Crawford School of Public Policy

CAMA

Centre for Applied Macroeconomic Analysis

Asymmetric Mortgage Channel of Monetary Policy: Refinancing as a Call Option

CAMA Working Paper 2/2025
January 2025

Sangyup Choi
Yonsei University
Centre for Applied Macroeconomic Analysis, ANU

Kimoon Jeong
University of Virginia

Jiseob Kim
Yonsei University

Abstract

We study how the call option-like refinancing structure can affect the transmission channel of monetary policy on consumption. Utilizing European data, we find that contractionary shocks induce a larger decline in consumption in countries with a higher share of adjustable-rate mortgages (ARMs), confirming the well-known finding. In contrast, consumption responses to expansionary shocks do not depend on this share, resulting in the asymmetric mortgage channel that has not been documented. Household-level microdata and quantitative analysis indicate that refinancing in response to a decline in the interest rate—akin to exercising call options—is the key to rationalizing our findings.

Keywords

adjustable-rate mortgages, refinancing, monetary policy, consumption, call option

JEL Classification

E21, E32, E44, E52, G21, G51

Address for correspondence:

(E) cama.admin@anu.edu.au

ISSN 2206-0332

Asymmetric Mortgage Channel of Monetary Policy: Refinancing as a Call Option*

Sangyup Choi† Kimoon Jeong‡ Jiseob Kim§

Yonsei University University of Virginia Yonsei University

December 19, 2024

Abstract

We study how the call option-like refinancing structure can affect the transmission channel of monetary policy on consumption. Utilizing European data, we find that contractionary shocks induce a larger decline in consumption in countries with a higher share of adjustable-rate mortgages (ARMs), confirming the well-known finding. In contrast, consumption responses to expansionary shocks do not depend on this share, resulting in the asymmetric mortgage channel that has not been documented. Household-level microdata and quantitative analysis indicate that refinancing in response to a decline in the interest rate—akin to exercising call options—is the key to rationalizing our findings.

JEL Classification: E21; E32; E44; E52; G21; G51

Keywords: Adjustable-rate mortgages; Refinancing; Monetary policy; Consumption; Call option

*We are thankful to George Alessandria, Yan Bai, Scott Baker, David Baqaee, Bharat Bhole, Mark Bils, Pauline Carry, Marc Dordal Carreras, Hyun-Soo Choi, Maximiliano Dvorkin, Rafael Guntin, Seolwoong Hwang, Ayse Imrohoroglu, Eungsik Kim, Sunghyun Henry Kim, Rishabh Kirpalani, Benny Kleinman, Eunmi Ko, Narayana Kocherlakota, Byoungchan Lee, Kyungwoo Lee, Paulo Lins, Eunseong Ma, Yueran Ma, Toshihiko Mukoyama, Kwangyong Park, Sunjin Park, Tarun Ramadorai, Dimitrije Ruzic, Liyan Shi, Ludwig Straub, Peter Tillmann, Michael Weber, and seminar participants at the Bank of Korea, CEA 2024 Conference, Hong Kong University of Science and Technology, Rochester Institute of Technology, University of Kansas, University of Rochester, 2024 KER International Conference, 2nd Yonsei Macroeconomics Workshop, 19th Annual Conference on Asia-Pacific Financial Markets, and Yonsei University for helpful comments. Jiseob Kim gratefully acknowledges the support and hospitality of the Department of Economics during his time as a visiting associate professor at the University of Rochester. Sangyup Choi: This research was supported by the Yonsei Signature Research Cluster Program of 2024 (2024-22-0172) and the Yonsei Fellow Program, funded by Lee Youn Jae. Jiseob Kim: This research was supported by the Yonsei Economics Research Fund (R. K. Cho Research Cluster Program). Any errors are the authors' responsibility.

†School of Economics, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, South Korea. Email address: sangyupchoi@yonsei.ac.kr.

‡Department of Economics, University of Virginia, 248 McCormick Rd., Charlottesville, VA 22904-4182, USA. Email address: bxm2vk@virginia.edu.

§School of Economics, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, South Korea. Email address: jiseob.kim@yonsei.ac.kr.

1 Introduction

This paper studies how monetary policy impacts consumption through the mortgage channel. Since mortgages typically constitute the largest portion of household debts, and their interest payments are highly susceptible to changes in the policy rate, especially for adjustable-rate mortgages (ARMs), the mortgage channel of monetary policy has been widely examined in the literature (Garriga, Kydland, and Sustek (2017), Di Maggio et al. (2017), Flodén, Kilström, Sigurdsson, and Vestman (2021), Pica (2021), Corsetti, Duarte, and Mann (2022), and more). The literature theoretically and empirically showed that monetary policy transmission is stronger in an economy with a higher share of ARMs.

Drawing on comprehensive aggregate and household-level microdata from multiple European economies, we analyze whether this transmission channel depends on the sign of monetary policy shocks and evaluate the influence of mortgage refinancing costs on these dynamics. The European data provides an ideal environment for answering the question for two reasons. First, the euro area member countries are subject to a common monetary policy shock, which alleviates the usual endogeneity concern about monetary policy. Second, there is substantial heterogeneity in the share of ARMS across countries (e.g., Calza, Monacelli, and Stracca (2013) and Corsetti et al. (2022)), which can sharpen identification.

Our empirical motivation is demonstrated in two steps. First, based on aggregate data from 18 European countries over the last two decades, we examined whether the role of ARMs in explaining consumption responses differs between monetary tightening and easing. We find that the consumption expenditure of an economy with a high share of ARMs tends to decrease more in response to contractionary monetary policy shocks, consistent with previous research such as Calza et al. (2013), Pica (2021), Corsetti et al. (2022), and Finck, Schmidt, and Tillmann (2023). Interestingly, under expansionary monetary policy shocks, consumption responses do not exhibit significant differences across the share of ARMs — a novel finding not present in the existing literature.

Second, household-level micro evidence also supports the macro-level findings. We utilize the panel structure of the Household Finance and Consumption Survey (HFCS) from the second to the fourth wave published by the European Central Bank (ECB) to examine whether consumption responses differ among mortgagors with and without ARMs when the ECB policy rate (measured by the Euro Overnight Index Average (EONIA) rate) decreases.[1] Our analysis reveals that consumption expenditure among mortgagors with ARMs does not significantly differ from that of mortgagors with fixed-rate mortgages (FRMs), in line with macro-level evidence. Differences in financial decisions and characteristics between mortgagors holding ARMs and those with non-ARMs do not account for these results. Thus, holding ARMs does not necessarily increase consumption expenditure more when monetary policy is expansionary.

We argue that the cost of call option-like refinancing (i.e., refinancing cost) is the main driving force behind this asymmetry. Consider an economy where FRMs predominate, and an expansionary monetary policy shock occurs. If mortgagors face substantial costs to switching mortgage types or obtaining additional loans through refinancing—manifested as a high option cost for refinancing—household consumption will experience minimal change. Conversely, if refinancing is less costly, mortgagors can refinance to lock in a permanently lower mortgage interest rate (i.e., exercise the call option). Consequently, the share of ARMs decreases, reflecting the compositional change in mortgage types, and consumption significantly increases. We also find a strong negative correlation between refinancing frequency and the share of ARMs in the data, indicating that lower refinancing costs (or higher refinancing frequencies) are indeed an important feature of countries with prevalent FRM mortgages.

Of course, due to the improvement in their balance sheets, mortgagors in an economy where ARMs are dominant also experience an increase in consumption. However, if refinancing is a costly option under the ARM economy, ARM mortgagors cannot permanently reduce their mortgage interest rate and thus experience only a temporary reduction in their interest payments. Consequently, consumption increases only during the period of expansionary policy stances.

Analysis based on the panel data from the HFCS suggests that refinancing can be an important channel for stimulating consumption. Mortgagors who refinance their mortgages tend to

[1] As will be explained later, the first wave of HFCS did not include information about consumption expenditure on goods and services, our main outcome variable. Additionally, the EONIA rate continued to decrease between the second and fourth waves of HFCS.

increase both non-durable and durable consumption expenditures compared to those who do not refinance. We find that the former group increased their consumption expenditure on goods and services by 6.8% more from the second wave (2014) to the third wave (2017) of the HFCS compared to the latter group. The value of vehicles, which captures expenditure on durable goods, also increased by 18% more among refinancers. However, the value of exercising the refinancing option is small when the policy rate decreases marginally between the third wave (2017) and the fourth wave (2021), leading to insignificant differences in consumption changes between refinancers and non-refinancers.

Given the challenges in directly measuring refinancing costs across countries and various frictions resulting in implicit costs beyond nominal costs, we infer them indirectly through refinancing frequency. To this end, we develop a heterogeneous agent model to calibrate these costs and match observed refinancing rates. Specifically, we analyze how contractionary and expansionary monetary policies affect consumption across different mortgage market structures, considering varying combinations of ARM shares and refinancing costs. In the model, each household makes endogenous decisions regarding homeownership and house size, chooses between long-term ARMs or FRMs, and decides whether to continue repaying mortgages as contracted, sell the house, refinance the mortgage, or default.

The primary distinctions between ARMs and FRMs lie in the variability of interest rates, the interest rate margins, and the type-specific origination costs. Reflecting the European mortgage market, mortgages in our model are recourse, granting lenders the right to recover losses by garnishing defaulters' future income and financial assets. The housing stock depreciates each period, prompting the construction sector to supply new housing based on a simple functional formula. Consequently, house prices are endogenously determined to clear the housing market.

Since it is challenging to calibrate for each European country, we instead calibrated the model to match key household finance moments of the German economy where micro-data necessary to match the key moments is more available than in other euro area economies. We then consider three counterfactual steady-state economies that differ from the benchmark in terms of the share of ARMs and refinancing costs. First, we recalibrate an economy that differs from the benchmark solely in the cost of refinancing. While the benchmark assumes high refinancing costs to match the refinancing rate, this experimental economy assumes costless refinancing while maintaining the benchmark share of ARMs and other key targeted moments. In the other two economies, ARMs are the only available mortgage option (an "ARM-only economy"), but they differ in refinancing costs—one has costly refinancing, and the other has costless refinancing—affecting the costs of changing loan terms and size.

Given four initial steady states, we model the annual risk-free rate, which captures monetary policy, unexpectedly increasing or decreasing by 0.5 percentage points and gradually converging back to the original level over the next four quarters (MIT monetary policy shocks). We assume that every market participant perfectly forecasts the risk-free rate path once they face the shock. Our simulation reveals that consumption responds asymmetrically as the cost of refinancing decreases. Specifically, when refinancing is costly, consumption responses to both monetary policy shocks amplify as the share of ARMs increases. However, as the cost of refinancing decreases, the mortgage channel of monetary policy becomes sign-dependent. With a high share of ARMs, consumption decreases more in response to the contractionary shock. At the same time, there are negligible differences in consumption responses across the share of ARMs under the expansionary shock, consistent with our novel findings.

The main driver is refinancing costs, which allow for changes in the composition of mortgage types (FRMs vs. ARMs) through exercising the refinancing option. When the cost of refinancing is low, a significant portion of mortgagors exercise the option to convert their mortgages into newly contracted FRMs during an expansionary shock. Due to the long-term nature of these contracts, they can lock in mortgage interest rates at a low level, thereby persistently improving their balance sheets and significantly increasing consumption. However, this mechanism is less effective when the cost of refinancing is sufficiently high, deterring mortgagors from exercising the costly refinancing option. In contrast, under a contractionary monetary policy shock, mortgagors have little incentive to exercise the refinancing option regardless of its costs, except for those experiencing temporary financial constraints (Chen, Michaux, and Roussanov (2020)). Consequently, the responses of consumption, as well as most macroeconomic and household finance-related variables, do not differ significantly under varying refinancing costs.

This paper is organized as follows. Section 2 reviews related papers. Asymmetric consumption responses to monetary policy shocks, which are our motivating empirical evidence, and the micro evidence for the refinancing channel are examined in Section 3. We introduce a quantitative model in Section 4 and present the calibration in Section 5. The main quantitative results are presented in Section 6. Section 7 concludes the paper.

2 Literature review

This paper is related to several strands of research investigating the transmission channels of monetary policy, mortgage structures, refinancing, and optimal consumption and borrowing decisions through empirical and theoretical analysis. In terms of research questions, the most relevant papers are Rubio (2011), Calza et al. (2013), Garriga et al. (2017), Di Maggio et al. (2017), and Flodén et al. (2021), which examine the mortgage channel of monetary transmission. These studies explore the impact of different mortgage types (FRMs vs. ARMs) on consumption in response to monetary policy shocks, concluding that monetary policy amplifies consumption in economies dominated by ARMs. However, prior research does not investigate potential asymmetry in this mechanism between contractionary and expansionary shocks. This paper addresses this gap and examines the mechanisms behind these asymmetric responses.

Our central mechanism for elucidating asymmetric consumption responses is refinancing costs, which can be interpreted as the cost of exercising a refinancing (call) option. This study is not the first to scrutinize the role of refinancing in stimulating consumption. For example, Di Maggio, Kermani, and Palmer (2019) and Byrne, Devine, King, McCarthy, and Palmer (2023) have empirically and experimentally demonstrated that refinancing can spur consumption during an expansionary monetary policy stance. In terms of theoretical underpinnings, Greenwald (2018) proposes that easy prepayment (referred to as refinancing in our study) can empower mortgagors to lock in low mortgage interest rates, thereby amplifying mortgage credit and output in response to expansionary shocks, aligning with the mechanism examined in our research. Although we do not explicitly model borrowers' heterogeneous (in)attention to refinancing decisions, as done by Berger, Milbradt, Tourre, and Vavra (2023), Byrne et al. (2023), and Zhang (2024), such frictions in exercising the refinancing option can be interpreted as our modeled refinancing cost. While complementing these works, our study distinguishes itself by focusing on the heterogeneity of mortgage types both within and between economies and by examining how these differences interact with the refinancing channel.

Beyond consumption responses, extensive literature examines the macroeconomic effects of monetary policy through refinancing. The mechanisms by which refinancing influences real macroeconomic variables include aggregate debt levels (Alpanda and Zubairy (2019)), regional heterogeneity in home equity (Beraja, Fuster, Hurst, and Vavra (2019)), households' age-specific loan size and income path (Wong (2021)), historical interest rate paths (Berger, Milbradt, Tourre, and Vavra (2021) and Eichenbaum, Rebelo, and Wong (2022)), liquidity incentives (Chen et al. (2020)), and banking sector competitiveness (Aastveit and Anundsen (2022)) Instead, we focus on consumption and aim to resolve puzzling empirical findings through the lens of the refinancing channel.

Besides refinancing, other institutional characteristics—such as financial integration, housing and labor markets, and liquidity constraints—can also affect the transmission channel of monetary policy on macro variables. For example, Cloyne, Ferreira, and Surico (2020) and Almgren, Gallegos, Kramer, and Lima (2022) argued that the share of hand-to-mouth (HtM) households is an important factor, and Corsetti et al. (2022) examined heterogeneity in wage rigidity, the shares of HtM and ARMs, and the homeownership rate. Although we do not consider non-mortgage-related factors, our results show that the call option-like channel of refinancing helps explain the asymmetric responses of consumption to monetary policy.

Our findings also relate to the long-standing literature on the asymmetric macroeconomic effect of monetary policy. For example, there have been many studies on whether the macroeconomic effect of monetary policy shocks depends on their sign (Cover (1992), Weise (1999), Angrist, Jordà, and Kuersteiner (2018), Barnichon and Matthes (2018)) or the underlying state of the economy (Tenreyro and Thwaites (2016), Jordà, Schularick, and Taylor (2020), Alpanda, Granziera, and Zubairy (2021), Choi, Willems, and Yoo (2024)). We contribute to the literature by presenting new evidence that the interaction between mortgage market structure (i.e., ARM vs. FRM) and refinancing costs can generate the asymmetric macroeconomic effects of monetary policy. To the extent that household refinancing decisions can be affected by the state of the economy (Chen et al. (2020); DeFusco and Mondragon (2020); Eichenbaum et al. (2022)), our findings may help reconcile the contrasting evidence found in the existing literature.

After the seminal theoretical framework for endogenous mortgage choices by Campbell and Cocco (2003), many researchers have examined the driving forces that affect the heterogeneity of the share of ARMs across countries and the within-country fluctuation over time.[2] Although we do not explicitly model the financial and non-financial characteristics influencing the share of ARMs, we complement existing research by demonstrating, both empirically and theoretically, that monetary policy significantly affects ARM share fluctuations. Furthermore, our findings show that prolonged low interest rates reduce the share of ARMs, consistent with the data.

Lastly, our quantitative model structure is closely related to papers that examine households' optimal housing tenure and mortgage choices under the framework of heterogeneous agent models.[3] Most of them focus on the financial crisis period and provide policy implications to stabilize macro volatility. In contrast, we set up a model to examine the mortgage refinancing channel that can improve the efficacy of monetary policy.

3 Empirical evidence

In this section, we present macro- and micro-level empirical evidence of asymmetric consumption responses to monetary policy changes and demonstrate that refinancing serves as the primary channel driving our findings. First, we provide macro evidence indicating that consumption responses, dependent on the state (i.e., the share of ARMs), exhibit asymmetry between contractionary and expansionary monetary policy shocks. Specifically, monetary tightening leads to a greater reduction in consumption expenditures in economies with a higher share of ARMs. In contrast, under expansionary shocks, the consumption responses do not signifi-

[2]The former topic is studied by Ehrmann and Ziegelmeyer (2017), Badarinza, Campbell, and Ramadorai (2018), and Albertazzi, Fringuellotti, and Ongena (2024). Utilizing US data, Koijen, Hemert, and Nieuwerburgh (2009), Moench, Vickery, and Aragon (2010), Coulibaly and Li (2009), and Johnson and Li (2014) investigated factors determining the share of ARMs and explained its volatility. Andersen, Campbell, Cocco, Hansman, and Ramadorai (2023) examined the same topic using Danish administrative data.

[3]Chatterjee and Eyigungor (2015), Corbae and Quintin (2015), Hatchondo, Martinez, and Sánchez (2015), Campbell and Cocco (2015), Mitman (2016), Kim (2020), Kaplan, Mitman, and Violante (2020), Guren, Krishnamurthy, and Mcquade (2021), Gete and Zecchetto (2024), and more.

cantly differ with the share of ARMs, a phenomenon not previously explored in the literature. Second, utilizing country-household-level panel data from the HFCS, we find that consumption responses to the decrease in policy rates are not significantly different between ARM and FRM mortgagors, corroborating the macro-level findings.

Third, we explore various hypotheses to account for the asymmetric consumption responses across different shares of ARMs, including disparities in savings behavior, non-mortgage debt repayments, borrowing constraints, fiscal policies, and responses of mortgage interest rates but find that these factors do not sufficiently explain the observed asymmetries. Finally, we provide micro-level evidence from the HFCS data that refinancing is the critical channel through which expansionary shocks influence consumption regardless of the underlying mortgage structure: mortgagors who refinance in response to a policy rate decrease exhibit a larger increase in consumption compared to those who do not refinance.

3.1. Empirical motivation: Macro evidence

We sampled 18 euro area countries that share a common monetary policy but display varying shares of ARMs across countries and over time.[4] To investigate whether the influence of the mortgage structure on consumption is symmetric between contractionary and expansionary monetary policy shocks, we employ the state-dependent local projection (LP) method, as described in Jorda (2005) and Ramey and Zubairy (2018).

$$
\begin{aligned}
\Delta y_{i,t+h} = & I_t \sum_{j=0}^{4} \left(\theta^P_{j,h} \text{SARM}_{i,t} \varepsilon_{t-j} + \beta^P_{j,h} \varepsilon_{t-j} + \gamma^P_{j,h} \text{macro}_{it-j} \right) \\
& + (1 - I_t) \sum_{j=0}^{4} \left(\theta^N_{j,h} \text{SARM}_{i,t} \varepsilon_{t-j} + \beta^N_{j,h} \varepsilon_{t-j} + \gamma^N_{j,h} \text{macro}_{i,t-j} \right) \\
& + \sum_{j=1}^{4} \mu_j y_{i,t-j} + \text{Linear and Quadratic Time Trend}_t + (C_i + T_t) + e_{i,t+h}
\end{aligned}
$$

where the subscript i denotes the country, and t represents time measured in quarters. The primary dependent variable is the logarithmic difference in consumption expenditure.

[4]The 18 countries included in the sample are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Portugal, Slovakia, Slovenia, and Spain.

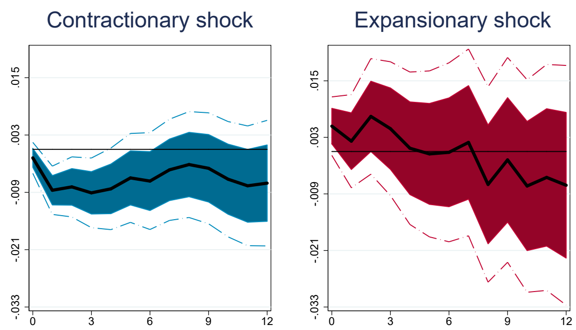
The variable ε_t represents the monetary policy shock, identified using the high-frequency approach detailed in Jarociński and Karadi (2020), and is extended to cover data up to June 2023. The function I_t is a dummy variable indicating the sign of the monetary policy shock, taking the value of one for contractionary shocks and zero otherwise. We account for macroeconomic conditions, denoted by $macro_{i,t}$, by incorporating GDP growth rates and inflation rates, as well as lags of the dependent variable. Additionally, we control for both linear and quadratic time trends.

The variable $\text{SARM}_{i,t}$ denotes the share of ARMs. Since the share of ARMs is an endogenous variable affected by monetary policy and is highly volatile in some sample countries, we measure it at a low frequency to capture persistent country-specific characteristics. We employ three measurement approaches. First, we calculate the ratio of outstanding residential ARM balances to the total balances of residential mortgages for each country and each wave of HFCS, averaging them across waves. This provides the share of ARMs which varies across countries but remains constant over time (refer to Table H1 in the Appendix). Second, we use the quarterly share of new loans to households for house purchases with a variable rate or an initial rate fixation period of up to one year in total new loans for house purchases from the ECB. We then extract the trend component using the HP filter to generate low-frequency data for each country (see Figure I1 in the Appendix). Third, we define an indicator function that equals one if the share of ARMs measured by HFCS is larger than 50%, and zero otherwise.

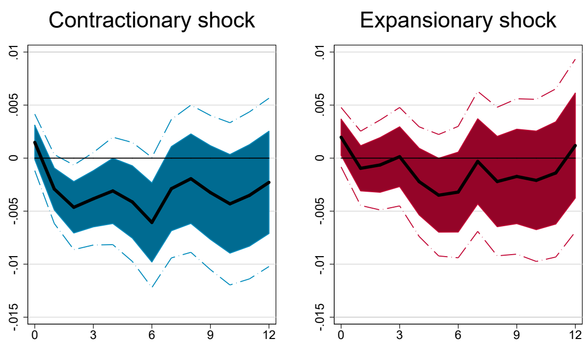
In the first definition of the share of ARMs, we exclude both the country-fixed effect C_i and the time-fixed effect T_t. Excluding the time-fixed effect allows us to estimate the direct responses of outcome variables to monetary policy shocks, regardless of the share of ARMs. Also, the model without the country-fixed effect enables us to utilize the variation across countries for identification purposes. In the second definition, we include both the time and country-fixed effects to account for impacts from the variation of the share of ARMs within a country. This model identification, however, cannot estimate the direct impacts of monetary policy shocks on consumption $\beta^P_{j,h}$ and $\beta^N_{j,h}$. In the third definition, the country and time-fixed effects are not included. In this specification, we examine the differing responses of consumption for both groups (countries with low vs. high shares of ARMs) to monetary policy shocks.

Figure 1: Consumption responses to contractionary and expansionary monetary policy shocks: The role of ARM share

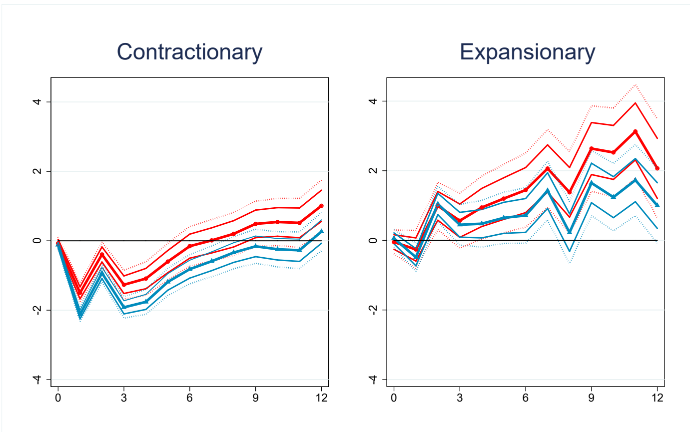
(a) SARM: the ratio of outstanding balances measured from the HFCS



(b) SARM: the trend component of the ratio of newly issued balances.



(c) SARM: one if the share of ARMs $\geq 50\%$, and zero otherwise



This figure presents the responses of consumption expenditure to a one standard deviation increase (contractionary, first column) and decrease (expansionary, second column) in monetary policy shocks, depending on the share of ARMs, respectively. The variable SARM is measured in three ways: the stock ratio from HFCS (panel (a)), the trend component of the flow ratio (panel (b)), and the indicator that is one if the stock ratio is larger than 50%, and zero otherwise (panel (c)). In panels (a) and (b), the solid (dashed) lines represent 68% (90%) confidence intervals. In panel (c), the responses for a low share of ARM economies are depicted by a red line, while those for a high share of ARM economies are illustrated with a blue line. Dashed (dotted) lines denote confidence intervals of 68% (90%).

We estimate the model using data from 2003q1 to 2023q2.[5] Each panel in Figure 1 presents our estimation results. The first (second) column represents responses to contractionary (expansionary) monetary policy shocks. The first two panels present the estimated coefficients $\theta^P_{0,h}$ and $\theta^N_{0,h}$, where $h = 0, 1, 2, ..., 12$, under the first and second definitions of the share of ARMs, respectively. Both definitions of the share of ARMs show similar results. During contractionary monetary policy periods, economies with a higher share of ARMs tend to experience larger decreases in consumption. However, expansionary monetary policy shocks do not differentiate consumption responses across shares of ARMs.

In panel (c), we present $\beta^P_{0,h}$ and $\beta^N_{0,h}$ for economies with low shares of ARMs (red line) and $\theta^P_{0,h} + \beta^P_{0,h}$ and $\theta^N_{0,h} + \beta^N_{0,h}$ for those with high shares of ARMs (blue line). Consistent with previous panels, there are divergent responses in consumption across shares of ARMs under contractionary shocks. However, we observe no significant differences in consumption under expansionary shocks. Though not statistically significant, consumption for economies with high shares of ARMs increases less than that for economies with low shares of ARMs — a result opposite to previous research. Thus, the transmission of monetary policy on consumption expenditure by the share of ARMs exhibits asymmetry in the sign of monetary policy shocks.[6]

To ensure the robustness of our results, we utilize alternative definitions of monetary policy shocks, incorporate additional macroeconomic control variables, and examine outcomes for both durable and nondurable consumption expenditures. First, we employ monetary policy shocks identified by Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) and Kerssenfischer (2022).[7] Figure I3 in the Appendix, based on the same econometric specifications, shows a pronounced impact on consumption expenditures in economies with a higher share of ARMs under contractionary monetary policy. In contrast, consumption responses do not differ significantly across the share of ARMs under expansionary shocks, which aligns with our main results.

[5] Detailed data descriptions and sources are presented in the Appendix (see Tables H2 and H3).

[6] In addition to coefficients on interaction terms, Figure I2 in the Appendix presents responses of major macro variables (GDP, consumption, investment, and mortgage debt) to monetary policy shocks, $\beta^P_{0,h}$ and $\beta^N_{0,h}$, under the first definition of SARM. The responses of these variables align with theoretical expectations, indicating that the monetary policy shock used in this paper is well-identified.

[7] Using the Press Release Window German bond 3-month shock series from Altavilla et al. (2019), we capture immediate bond yield reactions to ECB policy announcements. Additionally, we utilize 'pure policy' shock data from Kerssenfischer (2022), which distinguish policy adjustments from central bank information effects.

Second, our findings remain robust even after including additional macroeconomic control variables, such as per capita nominal GDP, financial depth, government size, and trade and financial openness, which are known to affect the effectiveness of monetary policy shocks (see Figure I4 in the Appendix). Third, we observe consistent results for both durable and nondurable consumption expenditures in response to monetary policy shocks, as demonstrated in Figure I5 in the Appendix.

3.2. Empirical motivation: Micro evidence

By leveraging the panel structure of the HFCS, we provide evidence that ARM mortgagors do not necessarily increase consumption more than FRM mortgagors in response to policy rate decreases. The timing of the surveys for each wave of the HFCS is depicted in Figure 2.[8] Although the ECB surveys approximately 20 European countries cross-sectionally in each wave, we can generate panel data for only a subset of countries, depending on the wave (ECB (2023)). Furthermore, our main outcome variable, consumption expenditure on goods and services, was not surveyed in the first wave. Consequently, we use waves 2 through 4 of the HFCS to generate an unbalanced panel dataset: six countries for the waves 2-3 panel and nine countries for the waves 3-4 panel.[9]

The EONIA rate has steadily decreased during our analysis periods. The rate decreased by 0.49 percentage points between Wave 2 and Wave 3 and by 0.15 percentage points between Wave 3 and Wave 4. Thus, comparing the Wave 2-3 panel to the Wave 3-4 panel allows us to examine different responses of consumption to the different changes in the ECB policy rate.

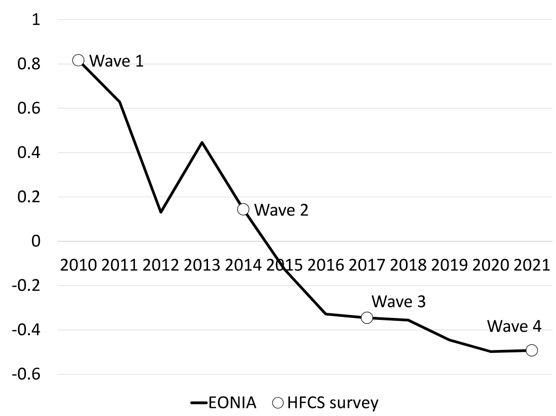
Consider the following household-level panel regression:

$$\Delta y_{i,j,t} = \beta_t (\text{Mortgage structure})_{i,j,t} I_t + \Delta X_{i,j,t} + \Lambda_{j,t} + \varepsilon_{i,j,t},$$

[8] The exact interview timing somewhat varies across countries and households, even within the same country. Despite these variations, we calculate the average survey timing and present it in Figure 2.

[9] The countries included in the wave 2-3 panel data are Belgium, Germany, Spain, Italy, Cyprus, and Malta. The countries included in the wave 3-4 panel data are Belgium, Germany, Estonia, Spain, France, Italy, Cyprus, Malta, and Slovakia. Although we could generate wave 3-4 panel data for Finland, it does not contain information on mortgage types (ARMs vs. FRMs). Therefore, Finland is excluded from our micro-data analysis.

Figure 2: EONIA rate and survey timing of HFCS



This figure shows the EONIA rate and the survey timing for each wave of the HFCS.

where i represents households; j represents countries; $t \in \{2,3,4\}$ represents the survey wave; $X_{i,j,t}$ is a set of control variables; $\Lambda_{j,t}$ are the country$\times$time-fixed effects, respectively. We employ two types of dependent variables y: (1) the logarithm of consumption expenditure on consumer goods and services, and (2) the logarithm of the total value of vehicles. The former is directly surveyed in HFCS and measures the expenditure on non-durable goods.[10] Since the survey does not include expenditures on durable goods, we use expenditures on vehicles to proxy them.

The variable *Mortgage structure* captures each mortgagor's share of ARMs, which will be specified below. By interacting it with the time-fixed effect, we can examine how mortgage types differently affect consumption expenditure when the ECB policy rate changes. Control variables include household income, the value of the main residential home, and the balance of residential mortgages. Importantly, $\Lambda_{j,t}$, which cannot be included in the macro-level estimation, absorb various confounding factors, such as the country-specific decline in the actual mortgage rates, time-varying credit supply side conditions, and slow-moving institutional factors, thereby sharpening identification. All variables are converted into real terms using deflating parameters provided by ECB (2016), ECB (2020), and ECB (2023).

To illustrate that holding ARMs does not necessarily lead to a larger increase in consumption

[10] In HFCS, a survey question asks for the amount spent on consumer goods and services (variable code HI0220). It includes all household expenses (food, utilities, childcare and health care expenses, etc.) but excludes consumer durables (e.g., cars, household appliances, etc.), rent, loan repayments, insurance policies, and renovation.

when the policy rate decreases, we define the variable *Mortgage structure* as follows:

$$(\text{Mortgage structure})_{i,j,t} = \begin{Bmatrix} 1 & \text{if the share of ARMs}_{i,j,t-1} \geq 0.5 \\ 0 & \text{if the share of ARMs}_{i,j,t-1} < 0.5 \end{Bmatrix}$$

The share of ARMs is defined as the ratio of the total balance of residential ARMs to the total balance of residential mortgages.[11] The variable *Mortgage structure* is equal to one if the share in the previous wave is larger than 50%, and zero otherwise.

We also define the variable as the ratio of the ARM balance to the total household debt balance.

$$(\text{Mortgage structure})_{i,j,t} = \frac{\text{ARM balances}_{i,j,t-1}}{\text{Total household debt}_{i,j,t-1}}$$

Households might have multiple types of debt, including unsecured loans, credit card debts, auto loans, and educational loans. Since the payment burden of ARMs often constitutes the largest portion of total debt and is highly sensitive to changes in policy rates, this variable reflects the relative significance of varying mortgage payment burdens within the total debt.

As shown in the first two panels of Table 1, the consumption expenditure responses of ARM mortgagors are not statistically different from those of FRM mortgagors when the ECB reduces the policy rate. Additionally, despite a more significant policy rate reduction during waves 2-3 (denoted by $I\{Wave3\}$), we do not observe a differential response in consumption expenditures—whether durable or non-durable—between FRM and ARM mortgagors. These results hold under both definitions of the share of ARMs. We also directly consider the change in the country-level real EONIA rate, defined as the EONIA rate adjusted for country-level inflation, and construct the independent variable as the interaction between this rate and the share of ARMs. As indicated in Table H4 in the Appendix, our main findings remain consistent. This aligns with the macro evidence, which shows that consumption responses do not vary significantly with the share of ARMs.

[11] As some households hold multiple types of residential mortgages, we define the ratio based on total balances.

Table 1: Micro evidence of consumption responses to policy rate decreases

	Δln(C)				Δln(Car value)			
$I\{ARM@(t-1)\}I\{Wave3\}$	0.025				0.065			
	(0.028)				(0.079)			
$I\{ARM@(t-1)\}I\{Wave4\}$	0.0005				0.120			
	(0.026)				(0.070)			
(ARM-to-debt ratio @$(t-1)$)$I\{Wave3\}$		0.041				0.049		
		(0.030)				(0.083)		
(ARM-to-debt ratio @$(t-1)$)$I\{Wave4\}$		0.0001				0.070		
		(0.026)				(0.071)		
$I\{Refi\}_{Control:HO\ w/\ mortgages}I\{Wave3\}$			0.068*				0.183*	
			(0.039)				(0.102)	
$I\{Refi\}_{Control:HO\ w/\ mortgages}I\{Wave4\}$			-0.001				0.026	
			(0.028)				(0.076)	
$I\{Refi\}_{Control:HO\ w/o\ mortgages}I\{Wave3\}$				0.068*				0.229**
				(0.038)				(0.100)
$I\{Refi\}_{Control:HO\ w/o\ mortgages}I\{Wave4\}$				0.016				0.126
				(0.031)				(0.079)
Number of obs (per imputation)	5,680	5,680	5,680	17,228	4,861	4,861	4,861	13,676

This table presents responses of consumption expenditures, specifically non-durable goods and services (measured by consumer goods and services, C), and durable goods (measured by car values, *Car value*), by mortgage structures interacted with the time fixed effect. Two types of mortgage structures are considered: the share of ARMs and the use of mortgage refinancing. Coefficients for control variables are not reported. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

3.3. Potential explanations for asymmetric consumption responses

This subsection explores potential hypotheses that could explain the previously reported asymmetric consumption responses.

(Repayment of non-mortgage debts) Following the automatic savings on mortgage interest resulting from an expansionary monetary shock, ARM mortgagors might opt to reduce their non-mortgage debt balances (e.g., credit cards, consumer loans, and credit lines), thereby potentially limiting their capacity to increase consumption. However, our analysis does not support this hypothesis. We focused on mortgagors with positive balances on both mortgages and non-mortgage debts at wave $t-1$, defined changes in non-mortgage balances as the dependent variable, and regressed it against the outlined independent variables. As reported in Table H5 in the Appendix, the changes in non-mortgage balances between ARM and FRM mortgagors are not statistically different.[12]

[12] In this analysis, we define two types of dependent variables: (1) the logarithmic difference in the non-mortgage balance and (2) an indicator function that equals one if the (positive) non-mortgage balance decreases and zero otherwise. For the first definition, if the balance at wave t is zero, we set its logarithmic balance to zero.

(Different saving patterns) Another potential explanation for the non-divergent consumption response could be differences in saving behavior between ARM and FRM mortgagors. An expansionary monetary policy shock increases disposable income for ARM mortgagors, which could lead them to save more, thereby resulting in a negligible difference in consumption responses between the two types of mortgagors. Since the HFCS does not survey household-level saving amounts, we indirectly measure saving patterns by examining the change in net wealth, regressing it against the same independent variables. However, we do not find significant differences in saving patterns between ARM and FRM mortgagors (see Table H6 in the Appendix).[13]

(Different financial constraints) Our findings may be influenced by varying ex-ante borrowing constraints among mortgagors. When households face greater financial constraints, their consumption typically responds more strongly to expansionary monetary policy shocks. Therefore, we investigate whether ARM mortgagors experience different degree of borrowing constraints than FRM mortgagors. If ARM mortgagors face weaker constraints than their FRM counterparts, their consumption response might be less pronounced, leading to non-divergent consumption patterns across mortgage types. The HFCS survey data provide insights into households' credit constraints, derived from (1) experiences of credit refusal or reduction, and (2) perceived credit constraints.[14] We employ regression analysis to examine the relationship between mortgage types and these two measures of credit constraints. Our analysis reveals no significant differences in borrowing constraints based on mortgage types (see Table H7 in the Appendix).

(Different fiscal policy responses) Given a single monetary policymaker, fiscal spending across European countries may vary based on their share of ARMs following monetary policy shocks. For example, a government with a lower share of ARMs anticipates that consumption cannot be sufficiently stimulated after an expansionary shock from the ECB. Consequently, government spending might increase more in such an economy, thereby narrowing the gap in con-

[13]We define two types of dependent variables: (1) the logarithmic difference in net wealth and (2) an indicator function that equals one if net wealth increases and zero otherwise. For the first definition, we exclude those samples from the analysis if net wealth is zero or negative.

[14]The former is gauged by the survey question regarding experiences of credit refusal or reduction among those applying for credit in the past three years (variable code DOCREDITREFUSAL). The latter includes households whose credit applications were denied or who refrained from applying for credit due to perceived credit constraints (variable code DOCREDITC).

sumption responses across different shares of ARMs. As illustrated in Figure I6 in the Appendix, fiscal policy stances do not differ significantly based on the proportion of ARMs following contractionary and expansionary monetary policy shocks.

(Mortgage interest rate responses across the share of ARMs) Although the ECB is the sole monetary policy authority in Europe, mortgage interest rates in each country may respond differently to changes in the policy rate. Whereas the inclusion of country$\times$time-fixed effects in the household-level panel regression largely addressed the concern that these differing responses of mortgage interest rates drove asymmetric consumption responses, we still calculate country-level correlation coefficients between the monthly and quarterly differences of the EONIA rate and mortgage interest rates and analyze whether they vary systematically with the share of ARMs. As shown in Figure I7 in the Appendix, the correlation coefficients between these variables are close to zero, indicating no systematic relationship and thus failing to explain our empirical findings.

3.4. The role of refinancing channel

Previously, we demonstrated that the share of ARMs alone does not sufficiently explain the transmission of monetary policy to consumption, particularly in the case of expansionary shocks. This raises the natural question: why does the consumption response to contractionary monetary policy shocks align with previous literature, whereas it differs for expansionary shocks? We posit that mortgage refinancing serves as a crucial transmission mechanism. Following a contractionary shock, households simply do nothing as their mortgage rate is fixed at a lower rate. However, following an expansionary shock, households with access to low-cost refinancing can easily lock in mortgage interest rates at low levels (i.e., exercising call options), strengthening their financial positions over the mortgage term and increasing consumption. This asymmetry distinguishes the refinancing channel from a standard narrative on variable vs. fixed-rate mortgages as a determinant of monetary policy effectiveness.

By utilizing the panel structure of HFCS, we provide supportive evidence that refinancing serves as a primary channel for stimulating consumption in response to expansionary shocks.[15] To explore this, we define the variable *Mortgage structure* as follows:

$$(\text{Mortgage structure})_{i,j,t} = \begin{cases} 1 & \text{if refinancing between wave t and t-1} \\ 0 & \text{no refinancing} \end{cases}$$

We establish an indicator function that equals one if a household has refinanced since the last survey wave and zero otherwise. Depending on the definition of control groups, we construct two distinct indicator functions. The first control group consists of homeowners with mortgages who did not refinance between survey waves. The second group is homeowners without mortgages, thus excluding any refinancing activity. To address potential selection effects among those who choose to refinance, we analyze both control groups to ensure the robustness of our findings.

The coefficient on refinancing usage for the panel period spanning waves 2 to 3 is positive and statistically significant, regardless of the definition of indicator functions (see the last two panels of Table 1). This implies that households that refinance mortgages increase consumption expenditures more than those without refinancing when the policy rate declines. However, the decline in the policy rate was smaller under the wave 3-4 panel period. This mitigates the monetary policy transmission channel through refinancing and thus leads to statistically insignificant responses in consumption expenditures. This refinancing channel applies to both non-durable and durable goods expenditures. As shown in Table H4 in the Appendix, the refinancing channel remains effective across different econometric specifications, although its statistical significance regarding the change in car value disappears.

While we mitigate the selection issue by employing two types of control groups, it is still possible that households opting to refinance their mortgages differ from those choosing not to, potentially influencing our empirical results. To address this critique, we regress the previously defined refinancing indicator function against ex-ante household financial characteristics. As shown in Table H8 in the Appendix, households that either refinance or abstain from refi-

[15] Due to the gradual decline in the ECB policy rate since the inception of the HFCS survey, we are unable to examine the impact of contractionary shocks on consumption through households' refinancing decisions.

nancing exhibit non-distinguishable ex-ante credit histories. However, households with longer remaining mortgage terms and/or higher financial assets are more likely to pursue refinancing. This underscores the significant costs associated with mortgage refinancing. Accordingly, households with shorter remaining terms may be deterred by these costs and less inclined to adjust their mortgage agreements favorably.[16] Moreover, households with limited financial assets may find the financial burden of refinancing prohibitive (DeFusco and Mondragon (2020)). Essentially, households make refinancing decisions (i.e., exercising options) weighing potential benefits and costs. As call options become more valuable when an increase in underlying asset prices is larger, households are more inclined to refinance following a substantial decline in the policy rate.

(Empirical plausibility of the refinancing channel) Our findings suggest that refinancing, akin to a call option structure, can trigger shifts in mortgage composition (ARMs vs. FRMs) under an expansionary shock. Specifically, mortgagors convert their mortgages to new FRMs, locking in lower interest rates over the long term. Given the nature of a long-term mortgage contract, this improvement in their financial position can persistently enhance their balance sheets, thereby stimulating consumption. Despite its intuitive appeal, a natural question arises: is this channel empirically plausible given the actual cost of refinancing that households pay?

According to a French mortgage broker France Home Finance (www.francehomefinance.com), "As a rule of thumb, refinancing is beneficial if the new rate is at least 1% lower than the current rate and the outstanding balance is over 50,000 euros," suggesting that the cost of refinancing is far from prohibitively high, especially in a country with a high share of FRMs.[17] Given the actual decline in the mortgage rates between HFCS waves, this anecdotal evidence helps us understand the significant (insignificant) effect of refinancing between wave 2 and 3 (wave 3 and 4)

[16]Theoretical insights from Berger et al. (2021) suggest that households with shorter remaining mortgage durations are less likely to refinance.

[17]While directly measuring the cost of refinancing across European countries presents significant challenges, it is plausible that this cost has fallen with the rapid advancement of FinTech. For example, Fuster, Plosser, Schnabl, and Vickery (2019) found that FinTech lending has alleviated frictions in refinancing and borrowers indeed refinance more in areas with more FinTech lending. Relatedly, Bartlett, Morse, Stanton, and Wallace (2022) showed that the rate disparities for minority borrowers were substantially lower for the Federal Housing Administration refinance loans extended by FinTech lenders, suggesting the role of FinTech in mitigating refinancing frictions. Using a calibrated model, Buchak, Chau, and Jørring (2023) find that the FinTech customer acquisition technology reduces the mental cost of refinancing by roughly 1,500 USD.

in Table 1. While the average decline in the mortgage rate of 18 countries in the sample is 1.12% with a standard deviation of 0.72% between waves 2 and 3, the corresponding values are only 0.45% and 0.21% between waves 3 and 4, which suggests that the benefit of refinancing between waves 3 and 4 is unlikely to exceed its cost.

Nevertheless, there exist various frictions in access to mortgage refinancing, such as financial illiteracy, rational inattention, and psychological factors (e.g., Agarwal, Rosen, and Yao (2016); Keys, Pope, and Pope (2016); Garriga et al. (2017); Andersen, Campbell, Nielsen, and Ramadorai (2020); Berger et al. (2023)), which makes it difficult to observe true refinancing costs. Thus, for a more systematic approach, we build a quantitative model and calibrate the refinancing cost to match observed refinancing rates from the HFCS.[18] This allows us to theoretically analyze the call option-like mechanism of refinancing in response to both contractionary and expansionary monetary policy shocks. Indeed, there is a statistically significant negative relationship between refinancing frequency and the share of ARMs, suggesting that countries with lower refinancing costs (or higher refinancing frequency) tend to favor FRMs (see Figure I8 in the Appendix). As a result, even economies with a lower share of ARMs may experience significant consumption increases following an expansionary shock.

4 Quantitative Model

This section introduces a heterogeneous agent model that mirrors the structure of the European mortgage finance market. We theoretically examine consumption responses to both contractionary and expansionary monetary policy shocks across varying shares of ARMs and investigate how refinancing costs influence consumption responses. Our analysis reveals that consumption responses to monetary policy shocks are not necessarily amplified as the share of ARMs increases, which contrasts with previous findings (e.g., Rubio (2011), Calza et al. (2013), and Garriga et al. (2017)). Consistent with existing literature, our quantitative exercises indicate that consumption declines more in response to contractionary shocks as the share of ARMs in-

[18] For each wave of the HFCS, we calculate the ratio of households that refinanced their mortgages within the past three years to the total number of mortgagors, averaging the results across waves 1–4.

creases. However, an increased share of ARMs does not invariably lead to a larger increase in consumption in response to expansionary shocks; rather, refinancing costs (or costs of exercising refinancing options) play a crucial role in shaping consumption responses. Given the limitations of available data, particularly regarding country-level refinancing costs, a model-based analysis is essential for obtaining a more comprehensive understanding of this mechanism.[19]

(Preferences) Time is discrete and infinite and is indexed by $t = 0, 1, 2, ...$ There are three market participants: households, mortgage lenders, and the construction sector. Households maximize their lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, h_t, s_t\right),$$

where c_t is consumption, $h_t \in \{h_S, h_L\}$ is the housing service (or the house size) with $h_L > h_S$, and $s_t \in \{0, 1\}$ is an indicator function that is one if a household is a homeowner and zero if it is a renter. The household's periodic utility is defined as follows:[20]

$$u\left(c_t, h_t, s_t\right) = \left\{ \begin{array}{ll} ln(c_t) + ln(h_t) & if\ s_t = 1; h_t \in \{h_S, h_L\} \\ ln(c_t) + ln(\omega h_t) & if\ s_t = 0; h_t = h_S \end{array} \right\}$$

Households can choose whether to stay in an owner-occupied house or a rental house. If the household decides to be a homeowner, it can endogenously choose the size of the house. However, renters can stay only in a small-sized home h_S and receive extra utility benefits and/or costs ω.

(Idiosyncratic shocks) There are three types of idiosyncratic shocks: income, interest rates, and depreciation/appreciation shocks. First, households receive an exogenous (log) income stream e that is the sum of persistent and transitory components: $\ln(e) = z + \nu$. The persis-

[19] The model structure outlined in this section builds on the frameworks of Chatterjee and Eyigungor (2015), Corbae and Quintin (2015), Hatchondo et al. (2015), and Gete and Zecchetto (2024). However, unlike these prior studies, our model incorporates endogenous mortgage type choices (ARMs vs. FRMs) and a non-recourse mortgage structure, specifically reflecting the characteristics of the European mortgage finance market. It also examines consumption responses to MIT monetary policy shocks under different shares of ARMs and/or refinancing costs. Detailed value functions and optimization problems are provided in Appendix A.

[20] I use the log utility function where (log) consumption and (log) housing service are additively separable, as in Corbae and Quintin (2015).

tent component of income z follows an AR(1) process (i.e., $z_t = \rho z_{t-1} + \epsilon_t$), and ν is the transitory component. Idiosyncratic shock processes are defined as follows: $\epsilon_t \sim i.i.d.N\left(0, \sigma_\epsilon^2\right)$ and $\nu \sim i.i.d.N(0, \sigma_\nu^2)$.

Second, households can accumulate financial assets a with the (one-period) interest rate $r + b$, where the risk-free rate r is exogenously given as in a standard small-open economy model, and the idiosyncratic interest rate shock b is defined by $b \sim i.i.d.N\left(0, \sigma_b^2\right)$. Under the steady state, the risk-free rate does not change. However, we will consider experimental economies where this rate unexpectedly changes (i.e., an MIT monetary policy shock) and examine how macro and household finance variables respond to such shocks.

There are two rationales for introducing the interest rate shock. First, as explained later, the rate $r + b$ is the index rate for the mortgage contract. Without modeling variations in the index rate, it is not possible to generate the co-existence of both FRMs and ARMs under the steady state. Second, HFCS shows that the variation in households' borrowing interest rates, even after controlling for their financial and non-financial characteristics, is significant.[21]

Third, every homeowner faces depreciation and appreciation shocks. More specifically, if a homeowner stays in a large-sized (small-sized) home, she can face a depreciation (appreciation) shock with a probability δ^- (δ^+). Then, the size of the home becomes h_S (h_L). The main purpose of introducing the shocks is to match the distribution of the LTV ratio and households' net wealth.[22]

(House and rent prices) There are two housing-related prices: the owner-occupied unit house price p and the unit rent price z. Thus, the value of the house is ph, and the actual rent payment is given by zh_S.

We model the owner-occupied and rental housing markets as independent. As explained later, there is a construction sector that supplies owner-occupied houses. Thus, the unit house price is endogenously determined to clear the owner-occupied house market. For simplicity,

[21] As examined in Appendix C, we regress the mortgage interest rate on household financial and non-financial characteristics and find that more than 50% of the variation cannot be explained by these factors. Thus, a significant proportion of the variation in borrowing interest rates cannot be explained by household-specific features, which justifies the existence of the idiosyncratic shock.

[22] Since the model has an LTV regulation, it is not possible to match the distribution of LTV without modeling such idiosyncratic shocks. It also increases households' precautionary saving and thus affects their saving behavior and net wealth.

we do not consider the rental housing market. The unit rent price is exogenously given and calibrated to match the house-value-to-rent ratio.

(Mortgage structure) Homebuyers can access long-term mortgages.[23] When a renter buys an owner-occupied house at time t, she can take out a mortgage $m (\geq 0)$ with the (unit bond) price of q. Then, the total outstanding mortgage is given by mq. The mortgage price q is endogenously determined, reflecting each household's default risk, which will be clarified later. When a household takes out a new mortgage, it incurs an origination cost ξ that is proportional to the initial balance.

Each household can choose the mortgage type k: FRMs vs. ARMs. If the household chooses the FRM, the mortgage interest rate will not change until the end of the contract. On the other hand, the rate for ARMs changes depending on the realization of interest rate shocks. For each mortgage type $k \in \{FRM, ARM\}$, its mortgage interest rate i is the sum of the risk-free rate, the idiosyncratic interest rate shock, and the type-specific margin rate θ_k. In other words, when the mortgage is contracted at time t, the interest rate stream for FRMs is given by $i_t = i_{t+1} = i_{t+2} = \ldots = r_t + b_t + \theta_{FRM}$. For ARMs, the rate is given by $i_{t+l} = r_{t+l} + b_{t+l} + \theta_{ARM}$ where $l \geq 0$. In addition, when the home buyer chooses a certain mortgage type k, a type-specific (one-time) loan origination fee ξ_k that is proportional to the initial mortgage balance is incurred.

If the household takes out the mortgage at time t, its balance proportionally decreases by the rate $\eta \in (0, 1)$ every period. That is, the mortgage balance starting from time $t+1$ geometrically decreases as follows: $(m, \eta m, \eta^2 m, \eta^3 m, ...)$. This declining balance can be interpreted as the amortization scheme or the mortgage contract length.[24] The household with the mortgage must pay both the principal and the interest. Then, the payment stream starting from time $t+1$ is given by $\{ m (1-\eta+i_{t+1}) / (1+i_{t+1}), m\eta (1-\eta+i_{t+2}) / (1+i_{t+2}), m\eta^2 (1-\eta+i_{t+3}) / (1+i_{t+3}), ... \}$.[25]

[23] For simplicity, we do not model second mortgages, home equity loans, home equity lines of credits (HELOCs), and unsecured credits. It would be an interesting research avenue to embed such non-mortgage debts and examine their impacts on macro and household finance variables from monetary policy shocks.

[24] Suppose the household signs a mortgage contract at time t. Then, we can interpret that the contract terminates at time $t+1$ with a probability of $(1-\eta)$, at time $t+2$ with a probability of $\eta(1-\eta)$, and so on. Given this, the expected mortgage contract length can be derived by $\sum_{t=0}^{\infty}(1-\eta)\eta^t(t+1) = 1/(1-\eta)$.

[25] The timing assumption of the loan balance and payments is as follows. When the household takes out the mortgage at time t, its borrowed balance is qm. The balance becomes m at time $t+1$ and then geometrically decreases. Since the payment starts from time $t+1$, the gross mortgage interest rate $1+i$ must be divided to equalize

(Households' problems) A renter decides whether to stay in a rental house or buy an owner-occupied house with mortgages. If the renter decides to stay in a rental house, she pays the periodic rent, accumulates financial assets, and postpones the homeownership decision to the next period. If the household buys a house, it saves financial assets, chooses the house size, pays the housing transaction cost, which is a fraction χ_B of the house value, and faces the maximum LTV limit μ. When the home purchaser takes out the mortgage, she must choose the mortgage type (FRMs vs. ARMs).

At the start of each period, the homeowner faces three types of idiosyncratic shocks. After observing them, she decides whether to repay the mortgage as contracted, sell the house, refinance loans, or default.[26]

When the household sells the house, it pays the remaining debt balance and the housing transaction cost, which is a fraction χ_S of the current house value. It then becomes a renter, stays in a small-sized home, and pays the periodic rent.

Once the household refinances loans, it must pay two types of refinancing costs: a fraction ξ_R of the currently remaining loan balance and a fixed cost ξ_{RF}. The household repays the remaining loans, then it can borrow again under the new contract term (mortgage type and balance) and is eligible to switch its house size with transaction costs.

The homeowner can potentially default after experiencing adverse shocks and lose homeownership. We model that mortgages are recourse, reflecting the European mortgage market structure (Cerutti et al. (2017) and Gete and Zecchetto (2024)). Thus, the defaulting household loses the ownership of its home and compensates lenders for uncollected losses with their future income and financial assets. More specifically, if lenders incur losses even after foreclosing the house, the defaulting household must compensate them, which is the proportion κ of their current income and financial assets. If lenders still cannot fully recover their losses, uncollected balances are rolled over with the risk-free rate r. In the next period, the defaulting household compensates lenders again by the amount of $\kappa(a + e)$. When the uncollected balance becomes

the present value of payments and the loan balance at time $t + 1$.

[26] In many countries, households' mortgage interest payments are tax-deductible from their taxable income. However, Germany, which is our main benchmark target economy, does not allow tax deductions (Cerutti, Dagher, and Dell'Ariccia (2017)). Thus, we do not include such a component in the model.

zero, the household's bad credit record is eliminated. We also model that its bad credit history becomes good with a probability γ even if there is a positive remaining unpaid balance. Once the defaulting household's credit record is recovered, it can be eligible to be a homeowner and re-access the mortgage market. In Appendix G, we also examine an economy where mortgages are non-recourse, the dominant mortgage structure in the US (Feldstein (2008)), and compare the results under two mortgage structures.[27]

(Mortgage lenders' problems) The mortgage market is competitive, and mortgage lenders are risk-neutral. There is no information asymmetry among market participants. The mortgage lender discounts future cash inflow with the contracted mortgage interest rate i. In other words, the discounting rate is fixed until the end of the contract if the household uses FRMs, while that for ARMs changes depending on the realization of interest rate states.

When the mortgage lender makes the loan contract, she takes into account the possibility of household defaults and proposes mortgage bond prices. When the household repays the mortgage as contracted, the lender can receive the periodic payment and would expect to recover future cash inflow. If the household either sells the house or refinances the mortgage, the lender can fully recover the mortgage balance, and the contract terminates. After the default, the lender forecloses the house and (partially) recovers their losses by selling it. However, she cannot fully recover the value of the foreclosed house, and thus, a foreclosure cost is incurred, which is a fraction χ_D of the house value. In addition to the proceeds from the foreclosure sale, lenders can also recover their losses by garnishing (some portion of) the income and financial assets of the defaulted household. If they still incur losses, lenders are eligible to roll over the uncollected loan balance and garnish the defaulted household's income and financial assets in the next period. Once the remaining balance becomes zero or the household's credit record recovers, the loan contract terminates.

If the lender anticipates significant losses on the mortgage contract, the zero-profit condition necessitates charging high-risk premiums, which lowers the bond price. Conversely, if the lender expects full recovery of the loan balance as contracted, no default risk premium is charged.

[27]Under the non-recourse mortgage structure, defaulting households immediately lose homeownership and do not compensate lenders' losses from their future income and financial assets. Consequently, lenders might not fully recover their losses even after completing the foreclosure process.

(Housing market dynamics) Every period, the fraction δ of owner-occupied housing stocks is depreciated. In turn, the construction sector endogenously supplies owner-occupied houses I_{RI} in the following manner: $I_{RI} = \psi_1 p^{\psi_2}$. The parameter ψ_1 is the scaling parameter, and the parameter ψ_2 is the house supply elasticity.[28]

In the model, homeowners can switch their house sizes both voluntarily and involuntarily. At the same time, an increase in home buyers (sellers) leads to a decrease (an increase) in available owner-occupied housing stocks in the market. Thus, the number of housing stocks that are newly released into the market can be expressed as follows:

$$H_{+stocks} = \int_{Sell} hd\Psi + \int_{Default} hd\Psi + \int_{Refi,\Delta h<0} |\Delta h| d\Psi + \int_{Depreciation\ shock} |\Delta h| d\Psi$$

where Ψ is the invariant distribution. On the RHS, the first term is the addition of housing stocks from home sellers; the second term is from mortgage defaulters; the third term is from households that reduce the house size with refinancing; the fourth term is from large-sized homeowners who receive the depreciation shock and thus involuntarily reduce their home size.

On the flip side, either buying homes or increasing house sizes leads to a decrease in available housing stocks in the market.

$$H_{-stocks} = \int_{Buy} hd\Psi + \int_{Refi,\Delta h>0} |\Delta h| d\Psi + \int_{Appreciation\ shock} |\Delta h| d\Psi$$

The first term on the RHS is the new home purchases by renters; the second term is from households that increase the house size after refinancing; the third term is from small-sized homeowners who received the appreciation shock.

(Definition of a stationary equilibrium) An equilibrium consists of value functions, household optimal policy functions, mortgage prices, the owner-occupied unit house price, and an invariant distribution such that:[29]

1. Given mortgage price functions and the unit house price, each household solves its maxi-

[28]Following Floetotto, Kirker, and Stroebel (2016), Lim (2018), and Cho, Li, and Uren (in press), we simplify the residential investment function to make the model computationally tractable.

[29]The detailed computation algorithm is presented in Appendix B.

mization problems.

2. Given households' optimal policy functions and the unit house price, the mortgage price functions are competitively determined (i.e., lenders' zero-profit conditions).

3. The stationary distribution is invariant in the long run.

4. Let H be the total owner-occupied house stock. The unit house price is pinned down to clear the owner-occupied house market as follows: $H' = (1-\delta)\,H + H_{+stocks} - H_{-stocks} + I_{RI}$.

5 Calibration

This section presents how we calibrate the benchmark economy. We then report model-generated mortgage and household-finance-related moments and compare them with the data.

5.1. Model parametrization

While our model parameters are calibrated using data from the German economy due to its comprehensive availability, it is important to emphasize that the model does not explicitly capture certain idiosyncratic features of the German housing market. Instead, the framework is designed to be more general, especially inferring refinancing costs, which are challenging to observe directly in data. A number of parameters are exogenously chosen from previous literature and micro-level data, mostly from HFCS (wave 1—3).[30] Others are endogenously determined to match housing- and mortgage-related moments. In the model, a period is a quarter. Table 2 summarizes the model parameters.

(Idiosyncratic shock parameters) Household income is decomposed into two parts: persistent and transitory income shocks. Based on the model in Storesletten, Telmer, and Yaron (2004), Bayer and Juessen (2012) estimate the income process of Germany. Since they estimated annual basis parameters, we convert them into a quarterly basis using the methodology in Chang and Kim (2006). Then, the persistent component of the quarterly income process parameters (ρ, σ_ϵ) is set to (0.975, 0.091). The standard deviation of the transitory component of the quarterly income process is 0.086. I construct three grid points for the persistent income process and three

[30] Since the fourth wave of HFCS is surveyed after COVID-19, we mainly use the pre-COVID waves.

Table 2: Calibration

Parameter	Description	Value	Target / Source
Non-target parameters			
ρ	Persistence in the income process	0.975	Bayer and Juessen (2012)
σ_ϵ	SD of persistent income	0.091	Bayer and Juessen (2012)
σ_ν	SD of transitory income	0.086	Bayer and Juessen (2012)
θ_{ARM}	ARM margin	0.294%	Average ARM rate and government bond rate
θ_{FRM}	FRM margin	0.302%	Average FRM rate and government bond rate
ξ	Mortgage origination cost	0	Normalized to zero
ξ_{ARM}	Origination cost of using ARMs	0	Normalized to zero
η	Mortgage amortization	0.983	15-year contract
ξ_R	Variable refinance cost	0.01	Early repayment charge in Germany
κ	Recourse parameter	0.25	Hatchondo et al. (2015)
γ	Default penalty	0.042	Gros (2014)
h_S	Small home size	1	Normalized to one
h_L	Large home size	1.83	HFCS
χ_B	Transaction cost — Buying	0.108	Kaas, Kocharkov, Preugschat, and Siassi (2020)
χ_S	Transaction cost — Selling	0.029	Kaas et al. (2020)
δ	Housing stock depreciation rate	0.25%	Kaas et al. (2020)
ψ_2	Elasticity of house supply	0.428	Caldera and Åsa Johansson (2013)
r	Risk-free rate	0.638%	Kaas et al. (2020)
μ	LTV ratio limit	0.8	Cerutti et al. (2017)
χ_D	Foreclosure cost	0.22	Pennington-Cross (2006)
Target parameters			
β	Discount factor	0.991	Liquid-asset-to-quarterly-income ratio
ω	Rent benefit	1.466	Homeownership rate
ξ_{FRM}	Origination cost of using FRMs	0.037	Share of ARMs
ξ_{RF}	Fixed refinance cost	0.050	Refinance rate
z	Rent price	0.230	House-value-to-quarterly-rent ratio
ψ_1	Scaling parameter for investment	46.9	House-value-to-quarterly-income ratio
$\delta^+ = \delta^-$	Appreciation/depreciation shock	0.021	Net-wealth-to-quarterly-income ratio
σ_b	SD of idiosyncratic interest rate	0.008	Consumption ratio for ARM and FRM mortgagors

This table presents the benchmark calibration strategy. "Non-target parameters" are parameters that are chosen exogenously from the literature and/or the data. "Target parameters" are endogenously determined to match household finance moments.

for the transitory income process using Tauchen (1986). In turn, the number of grid points for the idiosyncratic income process is nine.

(Mortgage-related parameters) Following the definition in Badarinza et al. (2018), we define ARMs as mortgages where mortgage interest rates change at least once per year. Since the mortgage interest rate is the sum of the index rate and the margin rate, we set the quarterly ARM margin θ_{ARM} as 0.29%, which is the difference between the ARM interest rate and the German government bond rate. Similarly, the FRM margin is set as 0.30%.[31] We normalize the mortgage origination cost and the cost of using ARMs to zero.

Since the standard maturity for residential mortgages is 15 years, we set the amortization parameter η to 0.98 (Cerutti et al. (2017); HFCS tabulation results). When a household decides to refinance the mortgage, it prepays the current loan, takes out a new loan with a new contract term, and incurs a refinance cost. We set the variable cost for refinancing at one percent of the remaining balance, reflecting the German prepayment penalty.[32] Since households may not fully understand or utilize the benefits of refinancing (Keys et al. (2016)), possibly due to lack of financial literacy or inattention (Gerardi, Willen, and Zhang (2023)), the fixed refinance cost is endogenously determined to match the actual refinance rate.

After the default, households must compensate lenders' losses by using their current and future out-of-pocket income and financial assets. We set the recourse parameter κ as 25%, following Hatchondo et al. (2015) and Gete and Zecchetto (2024). However, defaulted households can possibly recover their credit records and are eligible to re-access the mortgage market with the probability γ. According to Gros (2014), those households are usually excluded from the credit market between five to seven years. We thus set the default penalty parameter as 0.042, which is the six years of credit market exclusion.

(Housing-related parameters) Homeowners can choose their house size. I normalize the size of a small house as one. In HFCS, there is a survey question that asks the size of residential

[31] The source of interest rates for ARMs and FRMs are the Deutsche Bundesbank (BBK01.SU0049 and BBK01.SU0046, respectively), and the government bond rate is from FRED (IRLTLT01DEM156N). We calculated the margin between 1991 and 2014 and averaged them.

[32] In Germany, there are no specific legal guidelines for the refinance (or prepayment) cost. Commercial banks internally calculate their potential losses and charge them to customers. However, there is a maximum prepayment penalty for consumer loans, which is one percent of the amount repaid early. We select the variable cost of refinancing as this value.

homes (in square meters). Consistent with our model assumption, homeowners stay in larger-sized homes than renters. The size of the large home is measured by the average house size for homeowners conditional on their house size being larger than renters' average home size. Its size is 83% larger than the average renters' home size. Thus, we set the size of a large home as 1.83.

When the household sells or buys a house, transaction costs are incurred. Following Kaas et al. (2020), the transaction cost is 10.8% of the house value for buying and 2.9% for selling. Housing stocks are depreciated with the rate δ. We select this value as 0.25% per quarter from Kaas et al. (2020). The owner-occupied house supply elasticity is given by 0.43, which comes from Caldera and Åsa Johansson (2013).

(Further parameters) Following Kaas et al. (2020), we choose the quarterly risk-free rate r as 0.64%. The LTV limit in Germany is 80% (Cerutti et al. (2017)). When the household defaults on mortgages, financial intermediaries face the foreclosure cost. Since mortgage foreclosure is a rare event in Germany, it is hard to estimate this (unrealized) cost. However, we set this cost as 22% of the house value, which is standard in the US (Pennington-Cross (2006)).

(Endogenously determined parameters) Nine free parameters are endogenously determined: the discount factor β, the extra benefit/cost from staying in a rental house ω, the origination cost of FRMs ξ_{FRM}, the fixed refinancing cost ξ_{RF}, the unit rent price z, the scaling parameter for the construction function ψ_1, the appreciation shock δ^+, the depreciation shock δ^-, and the standard deviation of the idiosyncratic interest rate shock σ_b. To reduce the computational burden, we assume that the appreciation and depreciation shocks are the same: $\delta^+ = \delta^-$. Then, for the remaining eight parameters, we jointly match the homeownership rate (42.2%, Kaas et al. (2020)), the financial-asset-to-quarterly-income ratio (2.76; HFCS), the share of ARMs (16%; HFCS), the quarterly refinance rate (1.53%; HFCS),[33] the house-value-to-quarterly-income ratio (19.2; HFCS), the house-value-to-quarterly-rent ratio (86.4; HFCS), the net-wealth-to-quarterly-income ratio (9.8; HFCS), and the ratio of ARM to FRM mortgagors' consumption (0.91; HFCS). Regarding the data moments, we calculate each from the wave 1-3 HFCS and average them

[33]The ratio is calculated by dividing the number of households that refinanced over the last three years by the number of mortgagors and then converting this to a quarterly basis by dividing by 12.

across waves.

5.2. Model fit

This subsection presents calibration results and compares model-generated moments with their data counterparts. Table 3 presents household finance moments generated by the model economy and the data. Through calibration, we matched eight data moments. Although we do not directly target them, the model can successfully reflect several data moments.[34]

Table 3: Benchmark steady-state economy

	(1) Data	(2) Benchmark
Targeted statistics		
Homeownership rate	42.2%	42.4%
Financial-asset-to-quarterly-income ratio	2.76	2.76
Share of ARMs	0.16	0.16
Quarterly refinance rate	0.015	0.015
House-value-to-quarterly-income ratio	19.2	18.9
House-value-to-quarterly-rent ratio	86.4	86.3
Net-wealth-to-quarterly-income ratio	9.8	9.1
(Consumption | ARM mortgagors)/(Consumption | FRM mortgagors)	0.91	0.89
Non-targeted statistics		
LTV ratio	39%	21%
PTI ratio	12%	9.3%
Mortgage foreclosure rate	0%	0%
Share of poor hand-to-mouth (PHtM) households	12.9%	8.5%
Share of wealthy hand-to-mouth (WHtM) households	11.4%	4.6%
(Income | ARM mortgagors)/(Income | FRM mortgagors)	0.93	0.83
(Fin asset | ARM mortgagors)/(Fin asset | FRM mortgagors)	0.65	0.59
(House value | ARM mortgagors)/(House value | FRM mortgagors)	1.00	0.99
PTI ratio for FRM mortgagors	0.12	0.09
PTI ratio for ARM mortgagors	0.13	0.09
Average MPC		0.10

This table presents the calibration result under the benchmark economy. "Targeted statistics" are matched moments as a result of the calibration. "Non-targeted statistics" are model-generated moments that are not explicitly targeted through the calibration. The source of the data is the HFCS (wave 1 – 3).

The model slightly underestimates the average LTV (PTI) ratio for homeowners: 39 percent (12 percent) in the data and 21 percent (9.3 percent) in the model. Since the loan balance and the

[34]The source of the data in Table 3 is the wave 1-3 HFCS unless otherwise noted.

payment burdens are not significant, households in the model do not default on their mortgages, consistent with the rarity of mortgage foreclosures in Germany (Kaas et al. (2020)).[35]

Figure I9 in the Appendix shows the distributions of the LTV and PTI ratios both in the model and the data. Although the model generates a portion of mortgagors with small balances, the two loan distributions are generally similar between the model and the data. Even though there is a maximum LTV regulation in Germany, the microdata shows that a non-negligible number of households hold mortgages with LTV ratios higher than the limit. In the model, appreciation and depreciation shocks make it possible to generate households whose LTV ratios are higher than 80% even under the steady state.

According to the tabulation from Almgren et al. (2022), the share of poor and wealthy hand-to-mouth (HtM) households in Germany are 12.9% and 11.4%, respectively.[36] While the model underestimates these shares (8.5% and 4.6%, respectively), it predicts that the former is greater than the latter, consistent with the data counterpart.

In our model, households endogenously choose their mortgage types. Thus, we need to examine the financial characteristics of FRM and ARM mortgagors and compare them with the data. Both in the model and the data, ARM mortgagors have lower income and financial assets than FRM mortgagors, while the house values of the two groups are the same. The data show that the PTI ratios of both FRM and ARM mortgagors are almost the same, which is also consistent with our model results.

Lastly, the model generates an average MPC of 0.10, which is within the range of meta-analysis results from Havranek and Sokolova (2020). Using the model-generated data, we examine the heterogeneity of MPC by households' liquidity positions. Consistent with previous literature, households that are financially constrained (i.e., low liquid assets, low income, and HtM households) have a higher MPC (See Appendix E for more details).

[35] Appendix D presents mortgage price schedules q by state variables. Mortgage bond prices decrease, reflecting higher risk premiums, as households are more likely to default in the future. In the steady state, no households make decisions within the range of positive default probability, making defaults an off-equilibrium event.

[36] Following the benchmark definition of HtM households in Kaplan, Violante, and Weidner (2014), we classify households as HtM if their financial assets are less than their weekly income. We further distinguish between wealthy HtM households with positive home equity and poor HtM households with non-positive home equity. The overall results remain largely unchanged even when we apply modified definitions of HtM households.

6 Consumption responses to monetary policy shocks

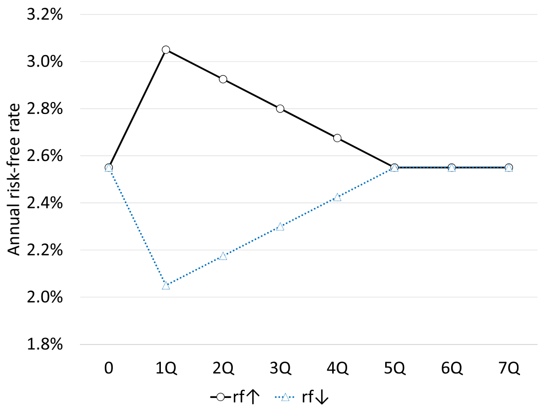
In this section, we examine responses of consumption to both expansionary and contractionary monetary policy shocks across the share of ARMs and refinancing costs. Using our benchmark steady-state economy, we present how consumption responds to these monetary policy shocks and study how the endogenously determined share of ARMs drives results. Subsequently, we assess whether the model-simulated microdata can generate results consistent with the analysis based on the HFCS counterparts reported in Section 3.

Figure 3: Transition analysis road maps

(a) Experimental calibration

Four calibrated steady-state economies		Refinance cost	
		Costly refinance (Match the refi rate)	Costless refinance (ξ_{RF}=0)
Share of ARMs	16% Share for the German economy	**A** *BM; Reflect the German economy*	**B**
	100% ARM-only economy	**C**	**D**

(b) Risk-free rate path



Panel (a) presents the calibration strategies for four steady-state economies. Economy A represents the benchmark economy. The other three economies are experimental, differing from the benchmark in terms of the share of ARMs and fixed refinancing costs. Panel (b) illustrates the paths of the risk-free rate under expansionary and contractionary (MIT) monetary policy shocks. The black solid (blue dotted) line represents the contractionary (expansionary) shock, where the annual risk-free rate unexpectedly increases (decreases) by 0.5 percentage points, gradually decreases (increases) over the next four quarters, and then converges to the original level.

Next, we consider three additional experimental steady-state economies that differ in terms of the share of ARMs and refinancing costs (see panel (a) in Figure 3). In Economy B, we newly recalibrate the model with costless refinancing ($\xi_{RF} = 0$) while matching the benchmark share of ARMs.[37] In both Economies C and D, households can only access ARMs (referred to as the "ARM-only economy"). We adjust the cost of using FRMs (ξ_{FRM}) to the minimum value that generates a share of ARMs equal to one.[38] In the former, we adjust the fixed refinance cost to

[37]In this experiment, seven free parameters, excluding the fixed refinance cost ξ_{RF}, are calibrated to match seven targeted moments, except for the refinance rate.

[38]When the cost of using FRMs is greater than or equal to one, the share of ARMs is naturally 100 percent.

match the actual German refinance rate, whereas in the latter, the fixed refinancing cost is set to zero (see Table H9 for the detailed parametrization strategy).[39]

For each calibrated steady-state economy, we examine the call option-like channel of refinancing under monetary policy shocks by considering the interaction between the share of ARMs and refinancing costs. Specifically, by comparing (independently simulated) transition paths under Economies A and C, we assess how monetary policy shocks differentially impact consumption based on the ARM share. Next, we analyze the transition paths of Economies B and D, comparing them with the former to examine the role of the refinancing channel. To further elucidate the role of refinancing, we compare the paths of Economies A and B. Our analysis indicates that a crucial channel for transmitting expansionary shocks to consumption is the refinancing cost: low refinancing costs enable households to exercise the refinance option more readily, thereby amplifying consumption responses.

The timing of our main transition analysis is as follows: At time zero, we initialize the steady-state economy. In the subsequent period (or quarter), we introduce an unexpected increase (decrease) of 0.5 percentage points in the annual risk-free rate, which gradually reverts over the following four periods, capturing the effects of a contractionary (expansionary) MIT monetary policy shock. Panel (b) in Figure 3 illustrates the paths of the risk-free rate under both monetary policy shocks. Each market participant perfectly understands and anticipates the future risk-free rate path upon encountering the shock at time one.

6.1. Consumption responses under the benchmark economy

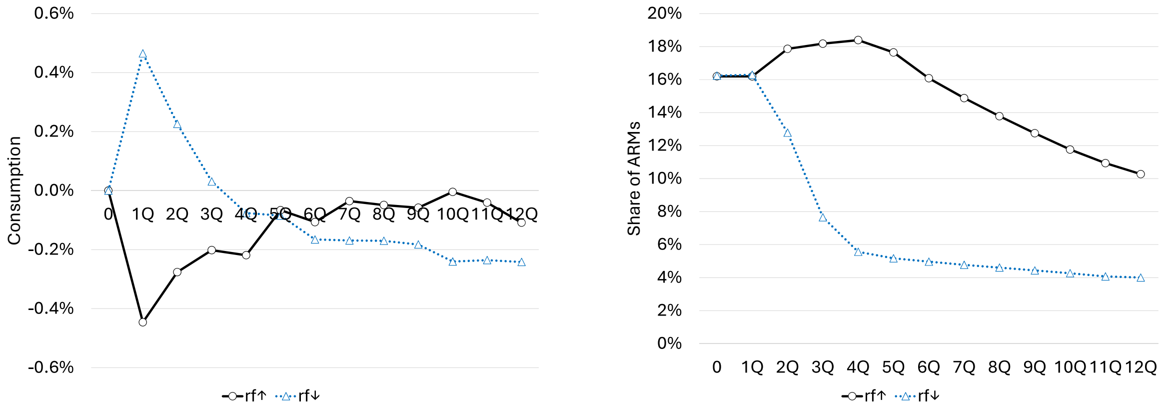
Consistent with standard macroeconomic evidence, a contractionary monetary policy shock leads to a decrease in consumption, while an expansionary shock increases consumption (see panel (a) in Figure 4). The primary channels driving these results are the significant proportion of borrowing-constrained households, their mortgage borrowing, and housing transactions. When

However, we model this cost as the minimum value that generates a steady-state share of 100 percent, allowing for changes in the share of ARMs with variations in monetary policy.

[39] Seven free parameters are endogenously determined in Economy C, and six parameters are determined in Economy D. In the former, compositional moments between ARM and FRM are not targeted, while the refinance rate is not additionally targeted in the latter.

Figure 4: Responses of consumption and the share of ARMs to monetary policy shocks

(a) Consumption (b) Share of ARMs



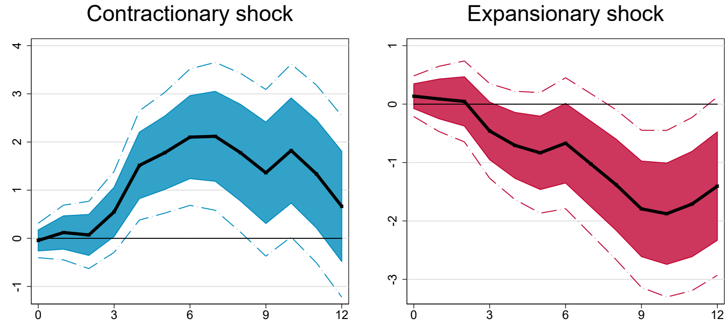
These figures present the responses of consumption (panel (a)) and the share of ARMs (panel (b)) to both expansionary and contractionary monetary policy shocks under the benchmark economy. The black line represents the response to the contractionary shock, and the blue dotted line represents the expansionary shock.

the risk-free rate rises, the cost of mortgage borrowing, including refinancing, increases, and the interest payment burden for current ARM holders rises accordingly. As a result, homeowners respond by downsizing their housing, repaying debts, and incurring associated transaction costs, all of which contribute to a decline in house prices and, consequently, consumption (see Figure I10 in the Appendix). This mechanism reverses under an expansionary shock, which is similar to the cash-flow channel of monetary policy in Flodén et al. (2021).

Although the absolute deviation of the risk-free rate from the initial level is the same under both shocks, consumption responses are not exactly symmetric: consumption responds slightly more to the expansionary shock than to the contractionary shock. The main driving force is the asymmetric structure in the household decision to refinance, leading to different responses in the share of ARMs under both shocks (see panel (b) in Figure 4). When there is an increase in the risk-free rate, households have less incentive to refinance and switch their mortgages to FRMs (see Figure I10). Financially constrained households that decide to refinance tend to use ARMs and wait for the risk-free rate to normalize in the near future. Consequently, the share of ARMs temporarily increases after the shock, but it decreases when the risk-free rate returns to its normal level.

Conversely, when there is a decrease in the risk-free rate, the share of ARMs persistently decreases. Since the expansionary shock is a one-time event in our model and mortgages are long-term contracts, many households switch their mortgages to FRMs via refinancing and lock in their mortgage interest rates at a low level. By switching mortgage types or newly taking out FRMs during shock periods, these households experience a positive persistent income shock and can significantly increase consumption. However, the corresponding rise in mortgage balances increases payment burdens, thereby constraining the potential increase in consumption.

Figure 5: Endogenous responses of the share of ARMs to monetary policy shocks



This figure presents the responses of the share of ARMs to a one standard deviation increase (contractionary, left) and decrease (expansionary, right) in monetary policy shocks, respectively. The response variable SARM is measured as the ratio of the amount of newly issued ARMs to the total amount of new mortgages from the ECB. The solid (dashed) lines represent 68% (90%) confidence intervals.

Consistent with the model results, macro-level data also reveals that the share of ARMs endogenously responds to both contractionary and expansionary monetary policy shocks. Following the state-dependent LP model proposed in Section 3, the quarterly share increases (decreases) in response to contractionary (expansionary) shocks (refer to Figure 5).[40] Moreover, the expansionary shock exhibits prolonged impacts on the share of ARMs, consistent with the model prediction that the share of ARMs tends to be more persistently affected by the expan-

[40]The share of adjustable-rate mortgages (ARMs) is defined as the newly issued balances of ARMs divided by the newly issued total mortgage balance, measured quarterly. The state-dependent LP model is given by

$$\begin{aligned}\Delta SARM_{i,t+h} =& I_t \sum_{j=0}^{4} \left(\beta^P_{j,h}\varepsilon_{t-j} + \gamma^P_{j,h}\text{macro}_{it-j}\right) + (1-I_t)\sum_{j=0}^{4}\left(\beta^N_{j,h}\varepsilon_{t-j} + \gamma^N_{j,h}\text{macro}_{i,t-j}\right)\\ &+ \sum_{j=1}^{4}\mu_j \text{SARM}_{i,t-j} + \text{Linear and Quadratic Time Trend}_t + e_{i,t+h}\end{aligned}$$

A different model structure that includes the country fixed effect does not alter the results (see Figure I11 in the Appendix).

sionary shock than by the contractionary shock.

Under a contractionary shock, the mortgage default premium for new home buyers, defined as the difference between the mortgage interest rate induced by the bond price ($1/q - 1$) and the current risk-free rate, increases. This increase reflects potential deterioration in their balance sheet conditions (see Figure I12 in the Appendix). Meanwhile, the premium for new home buyers remains largely unchanged under an expansionary shock. This stability results from the balancing of two opposing forces. First, a (long-term fixed) low-interest payment burden can mitigate the default probability. Second, low-income and low-asset renters choose to become homeowners to capitalize on the low market interest rate, thereby increasing the default premium. Given the compositional changes in homeowners following the expansionary shock, an increase in consumption only through the refinancing channel is not necessarily evident.

In Figure I13 in the Appendix, we investigate the impact of changes in house prices on our consumption responses. Specifically, we examine scenarios in which house prices (ph) remain unchanged even after monetary shocks. In this exercise, we adjust the mortgage origination cost ξ over time to maintain a constant house price.[41] The absolute volatility of consumption responses is mitigated under both shocks. This mitigation is influenced by two factors: the origination cost and the house value. An increase (decrease) in the house value, relative to the benchmark, encourages (discourages) households to consume more, while an increase (decrease) in the origination cost decreases (increases) consumption.[42].

6.2. Model-generated micro analysis of consumption responses

We investigate whether the model-simulated microdata can generate heterogeneous responses of consumption to monetary policy shocks by mortgage types and refinance decisions, consistent with the analysis based on HFCS counterparts. In our simulation, since every market participant realizes the monetary policy shocks at time 1 (or 1Q), we generate balanced panel data between time 0 and time 1. Following the same empirical model structure, we regress the logarithmic

[41] The unit house price p is determined to clear the owner-occupied housing market.

[42] In Appendix F, we explore the role of mortgage contract terms (η) in the responses of consumption to both monetary policy shocks. We also examine how the recourse and non-recourse mortgage structures impact our results in Appendix G

changes in consumption on the variable *Mortgage structure*. This variable is defined in two ways: (1) an indicator function that equals one if the household has ARMs and zero if it has FRMs at time 0 (denoted as "$I\{ARM\}$") and (2) an indicator function that equals one if the household refinances between time 0 and time 1 and zero if it maintains the mortgage contract (denoted as "$I\{refi\}$"). To ensure consistency with the data counterpart, we include the following control variables: logarithmic differences in house value, income, and mortgage balances.

Table 4: Model-generated consumption responses by mortgage types and refinancing decisions

	Contractionary shock	Expansionary shock
$I\{ARM\}$	-0.035***	-0.012***
	(0.001)	(0.001)
$I\{refi\}$	0.135***	0.164***
	(0.003)	(0.003)

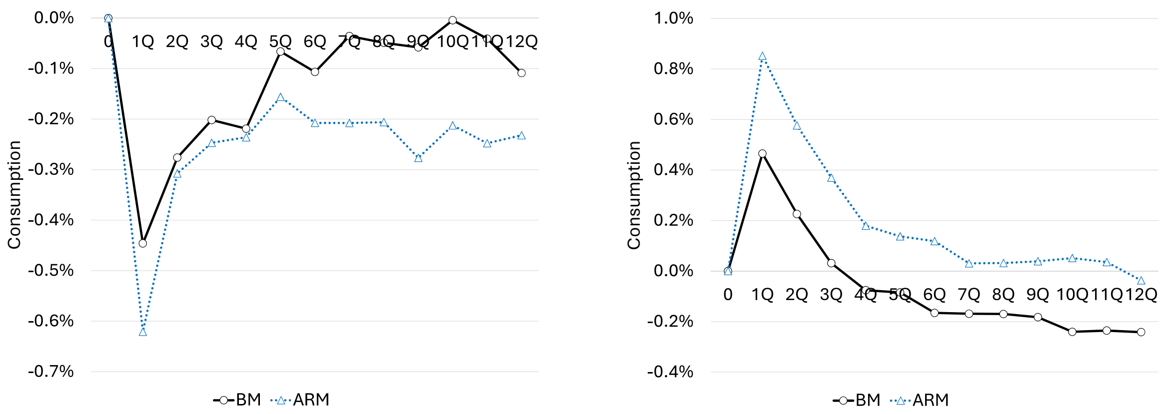
This table presents the model-generated response of consumption to contractionary and expansionary monetary policy shocks. For each shock scenario, we generate a balanced panel between time 0 and 1 (or 1Q). We regress the logarithmic difference in consumption on an indicator function for having ARMs at time 0 (the first panel) and on refinancing mortgages between time periods (the second panel), along with control variables. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

Table 4 presents coefficients on the variable *Mortgage structure* for each monetary policy shock. As reported in the first panel, ARM mortgagors experience a greater decrease in consumption than FRM mortgagors under the contractionary shock, consistent with our macro data evidence. Under the expansionary shock, however, average consumption for FRM mortgagors increases consumption slightly more than ARM mortgagors, although the coefficient is smaller than under the contractionary shock. This result suggests that a high share of ARMs does not necessarily lead to amplified consumption responses to expansionary monetary policy shocks.

In the second panel, refinancing emerges as the primary channel transmitting monetary policy shocks, especially expansionary ones, to consumption. Households that refinance can adjust their mortgage contract terms favorably, capitalizing on the current monetary policy stance to increase consumption. While the refinancing channel in stimulating consumption is stronger under the expansionary shock, in our simulation, refinancing enables households to alleviate liquidity constraints and increase consumption, even under the contractionary shock (Chen et al. (2020)).

Figure 6: Responses of consumption under the benchmark and the ARM-only economies

(a) Contractionary shock (b) Expansionary shock



This figure illustrates consumption responses to both contractionary (panel (a)) and expansionary (panel (b)) monetary policy shocks. The black solid line represents the benchmark, while the blue dotted line corresponds to the ARM-only economy.

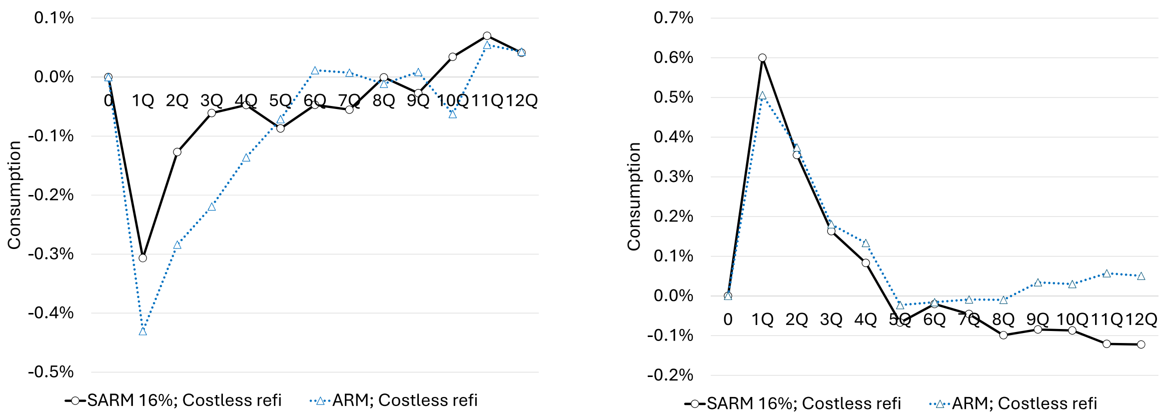
6.3. Consumption responses across the share of ARMs under varying refinancing costs

We consider an experiment economy where ARMs are the only available mortgage option (Economy C in Panel (a) of Figure 3). To investigate this scenario, we recalibrate parameters to match seven key moments. Given the initial steady-state ARM-only economy, we model every market participant unexpectedly encountering either an expansionary or a contractionary monetary policy shock, as illustrated in Panel (b) of Figure 3. For each shock, we compare the benchmark transition outlined in the previous subsection with the counterfactual transition, aiming to examine asymmetric responses in consumption across the share of ARMs.

Unlike our empirical evidence, consumption responds more when the share of ARMs increases (Figure 6). In line with the arguments presented in Calza et al. (2013), Garriga et al. (2017), and Flodén et al. (2021), the unexpected increase (decrease) in the risk-free rate raises (decreases) the payment burden for ARM mortgagors, negatively (positively) impacting their balance sheets and leading to a reduction (increase) in consumption. This monetary policy transmission channel is more pronounced in the experimental transition, resulting in greater amplification in consumption compared to the benchmark.

Figure 7: Responses of consumption under costless refinancing economies

(a) Contractionary shock (b) Expansionary shock



This figure illustrates consumption responses under two experimental costless refinancing economies to both contractionary (panel (a)) and expansionary (panel (b)) monetary policy shocks. The initial steady state represented by the black solid line corresponds to the economy where the share of ARMs is matched to the benchmark, while the blue dotted line represents the ARM-only economy.

Furthermore, households in the ARM-only economy tend to downsize their homes more during contractionary shocks to alleviate direct budget constraints, resulting in a significant decline in mortgage balances. Decumulating debt, coupled with transaction costs associated with downsizing, can also negatively affect consumption. Conversely, an expansionary shock offers immediate but temporary relief to mortgagors' budget constraints in the experimental economy. Consequently, households are less likely to opt for larger homes and are more inclined to immediately increase consumption due to their reduced interest costs (see Figure I14 in Appendix).

How can we reconcile the differences in consumption responses across the share of ARMs between the data and the model? The empirical evidence supports that the cost of refinancing is the key parameter determining asymmetric responses. To investigate this, we consider two experimental economies where the fixed refinancing cost is zero ($\xi_{RF} = 0$) but differ in the share of ARMs. In one economy, the cost of using FRMs is set to match the benchmark share of ARMs (Economy B in Panel (a) of Figure 3). In the other economy, we set this cost to the minimum value that generates a 100 percent share of ARMs (Economy D). We recalibrate the remaining parameters to match the target moments of the benchmark and examine the responses of consumption to both types of monetary policy shocks.

When refinancing costs decrease, consumption responses depending on the share of ARMs become asymmetric between monetary tightening and easing: in an ARM-only economy, consumption decreases more under a contractionary shock, whereas responses to an expansionary shock are similar across different ARM shares (see Figure 7). This is primarily due to the call option-like structure of the refinancing channel that enables a compositional shift in mortgage types within Economy B, where lower refinancing costs enable a switch to FRMs, thereby maintaining low mortgage rates, facilitating additional loans, and boosting consumption. (see Figure I15 in the Appendix). Although mortgagors in the ARM-only economy can also immediately benefit from low mortgage interest rates after the shock, fixing their rates at a low level incurs significant costs. Consequently, these mortgagors experience only temporary positive income shocks, while mortgagors in Economy B can enjoy persistent balance sheet improvements. Thus, an increased ARM share alone does not guarantee an amplified consumption response to an expansionary shock; rather, the critical channel is the cost of exercising the refinancing option.

To further investigate the importance of the refinancing channel, we compare the benchmark response in consumption to the expansionary shock with experimental economies where the fixed refinancing cost is either costless or prohibitively high.[43] As shown in Figure I16 in the Appendix, consumption responds more as the refinancing cost decreases. The key mechanism for this result is the ease of switching current mortgages into new FRMs, which locks in mortgage interest rates at a low level. In other words, when the option cost of refinancing increases, households cannot capitalize on lowering their mortgage interest rates or cashing out larger mortgages through refinancing. Consequently, their ability to increase consumption is limited. Additionally, the response of the ARM share is attenuated as the cost of refinancing increases.

[43]We consider two experimental steady-state economies where ARM shares are both 16 percent but differ in the refinancing cost. In the costless refinancing economy, we set the fixed refinance cost to zero (Economy B). In the other economy, we eliminate the option for mortgage refinancing (the so-called "no refi" economy). For each scenario, we recalibrate the steady-state economy to match seven free parameters, except for the refinancing rate. Table H9 in the Appendix reports calibrated parameters.

7 Conclusion

In this paper, we have investigated how mortgage refinancing, which is akin to the call option structure, characterizes consumption responses to monetary policy shocks. Our focus on refinancing costs is motivated by the asymmetric role of the share of ARMs between monetary contractions and expansions. On the one hand, consumption in an economy dominated by ARMs is more responsive to contractionary monetary policy shocks compared to an economy with predominantly FRMs, consistent with prior literature. On the other hand, during an expansionary shock, both macro- and micro-level evidence indicate no substantial differences in consumption based on the share of ARMs: a novel finding in the literature.

We find that mortgage refinancing is the primary channel for asymmetric consumption responses to monetary policy shocks. Given the difficulty in directly measuring refinancing costs due to implicit frictions, we calibrate these costs and explore the mechanism through a quantitative exercise. Even if most mortgagors hold FRMs, they can refinance their loans under an expansionary shock, switch to new FRMs with locked-in lower interest rates, and thereby achieve persistent improvements in their balance sheet condition. This process amplifies consumption responses more than in an economy where most mortgages are ARMs. However, this mechanism becomes ineffective when refinancing costs are high.

The proposed mechanism of asymmetric mortgage refinancing as a transmission channel of monetary policy goes beyond the well-known channel of adjustable vs. fixed-rate mortgages. However, we acknowledge that refinancing may not be the sole channel explaining asymmetric consumption response phenomena. As mentioned in Corsetti et al. (2022) and Almgren et al. (2022), factors such as financial constraints and literacy, labor market conditions, financial development and integration, housing market conditions, country-specific banking characteristics, and cultural influences could contribute to explaining asymmetric consumption responses and impact the monetary policy transmission channel. Exploring these financial, institutional, and behavioral factors influencing consumption dynamics would be an intriguing avenue for further research.

References

Aastveit, K. A., & Anundsen, A. K. (2022, October). Asymmetric effects of monetary policy in regional housing markets. *American Economic Journal: Macroeconomics*, *14*(4), 499-529.

Agarwal, S., Rosen, R. J., & Yao, V. (2016). Why do borrowers make mortgage refinancing mistakes? *Management Science*, *62*(12), 3494–3509.

Albertazzi, U., Fringuellotti, F., & Ongena, S. (2024). Fixed rate versus adjustable rate mortgages: Evidence from euro area banks. *European Economic Review*, *161*, 104643.

Almgren, M., Gallegos, J.-E., Kramer, J., & Lima, R. (2022). Monetary policy and liquidity constraints: Evidence from the euro area. *American Economic Journal: Macroeconomics*, *14*(4), 309–340.

Alpanda, S., Granziera, E., & Zubairy, S. (2021). State dependence of monetary policy across business, credit and interest rate cycles. *European Economic Review*, *140*, 103936.

Alpanda, S., & Zubairy, S. (2019). Household debt overhang and transmission of monetary policy. *Journal of Money, Credit and Banking*, *51*(5), 1265-1307.

Altavilla, C., Brugnolini, L., Gürkaynak, R., Motto, R., & Ragusa, G. (2019). Measuring euro area monetary policy. *Journal of Monetary Economics*, *108*(C), 162-179.

Andersen, S., Campbell, J. Y., Cocco, J., Hansman, C., & Ramadorai, T. (2023). Heterogeneous mortgage choice: Evidence from Denmark. *Working Paper*.

Andersen, S., Campbell, J. Y., Nielsen, K. M., & Ramadorai, T. (2020). Sources of inaction in household finance: Evidence from the danish mortgage market. *American Economic Review*, *110*(10), 3184–3230.

Angrist, J. D., Jordà, Ò., & Kuersteiner, G. M. (2018). Semiparametric estimates of monetary policy effects: String theory revisited. *Journal of Business & Economic Statistics*, *36*(3), 371–387.

Badarinza, C., Campbell, J. Y., & Ramadorai, T. (2018). What calls to ARMs? international evidence on interest rates and the choice of adjustable-rate mortgages. *Management Science*, *64*(5), 2275-2288.

Barnichon, R., & Matthes, C. (2018). Functional approximation of impulse responses. *Journal of Monetary Economics*, *99*, 41–55.

Bartlett, R., Morse, A., Stanton, R., & Wallace, N. (2022). Consumer-lending discrimination in the fintech era. *Journal of Financial Economics*, *143*(1), 30–56.

Bayer, C., & Juessen, F. (2012). The life-cycle and the business-cycle of wage risk — cross-country comparisons. *Economics Letters*, *117*(3), 831-833.

Beraja, M., Fuster, A., Hurst, E., & Vavra, J. (2019). Regional heterogeneity and the refinancing channel of monetary policy. *Quarterly Journal of Economics*, *134*(1), 109–183.

Berger, D., Milbradt, K., Tourre, F., & Vavra, J. (2021, September). Mortgage prepayment and path-dependent effects of monetary policy. *American Economic Review*, *111*(9), 2829-78.

Berger, D., Milbradt, K., Tourre, F., & Vavra, J. (2023). Refinancing frictions, mortgage pricing and redistribution. *Working Paper*.

Buchak, G., Chau, V., & Jørring, A. (2023). Integrated intermediation and fintech market power. *Available at SSRN 4552425*.

Byrne, S., Devine, K., King, M., McCarthy, Y., & Palmer, C. (2023, March). *The last mile of monetary policy: Inattention, reminders, and the refinancing channel* (Working Paper No. 31043). National Bureau of Economic Research.

Caldera, A., & Åsa Johansson. (2013). The price responsiveness of housing supply in OECD countries. *Journal of Housing Economics*, *22*(3), 231-249.

Calza, A., Monacelli, T., & Stracca, L. (2013, 01). Housing Finance and Monetary Policy. *Journal of the European Economic Association*, *11*(Supplement 1), 101-122.

Campbell, J. Y., & Cocco, J. F. (2003, 11). Household Risk Management and Optimal Mortgage Choice. *Quarterly Journal of Economics*, *118*(4), 1449-1494.

Campbell, J. Y., & Cocco, J. F. (2015). A model of mortgage default. *Journal of Finance*, *70*(4), 1495–1554.

Cerutti, E., Dagher, J., & Dell'Ariccia, G. (2017). Housing finance and real-estate booms: A cross-country perspective. *Journal of Housing Economics*, *38*, 1-13.

Chang, Y., & Kim, S.-B. (2006). From individual to aggregate labor supply: A quantitative analysis based on a heterogeneous agent macroeconomy. *International Economic Review*, *47*(1), 1-27.

Chatterjee, S., & Eyigungor, B. (2015). A quantitative analysis of the US housing and mortgage markets and the foreclosure crisis. *Review of Economic Dynamics*, *18*(2), 165—184.

Chen, H., Michaux, M., & Roussanov, N. (2020). Houses as atms: Mortgage refinancing and macroeconomic uncertainty. *Journal of Finance*, *75*(1), 323-375.

Cho, Y., Li, S. M., & Uren, L. (in press). Investment housing tax concessions and welfare: A quantitative study for Australia. *International Economic Review*.

Choi, S., Willems, T., & Yoo, S. Y. (2024). Revisiting the monetary transmission mechanism through an industry-level differential approach. *Journal of Monetary Economics*, 103556.

Cloyne, J., Ferreira, C., & Surico, P. (2020, 01). Monetary Policy when Households have Debt: New Evidence on the Transmission Mechanism. *Review of Economic Studies*, *87*(1), 102-129.

Corbae, D., & Quintin, E. (2015). Leverage and the foreclosure crisis. *Journal of Political Economy*, *123*(1), 1–65.

Corsetti, G., Duarte, J. B., & Mann, S. (2022, 06). One Money, Many Markets. *Journal of the European Economic Association*, *20*(1), 513-548.

Coulibaly, B., & Li, G. (2009). Choice of mortgage contracts: Evidence from the survey of consumer finances. *Real Estate Economics*, *37*(4), 659-673.

Cover, J. P. (1992). Asymmetric effects of positive and negative money-supply shocks. *Quarterly Journal of Economics*, *107*(4), 1261–1282.

DeFusco, A. A., & Mondragon, J. (2020). No job, no money, no refi: Frictions to refinancing in a recession. *Journal of Finance*, *75*(5), 2327–2376.

Di Maggio, M., Kermani, A., Keys, B. J., Piskorski, T., Ramcharan, R., Seru, A., & Yao, V. (2017, November). Interest rate pass-through: Mortgage rates, household consumption, and voluntary deleveraging. *American Economic Review*, *107*(11), 3550-88.

Di Maggio, M., Kermani, A., & Palmer, C. J. (2019, 12). How Quantitative Easing Works: Evidence on the Refinancing Channel. *Review of Economic Studies*, *87*(3), 1498-1528.

ECB. (2016). The household finance and consumption survey: Methodological report for the second wave. *Statistics Paper Series*, *17*.

ECB. (2020). The household finance and consumption survey: Methodological report for the 2017 wave. *Statistics Paper Series*, *35*.

ECB. (2023). The household finance and consumption survey: Methodological report for the 2021 wave. *Statistics Paper Series*, *45*.

Ehrmann, M., & Ziegelmeyer, M. (2017). Mortgage choice in the euro area: macroeconomic determinants and the effect of monetary policy on debt burdens. *Journal of Money, Credit and Banking*, *49*(2-3), 469–494.

Eichenbaum, M., Rebelo, S., & Wong, A. (2022, March). State-dependent effects of monetary policy: The refinancing channel. *American Economic Review*, *112*(3), 721-61.

Feldstein, M. (2008). How to help people whose home values are underwater. *The Wall Street Journal*.

Finck, D., Schmidt, J., & Tillmann, P. (2023). Mortgage debt and time-varying monetary policy transmission. *Macroeconomic Dynamics*, *27*(2), 506–531.

Flodén, M., Kilström, M., Sigurdsson, J., & Vestman, R. (2021). Household debt and monetary policy: Revealing the cash-flow channel. *Economic Journal*, *131*(636), 1742–1771.

Floetotto, M., Kirker, M., & Stroebel, J. (2016). Government intervention in the housing market: Who wins, who loses? *Journal of Monetary Economics*, *80*, 106-123.

Fuster, A., Plosser, M., Schnabl, P., & Vickery, J. (2019). The role of technology in mortgage lending. *Review of Financial Studies*, *32*(5), 1854–1899.

Garriga, C., Kydland, F. E., & Sustek, R. (2017, 05). Mortgages and Monetary Policy. *Review of Financial Studies*, *30*(10), 3337-3375.

Gerardi, K., Willen, P. S., & Zhang, D. H. (2023). Mortgage prepayment, race, and monetary policy. *Journal of Financial Economics*, *147*(3), 498-524.

Gete, P., & Zecchetto, F. (2024). Mortgage design and slow recoveries: The role of recourse and default. *Review of Economic Studies*, *91*(2), 1039–1084.

Ghent, A., & Kudlyak, M. (2011). Recourse and residential mortgage default: Evidence from US states. *Review of Financial Studies*, *24*(9), 3139–3186.

Greenwald, D. (2018). The mortgage credit channel of macroeconomic transmission. *MIT Sloan Research Paper*(5184-16).

Gros, D. (2014). Why has the US recovered more quickly than Europe? *World Economic Forum*.

Guren, A. M., Krishnamurthy, A., & Mcquade, T. J. (2021). Mortgage design in an equilibrium model of the housing market. *Journal of Finance*, *76*(1), 113-168.

Hatchondo, J. C., Martinez, L., & Sánchez, J. M. (2015). Mortgage defaults. *Journal of Monetary Economics*, *76*, 173—190.

Havranek, T., & Sokolova, A. (2020). Do consumers really follow a rule of thumb? three thousand estimates from 144 studies say "probably not". *Review of Economic Dynamics*, *35*, 97-122.

Jarociński, M., & Karadi, P. (2020, April). Deconstructing monetary policy surprises—the role of information shocks. *American Economic Journal: Macroeconomics*, *12*(2), 1-43.

Johnson, K. W., & Li, G. (2014). Are adjustable-rate mortgage borrowers borrowing constrained? *Real Estate Economics*, *42*(2), 457-471.

Jorda, O. (2005, March). Estimation and inference of impulse responses by local projections. *American Economic Review*, *95*(1), 161-182.

Jordà, Ò., Schularick, M., & Taylor, A. M. (2020). The effects of quasi-random monetary experiments. *Journal of Monetary Economics*, *112*, 22–40.

Kaas, L., Kocharkov, G., Preugschat, E., & Siassi, N. (2020, 04). Low Homeownership in Germany—a Quantitative Exploration. *Journal of the European Economic Association*, *19*(1), 128-164.

Kaplan, G., Mitman, K., & Violante, G. L. (2020). The Housing Boom and Bust: Model Meets Evidence. *Journal of Political Economy*, *128*(9), 3285-3345.

Kaplan, G., Violante, G. L., & Weidner, J. (2014). The wealthy hand-to-mouth. *Brookings Papers on Economic Activity*, *Spring*, 77-138.

Kerssenfischer, M. (2022). Information effects of euro area monetary policy. *Economics Letters*, *216*(C), S0165176522001653.

Keys, B. J., Pope, D. G., & Pope, J. C. (2016). Failure to refinance. *Journal of Financial Economics*, *122*(3), 482–499.

Kim, J. (2020). How unsecured credit policies influence mortgage and unsecured loan defaults. *Journal of Money, Credit and Banking*, *52*(5), 1271-1304.

Koijen, R. S., Hemert, O. V., & Nieuwerburgh, S. V. (2009). Mortgage timing. *Journal of Financial Economics*, *93*(2), 292-324.

Lim, T. (2018). Housing as collateral, financial constraints, and small businesses. *Review of Economic Dynamics*, *30*, 68-85.

Mitman, K. (2016). Macroeconomic effects of bankruptcy and foreclosure policies. *American Economic Review*, *106*(8), 2219–55.

Moench, E., Vickery, J., & Aragon, D. (2010). Why is the market share of adjustablerate mortgages so low? *Current Issues in Economics and Finance*, *16*(8).

Pennington-Cross, A. (2006). The value of foreclosed property. *Journal of Real Estate Research*, *28*(2), 193–214.

Pica, S. (2021). Housing markets and the heterogeneous effects of monetary policy across the euro area. *Available at SSRN 4060424*.

Ramey, V. A., & Zubairy, S. (2018). Government spending multipliers in good times and in bad: Evidence from us historical data. *Journal of Political Economy*, *126*(2), 850-901.

Rubio, M. (2011). Fixed- and variable-rate mortgages, business cycles, and monetary policy. *Journal of Money, Credit and Banking*, *43*(4), 657-688.

Storesletten, K., Telmer, C. I., & Yaron, A. (2004). Consumption and risk sharing over the life cycle. *Journal of Monetary Economics*, *51*(3), 609–633.

Tauchen, G. (1986). Finite state Markov-chain approximations to univariate and vector autoregressions. *Economics Letters*, *20*(2), 177–181.

Tenreyro, S., & Thwaites, G. (2016). Pushing on a string: Us monetary policy is less powerful in recessions. *American Economic Journal: Macroeconomics*, *8*(4), 43–74.

Weise, C. L. (1999). The asymmetric effects of monetary policy: A nonlinear vector autoregression approach. *Journal of Money, Credit and Banking*, 85–108.

Wong, A. (2021). Refinancing and the transmission of monetary policy to consumption. *mimeo*.

Zhang, D. (2024). Closing costs, refinancing, and inefficiencies in the mortgage market. *Working Paper*.

Online Appendix (not for publication)

A Optimal problems

This section presents households' and mortgage lenders' optimal problems in a detailed manner.

A.1. Households' problems

There are two types of households at the beginning of each period: renters and homeowners. We introduce how each household makes its optimal decisions.

- Renters' problems

A renter decides whether to stay in a rental house (V_{RR}) or to buy an owner-occupied house (V_{RH}).

$$V_R\left(a,e,b\right) = \max\left\{V_{RR}\left(a,e,b\right), V_{RH}\left(a,e,b\right)\right\}$$

If the renter decides to stay in a rental house, she solves the following problem:

$$V_{RR}\left(a,e,b\right) = \max_{c\geq 0, a'\geq 0} u\left(c,h_S,0\right) + \beta E V_R\left(a',e',b'\right)$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + zh_S = a + e$$

Renters stay in a small-sized home h_S and pay the periodic rent zh_S. Renters cannot borrow but can save financial assets a' with the current interest rate $r+b$ where r is the risk-free rate and b is the idiosyncratic interest rate shock.

Renters who decide to buy an owner-occupied house solve the following problem:

$$V_{RH}(a,e,b) = \max_{\substack{c\geq 0, a'\geq 0, h'\in\{h_S,h_L\},\\ m'\geq 0,\ k'\in\{FRM,ARM\}}} u(c,h',1)$$

$$+\beta E\left[\begin{array}{c} \left(I_{h'=h_S}(1-\delta^+) + I_{h'=h_L}\delta^-\right) V_H(a',e',b',h_S,m',k',i') \\ +\left(I_{h'=h_S}\delta^+ + I_{h'=h_L}(1-\delta^-)\right) V_H(a',e',b',h_L,m',k',i') \end{array}\right]$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + (1+\chi_B)\,ph'$$

$$= a + e + (1-\xi-\xi_k)\, q(a',e,b,h',m',k',i)\, m'$$

$$q(a',e,b,h',m',k',i)\, m' \leq \mu p h'$$

$$i = i' = r + b + \theta_{FRM} \text{ if } k' = FRM$$

$$i = r + b + \theta_{ARM} \text{ and } i' = r' + b' + \theta_{ARM} \text{ if } k' = ARM$$

When the renter purchases a house, she chooses the saving a', the size of the house h', takes out the mortgage m', and the mortgage type k'. The transaction cost for buying a house is the fraction χ_B of the house value. The purchaser can take out the mortgage in the amount of $q(\cdot)m'$ with the LTV limit μ. The mortgage origination cost is the fraction ξ of the loan balance. If the household chooses the FRM ($k' = FRM$), the mortgage interest rate is fixed until the end of the contract, which is the sum of the risk-free rate r, the initial idiosyncratic interest rate shock b, and the FRM margin θ_{FRM}. If it uses the ARM ($k' = ARM$), the mortgage interest rate is subject to change depending on the realization of interest rate shocks. The initial interest rate for ARM is the sum of the current risk-free rate r, the current idiosyncratic interest rate shock b, and the ARM margin θ_{ARM}. In the next period, if the risk-free rate becomes r' and the idiosyncratic interest rate shock is b', its interest rate becomes $r' + b' + \theta_{ARM}$. The origination cost of using either FRMs or ARMs is ξ_k, which is calibrated to match the share of ARMs in the data. Prices for the mortgage $q(\cdot)$, which reflects household default risk, will be specified in the mortgage lender's problem.

At the start of the next period, the appreciation and the depreciation shocks are realized. If the home buyer chooses a small-sized (large-sized) home and does not receive the appreciation (depreciation) shock, its home size will be also small (large) in the next period. However, if the small-sized (large-sized) homeowner receives the appreciation (depreciation) shock, her house size will be large (small).

In the next period, the value function V_H is defined as follows:

$$V_H\left(a, e, b, h, m, k, i\right) = \max\left\{V_{HP}, V_{HR}, V_{HS}, V_D\right\}$$

where each value function represents homeowners' available options: repaying loans as contracted (V_{HP}), refinancing loans (V_{HR}), selling the house (V_{HS}), and defaulting on loans (V_D).

- Homeowners' problems

If the homeowner repays the mortgage as contracted, she solves the following problem:

$$V_{HP}\left(a, e, b, h, m, k, i\right) = \max_{c \geq 0, a' \geq 0} u\left(c, h, 1\right)$$

$$+\beta E \left[\begin{array}{c} \left(I_{h=h_S}\left(1-\delta^{+}\right) + I_{h=h_L}\delta^{-}\right) V_H\left(a', e', b', h_S, \eta m, k, i'\right) \\ + \left(I_{h=h_S}\delta^{+} + I_{h=h_L}\left(1-\delta^{-}\right)\right) V_H\left(a', e', b', h_L, \eta m, k, i'\right) \end{array} \right]$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + \frac{m\left(1-\eta+i\right)}{1+i} = a + e$$

$$i' = i \text{ if } k = FRM$$

$$i' = r' + b' + \theta_{ARM} \text{ if } k = ARM$$

The household repays the principal (the fraction $1-\eta$) and the interest (the rate i) of the mortgage m. Then, the mortgage balance reduces to ηm in the next period.[44] The next period's mortgage interest rate does not change if the mortgage is FRM ($k = FRM$). However, the mortgage interest rate for ARMs changes depending on the realization of interest rates.

[44]The household currently owes a balance m and starts repaying the loan from the current period. To take into account the consistent timing for present values of repayments, the additional term $1+i$ must be divided.

When the household decides to refinance loans, its problem is defined as follows:

$$V_{HR}(a,e,b,h,m) = \max_{\substack{c\geq 0, a'\geq 0, h'\in\{h_S,h_L\},\\ m'\geq 0,\ k'\in\{FRM,ARM\}}} u(c,h',1)$$

$$+\beta E\left[\begin{array}{c}\left(I_{h'=h_S}(1-\delta^+) + I_{h'=h_L}\delta^-\right)V_H(a',e',b',h_S,m',k',i') \\ +\left(I_{h'=h_S}\delta^+ + I_{h'=h_L}(1-\delta^-)\right)V_H(a',e',b',h_L,m',k',i')\end{array}\right]$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + (1+\xi_R)m + \xi_{RF} + I_{h\neq h'}\left(-(1-\chi_S)ph + (1+\chi_B)ph'\right)$$

$$= a + e + (1-\xi-\xi_k)\,q(a',e,b,h',m',k',i)\,m'$$

$$q(a',e,b,h',m',k',i)\,m' \leq \mu ph'$$

$$i = i' = r + b + \theta_{FRM} \text{ if } k' = FRM$$

$$i = r + b + \theta_{ARM} \text{ and } i' = r' + b' + \theta_{ARM} \text{ if } k' = ARM$$

Once the household refinances, it repays the remaining loans, borrows again with the new contract term subject to the LTV limit, and pays the refinance fees. The refinancing cost is the fraction ξ_R of the remaining loan balance. At the same time, the fixed refinancing cost ξ_{RF} incurs. The household that refinances is also eligible to switch the size of the house and the mortgage type. It then has to pay the transaction cost from selling the old house (χ_S) and buying the new one (χ_B) and the mortgage type-specific origination cost (ξ_k).

The homeowner who sells her house solves the following problem:

$$V_{HS}(a,e,b,h,m) = \max_{c\geq 0, a'\geq 0} u(c,h_S,0) + \beta E V_R(a',e',b')$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + m + zh_S = a + e + (1-\chi_S)ph$$

Once the household sells the house, it receives the value of the house net the transaction cost and moves into a rental house. In addition, the household pays the remaining mortgage balance m. Since the household voluntarily sells the house, it is eligible to buy a new one in the next period.

When the household defaults on its (recourse) mortgage, it solves the following problem:

$$V_D(a,e,b,h,m) = \max_{c\geq 0, a'\geq 0} u(c,h_S,0) + \beta E \left[\begin{array}{c} (\gamma + (1-\gamma) I_{m'=0}) V_R(a',e',b') \\ + (1-\gamma) I_{m'>0} V_D(a',e',b',h'=0,m') \end{array} \right]$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + zh_S + x_D = a + e$$

$$x_D = \max\{0, \min\{m - (1-\chi_D)ph, \kappa(a+e)\}\}$$

$$m' = (1+r)\max\{m - (1-\chi_D)ph - x_D, 0\}$$

Since the mortgage is recourse, the defaulting household loses its homeownership and compensates the mortgage lender's losses through its income and financial assets. After foreclosing the house, the lender can recover $(1-\chi_D)ph$ where χ_D is the foreclosure cost. Since the defaulted mortgage balance is m, the lender incurs losses in the amount $m-(1-\chi_D)ph$.[45] The household must compensate the lender's entire losses or the fraction κ of its income and financial assets, whichever is smaller. If the household repays the latter, there still is the unrecovered mortgage balance $m-(1-\chi_D)ph - x_D$. Then, its balance is rolled over with the risk-free interest rate and becomes a new balance in the next period.

In the next period, if the lender's unrecovered losses become zero, the household is eligible to buy a new house by taking out mortgages. Also, we model that the bad credit record of defaulting households is erased with a probability of γ. Without credit recovery, the defaulting household cannot access the mortgage market and buy an owner-occupied house.

A.2. Mortgage lenders' problems

Under the perfect competition, mortgage lenders' profits must be zero. Also, let us assume that there is no asymmetric information among market participants. If mortgage lenders are risk

[45]The lender's loss $m-(1-\chi_D)ph$ cannot be a negative value. Since the foreclosure cost ξ_D is larger than the transaction cost for selling the house ξ_S, selling the house is a better option than defaulting on mortgages if $m-(1-\chi_D)ph$ is a non-positive number.

neutral, the mortgage price function $q(\cdot)$ can be defined as follows:

$$
\begin{aligned}
& q\left(a', e, b, h', m', k', i\right) m' \\
= \; & \frac{1}{1+i} E \left[\begin{array}{c}
\left(I_{h'=h_S}\left(1-\delta^{+}\right)+I_{h'=h_L}\delta^{-}\right) \left(\begin{array}{c}
I^{h_S}_{Pay} \left\{ \begin{array}{c} m' \frac{1-\eta+i'}{1+i'} \\ +q\left(a''_{V_{HP}}, e', b', h_S, \eta m', k', i'\right) \eta m' \end{array} \right\} \\
+\left(I^{h_S}_{Refi}+I^{h_S}_{Sell}\right) m' \\
+I^{h_S}_{Def} \left\{ \begin{array}{c} \min\left\{m', \left(1-\chi_D\right) p' h_S + x'_{D,h_S}\right\} \\ +\tilde{q}\left(a''_{V_D}, e', b', m''_{V_D,h_S}\right) m''_{V_D,h_S} \end{array} \right\}
\end{array} \right) \\
+\left(I_{h'=h_S}\delta^{+}+I_{h'=h_L}\left(1-\delta^{-}\right)\right) \left(\begin{array}{c}
I^{h_L}_{Pay} \left\{ \begin{array}{c} m' \frac{1-\eta+i'}{1+i'} \\ +q\left(a''_{V_{HP}}, e', b', h_L, \eta m', k', i'\right) \eta m' \end{array} \right\} \\
+\left(I^{h_L}_{Refi}+I^{h_L}_{Sell}\right) m' \\
+I^{h_L}_{Def} \left\{ \begin{array}{c} \min\left\{m', \left(1-\chi_D\right) p' h_L + x'_{D,h_L}\right\} \\ +\tilde{q}\left(a''_{V_D}, e', b', m''_{V_D,h_L}\right) m''_{V_D,h_L} \end{array} \right\}
\end{array} \right)
\end{array} \right]
\end{aligned}
$$

The home buyer takes out the mortgage in the amount of $q(\cdot)m'$ as presented on the left-hand side. The mortgage lender discounts the future cash inflow at the current mortgage interest rate i. If the household takes out the FRM, the lender's discounting interest rate is fixed until the termination of the contract. However, if it chooses the ARM, the discounting rate is subject to change as follows: $i' = r' + b' + \theta_{ARM}$.

After the loan contract, the lender's cash inflow is determined by the realization of the household's idiosyncratic shocks and its discrete choices. After facing the appreciation and the depreciation shocks at the start of the next period, each homeowner's house size is determined. Let $I^{h_j}_{Pay}$ be an indicator function that takes a value of one if the household's optimal decision is the repayment conditional on the house size of h_j, where $j \in \{S, L\}$, and zero otherwise.[46] Once the household repays the loan, the lender recovers the periodic payment $m'(1-\eta+i')/(1+i')$. In addition, the lender can expect to recover the future cash inflow $q(\cdot)\eta m'$ where $a''_{V_{HP}}$ is the saving policy for the loan payer. The mortgage balance becomes $\eta m'$.

[46]The indicator function is one if $max\{V_{HP}(\cdot,h_j), V_{HR}(\cdot,h_j), V_{HS}(\cdot,h_j), V_D(\cdot,h_j)\} = V_{HP}(\cdot,h_j)$ and zero otherwise.

The household can sell the house or refinance the loan depending on the realization of shocks. Let $I_{Sell}^{h_j}$ and $I_{Refi}^{h_j}$ be indicator functions each equal to one if the household sells the house and refinance mortgages, respectively, and zero otherwise.[47] If the household either sells the house or refinances loans, the lender recovers the remaining loan balance m' and the contract terminates.

When the household defaults on the mortgage, the foreclosure process initiates. Let $I_{Def}^{h_j}$ be an indicator function equal to one if the household defaults and zero otherwise.[48] Conditional on defaults, the lender can immediately recover either the mortgage balance or the sum of the house value net of the foreclosure cost and the garnishment from the defaulted household's income and financial assets, whichever is smaller. Here, the garnished amount is given by x'_{D,h_i} $= \max\{0, \min\{m' - (1-\chi_D)\,p'h_i,\ \kappa\,(a'+e')\}\}$. In the next period, the defaulted household still owes the rolled-over balance m''_{V_D,h_i}, which is given by $(1+r')\max\{m' - (1-\chi_D)\,p'h_i - x'_{D,h_i}, 0\}$. Because of the feature of the recourse mortgage, the defaulted mortgage contract will be terminated if either the household fully compensates the lender's losses or the bad credit record is recovered. Thus, the future cash stream generated by the defaulted household is $\tilde{q}(\cdot)m''_{V_D,h_L}$ where $\tilde{q}$ is defined as follows:

$$\begin{aligned}&\tilde{q}\left(a', e, b, m'\right) m' \\ =\ &\frac{(1-\gamma)\, I_{m'>0}}{1+r} E\left[\min\left\{m', x'_D\right\} + \tilde{q}\left(a''_{V_D}, e', b', m''_{V_D}\right) m''_{V_D}\right]\end{aligned}$$

where x'_D $(= \max\{0, \min\{m', \kappa\,(a'+e')\}\})$ is the garnishment from the defaulted household's future income and financial assets and m''_{V_D} $(= (1+r')\max\{m' - x'_D, 0\})$ is the remaining rolled-over balances.

Note that the mortgage market is competitive and thus lenders' profits are zero. Therefore, for each state variable, mortgage prices can be pinned down.

[47] The indicator function $I_{Sell}^{h_j}$ is one if $max\{V_{HP}(\cdot,h_j), V_{HR}(\cdot,h_j), V_{HS}(\cdot,h_j), V_D(\cdot,h_j)\} = V_{HS}(\cdot,h_j)$ and zero otherwise. The indicator function $I_{Refi}^{h_j}$ is one if $max\{V_{HP}(\cdot,h_j), V_{HR}(\cdot,h_j), V_{HS}(\cdot,h_j), V_D(\cdot,h_j)\} = V_{HR}(\cdot,h_j)$ and zero otherwise.

[48] The indicator function $I_{Def}^{h_j}$ is one if $max\{V_{HP}(\cdot,h_j), V_{HR}(\cdot,h_j), V_{HS}(\cdot,h_j), V_D(\cdot,h_j)\} = V_D(\cdot,h_j)$ and zero otherwise.

B Computation algorithm

Households' value and policy functions and mortgage price functions are solved over predetermined grid points. The number of grid points for a is 80, for e is 9 (which includes both three grid points for the persistent component and three for the transitory component of the income process), for b is 3, for h is 2, for m is 46, for k is 2, and for i is 5. The grid points for a and m are polynomially constructed where grids are finer at the lower bound.[49] When solving the decision rules for a', we allow searching and choosing off-the-grid points whose number of grids is 159. For notational simplicity, let $a(x)$ be the x-th grid point for a. The n-th grid point for a' is $a((n+1)/2)$ if n is an odd number and is $(a(n/2) + a(n/2+1))/2$ if n is an even number.

B.1. Algorithm for computing the steady state

1. Guess the scaling parameter for investment ψ_1 (or, equivalently, the unit house price p). For each state variable, guess the initial mortgage price schedules q^0.

2. Given prices, solve households' optimization problems via the value function iteration. If optimal choices are off-the-grid points, use linear interpolation.

3. Given households' value and policy functions and the unit house price, solve mortgage price schedules q^1.

4. If the inequality $\|q^1 - q^0\| < \varepsilon$ holds for each state variable, move to the next step. Otherwise, update mortgage price schedules q^0 and go back to step 2.

5. Given the converged value functions, policy functions, and price functions, check whether the owner-occupied housing market clears. Since the housing stock is invariant under the steady state, the housing market clearing condition is given by $\delta H = H_{+stocks} - H_{-stocks} + I_{RI}$. If the housing market clears, calculate the invariant distribution. Otherwise, update the scaling parameter ψ_1 (or, the unit house price p) and go back to step 1.

[49] We initially set the lower and the upper bounds. For example, let $\bar{a}$ be the upper bound and $\underline{a}$ be the lower bound of financial assets. Then, the x-th grid point of a is determined by $a(x) = \underline{a} + (\bar{a} - \underline{a})((x-1)/79)^z$, where $x = \{1, 2, 3, ..., 80\}$. Following Gete and Zecchetto (2024), we chose the vale z as 2.5.

B.2. Algorithm for computing the transition

1. Save the initial households' value and policy functions, mortgage price schedules, the unit house price, and the invariant distribution calculated in the stage of the steady-state economy. Since monetary policy shocks are not permanent, the initial economy is the same as the terminal economy. In calculating the transition, we assume that the economy converges to the new economy within 35 periods.[50]

2. Given the exogenous change in risk-free rates, guess the unit house price path.

3. Solve value, policy, and mortgage price functions in a backward manner.

4. Solve the distribution in a forward manner and check whether the owner-occupied housing market clears as follows: $H' = (1-\delta)\,H + H_{+stocks} - H_{-stocks} + I_{RI}$. If the market is cleared, terminate the computation. Otherwise, update the unit house price path and move to step 3.

C Empirical motivation for idiosyncratic interest rate shocks

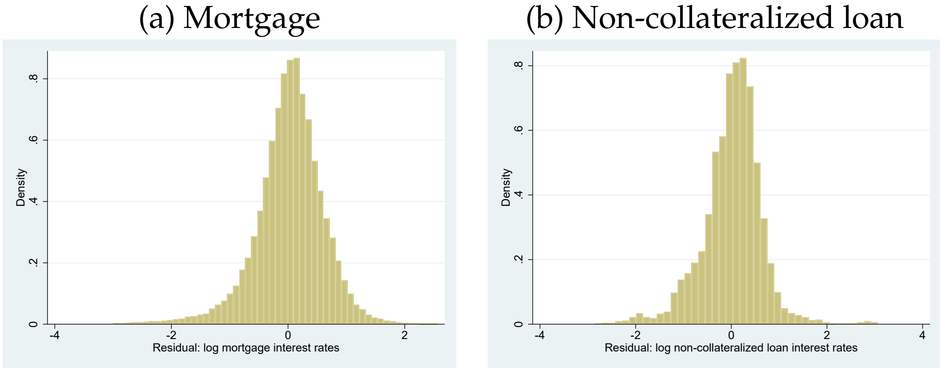
In this section, we provide empirical justification for introducing idiosyncratic interest rate shocks. The HFCS includes survey questions about interest rates for residential mortgages and non-collateralized loans. After appending data from the first to the fourth wave of the HFCS, we regress the (log) borrowing interest rates on households' financial and non-financial characteristics as follows:

$$ln(r_{i,j,t}) = \beta X_{i,j,t} + I_j + I_t + \varepsilon_{i,j,t},$$

where i represents the household, j the country, and t the survey wave. When the mortgage interest rate is the dependent variable, we include the following control variables: (log) home value, (log) financial assets, (log) income, (log) mortgage balance, the share of ARMs, the initial mortgage contract length, mortgage age (or time elapsed after the contract), a history of credit

[50] Since the number of total state variables is so large, we cannot increase the transition periods. When we increase it, the Fortran pops up an error message.

Figure C1: Distribution of interest rate residuals in mortgages and non-collateralized loans



This figure presents distribution of interest rate residual $\varepsilon_{i,j,t}$. Panel (a) is the distribution for the mortgage interest rate and panel (b) is that for non-collateralized loans.

refusals, age and age squared, and an education dummy.[51] Indicator functions I_j and I_t represent country and time fixed effects, respectively. Similarly, we examine the interest rates for non-collateralized loans.[52]

Even after controlling for several household-specific characteristics, our results indicate that the R^2 is 0.43 for mortgage interest rates and 0.32 for non-collateralized loans.[53] Consistent with these findings, Figure C1 illustrates the distribution of residuals for each estimation. This provides evidence that there are significant differences in the interest rates faced by each household, thereby justifying the inclusion of the idiosyncratic interest rate shock b in our model.

D Mortgage price schedules

This section presents mortgage price schedules under the benchmark steady state. Mortgage lenders observe households' optimal decisions — repayment, refinance, selling, or default — and offer loan prices that satisfy the zero-profit condition. If they anticipate incurring losses by contracting with a certain type of household, they charge low loan prices, reflecting high default

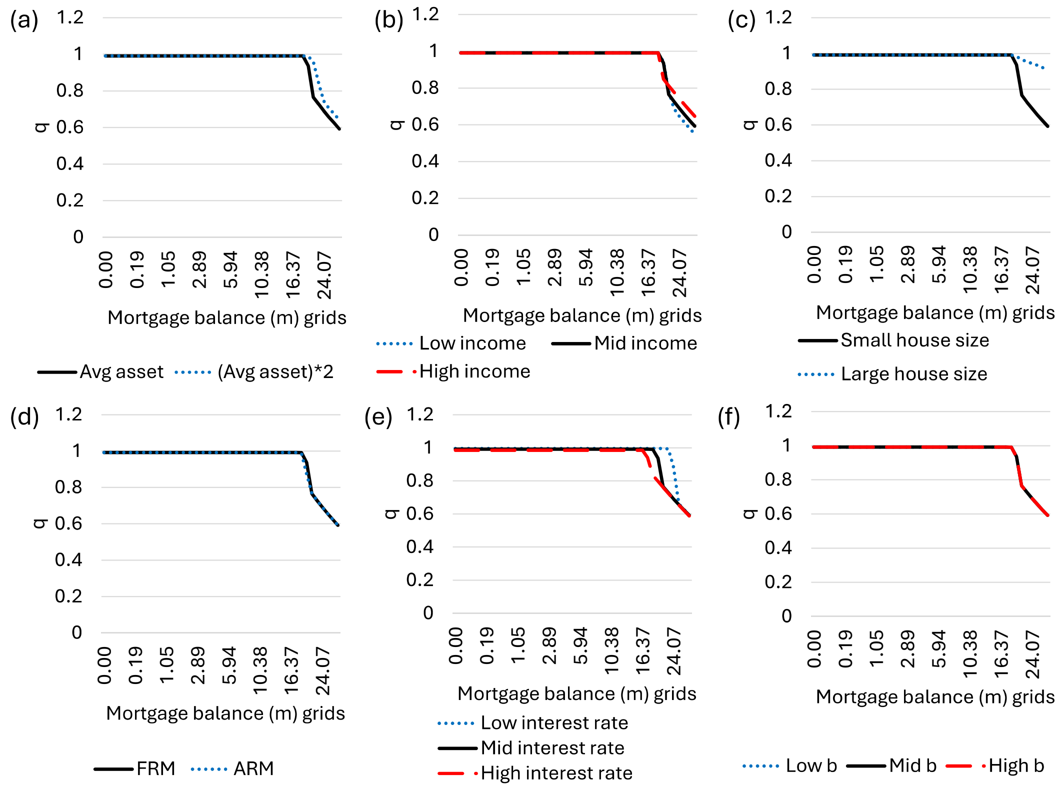
[51] In cases where a household holds multiple mortgages, we select the mortgage interest rate associated with the highest balance.

[52] In instances where a household holds multiple non-collateralized loans, we choose the interest rate associated with the highest balance. The list of control variables includes (log) real asset values, (log) financial assets, (log) income, (log) balance of non-collateralized loans, contract length, a history of credit refusals, age and age squared, and education dummies.

[53] The HFCS features multiple imputation, which expands the number of observations in the full dataset to five times the actual number of respondents. Here, we calculate R^2 for each implicate and then average them.

risk.

Figure D2: Mortgage price schedules



This figure presents benchmark mortgage price schedules $q\,(a, e, b, h, m, k, i)$ under different combinations of state variables. The x-axis is the mortgage balance m grid points. The black solid line is the schedule with the population averages of a and m, the medians of e, b, and i, the small house size h_S, and the FRM $k = FRM$. Panel (a): The asset a is twice the average (blue-dotted line). Panel (b): The income e is either the lowest (blue-dotted line) or the highest (red-dashed) among nine idiosyncratic income grid points. Panel (c): The house size h is h_L (blue-dotted line). Panel (d): The mortgage type k is ARM (blue-dotted line). Panel (e): The mortgage interest rate i is either the lowest (blue-dotted line) or the highest (red-dashed line) among five interest rate grid points. Panel (f): The idiosyncratic interest rate shock b is either the lowest (blue-dotted line) or the highest (red-dashed line) among three grid points.

Figure D2 presents mortgage price schedules under different state variables. An increase in the mortgage balance m raises households' default probability, leading to a decrease in the price. As households hold more financial assets a, the mortgage price increases, reflecting a decrease in default probability (panel (a)). Given the highly persistent income process e, households in high (low) income states are less (more) likely to default on their loans, resulting in an increase (decrease) in the mortgage bond price (panel (b)). Households residing in large-sized homes can better share income risk through cash-out refinancing, enjoy higher utility, and are thus less likely to default on mortgages (panel (c)). When households take out a large amount of ARMs, they are more susceptible to changes in the idiosyncratic interest rate shock compared to FRM mortgagors. Consequently, the mortgage price for ARMs is lower than that for FRMs within the (limited) range of mortgage grid points (panel (d)). An increase in the mortgage interest rate i results in a higher discount on future cash inflow, leading to a decrease in the bond price (panel (e)). Under the FRM, the realization of the idiosyncratic interest rate shock cannot affect default probabilities. Consequently, FRM mortgage price schedules remain the same across different values of b.

E Analysis of MPC

This section examines the heterogeneity of the model-generated MPC based on household financial statuses. Specifically, we regress the MPC on households' financial characteristics to investigate whether liquidity constraints increase the MPC. Instead of regressing the MPC on every state variable, we define a set of liquidity-related independent variables.

"Cash on hand" is defined as the total assets available before making consumption and saving decisions. "Liquid asset" refers to the financial asset minus transaction, origination, and refinancing costs, as well as mortgage payments. "Home equity" is calculated as the difference between the house value and the mortgage balance. For renters, home equity is set to zero.

As reported in Table E1, households with low liquidity tend to have higher MPC. Since homeowners can access liquidity through their home equity, their MPC is lower than that of renters. Additionally, households with low income are more likely to have higher MPC.

When we include indicator functions for WHtM and PHtM households, the (absolute) coefficients for liquidity-related variables decrease, and the model's explanatory power increases. Furthermore, our model-generated data show that the average MPC for WHtM households is higher than for PHtM households. Although WHtM households have the option to cash out funds through refinancing, this incurs significant costs.

Table E1: Analysis of MPC

	(1)	(2)	(3)	(4)
Cash on hand	-0.018***	-0.009***		
	(0.0002)	(0.0002)		
I{Homeowner}	-0.035***	-0.020***		
	(0.002)	(0.002)		
Liquid asset			-0.009***	-0.003***
			(0.0003)	(0.0003)
Income			-0.191***	-0.128***
			(0.003)	(0.003)
Home equity			-0.001***	-0.0004***
			(0.0001)	(0.0001)
I{WHtM}		0.356***		0.344***
		(0.004)		(0.007)
I{PHtM}		0.345***		0.328***
		(0.003)		(0.003)
Adjusted R^2	0.057	0.194	0.083	0.205

This table analyzes the relationship between households' MPC and their financial characteristics. The dependent variable is MPC and the OLS is used. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value $<$ 0.05; * p-value < 0.1.

F Analyzing the role of mortgage contract terms

Here, we investigate the influence of mortgage contract terms on our results. A shorter mortgage term, given a fixed mortgage balance, implies that mortgagors face higher periodic payments. Consequently, mortgage interest payments become more sensitive to changes in the policy interest rate. Conversely, a higher periodic payment burden incentivizes households to take out smaller mortgages, reducing consumption and making house prices less likely to be affected by monetary policy shocks.

In addition, two opposing forces come into play during an expansionary shock. First, given a large payment burden, financially constrained mortgagors can alleviate their interest burden, leading to increased consumption. Second, with shorter contract terms, the appeal of switching to FRMs to lock in low-interest rates diminishes compared to longer-term contracts. In other words, mortgagors have less incentive to opt for costly refinancing and benefit from low-interest rates over relatively short terms, resulting in a muted consumption response.

In our model, the parameter η captures the mortgage contract term and is set at 0.983 to reflect

Table F1: Calibration: The halved mortgage term

Parameter	Description	Value	Target / Source
Target parameters			
β	Discount factor	0.991	Liquid-asset-to-quarterly-income ratio
ω	Rent benefit	1.467	Homeownership rate
ξ_{FRM}	Cost of using FRMs	0.020	Share of ARMs
ξ_{RF}	Fixed refinance cost	0.074	Refinance rate
z	Rent price	0.231	House-value-to-quarterly-rent ratio
ψ_1	Scaling parameter for investment	52.7	House-value-to-quarterly-income ratio
$\delta^+ = \delta^-$	Appreciation/depreciation shock	0.021	Net-wealth-to-quarterly-income ratio
σ_b	SD of idiosyncratic interest rate	0.008	Cons ratio for ARM and FRM mortgagors

This table presents the calibration strategy under the economy where the mortgage term is halved ($\eta = 0.967$). All other non-target parameters are the same as our benchmark values.

the typical 15-year term observed in Germany. We then consider an experimental economy where the mortgage term is halved ($\eta = 0.967$). With the new term parameter, we recalibrate the model to match seven targeted moments while keeping other parameters consistent with those in Section 5 (see Table F1 for our calibration strategy). We then simulate the steady-state economy facing either a contractionary or an expansionary monetary policy shock.

Consumption responds similarly to a contractionary shock but exhibits a more pronounced reaction to an expansionary shock when the mortgage term is shortened. In the experimental economy, the contractionary shock increases interest payment burdens, yet the low mortgage balance mitigates the response of house prices. These two forces result in negligible differences in consumption responses. Conversely, under an expansionary shock, consumption increases more significantly. This is primarily driven by the temporary reduction in the interest payment burden, which outweighs the impact of locking in low interest rates.

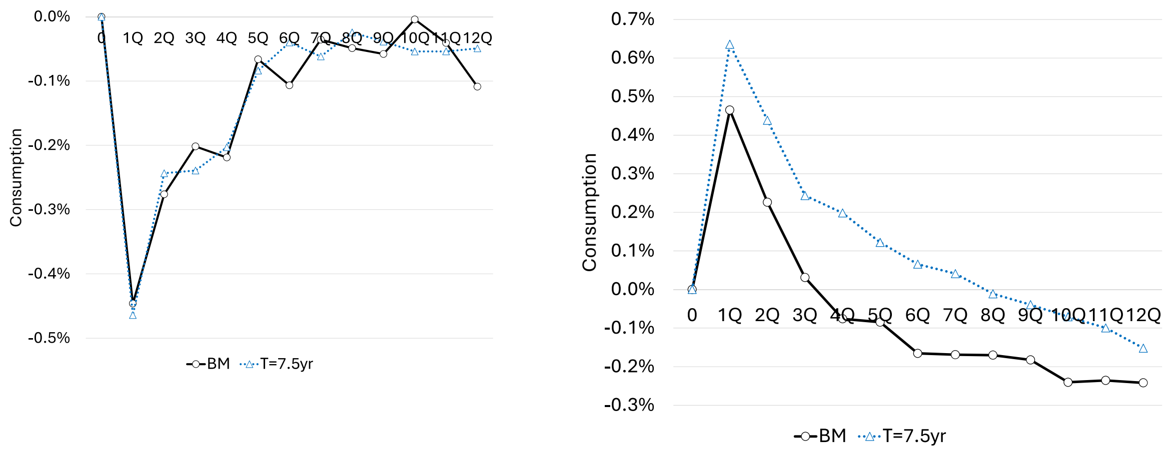
G Recourse vs. non-recourse mortgages

This section examines the impact of the recourse mortgage structure on our main results. While mortgages in European countries typically follow a recourse structure, it is widely known that most mortgages in the US are non-recourse.[54]

[54] Ghent and Kudlyak (2011) argued that each state in the US adopts different recourse/non-recourse mortgage structures. However, Feldstein (2008) stated that mortgages in the US are generally non-recourse.

Figure F1: Consumption responses under different mortgage terms

(a) Contractionary shock (b) Expansionary shock



This figure illustrates consumption responses to both contractionary (panel (a)) and expansionary (panel (b)) monetary policy shocks. The black solid line represents the benchmark ($\eta = 0.983$), while the blue dotted line corresponds to the economy where the mortgage term is halved ($\eta = 0.967$).

To consider the non-recourse mortgage economy, we need to change the households' value function when they default on mortgages as follows:

$$V_D(a,e,b) = \max_{c\geq 0, a'\geq 0} u(c,h_S,0) + \beta E \begin{bmatrix} \gamma V_R(a',e',b') \\ +(1-\gamma)V_D(a',e',b') \end{bmatrix}$$

$$s.t.$$

$$c + \frac{a'}{1+r+b} + zh_S = a + e$$

By construction, the defaulting household does not compensate the lender for its loss through (current and future) income or financial assets. In our model, the household incurs a default penalty by losing homeownership and being unable to access the mortgage market to purchase an owner-occupied house. However, the household's bad credit record can be recovered with probability γ, after which it becomes eligible to buy a house again. The mortgage lender's problem is simplified: the post-default expected cash flow function $\tilde{q}$ and the garnished balance x'_{D,h_j}, where $j \in \{S, L\}$, are set to zero. All other model components remain the same as in the benchmark model. We use the benchmark parameters as presented in Table 2.

Table G1: Steady states under recourse and non-recourse mortgage structures

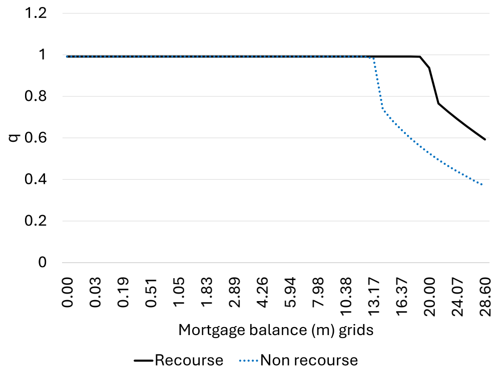
	(1) Recourse	(2) Non-recourse
Homeownership rate	42.4%	43.3%
Financial-asset-to-quarterly-income ratio	2.76	2.76
Share of ARMs	0.16	0.19
Quarterly refinance rate	0.015	0.015
House-value-to-quarterly-income ratio	18.9	18.8
House-value-to-quarterly-rent ratio	86.3	86.0
Net-wealth-to-quarterly-income ratio	9.1	9.2
(Consumption | ARM mortgagors)/(Consumption | FRM mortgagors)	0.89	0.88
LTV ratio	21%	20%
PTI ratio	9.3%	9.1%
Mortgage foreclosure rate	0%	0%
Share of PHtM households	8.5%	8.2%
Share of WHtM households	4.6%	4.9%
(Income | ARM mortgagors)/(Income | FRM mortgagors)	0.83	0.83
(Fin asset | ARM mortgagors)/(Fin asset | FRM mortgagors)	0.59	0.57
(House value | ARM mortgagors)/(Income | FRM mortgagors)	0.99	0.99
PTI ratio for FRM mortgagors	0.09	0.09
PTI ratio for ARM mortgagors	0.09	0.10
Average MPC	0.10	0.10

This table presents the steady-state economies under recourse and non-recourse mortgage structures. Column (1) represents the benchmark economy discussed in the main text. When computing the economy with non-recourse mortgages, we utilize the benchmark parameters reported in Table 2.

Table G1 compares the benchmark recourse economy with the experimental non-recourse economy. While most moments do not exhibit significant changes, some differences are observed in the mortgage balance and the share of ARMs between the two economies. Households in the non-recourse mortgage economy take out one percent fewer mortgages and hold a three percentage point higher share of ARMs compared to the benchmark economy.

The primary mechanism driving these results is the difference in mortgage price schedules between the two economies. The mortgage price in the non-recourse mortgage economy is lower than in the recourse mortgage economy, ceteris paribus (see Figure G1). In the non-recourse economy, mortgage lenders cannot fully recover their losses from the defaulter's future income and financial assets; they can only recover the value of the defaulted house, net of foreclosure costs. Consequently, lenders are incentivized to increase mortgage prices to compensate for potential losses. As a result of the higher mortgage costs, households in the non-recourse economy

Figure G1: Mortgage price schedules: Recourse vs. non-recourse mortgages



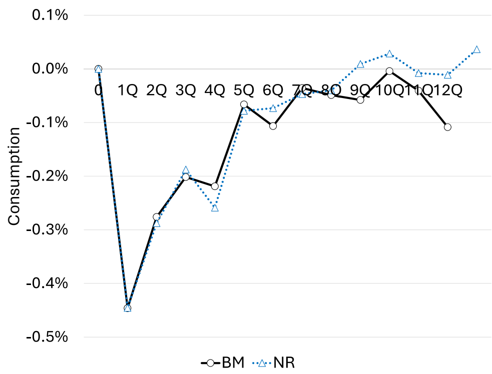
This figure presents mortgage price schedules $q\,(a, e, b, h, m, k, i)$ under recourse (black solid line) and non-recourse (blue dotted line) mortgage structures. The x-axis represents the mortgage balance m grid points. The population averages of a and m, the medians of e, b, and i, the small house size h_S, and the FRM $k = FRM$ are used.

tend to take out and refinance smaller mortgages. Given the high borrowing costs, households are more sensitive to the interest rate margins of different mortgage types: the interest margin for ARMs is lower than that for FRMs. This sensitivity leads to a higher share of ARMs.

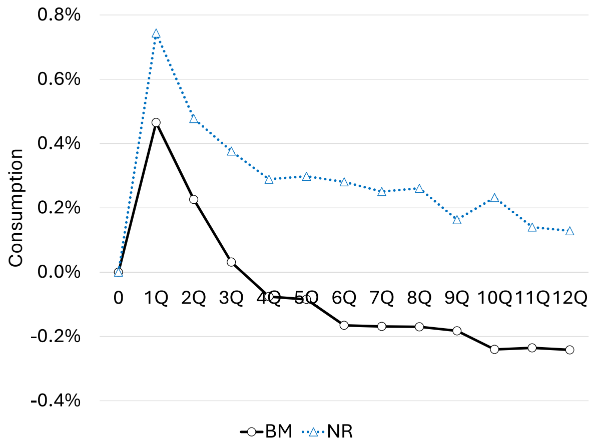
Next, we calculate the consumption responses in the non-recourse mortgage economy to both expansionary and contractionary monetary policy shocks and compare them with the benchmark counterparts. Under the contractionary shock, consumption responses are similar. A lower mortgage balance can mitigate the decrease in consumption, while the higher share of ARMs offsets this impact. In response to the expansionary shock, households in the non-recourse economy consume more than those in the recourse economy. Two forces drive this result. First, the share of ARMs in the non-recourse mortgage economy is higher than in the benchmark, leading to a stronger immediate response to the shock. Second, given the high borrowing costs, households in the non-recourse mortgage economy increase their mortgages less under the expansionary shock, which dampens the impact on consumption responses. In our simulation, the former impact dominates.

Figure G2: Responses of consumption under the recourse and non-recourse mortgage structures

(a) Contractionary shock



(b) Expansionary shock



This figure presents the responses of consumption to monetary policy shocks. Panel (a) and (b) are the responses to the contractionary and the expansionary shocks, respectively. The black solid line is the benchmark recourse mortgage economy and the blue-dotted line is the non-recourse mortgage economy.

H Additional tables

Table H1: Share of ARMs in the HFCS

	Wave 1	Wave 2	Wave 3	Wave 4	Average
Austria	74%	54%	65%	46%	60%
Belgium	35%	40%	32%	28%	34%
Cyprus	68%	56%	64%	71%	65%
Germany	19%	11%	18%	17%	16%
Estonia		86%	90%	98%	91%
Spain	87%	90%	86%	75%	84%
France	14%	9%	5%	2%	7%
Greece	43%	58%	60%	50%	53%
Ireland		87%	79%	62%	76%
Italy	51%	54%	60%	38%	51%
Lithuania			96%	92%	94%
Luxembourg	82%	73%	62%		72%
Latvia		89%	94%	88%	90%
Malta	82%	42%	70%	38%	58%
Portugal	86%	95%	94%	90%	91%
Slovenia	86%	78%	69%	52%	71%
Slovakia	44%	64%	73%	57%	59%

This table displays the proportion of ARMs as derived from the HFCS spanning waves 1 through 4. The proportion of ARMs is determined by the ratio of the total outstanding balances of residential ARMs to the total balances of all residential mortgages. Note that the balance of residential ARMs in Finland is not included in the HFCS data. However, for macro-level analysis, we adopt a share of 96% for Finland. This figure represents the average proportion of newly issued ARMs in Finland from the first quarter of 2003 to the second quarter of 2023, as depicted in Figure I1.

Table H2: Data description - Part 1

Variables	Definition	Source	Time
GDP	Gross domestic product at market prices; Chain linked volume; Calendar and seasonally adjusted data; Unit of measure: Euro	Statistical Office of the European Commission (Eurostat)	1999:Q1-2023:Q2 (Quarterly)
Price level and inflation rate	HICP - Overall index; Neither seasonally nor working day adjusted; Transformed into quarterly data with quarterly average	Statistical Office of the European Commission (Eurostat)	1999:M1-2023:M6 (Monthly)
Total consumption	Private final consumption; Chain linked volume; Calendar and seasonally adjusted data; Reference sector: Households and nonprofit institutions serving households (NPISH); Unit of measure: Euro	Statistical Office of the European Commission (Eurostat)	1999:Q1-2023:Q2 (Quarterly)
Durable and Non-durable	Final consumption expenditure of households - durable goods; Chain-linked volumes (2015), million euros; Seasonally and calendar adjusted data; nondurable is derived from total consumption minus durable	Statistical Office of the European Commission (Eurostat)	1999:Q1-2023 (Quarterly)
Investment	Gross fixed capital formation; Chain linked volume; Calendar and seasonally adjusted data; Unit of measure: Euro	Statistical Office of the European Commission (Eurostat)	1999:Q1-2023:Q2 (Quarterly)
Government total expenditure	Total government expenditure; CPI adjusted by authors (HICP index as denominator); Neither seasonally adjusted nor calendar adjusted; Unit of measure: Euro	European Central Bank (ECB); GFS - Government finance statistics	1999:Q1-2023:Q2 (Quarterly)
Mortgage debt outstanding	Lending for house purchase vis-a-vis domestic households reported by MFIs excl. ESCB; CPI adjusted by authors (HICP index as denominator); Neither seasonally nor working day adjusted; Outstanding amounts at the end of the period (stocks); BS counterpart sector: Households and non-profit institutions serving households; Balance sheet suffix: Euro; Transformed into quarterly data with quarterly average	European System of Central Banks (ESCB); BSI - Balance Sheet Items	2003:M1-2023:M6 (Monthly)
Mortgage interest rate	Bank interest rates - loans to households for house purchase (new business); Annualised agreed rate; BS counterpart sector: Households and non-profit institutions serving households	European Central Bank (ECB); MIR - MFI Interest Rate Statistics	2000:M1-2023:M6 (Monthly)

Table H3: Data description - Part 2

Variables	Definition	Source	Time
SARM, Share of Adjustable Rate of Mortgages (type1)	Share of new loans to households for house purchase with a floating rate or an initial rate fixation period of up to one year in total new loans from MFIs to households; Based on MIR data; Transformed into quarterly data with quarterly average	European Central Bank (ECB); RAI - Risk Assessment Indicators	2003:M1-2023:M6 (Monthly)
SARM, Share of Adjustable Rate of Mortgages (type2)	The ratio of total residential ARM balances to total residential outstanding mortgage balances	European Central Bank (ECB); Household Finance and Consumption Survey (HFCS)	Wave 1-4
Refinance Frequency	The ratio of households that reported refinancing their mortgage more than once in each wave of the survey	European Central Bank (ECB); Household Finance and Consumption Survey (HFCS)	Wave 1-4
Euro Overnight Index Average (EONIA) rate	A reference rate for the euro area, calculated as the weighted average of all overnight unsecured lending transactions in the interbank market by banks in the EONIA panel	European Central Bank (ECB); FM - Financial market data	1999:M1-2021:M12 (Monthly)
Monetary policy shock	Jarociński and Karadi (2020) (updated which rages to 2023m6); Transformed into quarterly data with quarterly summation	https://marekjarocinski.github.io/jkshocks/jkshocks.html	1999:M1-2023:M6 (Monthly)
Alternative monetary policy shock (type1)	Press Release Window for German bonds 3 month; Altavilla et al. (2019) (updated which rages to 2023.06.15); Transformed into quarterly data with quarterly summation	https://www.ecb.europa.eu/pub/pdf/annex/Dataset_EA-MPD.xlsx	2005.03.11-2023.06.15
Alternative monetary policy shock (type2)	Pure policy; Kerssenfischer (2022) (updated which rages to 2023.06.15); Transformed into quarterly data with quarterly summation	https://sites.google.com/site/markkerssenfischer	2002.03.07-2023.06.15
Per capita nominal GDP	Per capita nominal GDP in USD	World Bank WDI (World Development Indicators)	1999-2022 (Yearly)
Financial depth	Private bank credit to GDP	World Bank WDI	1999-2022 (Yearly)
Government size	Government total spending to GDP	World Bank WDI	1999-2022 (Yearly)
Trade openness	Sum of total exports and imports to GDP	World Bank WDI	1999-2022 (Yearly)
Financial openness	De facto measure; sum of total external assets and liabilities to GDP	The External Wealth of Nations Database, The Brookings Institution	1999-2022 (Yearly)

Table H4: Micro evidence of consumption responses: Robustness check

	Δln(C)				Δln(Car value)			
$I\{ARM@(t-1)\}\Delta(EONIA)$	-0.018				-0.084			
	(0.017)				(0.046)			
(ARM-to-debt ratio $@(t-1))\Delta(EONIA)$		-0.022				-0.077		
		(0.018)				(0.049)		
$I\{Refi\}_{Control:HO\ w/\ mortgages}\Delta(EONIA)$			-0.070***				-0.031	
			(0.027)				(0.072)	
$I\{Refi\}_{Control:HO\ w/o\ mortgages}\Delta(EONIA)$				-0.064**				-0.073
				(0.029)				(0.074)
Number of obs (per imputation)	5,680	5,680	5,680	17,228	4,861	4,861	4,861	13,676

This table presents responses of consumption expenditures by mortgage structures interacted with the changes in the real EONIA rate. The econometric model is given by:

$$\Delta y_{i,j,t} = \beta_1(\text{Mortgage structure})_{i,j,t}\Delta(EONIA)_{j,t} + \beta_2(\text{Mortgage structure})_{i,j,t}\Delta ln(GDP)_{j,t} + \beta_3\Delta(EONIA)_{j,t} + \beta_4\Delta ln(GDP)_{j,t} + \Delta X_{i,j,t} + I_j + \varepsilon_{i,j,t}.$$

Two types of mortgage structures are considered: the share of ARMs and the use of mortgage refinancing. The table reports the coefficient β_1 for each definition of the "mortgage structure." Coefficients for control variables are not reported. Standard errors are in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

Table H5: Responses of non-mortgage balances to policy rate decreases

	Δln(Non mortgage)		$I\{\downarrow$ in non mortgage$\}$	
$I\{ARM@(t-1)\}I\{Wave3\}$	-0.016		0.042	
	(0.391)		(0.045)	
$I\{ARM@(t-1)\}I\{Wave4\}$	-0.125		0.016	
	(0.327)		(0.034)	
(ARM-to-debt ratio $@(t-1))I\{Wave3\}$		0.136		-0.007
		(0.441)		(0.051)
(ARM-to-debt ratio $@(t-1))I\{Wave4\}$		0.043		-0.017
		(0.351)		(0.036)
Number of obs (per imputation)	2,447	2,447	2,447	2,447

This table presents the responses of non-mortgage balances based on mortgage structures interacted with the time fixed effect. In the first two columns, we sample households whose non-mortgage balances are positive at time $t-1$ and set the dependent variable as the log difference. If the balance at time t is zero, we set its log balance to zero. In the last two columns, we also sample households whose non-mortgage balances are positive at time $t-1$ and set the dependent variable as an indicator function that is one if the non-mortgage balance decreases from time $t-1$ to t, and zero otherwise. The OLS model is employed. Coefficients for control variables are not reported. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

Table H6: Responses of net wealth difference to policy rate decreases

	Δln(Net wealth)		$I\{\uparrow$ in net wealth$\}$	
$I\{ARM@(t-1)\}I\{Wave3\}$	0.047		0.011	
	(0.057)		(0.028)	
$I\{ARM@(t-1)\}I\{Wave4\}$	-0.014		0.028	
	(0.037)		(0.023)	
(ARM-to-debt ratio $@(t-1))I\{Wave3\}$		0.039		0.004
		(0.061)		(0.030)
(ARM-to-debt ratio $@(t-1))I\{Wave4\}$		-0.019		0.031
		(0.038)		(0.023)
Number of obs (per imputation)	5,377	5,377	5,681	5,681

This table presents the responses of the difference in net wealth based on the mortgage structures interacted with the time-fixed effect. In the first two columns, we sample households whose net wealth is positive at both time $t-1$ and t and set the dependent variable as the log difference. In the last two columns, the dependent variable is an indicator function that is one if net wealth increases from time $t-1$ to t, and zero otherwise. The OLS model is employed. Coefficients for control variables are not reported. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

Table H7: Borrowing constrained households by mortgage types

	$I\{$Credit constrained$\}$	$I\{$Credit refusal or reduction$\}$
$I\{ARM\}$	-0.001	0.017
	(0.006)	(0.011)
ln(income)	-0.037***	-0.043***
	(0.003)	(0.006)
ln(home value)	-0.014***	-0.015**
	(0.004)	(0.007)
ln(mortgage balance)	0.012***	0.011***
	(0.002)	(0.004)
Number of obs (per imputation)	12,589	6,022

This table investigates the heterogeneity of borrowing constraints among households based on their mortgage types. Borrowing constraints are assessed through two primary indicators: (1) credit refusal or reduction experiences among recent applicants within the last three years (designated as variable DOCREDITREFUSAL in the HFCS), and (2) identification of credit-constrained households using the indicator function (DOCREDITC). Analysis is conducted using an OLS model, controlling for both time and country fixed effects. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

Table H8: Financial characteristics of households that refinance

	$I\{Refi\}$			
I{Credit refusal or reduction@$(t-1)$}	-0.015		0.003	
	(0.031)		(0.026)	
I{Credit constrained households@$(t-1)$}		-0.013		0.008
		(0.022)		(0.018)
Remaining maturity @$(t-1)$	0.004***	0.004***		
	(0.001)	(0.001)		
I{Wave 4}			-0.048**	-0.031***
			(0.020)	(0.011)
Mortgage interest rate @$(t-1)$	0.002	0.006	0.006	0.005
	(0.008)	(0.005)	(0.006)	(0.004)
I{ARM@$(t-1)$}	-0.042	-0.030*	-0.018	-0.027**
	(0.027)	(0.017)	(0.022)	(0.013)
ln(income@$(t-1)$)	-0.011	-0.002	-0.004	0.007
	(0.015)	(0.009)	(0.013)	(0.008)
ln(home equity@$(t-1)$)	-0.007	-0.006	-0.013*	-0.015***
	(0.008)	(0.006)	(0.007)	(0.005)
ln(financial asset@$(t-1)$)	0.012**	0.008**	0.011**	0.005*
	(0.005)	(0.003)	(0.005)	(0.003)
HFCS panel wave	3-4	3-4	2-4	2-4
Number of obs (per imputation)	1,912	3,270	2,576	4,898

This table presents the financial characteristics of households that have refinanced mortgages. The dependent variable takes a value of one if the household with mortgages at wave $t-1$ refinances between waves $t-1$ and t, and zero otherwise. The first two columns utilize panel waves 3-4 of HFCS due to data availability on mortgage remaining maturity. In the last two columns, we incorporate the time-fixed effect using panel waves 2-4. Credit record evaluation is conducted through two methods: (1) analysis of credit refusal or reduction experiences among recent applicants within the last three years (designated as variable DOCREDITREFUSAL in the HFCS), and (2) identification of credit-constrained households using the indicator function (DOCREDITC). An OLS model is employed for analysis. Coefficients for the country-fixed effects are omitted. Standard errors are reported in parentheses. *** p-value < 0.01; ** p-value < 0.05; * p-value < 0.1.

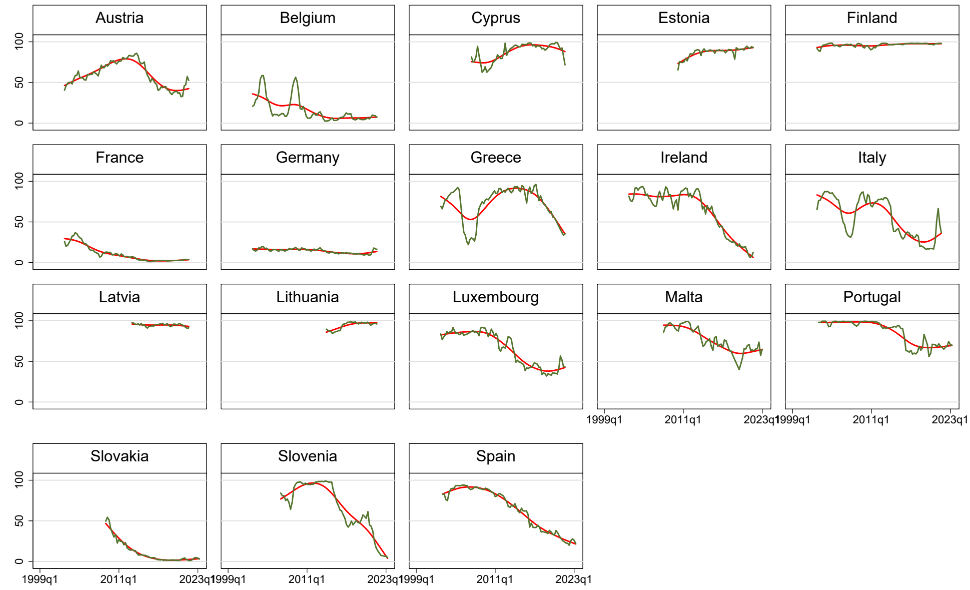
Table H9: Calibration: Experiment economies

Parameter	Description	B	C	D	No refi	Target / Source
β	Discount factor	0.991	0.991	0.991	0.990	Liquid-asset-to-quarterly-income ratio
ω	Rent benefit	1.471	1.462	1.464	1.454	Homeownership rate
ξ_{FRM}	Cost of using FRMs	0.026	0.063	0.050	0.045	Share of ARMs
ξ_{RF}	Fixed refinance cost	Zero	0.123	Zero	∞	Refinance rate
z	Rent price	0.227	0.230	0.226	0.232	House-value-to-quarterly-rent ratio
ψ_1	Scaling parameter for investment	51.5	42.8	59.4	51.2	House-value-to-quarterly-income ratio
$\delta^+ = \delta^-$	Appreciation/depreciation shock	0.022	0.021	0.022	0.024	Net-wealth-to-quarterly-income ratio
σ_b	SD of idiosyncratic interest rate	0.008	BM	BM	0.008	Consumption ratio for ARM and FRM mortgagors

This table presents the calibration strategy across different experimental economies. Column B represents an economy where the share of ARMs matches the benchmark, with a fixed refinancing cost of zero. Column C depicts an ARM-only economy, calibrated to match the benchmark refinancing rate. Column D also illustrates an ARM-only economy, but with a fixed refinancing cost of zero. In both Columns C and D, the cost of using FRMs is set to the minimum level required to eliminate the use of FRMs. Column "No refi" indicates an economy where the refinancing cost is prohibitively high, resulting in a refinancing rate of zero. All other non-targeted parameters are consistent with the benchmark values.

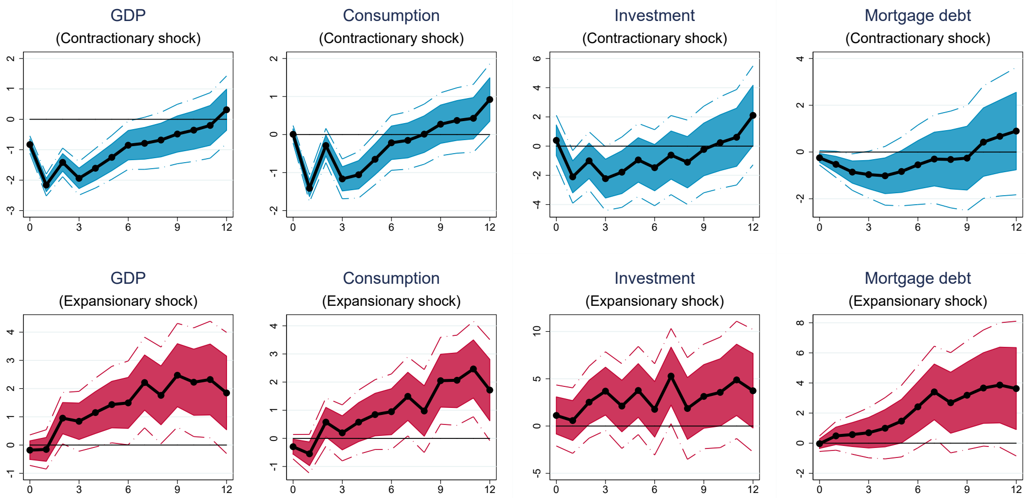
I Additional figures

Figure I1: Shares of ARMs in Euro countries



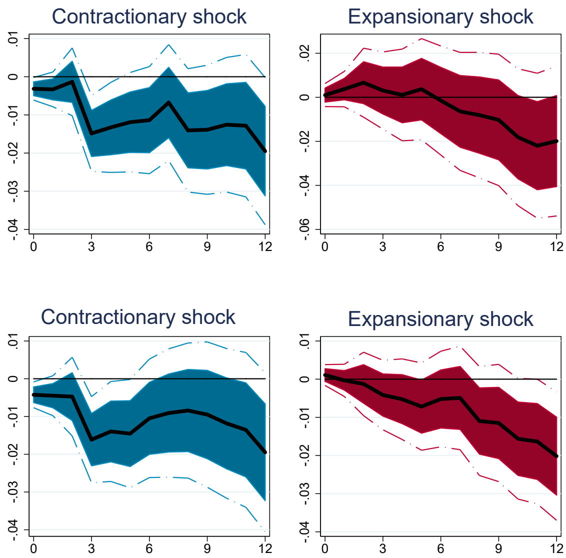
This figure illustrates the time-varying share of ARMs for 18 euro area countries from 2003Q1 to 2023Q2. The red line represents the raw data, while the green line depicts the trend component extracted by the HP filter with $\lambda = 1600$.

Figure I2: Responses of macro variables to monetary policy shocks



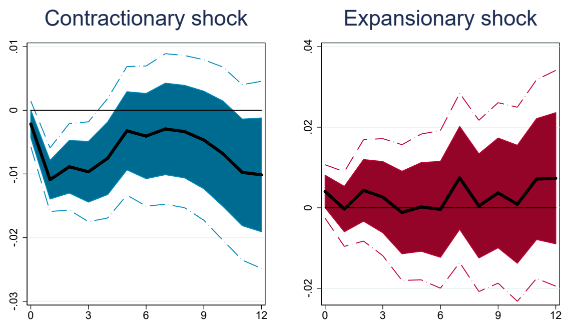
This figure presents responses of macro variables (GDP, consumption, investment, and total outstanding mortgage debt) to either a one standard deviation increase (contractionary, top) and decrease (expansionary, bottom) in monetary policy shocks. Each column plots $\beta^P_{0,h}$ (top, blue) and $\beta^N_{0,h}$ (bottom, red) in Section 3.1. with different dependent variables. The variable SARM is measured as a stock ratio from the HFCS and uses monetary policy shocks from Jarociński and Karadi (2020). The solid (dashed) lines represent 68% (90%) confidence intervals.

Figure I3: Robustness check: Alternative monetary policy shocks



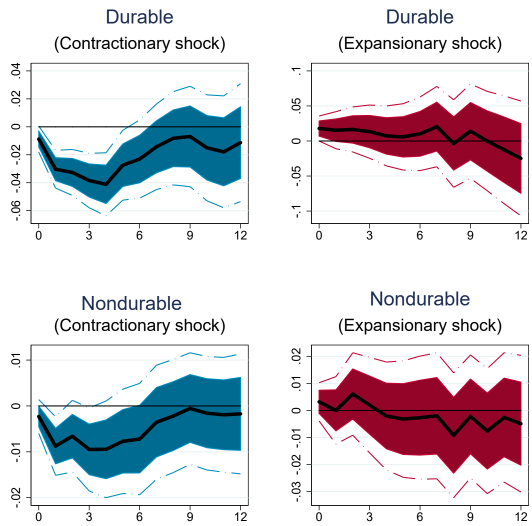
This figure presents the responses of consumption expenditure to a one standard deviation increase (contractionary, left) and decrease (expansionary, right) in monetary policy shocks, depending on the share of ARMs, respectively. The monetary policy shocks are defined according to Altavilla et al. (2019) (top panels) and Kerssenfischer (2022) (bottom panels). The variable SARM is measured as a stock ratio from the HFCS. The analysis covers the period from the first quarter of 1999 to the fourth quarter of 2019. The solid (dashed) lines represent 68% (90%) confidence intervals.

Figure I4: Robustness check: Analysis with additional control variables



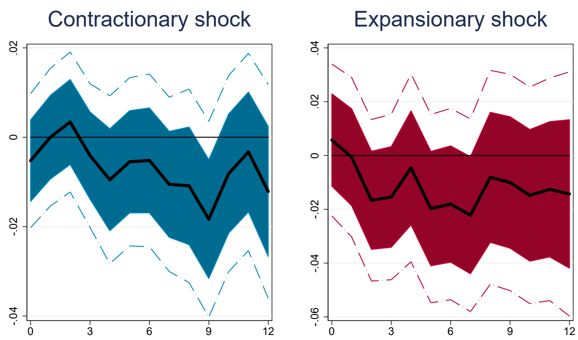
This figure presents the responses of consumption expenditure to a one standard deviation increase (contractionary, left) and decrease (expansionary, right) in monetary policy shocks, depending on the share of ARMs, respectively. The regression includes additional macroeconomic control variables: per capita nominal GDP in USD, financial depth (private bank credit to GDP), government size (government total spending to GDP), trade openness (sum of total exports and imports to GDP), and financial openness (de facto measure; sum of external assets and liabilities to GDP). Control variables are included with lags 0 to 4, alongside macro variables like GDP growth rate and inflation rate. The variable SARM is measured as a stock ratio from the HFCS. We utilize the monetary policy shocks defined in Jarociński and Karadi (2020). The solid (dashed) lines represent 68% (90%) confidence intervals.

Figure I5: Robustness check: Responses of durable and nondurable expenditures



This figure shows the impact of contractionary (left) and expansionary (right) monetary policy shocks on durable (top panels) and nondurable (bottom panels) goods expenditures, depending on the share of ARMs. We utilize the monetary policy shocks defined in Jarociński and Karadi (2020). The responses are to a one standard deviation increase (contractionary) and decrease (expansionary) in monetary policy shocks. The variable SARM is measured as a stock ratio from the HFCS. The solid (dashed) lines represent 68% (90%) confidence intervals.

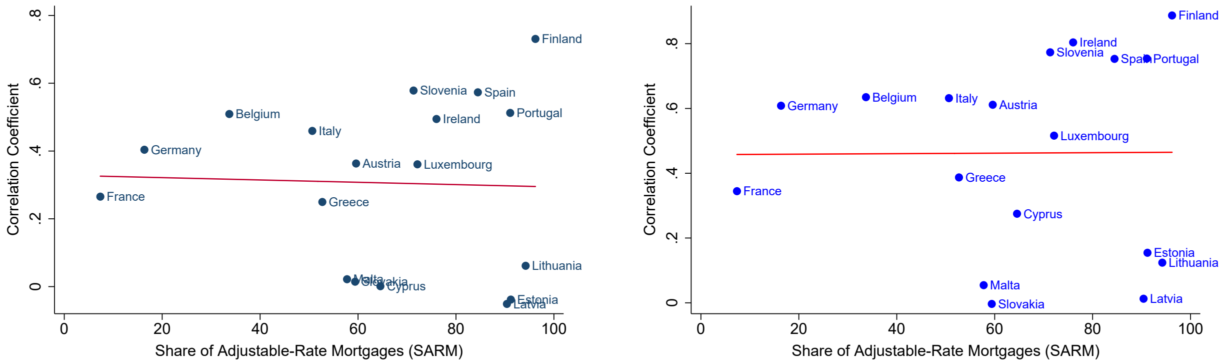
Figure I6: Government spending responses to monetary policy shocks across ARM shares



This figure illustrates the impact of contractionary (left) and expansionary (right) monetary policy shocks on government spending, which is dependent on the share of ARMs. The responses are to a one standard deviation increase (contractionary) and decrease (expansionary) in monetary policy shocks. The variable SARM is measured as a stock ratio from the HFCS, and the regression equation corresponds to that in Figure 1 and uses the same monetary policy shocks from Jarociński and Karadi (2020). The key difference lies in the dependent variable shift from consumption to government spending. The solid (dashed) lines represent 68% (90%) confidence intervals.

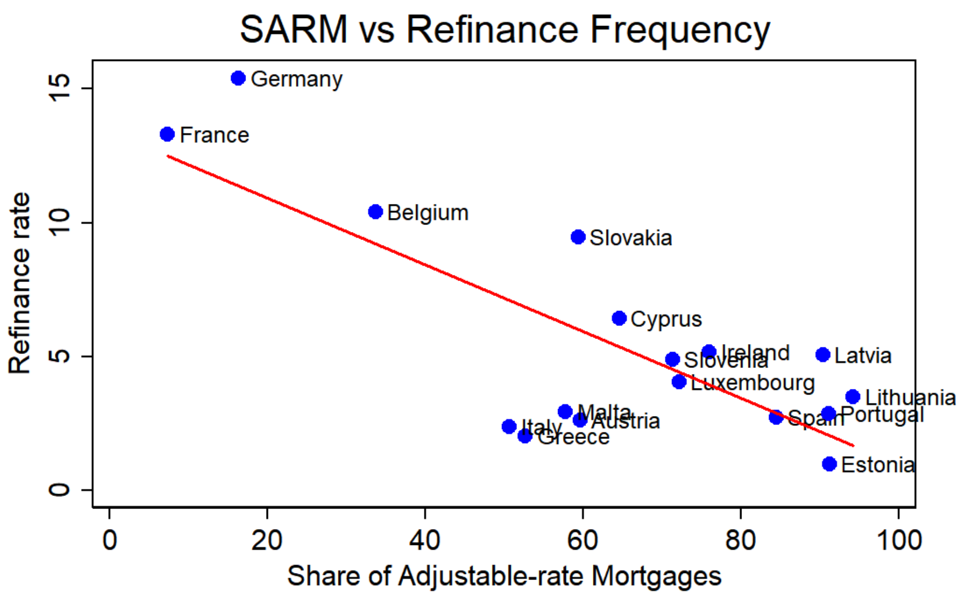
Figure I7: Mortgage interest rate responses to monetary policy across different shares of ARMs

(a) Monthly difference (b) Quarterly difference



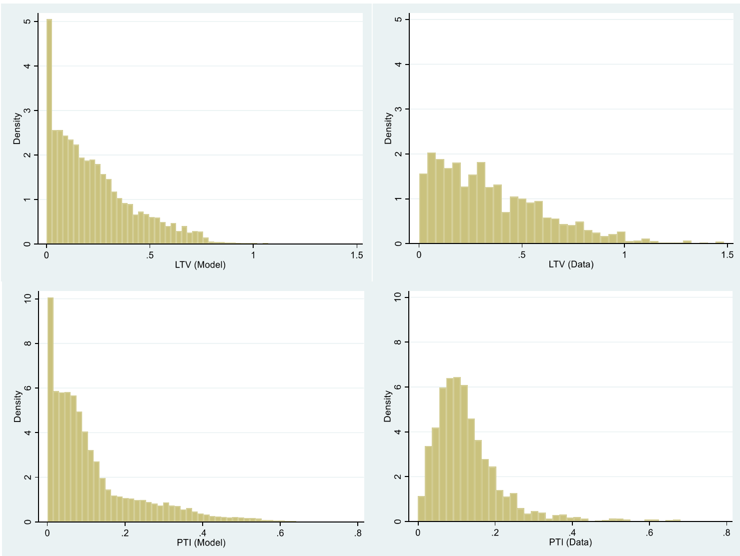
This figure presents scatter plots of the correlation coefficients between the first differences of the EONIA and mortgage interest rates (MIR) against the share of ARMs (derived from the HFCS). In calculating the correlation coefficients, panel (a) uses monthly differences, $\Delta\text{EONIA} = \text{EONIA}_t - \text{EONIA}_{t-1}$ and $\Delta\text{MIR} = \text{MIR}_t - \text{MIR}_{t-1}$, while panel (b) uses quarterly differences, $\Delta\text{EONIA} = \text{EONIA}_t - \text{EONIA}_{t-3}$ and $\Delta\text{MIR} = \text{MIR}_t - \text{MIR}_{t-3}$. The sample period spans from each European country's EU accession date to December 2019. The slope in panel (a) is -0.036 (p-value = 0.8876), and in panel (b), it is 0.007 (p-value = 0.9791).

Figure I8: Cross-country correlation between the share of ARMs and refinance frequency



This scatter plot presents the cross-country correlation between the share of ARMs and refinance frequency, with a correlation coefficient of 0.77 (p-value: 0.003). Refinance frequency is defined as the proportion of households that refinanced their mortgage within the past three years relative to the total number of mortgagors at the time of the survey. The share of ARMs is calculated as the ratio of total residential ARM balances to total residential mortgage balances, based on data from the HFCS. Finland and the Netherlands are excluded from the sample: the HFCS does not include Finland and lacks data on mortgage types for the Netherlands.

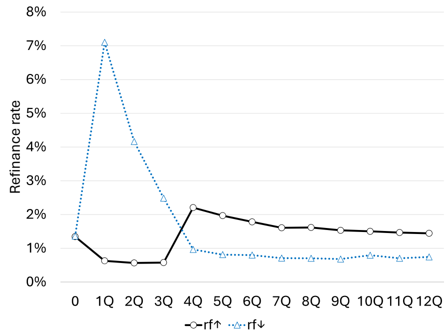
Figure I9: LTV and PTI distributions



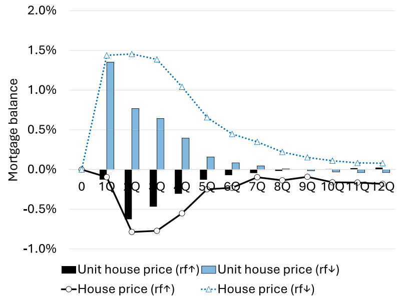
This figure presents distributions of the LTV ratios (top panels) and PTI ratios (bottom panels). The first column shows model-generated results, while the second column presents data sourced from HFCS (Wave 3).

Figure I10: Responses of the refinance rate, house prices, and mortgage balances to monetary policy shocks

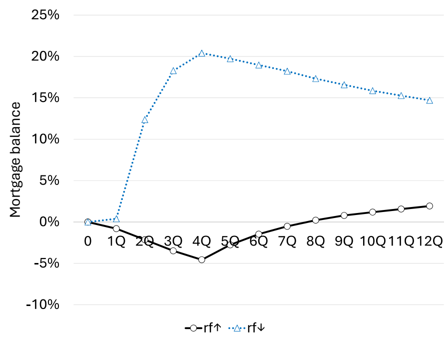
(a) Refinance rate



(b) House and unit house prices

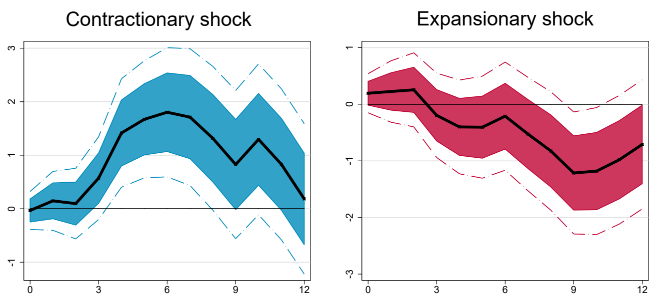


(c) Mortgage balances



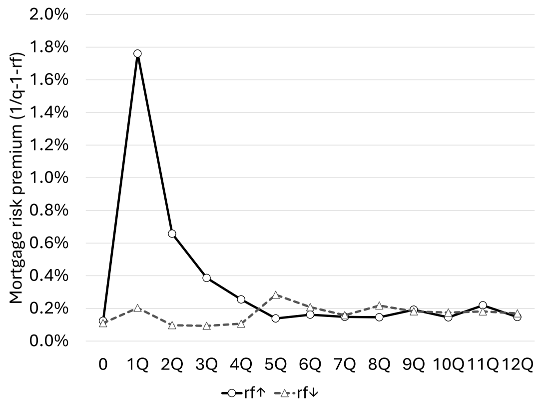
These figures present responses of the refinance rate (panel (a)), (unit) house prices (panel (b)), and mortgage balances (panel (c)) to both expansionary and contractionary monetary policy shocks under the benchmark economy. The black line represents the response to the contractionary shock, and the blue dotted line represents the expansionary shock.

Figure I11: Endogenous responses of the share of ARMs to monetary policy shocks with the country-fixed effect



This figure presents the responses of the share of ARMs to a one standard deviation increase (contractionary, left) and decrease (expansionary, right) in monetary policy shocks, respectively. The response variable is measured as the ratio of the amount of newly issued ARMs to the total amount of new mortgages from the ECB. A state-dependent LP model is used and the country fixed effect is included. The solid (dashed) lines represent 68% (90%) confidence intervals.

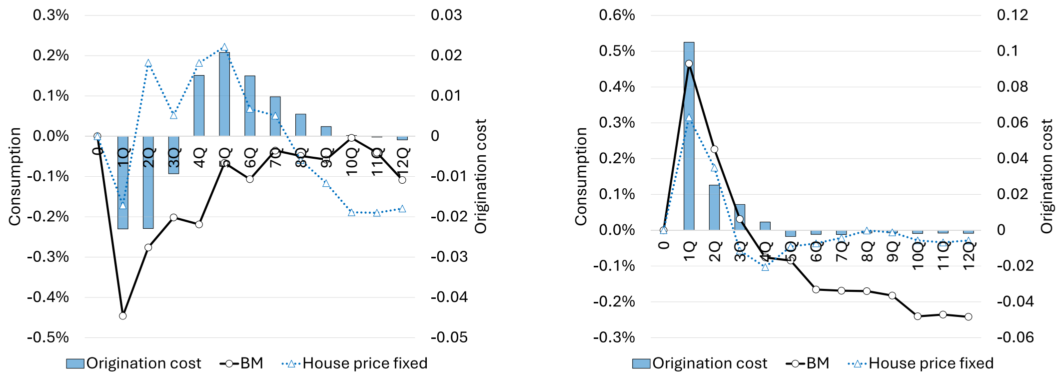
Figure I12: Responses of mortgage interest rate premiums



This figure displays the responses of newly issued mortgage interest rate premiums to contractionary shocks (the black solid line) and expansionary shocks (the blue dotted line). The figure highlights the difference between the mortgage interest rate, determined by the bond price $(1/q - 1)$, and the current risk-free rate.

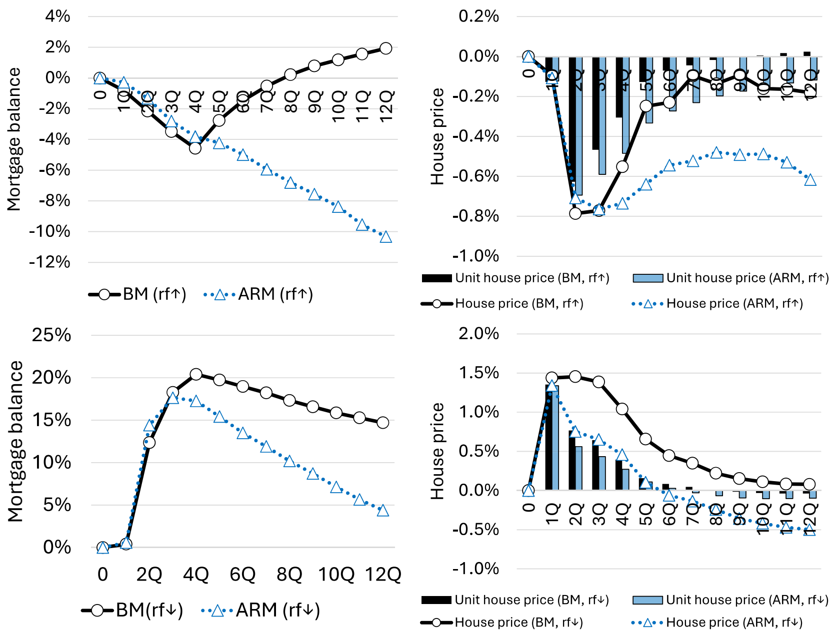
Figure I13: Consumption responses under fixed house values

(a) Contractionary shock (b) Expansionary shock



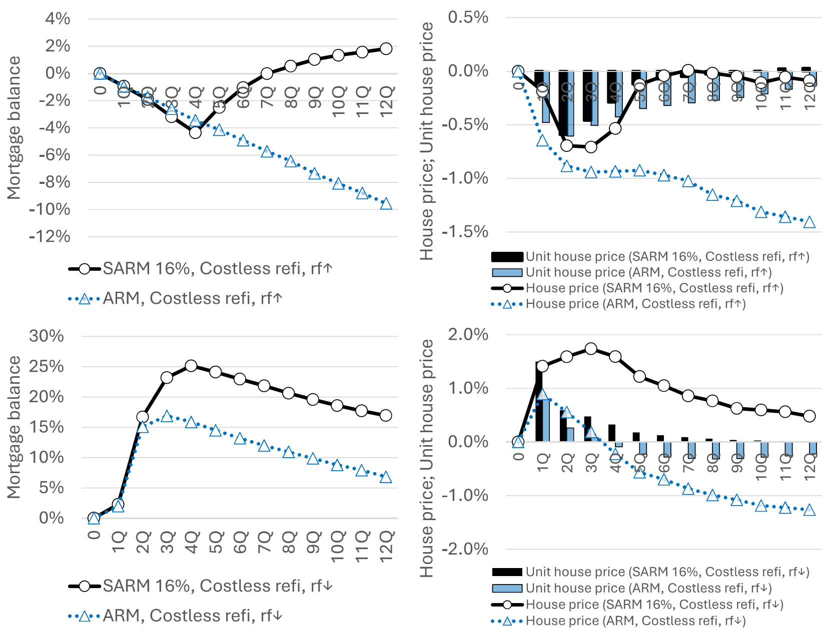
This figure compares consumption responses in the benchmark economy with those in a counterfactual economy where the house value (ph) remains constant throughout the transition path. Panels (a) and (b) depict contractionary and expansionary shocks, respectively. The solid black line represents the benchmark economy, while the blue dashed line indicates the counterfactual economy. The grey bar represents the calibrated mortgage origination cost ξ to maintain a constant house value.

Figure I14: Mortgage balance and house prices: Economies A vs. C



This figure presents responses of the mortgage balance and the (unit) house price under the contractionary and the expansionary monetary policy shocks. The first row is the response under the contractionary shock and the second row is the expansionary shock. The black solid line is the benchmark economy and the blue dotted line is the ARM-only economy.

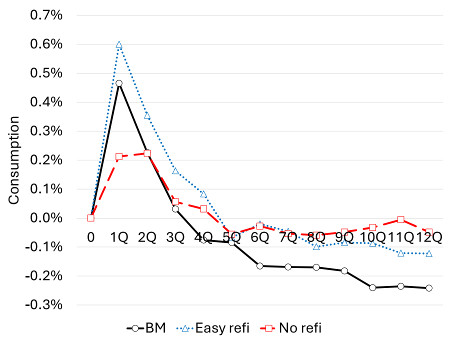
Figure I15: Mortgage balance and house prices: Economies B vs. D



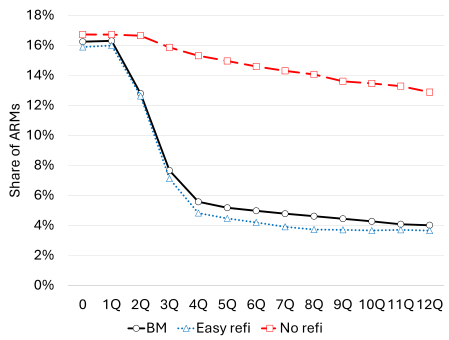
This figure illustrates the responses of the mortgage balance and the (unit) house price to contractionary and expansionary monetary policy shocks. The first row depicts the response to the contractionary shock, while the second row shows the response to the expansionary shock. The black solid (blue dotted) line represents the transition paths from the initial steady-state economy B (D).

Figure I16: Moment responses to the expansionary shock under different refinance costs

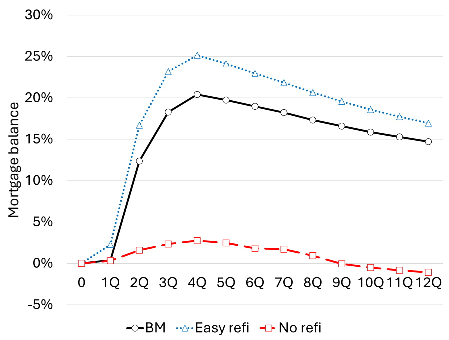
(a) Consumption



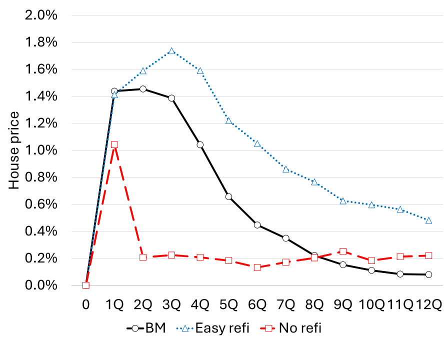
(b) Share of ARMs



(c) Mortgage balances



(d) House prices



This figure illustrates the responses of consumption, the share of ARMs, mortgage balance, and house prices to the expansionary monetary policy shock under different fixed refinancing costs ξ_{RF}. The black solid (blue dotted) line represents the transition paths from the initial benchmark steady-state economy (experiment economy B). The red dashed line shows the transition in a counterfactual economy where the refinancing option is eliminated, while maintaining the initial share of ARMs as in the benchmark.