area is the one of the right of the green line. In this area households have enough resources to satisfy their consumption needs and do not need to open a mortgage to buy their house. Hence, any additional resource they have is saved in the form of liquid balances a.

Overall, these policy functions show that poorer households are the ones who tend to borrow as much as possible through mortgages for their house purchase, while richer households can rely on their resources to a larger extent.

C.4 Alternative results with MPC-ARM Correlation