Housing Markets and the Heterogeneous Effects of Monetary Policy Across the Euro Area*

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Abstract

Monetary policy has heterogeneous effects across euro area countries. There are strong correlations between cross-country monetary policy potency and housing and mortgage market institutions, namely the share of adjustable-rate mortgages and the homeownership rate. To disentangle the relative importance of these institutions, I incorporate them into a quantitative currency-union New Keynesian model with rich household balance sheets. I calibrate the model to Spain and the euro area. The model fits well: the consumption response in Spain is 2.4 times stronger than the euro area in the model relative to 2.5 in the data. My results reveal that a higher adjustable-rate mortgage share and a higher homeownership rate interact to amplify the effects of monetary policy on economic activity due to smaller mortgage interest payments and a higher fraction of mortgaged homeowners operating in the market. I use the model to show that a banking union requiring shared financial regulation decreases the heterogeneous effects of monetary policy by weakening the pass-through to average mortgage interest rates. Finally, including house prices into the euro area price index stabilizes output at the cost of less stable goods inflation.

JEL: C22, E02, E12, E31, E43, E52, E58, F33, F45, G21, G51

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1 Introduction

Monetary policy has heterogeneous effects across countries in the euro area. For example, following a policy rate increase, aggregate consumption in Spain decreases more strongly than in Germany.[1] This has crucial policy implications because it means that the monetary authority stabilization properties are not uniform across the euro area.

Recent evidence suggests that housing wealth effects are an important driver of the euro area heterogeneous consumption responses to monetary policy (Slacalek, Tristani, and Violante (2020)). The literature, however, still lacks an understanding of what the specific mechanisms are behind the differential cross-country responses. In this paper, I link these heterogeneous responses to structural differences of the housing and mortgage markets. A novel focus of my work is to quantify in a structural model the role of the homeownership rate (HoR) and the share of adjustable-rate mortgages (ARMs), two features that are extremely different across European countries and that I show drive the empirical responses to monetary policy shocks.[2]

First, I provide refined evidence at the country level on the role of the housing and mortgage market institutions in the monetary transmission mechanism in the euro area. I show that countries that react the most to monetary policy shocks are those with higher HoR and higher ARM share. Second, I construct a quantitative model that pays particular attention to institutional details for the eurozone country-specific markets. A higher ARM share interact with a higher HoR to increase the potency of monetary policy through a stronger pass-through to average mortgage interest rates and a higher fraction of households that are active in the mortgage markets. Third, I use the model to argue that a euro-area-wide mortgage market requiring to issue the same ARM share across countries drastically reduces the heterogeneous effects of monetary policy. I finally discuss and quantify the output-inflation trade-off arising from introducing house prices into the euro area price index. While the monetary authority is able to stabilize output more effectively, it does so at the cost of higher goods inflation volatility.

Empirically, I perform an econometric analysis of monetary policy shocks across euro area countries using local projection methods (Jordà (2005)). I use high-frequency movements of the Overnight Indexed Swap (OIS) rates around policy announcements as identified monetary policy shocks. An expansionary monetary policy shock makes

[1] Corsetti, Duarte, and Mann (2021) find that a 25-basis-point increase in the policy rate decreases aggregate consumption in Spain by as much as 0.6% compared to a maximum decrease of about 0.05% in Germany. Slacalek, Tristani, and Violante (2020), with a different empirical methodology, reach a similar quantitative conclusion.

[2] To give a sense of the underlying cross-sectional heterogeneity, in 2014 the ARM share in Spain was around 90% compared to 45% in the euro area and 11% in Germany. By the same token, the HoR in Spain was 80% compared to 60% in the euro area and 44% in Germany.

some countries (Spain, Ireland, Finland) react two to four times more strongly than some others (Germany, France) which often do not have significant responses. I provide evidence of economically sizable and statistically significant correlations between the strength of monetary policy responses and country-specific housing and mortgage market institutions.

Countries that react the most in terms of aggregate consumption, house prices, newly issued mortgage loans, and mortgage interest rates are those that have a) a higher ARM share relative to total outstanding mortgages; b) higher HoR; and c) bigger fractions of homeowners with mortgages. The features of the housing and mortgage markets I focus on, however, do not necessarily jointly explain the heterogeneous monetary transmission mechanism. Countries that have a higher ARM share are also those that have higher HoR. Hence, an identification problem arises: it might well be that only one of these features explains the heterogeneity in practice, and not all of them.

To quantify the relative importance of ARM share and the HoR, I turn to a quantitative currency-union two-agents New Keynesian model. The model has a Home-Foreign structure as in Faia and Monacelli (2008). The Foreign country is a closed economy and can be thought of as a currency union: the euro area. The Home country is a small open economy and can be interpreted as any given euro area country. Within each country, households have rich balance sheets: they decide on long-term mortgage amounts and house size as in Greenwald (2018). The population is made of constrained borrowers and patient savers, while landlords provide rental units to the borrowers. The monetary authority employs a Taylor rule at the euro-area-level and equalizes the short interest rates across countries.

The novelty of this framework is that it allows me to analyze and compare the effects of specific features of the housing and mortgage markets in the transmission mechanism of monetary policy across the different euro area countries. In particular, the countries in the model economy crucially differ in two key housing and mortgage market institutions.

Firstly, borrowers are subject to within-period heterogeneity in utility from owning, leading them to endogenously choose whether to be homeowner or renter as in Greenwald and Guren (2019). This heterogeneity stems from true housing preference as well as household demographic characteristics not otherwise captured in the model. A country has a higher fraction of homeowners with mortgages than another one because households have on average a higher utility from owning. This difference in the distribution of owning utility across countries stands in for the quality of the rental market and ownership subsidies.[3]

Secondly, I assume that in each country households hold an exogenous fraction of fixed-rate mortgages (FRMs) and ARMs. While the mortgage type choice is in principle an

[3] Looking at the past few decades, Germany and France have traditionally had a strong social housing sector compared to Italy and especially to Spain. On the other hand, subsidies to owner-occupiers have been mostly absent in Germany but strongly present in Spain. For a more detailed quantitative comparison across a few countries, see Kaas et al. (2021).

endogenous household decision, I model it as exogenous because it is in practice influenced by country-specific housing finance regulation.[4] Importantly, countries with a higher ARM share display a stronger pass-through to average mortgage interest rates, which is also a correlation I demonstrate empirically.

I calibrate the Home economy to Spain and the Foreign economy to the euro area. I calibrate Spain to have a 90% ARM share and 80% HoR, with the proportion of homeowners with mortgages being 30%. Similarly, I calibrate the euro area to have a 45% ARM share and 60% HoR, with the proportion of homeowners with mortgages being 20%. As the main monetary policy experiment, I consider a near-permanent decrease of 1% in interest rates which shifts downward the whole term structure, and compare the monetary transmission mechanism across Spain and the euro area.[5]

As in the data, the model results show that Spain reacts more strongly than the euro area. Comparing the impulse response function peaks and troughs over a 15Q horizon, the average mortgage interest rate on the outstanding stock of mortgages in Spain reacts about 1.9 times more than the euro area relative to 1.8 in the data. Spanish households pay lower mortgage interest payments, and are thus able to leverage up relatively more than the euro area households. These effects combined deliver an aggregate consumption response in Spain which is 2.4 times stronger than the euro area relative to 2.5 in the data.

To understand the channels behind these responses, I use the model to disentangle how much of the monetary-policy-induced responses come from the differential ARM share as opposed to the differential HoR. The presence of a higher ARM share in Spain determines a stronger pass-through to the average mortgage interest rates. This is a cash-flow effect on borrowers, who can leverage up through new mortgages. Conversely, a higher HoR means that more mortgaged homeowners are active in the market and can therefore increase their mortgage stock.

Turning to aggregate consumption, however, I find that neither the ARM share nor the HoR can explain the aggregate consumption response of Spain relative to the euro area that I find in the baseline economy. However, when both channels are active together, more households can borrow against their houses while also paying less interests on their mortgages. This situation leads borrowers to spend relatively more on their non-durable consumption. Therefore, housing and mortgage market institutions interact to amplify the potency of monetary policy on economic activity.

Lastly, I use my quantitative model as a laboratory to study policy-relevant changes to

[4]For example, Bank of Spain (2017) makes it clear that the lack of long-term swap contracts available to banks prior to 2015 led them to only issue ARMs, as they couldn't hedge the interest rate risk.

[5]The permanent shock used in this paper stands for expected and persistent changes in the stance of the monetary authority. The relevant example is the one of the European Central Bank reducing the policy rates in 2008 in a persistent fashion.

the economic environment. In a first counterfactual, I analyze how a banking union alters the stabilization properties of the monetary authority. A banking union, modeled as a euro-area-wide mortgage market, is successful in decreasing the heterogeneous transmission mechanism of monetary policy when countries face similar financial regulations. If Spain is required to cut the ARM share difference with the euro area by half (from 90% to 70%), the aggregate consumption response differential between Spain and the euro area drops by around 40%. The consumption response differential vanishes completely when Spain is required to share the same mix of ARMs and FRMs as the euro area. Under these banking arrangements, the monetary authority faces a trade-off between a weakened heterogeneous transmission and a movement of resources towards the richer households of the economy.

In a second experiment, I build on the recent European Central Bank (ECB) monetary policy strategy review (ECB (2021)) according to which the euro area price index will include house prices in the near future. In the model, house prices are more volatile than goods prices. Therefore, including house price inflation into the Taylor rule forces the monetary authority to move interest rates less. Because of this, the volatility of output is mechanically reduced. At the same time, the monetary authority weights goods inflation less, therefore determining a higher goods inflation volatility.

Relation to the Literature. Empirically, this paper relates to existing work analyzing the effects of monetary policy across countries in the euro area including Lenza and Slacalek (2018), Almgren et al. (2019), Slacalek, Tristani, and Violante (2020), and Koeniger, Lennartz, and Ramelet (2021). Relative to these papers and given that my focus is on mortgage contracts, I show heterogeneous responses of aggregate variables to monetary shocks at the *longer end of the yield curve*. Corsetti, Duarte, and Mann (2021) show that consumption and house price reactions across countries strongly correlate empirically with the ARM share and HoR after a conventional monetary policy shock. My results complement theirs in two dimensions: firstly, by showing that this is true for newly issued mortgages and mortgage interest rates as well, pointing to the importance of mortgages in the transmission mechanism; and secondly, by analyzing a time period over which the ECB has faced the zero lower bound on short rates.

Turning to theoretical models, my work builds on papers focusing on small open economies and currency unions such as Gali and Monacelli (2005), Faia and Monacelli (2008), Gali and Monacelli (2008), De Paoli (2009) , Corsetti, Dedola, and Leduc (2010), and Gali and Monacelli (2016). This class of models features a representative agent in each country and derives closed-form solutions to study optimal monetary policy and different exchange rate policies. I instead build a quantitative model with rich within-country household balance sheets such as long-term mortgages and rental contracts in order to compare the effects of a common interest rate movement across countries for varying housing institutions.[6][7]

This work also relates to the class of New Keynesian models featuring housing and mortgage debt such as Iacoviello (2005), Iacoviello and Neri (2010), Rubio (2011), Calza, Monacelli, and Stracca (2013), Greenwald (2018), and Garriga, Kydland, and Šustek (2021). While these papers focus on a closed economy (usually the US), I study the dynamics to monetary policy shocks across countries in a currency union. The common interest rate is set by the central bank at the union level, and countries with different characteristics display heterogeneous effects to monetary policy.

A different strand of the literature uses heterogeneous agent models with rich specifications in terms of idiosyncratic risk and long-term mortgages. The downside of these models is that they cannot often incorporate monetary policy, endogenous prices, or endogenous output for computational reasons.[8] Hintermaier and Koeniger (2021) build a life-cycle incomplete market model to study the effects of house price and real interest rate shocks across the four largest economies in the euro area. They show that household finances and housing tenure choices play an important role in the transmission mechanism of monetary policy. My paper complement theirs by focusing on the interaction between the homeownership rates and long-term mortgages, with the latter being crucial to match the heterogeneous pass-through from policy rates to mortgage interest rates.

In this sense, my paper is closest to Greenwald (2018), which models rich household balance sheet with long-term FRMs. I extend that paper in two ways: a) by modeling both AMRs and FRMs in order to match data on euro area countries (which typically feature a mix of both mortgage types); and b) by modeling multiple countries in a currency-union.

[6] An older working paper version of Corsetti, Duarte, and Mann (2021) included a Home-Foreign framework to study changes in ARM share and loan-to-value constraints in a small open economy calibrated to Spain. Differently from that paper, I model long-term mortgages as well as the rental market both at the euro-area-level and at the small economy country level. Such a framework allows me to analyze the differential monetary policy transmission mechanism stemming from the dissimilar housing and mortgage market institutions alone, and also allows me to study the consequences at the country level of a euro-area-wide mortgage market.

[7] In my model, the Home and Foreign countries only differ in their housing institutions. In a similar fashion, Costain, Nuño, and Thomas (2021) build a currency-union model where the countries differ in their sovereign default risk.

[8] See, e.g., Chatterjee and Eyigungor (2015), Beraja et al. (2018), Berger et al. (2018), Eichenbaum, Rebelo, and Wong (2018), Wong (2019), Kaplan, Mitman, and Violante (2020).

2 The Empirical Relevance of Housing and Mortgage Markets in the Monetary Transmission

In this section I study the effects of monetary policy shocks across the early adopters of the euro for a variety of variables of interest. I then correlate the country-specific strength of monetary policy responses with the housing and mortgage institutions, namely the ARM share and the HoR.

There are two points worth stressing at this stage, stemming from the fact that the focus of the paper is on the housing and mortgage market. Firstly, I place particular emphasis on the responses to monetary policy shocks on price-to-rent ratios, mortgage interest rates, newly issued mortgages, and aggregate consumption. Secondly, I study monetary shocks to the longer end of the yield curve because my focus is on long-term mortgage contracts. As a consequence, my main empirical analysis looks over the "unconventional" time period 2007-2019, over which the ECB reached the zero-lower-bound on short rates.[9] The results in this section do not change quantitatively if I start the analysis in 2003 instead than in 2007.

2.1 Identification

My empirical analysis relies on high frequency identification of monetary policy shocks (an approach initiated by Kuttner (2001)) and uses local projection methods (Jordà (2005)).

In the context of high frequency identification in the US, monetary policy shocks have been identified as changes in Federal Funds futures around Federal Reserve announcements. In Europe, a few recent papers have adopted this approach by relying on movements in the Overnight Indexed Swap (OIS) rates around ECB announcements. The OIS is an interest rate swap over a specific maturity (say, 1 year) whereby two parties exchange a fixed interest rate for the floating European overnight interest rate. In essence, it is a measure of expectations about future overnight interest rates in the European interbank market. Hence, changes in OIS around ECB press conferences can be interpreted as *caused by* monetary policy.[10] I make use of the "Euro Area Monetary Policy Event Study Database" constructed by Altavilla et al. (2019), which provides changes in the median price of OIS rates at different maturities between the 10-minute window preceding each

[9]Over this period, the ECB has employed a variety of measures aimed at stimulating the economy without the possibility of moving the short rates. These measures include forward guidance and several programmes of asset purchases and long-term liquidity provision.

[10]The same identification approach for the euro area has been employed by Almgren et al. (2019) in the context of local projection instrumental variables methods, by Slacalek, Tristani, and Violante (2020) in the context of a BVAR, and by Corsetti, Duarte, and Mann (2021) in the context of a dynamic factor model. For a more detailed discussion on OIS rates, see Almgren et al. (2019).

ECB announcement and the 10-minute window following it. The identifying assumptions are that a) OIS rates before and after the announcements are only moved by monetary policy, and b) the ECB does not respond to changes in OIS rates.[11]

Given that the focus of this paper is on the role of mortgages in the transmission mechanism, I make use of unexpected movements in the longer end of the yield curve. I therefore pick the 2-year OIS changes, the longer yield curve maturity available in high frequency since the early 2000s. My results are robust to a conventional monetary policy analysis relying on movements on the shorter end of the yield curve, as shown in Appendix A.3.[12]

2.2 Data and Empirical Specification

The main analysis runs from 2007 Q1 to 2019 Q3 for the eleven early adopters of the euro: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain.[13] The variables of interest are aggregate consumption, price-to-rent ratios, quantity of newly issued mortgages, and mortgage interest rates on outstanding mortgages. Relevant euro area control variables are the harmonized index of consumer prices (HICP) and aggregate output. Mortgage interest rates are measured in annualized percentage terms, while all other variables are measured in log-levels.

Monetary policy shocks at the quarterly level are constructed by summing up the 2Y OIS changes within quarters. Data sources are outlined in Appendix B.

I estimate the response of the relevant variables to monetary policy shocks using local projections methods (Jordà (2005)). For each country c and each horizon h=0,..., H, I estimate the following specification:

$$y^c_{t+h} - y^c_{t-1} = \alpha^{h,c} + \beta^{h,c}\epsilon^{MP}_t + \sum_{k=1}^{K} \gamma^{h,c}_k X^{h,c}_{t-k} + u^{h,c}_t \quad (1)$$

where y is the variable of interest, ϵ^{MP} is the monetary policy shock, and X is a set of control variables. The impulse response functions are constructed, for each country c, from the sequence of the coefficients on the monetary policy shocks, that is $\{\beta^{h,c}\}^{H}_{h=0}$.

As a benchmark, I set the number of lags to K=2 quarters and the horizon of the impulse response function to H=10 quarters. The set of lagged controls X includes the

[11] Jarociński and Karadi (2020) separate monetary policy shocks from central bank information shocks. I abstract from this distinction in my analysis in order to focus on a broader measure of monetary shocks.

[12] Countries react more strongly following conventional policy shocks. This is true for all variables considered except for mortgage interest rates, which instead tend to react more severely following shocks to the longer end of the yield curve.

[13] The sample of countries with data on newly issued mortgages is a bit smaller, with Austria, Ireland, and Luxembourg missing.

left-hand-side variable, the monetary shock, the euro area mortgage interest rate, the euro area HICP, the euro area aggregate output, and the euro area price-to-rent ratio.

2.3 Heterogeneous Impulse Response Functions Across the Euro Area

In this section I present impulse response functions for each country to an expansionary shock of one standard deviation, as in Almgren et al. (2019). I construct 95% confidence intervals using Newey-West standard errors.

Figures 1 and 2 present two of the main empirical results of this paper. They show the impulse response functions of newly issued mortgages and outstanding mortgage interest rates, respectively. The results imply that a one standard deviation expansionary shock causes an increase in newly issued mortgages across the euro area, but that some countries react much more strongly than others. Spain, Portugal, Italy, and the Netherlands increase their flow of new mortgages by about 5%, while some other countries are less responsive. For example, the euro area peaks at around 1.8% and Germany at less than 1%.

The results on newly issued mortgages are echoed in the mortgage interest rate responses: rates decrease following a monetary expansion, highlighting a strong pass-through for some countries and a much weaker one for some others. Again, Spain and Portugal are among the countries that react the most, reaching a trough of about 0.1%.[14]

Heterogeneity in the transmission of monetary shocks across the euro area has been recently quantified by Corsetti, Duarte, and Mann (2021) using a dynamic factor model. They find significant heterogeneity in consumption, consumer prices, house prices, and unemployment. While I confirm their results on aggregate consumption and house prices, my analysis provides new evidence of heterogeneous responses in mortgage market variables (figures 1 and 2).

My model in Section 3 shows that the heterogeneous responses to mortgage-related variables are essential to explain the differential responses in aggregate consumption across euro area countries.

[14]Results on aggregate consumption and price-to-rent ratios are more standard and therefore provided in Appendix A.1. In terms of aggregate consumption, an expansionary monetary policy shock of one standard deviation leads to an increase in Spain of about 0.5%, which is more than double the response of the euro area. By the same token, the price-to-rent ratio increase in Spain by 1%, more than twice as much as in the euro area. I decide to focus on price-to-rent ratios instead of on house prices because these ratios are widely understood to be the basis of household decisions about whether to rent or to buy. However, the results of my analysis are virtually unchanged if I substitute price-to-rent ratios with house prices. This is because monetary policy in the euro area barely moves rents relative to house prices.

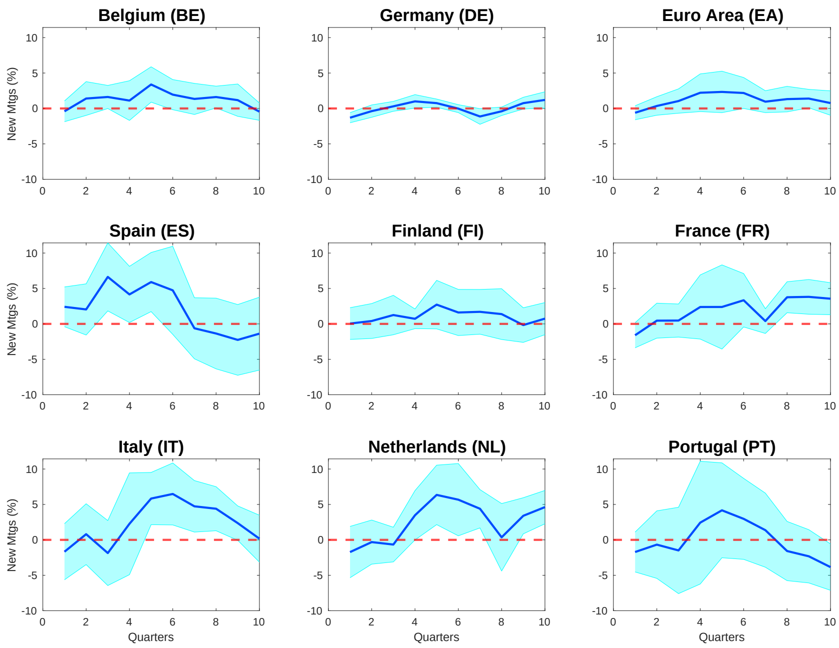


Figure 1: Impulse response functions of newly issued mortgages to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2007 Q1 to 2019 Q3, with the 2Y OIS changes as identified monetary policy shocks.

2.4 The Role of Housing and Mortgage Markets in the Monetary Transmission Mechanism

I next correlate the country-specific strength of monetary policy responses discussed in the previous section with key housing and mortgage market institutions. My data source is the second wave of the Eurosystem Household Finance and Consumption Survey (HFCS), which was administered between 2013 and 2015 and contains around 75 thousands families.[15]

For each country I compute the ARM share over the total outstanding mortgage stock. There are striking differences in this measure across euro area countries. Most notably, while the ARM share in Ireland, Spain, Finland, and Portugal is about 90%, the share in Germany and France is around 10%.

I define the homeownership rate as the fraction of households who own their main residence. I further distinguish between two related measures: The fraction of homeowners

[15]The HFCS is coordinated by the ECB and conducted in a decentralized manner, with each national central bank conducting the survey. The strength of the survey is that it is harmonized across countries, and contains detailed household-level data on assets, liabilities, and income. The HFCS is conducted every three years in most of the countries starting in 2010.

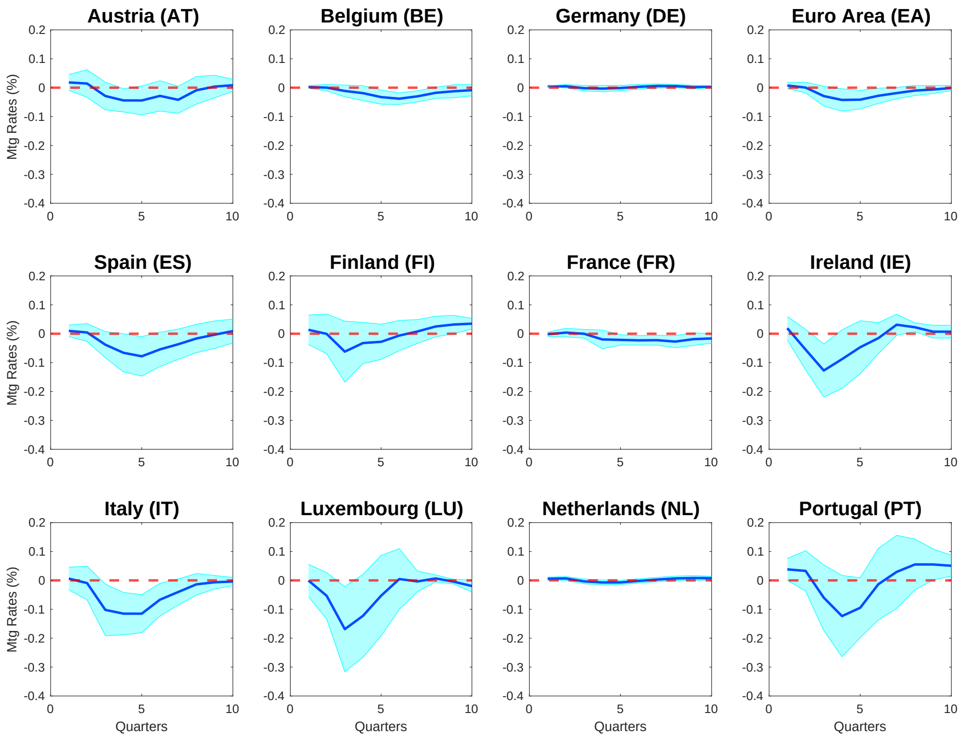


Figure 2: Impulse response functions of outstanding mortgage interest rates to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2007 Q1 to 2019 Q3, with the 2Y OIS changes as identified monetary policy shocks.

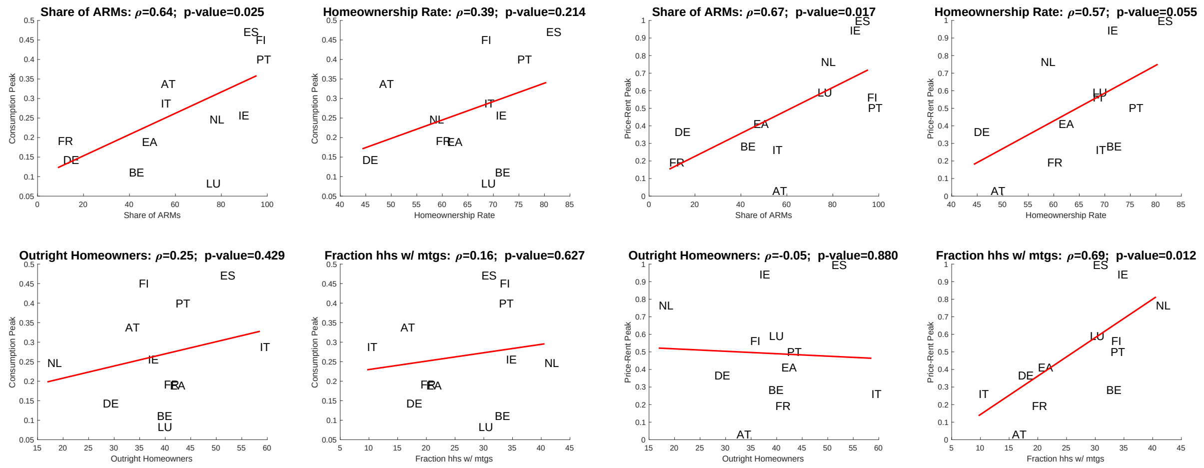
with mortgages and the fraction of them without mortgages (outright homeowners).[16]

Figures 3 and 4 display the relationships between the strength of monetary policy transmission in each country (monetary policy "effectiveness") and the previously discussed measures of housing and mortgage market characteristics. As in Burriel and Galesi (2018), Almgren et al. (2019), and Corsetti, Duarte, and Mann (2021), I measure country-specific monetary policy effectiveness by the peak response of the impulse response functions.[17] For the mortgage interest rate responses, I consider the trough responses given the pass-through from policy rates (recall Figure 2).

A few results stand out. Firstly, aggregate consumption (panel 3a), price-to-rent ratios (panel 3b), newly issued mortgages (panel 4a), and outstanding mortgage interest rates (panel 4b) react more strongly in countries that have higher ARM share and higher HoR. These relationships are in general statistically strong with p-values often below 5%, except for newly issued mortgages for which only 8 countries (instead of 11) are considered.

[16] Cloyne, Ferreira, and Surico (2019) provide evidence for the US and the UK that mortgagors respond more strongly to interest rate changes relative to renters and outright homeowners.

[17] An alternative measure is the cumulative impulse response over a specific time horizon. The qualitative results of this section don't change when using cumulative responses.



(a) Consumption Peaks **(b)** Price-to-Rent Peaks

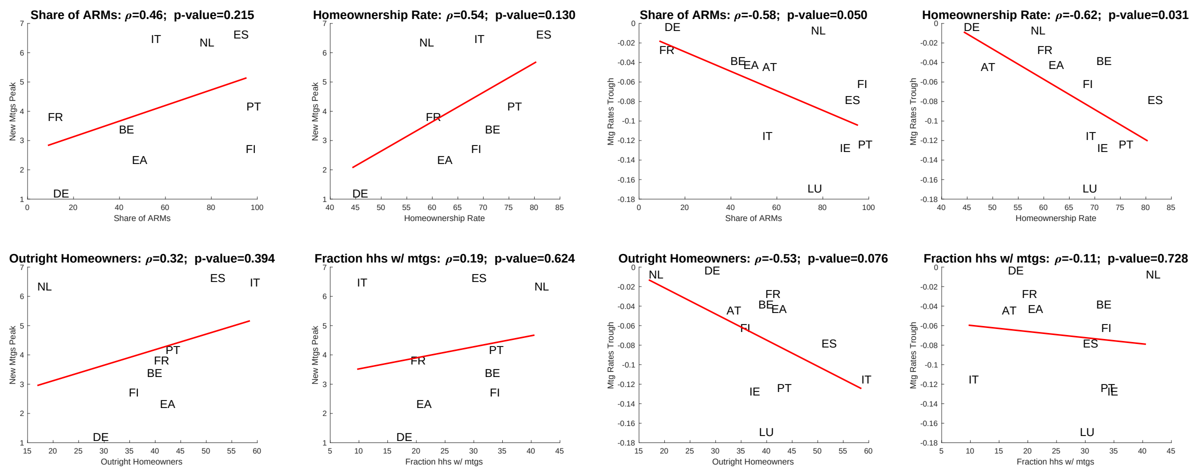
Figure 3: Scatter plots of impulse response function intensities and housing and mortgage market characteristics.

Note: On the y-axis, I measure the strength of monetary policy by means of peak responses for both aggregate consumption and price-to-rent ratios. On the x-axis of each subplot, I make use of ARM shares and of various homeownership measures. For each country, the impulse response functions are estimated using equation (1) over the period 2007 Q1 to 2019 Q3, with the 2Y OIS changes as identified monetary policy shocks. The corresponding impulse response functions are shown in Figures A.1 and A.2 of Appendix A.1. Calculations of housing and mortgage market characteristics are based on the Eurosystem Household Finance and Consumption Survey.

Secondly, it is interesting to disaggregate the correlations with the HoR into its components. For example, responses to price-to-rent ratios across countries are strongly correlated with their HoRs (recall panel 3b). This correlation is entirely driven by the fraction of households holding mortgages (correlation of 0.69 and p-value of 0.012) rather than by the fraction of outright homeowners.

It is worth stressing at this point that existing research correlates monetary policy effectiveness with characteristics of the housing and mortgage markets. Calza, Monacelli, and Stracca (2013) document that aggregate consumption and house price responses are stronger for countries with relatively more variable-rate mortgages. This same result has been confirmed for euro area countries by Corsetti, Duarte, and Mann (2021), who also find strong correlations with HoRs. I complement these two papers by showing that the strikingly different responses of mortgage market variables across countries correlate strongly with housing characteristics (Figure 4). For each country, I additionally split the HoR into its two components (fractions of homeowners with and without mortgages) showing that both are often significant in explaining the underlying heterogeneity.[18]

[18] Almgren et al. (2019) document that in the euro area the variable that correlates the most with output responses is the fraction households who are wealthy hand-to-mouth. Most of these households own the property in which they live without a mortgage on it. In my analysis, these households are



(a) New Mortgages Peaks **(b)** Mortgage Interest Rate Troughs

Figure 4: Scatter plots of impulse response function intensities and housing and mortgage market characteristics.

Note: On the y-axis, I measure the strength of monetary policy by means of peak responses for newly issued mortgages, and trough responses for mortgage interest rates. On the x-axis of each subplot, I make use of ARM shares and of various homeownership measures. For each country, the impulse response functions are estimated using equation (1) over the period 2007 Q1 to 2019 Q3, with the 2Y OIS changes as identified monetary policy shocks. The corresponding impulse response functions are shown in Figures 1 and 2. Calculations of housing and mortgage market characteristics are based on the Eurosystem Household Finance and Consumption Survey.

2.5 Housing and Mortgage Market Institutions are Correlated Across the Euro Area

The main takeaway from Figures 3 and 4 is that monetary policy effectiveness is strongly related to a few housing and mortgage market characteristics. Country-specific institutions, however, do not necessarily jointly explain the heterogeneous monetary transmission mechanism.

Figure 5 shows that countries that have a higher HoR are also those that have higher ARM shares, higher fraction of households holding mortgages, and higher fraction of outright homeowners. Therefore, an identification problem in the form of multicollinearity arises: It might be that only one of those features explain the heterogeneous monetary transmission mechanism in practice, not all of them.

Section 3 builds a quantitative currency-union New Keynesian model with the purpose of providing intuitions of the mechanisms at work as well as of quantifying the relative importance of each of the previously mentioned country-specific housing features.

captured by the outright homeowners.

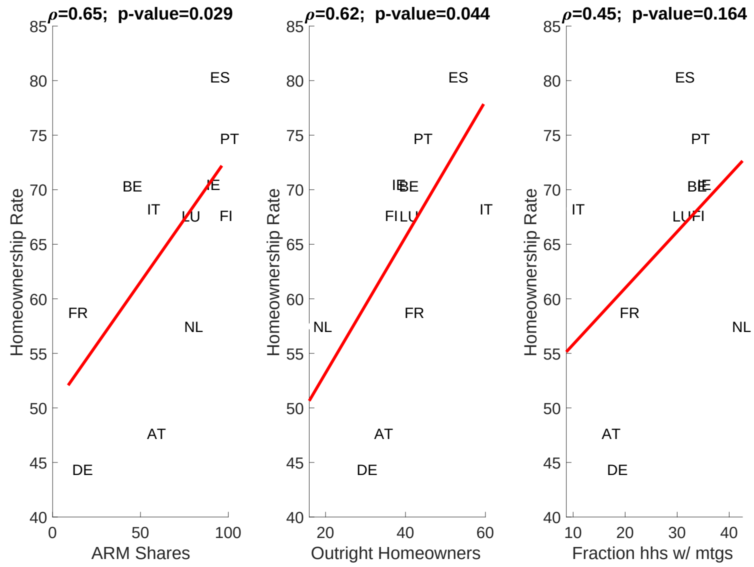


Figure 5: Scatter plots of the ARM shares and various measures of HoR.
Note: These calculations are based on the Eurosystem Household Finance and Consumption Survey.

3 A Currency-Union Two-Agent New Keynesian Model

In order to disentangle the role of the housing and mortgage market institutions in the monetary transmission mechanism as well as to quantify the relative importance of the ARM share and the HoR, I build a discrete time currency-union Two-Agent New Keynesian model. The main contribution of the paper is to complement the Home-Foreign type of model (Faia and Monacelli (2008)) with detailed within-country housing and mortgage market institutions.

A unified framework makes it possible to determine the important role of housing and mortgage market institutions to heterogeneous monetary policy transmission. It is policy relevant because it allows me to explore how changes across countries to the aforementioned institutions affect the central bank's ability to stimulate the economy.

3.1 Model Setup

The world economy is composed of two countries: Home and Foreign. As formally described later on, I assume that the Home economy is small relative to Foreign. Each economy consists of a family of borrowers, a family of savers, and a family of landlords who transact in the housing and mortgage markets. Given the small size of Home relative to Foreign, one can think of Foreign as the euro area and Home as any country belonging to the currency union. Therefore, the monetary authority decides the interest rate at the Foreign level and equalizes the short interest rates across countries.

In terms of notation, variables with an asterisk denote Foreign quantities while variables without an asterisk denote Home quantities. In the discussion that follows, I focus on the Home economy and note the ways in which the Foreign economy differs from Home.

Preferences. The households in this economy are indexed by $j \in \{b, s\}$, standing for borrowers and savers. The borrowers belong to a family with measure χ_b and have a discount factor β_b, while the savers belong to a family with measure $\chi_s = 1 - \chi_b$ and have a discount factor $\beta_s > \beta_b$. Households belonging to the same family trade consumption and housing services within the family, providing perfect insurance against idiosyncratic risk. As a consequence, each family can be aggregated up to a representative agent.

Borrowers and savers maximize their expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_j^t u \left(\frac{C_{j,t}}{\chi_j}, \frac{N_{j,t}}{\chi_j}, \frac{H_{j,t}}{\chi_j} \right), \tag{2}$$

where $C_{j,t}/\chi_j$ is per-capita non-durable consumption of agent j, $N_{j,t}/\chi_j$ is per-capita labor hours supplied, and $H_{j,t}/\chi_j$ is per-capita housing services. The per-period utility function takes the form:

$$u(C, N, H) = \log(C) + \xi \log(H) - \iota \frac{N^{1+\phi}}{1+\phi}.$$

where ξ is an housing preference parameter, ι is a labor disutility parameter, and ϕ is the inverse Friesch elasticity of labor supply.[19]

Finally, there is a family of risk-neutral landlords who maximizes the sum of discounted profits coming from renting out housing units to borrowers. This family can be aggregated up to a representative firm, which it is owned by the savers of the economy.[20]

Mortgage contract. The only source of borrowing in the model economy is through mortgages, modeled as a nominal perpetuity with geometrically declining payments as in Chatterjee and Eyigungor (2015) and Greenwald (2018). As standard in this class of models, the impatient households borrow mortgages while the patient households issue them.[21]

One of the key aspects of the model is to explicitly allow for the fact that any economy has a specific mix of fixed-rate mortgages and adjustable-rate ones. Specifically, I assume that borrowers hold an exogenous fraction α of fixed-rate mortgages and a fraction $(1 - \alpha)$

[19]This same functional form of the utility function has been used in related papers (Iacoviello and Neri (2010), Greenwald (2018)). Assuming a more general CRRA utility of consumption with a risk aversion parameter of 2 or a more general function for housing services is inconsequential for the main results of this paper.

[20]As argued by Greenwald and Guren (2019), a key assumption for realist joint dynamics of credit conditions and house prices is the imperfect segmentation in the housing market. I follow them and assume this to be the case in both Home and Foreign.

[21]See for example Iacoviello (2005), Iacoviello and Neri (2010), Rubio (2011), and Greenwald (2018).

of adjustable-rate ones.[22] This allows me to differentiate the Home and Foreign country based on ARM share, and allows me to study the dynamic effects of changes in the ARM share in each economy.

While the mortgage type choice is in principle an endogenous household decision, I model it as exogenous because it is influenced by country-specific housing finance regulation in practice. For example, Bank of Spain (2017) makes it clear that the lack of long-term swap contracts available to banks prior to 2015 led them to only issue ARMs, as they couldn't hedge the interest rate risk. Furthermore, the ARM share across countries is relatively stable over time (see Figure 1 in Badarinza, Campbell, and Ramadorai (2018)).

To show the workings of the contract, suppose a lender gives a borrower 1€ at time t. Then the savers receive $(1-\nu)^k(\alpha q_t^F + (1-\alpha)q_{t+k-1}^A)$€ at time $t+k$, for all $k>0$, where ν is the fraction of principal paid each period, q_t^F is the mortgage interest rate on FRMs, and q_t^A is the mortgage interest rate on newly issued as well as outstanding ARMs. As discussed later, in equilibrium the mortgage interest rate on ARMs q_t^A equals the nominal risk-free interest rate on bonds R_t.

In this economy, a fraction ρ of borrowers repays the outstanding balance on their loan in order to refinance. They can then choose a new loan size m_{bt} subject to a loan-to-value (LTV) constraint. The LTV constraint is expressed as $m_{bt} \leq \theta^{LTV} p_t^h h_{bt}$, where θ^{LTV} is the maximum LTV ratio, p_t^h is the housing price, and h_{bt} is the newly purchased house size. Notice that the LTV constraint only applies at origination, a feature common to the US as well as to euro area countries.

As there are fixed-rate mortgages in this economy, borrowers accumulate promised payments on their existing mortgage contracts, $X_{b,t}$. These promised payments include all the mortgage interest rates on FRMs that households have previously locked-in. Specifically:

$$X_{b,t} = \underbrace{\rho q_t^F m_{b,t}}_{NewLoans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1} X_{b,t-1}}_{OldLoans}$$

where π_t is the inflation rate.

Therefore, the average mortgage interest rate on all outstanding FRMs is defined as $\bar{q}_t^F \equiv X_{b,t}/M_{b,t}$, where $M_{b,t}$ are total debt balances. Finally, I can define the average mortgage interest rate on all outstanding mortgages $\bar{q}_t^{out} \equiv \alpha \bar{q}_t^F + (1-\alpha) q_t^A$ and the average mortgage interest rate on newly mortgages $\bar{q}_t^{new} \equiv \alpha q_t^F + (1-\alpha) q_t^A$. The average

[22]Close papers in this aspect are Rubio (2011) and Garriga, Kydland, and Šustek (2017), both calibrated to the US. Rubio (2011) assumes 2 different types of borrowers, those holding fixed-rate mortgages and those holding adjustable-rate ones. Similarly to my setting, instead, Garriga, Kydland, and Šustek (2017) assume there is only one representative agent who can choose endogenously between mortgage types. While feasible in principle, I refrain from endogenizing the choice between mortgage types for the reasons discussed in the main text.

mortgage interest rates influence the borrower mortgage payments and critically depend on the country-specific ARM share.

Additional financial contracts. Savers in each economy can trade a one-period nominal bond b_t, which delivers a risk-free interest rate R_t and is in zero net supply. The nominal interest rate is controlled by the monetary authority through its Taylor rule in the Foreign economy.

Moreover, savers of both economies have access to a complete set of contingent claims traded internationally. This assumption delivers the standard international risk sharing formula in equilibrium.

Housing. As for mortgages, a fraction ρ of the borrowers, the savers, and the landlords can decide in each period the optimal house size to buy, denoted by h_j, $j \in \{b, s, l\}$.[23] At the start of each period, homeowners pay a constant maintenance cost δ on their outstanding house value. The supply of owned houses is fixed and equal to $\bar{H}$.[24]

Borrowers have the option of renting or owning. I follow Greenwald and Guren (2019) and assume that every period they receive a stochastic service flow (positive or negative) from owning housing. In particular, if a borrower i owns one unit of housing, she receives $\omega^i_{b,t}$ of the numeraire (the final good), where $\omega^i_{b,t} \sim \Gamma_{\omega,b}$ is i.i.d. across borrowers and time. This inter-period heterogeneity guarantees that in each period the borrowers with a high enough owning utility benefit want to own housing, while the rest want instead to rent. As it will become clear later on, the threshold utility benefit from owning depends in equilibrium on the aggregate macroeconomic conditions.

The borrower heterogeneity from owning stems from true housing preference as well as household demographic characteristics not otherwise captured in the model. Under this structure, a differential HoR between Home and Foreign can be achieved by assuming that one country features a distribution $\Gamma_{\omega,b}$ with a different mean than the other country. This difference in the distribution of owning utility across countries stands in for the quality of the rental market and ownership subsidies. To give a concrete example, Germany has the lowest homeownership rate of the euro area (40%) which is typically thought to result from its extensive social housing sector (see Voigtländer (2009) for a qualitative analysis and Kaas et al. (2021) for a quantitative one). Furthermore, for the past few decades German households did not benefit from high subsidies the way households in other European

[23]The exogenous fraction ρ can be interpreted as a moving shock. More generally, ρ represents the overall fraction of households who are active in both the housing and mortgage markets.

[24]The presence of a flexible housing supply would imply smaller movements in house prices. Because demand-driven shocks typically move house prices and rents in the same direction under a fixed supply specification, the assumption of fixed housing supply is inconsequential for price-to-rent ratios.

countries such as Spain and the Netherlands did (see also Van den Noord (2005) for a detailed analysis of tax treatments).

Landlords also receive a stochastic service flow from owning housing. This form of heterogeneity within the family of landlords can stand in for the fact that some houses are more suitable to rent than others due to geography or moral hazard. Differences across countries in this heterogeneity might stem for institutional aspects characterizing the housing construction sector. For example, following the Second World War, the German government provided direct subsidies and tax-privileges to landlords in order to promote construction of homes – which did not happen in other countries.[25] If a landlord i owns one unit of housing, she receives $\omega^i_{l,t}$ of the numeraire, where $\omega^i_{l,t} \sim \Gamma_{\omega,l}$ is i.i.d. across landlords and time.

Landlords buy housing units to transform them into rental units for use by borrowers. Because the heterogeneous utility benefits to borrowers and landlords do not necessarily stand in for financial benefits or costs as previously discussed, they are rebated lump-sum to them in equilibrium.

Finally, savers are allowed to transact in the housing markets with the borrowers and landlords although they never rent.

The labor market features sticky-wage frictions that are standard in the New Keynesian literature (Erceg, Henderson, and Levin (2000), Schmitt-Grohé and Uribe (2005), and Auclert, Rognlie, and Straub (2018)). I assume that households provide hours of work to a continuum of unions and face quadratic utility costs of adjusting the nominal wage set by the unions. Appendix C.2 provides the details and the derivations. I show that under a symmetric equilibrium, all households work the same number of hours:

$$\frac{N_{b,t}}{\chi_b} = \frac{N_{s,t}}{\chi_s} = N_t,$$

where N_t is aggregate labor demand, and that the Wage Phillips Curve takes the form:

$$\pi^W_t(\pi^W_t - 1) = \frac{\varphi}{\psi} N_t \left(u^N(N_t) - \frac{\varphi - 1}{\varphi}(1-\tau)\frac{W_t}{P_t}\tilde{u^c} \right) + \tilde{\beta}\pi^W_{t+1}(\pi^W_{t+1} - 1).$$

where $\tilde{u^c} = \chi_b u^c(C_{b,t}/\chi_b) + \chi_s u^c(C_{s,t}/\chi_s)$ is the average marginal utility, and $\tilde{\beta} = \chi_b * \beta_b + \chi_s * \beta_s$ is the average discount factor in the economy.

The borrowers choose consumption $C_{b,t}$, new mortgages $m_{b,t}$, new house size $h_{b,t}$, and housing services $s_{b,t}$. Due to frictions in the labor market, they take hours worked $N_{b,t}$ as given. The endogenous state variables are: total start-of-period housing $H_{b,t-1}$, total

[25] Although I model heterogeneity in the owning utility of landlords, I do not generate cross-country differences in this way.

start-of-period debt balances $M_{b,t-1}$, and total promised payments on existing debt $X_{b,t-1}$. Thus they maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_b^t u\left(\frac{C_{b,t}}{\chi_b}, \frac{N_{b,t}}{\chi_b}, \frac{s_{b,t}}{\chi_b}\right),$$

while facing a set of constraints. First, the budget constraint reads:

$$\begin{aligned} C_{b,t} \leq\ & \underbrace{(1-\tau)\frac{W_t}{P_t}N_{b,t}}_{LaborIncome} + \underbrace{\rho(m_{b,t} - (1-\nu)\pi_t^{-1}M_{b,t-1})}_{NetMortgageIssuance} - \underbrace{\rho p_{h,t}(h_{b,t} - H_{b,t-1})}_{NetHousingPurchases} \\ & - \underbrace{\pi_t^{-1}\nu M_{b,t-1}}_{PrincipalPayment} - \underbrace{\pi_t^{-1}(1-\tau)[\alpha X_{b,t-1} + (1-\alpha)q_{t-1}^A M_{b,t-1}]}_{InterestPayment} - \underbrace{\delta p_{h,t} H_{b,t-1}}_{Maintenance} \\ & - \underbrace{p_{r,t}(s_{b,t} - H_{b,t-1})}_{Rent} + \underbrace{\left(\int_{\bar{\omega}_{b,t-1}} \omega d\Gamma_{\omega,b}\right) A_{b,t-1}}_{OwnerSurplus} + \underbrace{T_{b,t}}_{Rebate}, \end{aligned}$$

where W_t/P_t is the real wage, π_t is the inflation rate, $p_{h,t}$ is the house price, $p_{r,t}$ is the rental rate, ω is the utility benefit from owning, and $A_{b,t-1}$ is an expression that is uninfluential for the results and that can be found in Appendix C.1.1. Notice that in equilibrium all borrowers with $\omega_{i,t} > \bar{\omega}_{b,t}$ choose to be homeowners, where $\bar{\omega}_{b,t}$ is defined by market clearing:

$$\Gamma_{\omega,b}(\bar{\omega}_{b,t}) = \frac{H_{l,t}}{H_{b,t} + H_{l,t}},$$

where the LHS is the fraction of borrowers who rent, and the RHS is the fraction of housing services consumed by the borrower that is rented out by the landlord. The quantity $T_{b,t}$ rebates lump-sum the taxed income, the deducted interest payments, and the utility benefits from owning (all in real terms).

Second, the borrower is subject to an LTV constraint applied only at origination:

$$m_{b,t} \leq \theta^{LTV} p_t^h h_{b,t},$$

Finally, the laws of motion for the state variables are:

$$\begin{aligned} M_{b,t} &= \underbrace{\rho m_{b,t}}_{NewLoans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}M_{b,t-1}}_{OldLoans} \\ X_{b,t} &= \underbrace{\rho q_t^F m_{b,t}}_{NewLoans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}X_{b,t-1}}_{OldLoans} \\ H_{b,t} &= \underbrace{\rho h_{b,t}}_{NewHousing} + \underbrace{(1-\rho)H_{b,t-1}}_{OldHousing}. \end{aligned}$$

The landlords belong to a family whose purpose is to buy housing $h_{l,t}$ and rent it out to borrowers. The endogenous state variables are the total start-of-period housing $H_{l,t-1}$.

Because they are risk-neutral, landlords can be aggregated up to look like a representative firm, which is owned by the savers and maximizes the sum of discounted profits:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^s F_t,$$

where $\Lambda_{0,t}^s$ is the stochastic discount factor (SDF) of the savers. The budget constraint reads:

$$F_t \leq \underbrace{p_{r,t} H_{l,t-1}}_{Rent} - \underbrace{\rho p_{h,t}(h_{l,t} - H_{l,t-1})}_{NetHousingPurchases} - \underbrace{\delta p_{h,t} H_{l,t-1}}_{Maintenance} + \underbrace{\left(\int_{\bar{\omega}_{l,t-1}} \omega d\Gamma_{\omega,l} \right) A_{l,t-1}}_{OwnerSurplus} + \underbrace{T_{l,t}}_{Rebate},$$

where the quantity $T_{l,t}$ rebates lump-sum the owner utility benefits received by the landlords. Similarly to the borrower's problem, market clearing imposes:

$$\Gamma_{\omega,l}(\bar{\omega}_{l,t}) = \frac{H_{b,t}}{H_{b,t} + H_{l,t}},$$

Finally, the law of motion of housing stock $H_{l,t}$ is:

$$H_{l,t} = \underbrace{\rho h_{l,t}}_{NewHousing} + \underbrace{(1-\rho) H_{l,t-1}}_{OldHousing}.$$

The savers choose consumption $C_{s,t}$, bonds B_t, new mortgages $m_{s,t}$, and new house size $h_{s,t}$. As the borrowers, they take hours worked $N_{s,t}$ as given due to frictions in the labor market. The endogenous state variables are: total start-of-period housing $H_{s,t-1}$, total start-of-period debt balances $M_{s,t-1}$, total promised payments on existing debt $X_{s,t-1}$, and total bond position B_{t-1}. They maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_s^t u \left(\frac{C_{s,t}}{\chi_s}, \frac{N_{s,t}}{\chi_s}, \frac{H_{s,t}}{\chi_s} \right),$$

while facing a set of constraints. First, the budget constraint reads:

$$\begin{aligned} C_{s,t} \leq & \underbrace{(1-\tau)\frac{W_t}{P_t} N_{s,t}}_{LaborIncome} - \underbrace{\rho(m_{s,t} + (1-\nu)\pi_t^{-1} M_{s,t-1})}_{NetMortgageIssuance} - \underbrace{\rho p_{h,t}(h_{s,t} - H_{s,t-1})}_{NetHousingPurchases} + \underbrace{\pi_t^{-1} \nu M_{s,t-1}}_{PrincipalPayment} + \underbrace{T_{s,t}}_{Rebate} \\ & + \underbrace{\pi_t^{-1}[\alpha X_{s,t-1} + (1-\alpha) q_{t-1}^A M_{s,t-1}]}_{InterestPayment} - \underbrace{(R_t^{-1} B_t - \pi_t^{-1} B_{t-1})}_{NetBondPurchases} - \underbrace{\delta p_{h,t} \bar{H}_s}_{Maintenance} + \underbrace{F_t}_{ProfitsLandlord}, \end{aligned} \tag{3}$$

where the quantity $T_{s,t}$ rebates lump-sum the taxed income.

Second, the laws of motion of mortgage balance $M_{s,t}$, total promised payments on existing debt $X_{s,t}$, and housing stock $H_{s,t}$ are:

$$\begin{aligned} M_{s,t} &= \underbrace{\rho m_{s,t}}_{NewLoans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1} M_{s,t-1}}_{OldLoans} \\ X_{s,t} &= \underbrace{\rho q_t^F m_{s,t}}_{NewLoans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1} X_{s,t-1}}_{OldLoans} \\ H_{s,t} &= \underbrace{\rho h_{s,t}}_{NewHousing} + \underbrace{(1-\rho) H_{s,t-1}}_{OldHousing}. \end{aligned}$$

Finally, I assume that savers (both at Home and in Foreign) have access to complete markets both nationally and internationally.[26] This leads to the standard risk sharing formula (Chari, Kehoe, and McGrattan (2002)):

$$u^{*,c}_{s,t} = u^{c}_{s,t} Q_t \tag{4}$$

where $u^{*,c}_{s,t}$ ($u^{c}_{s,t}$) is the marginal utility of consumption of the savers in the Foreign (Home) economy, and Q_t is the real exchange rate. Intuitively, a unit of consumption in Foreign has to provide the same utility as a unit of consumption at Home adjusted by the real exchange rate across the two countries.

The final good sector is operated by perfectly competitive producers who face a simple linear aggregate production technology with flexible prices:

$$Y_t = N_t.$$

As a consequence, the final goods price is given by $P_t = W_t$ and profits are zero. This implies that a) the real wage is equal to unity: $W_t/P_t = 1$; and b) price inflation equals wage inflation: $\pi_t \equiv P_t/P_{t-1} = \pi^W_t \equiv W_t/W_{t-1}$.

The world economy is composed of two countries – Home and Foreign. I follow Faia and Monacelli (2008) and assume that the Home economy is small relative to Foreign.

Aggregate consumption in each economy is described by an index of domestic and imported bundle of goods. Each consumption bundle is composed of imperfectly substitutable varieties. Appendix C.3 details all the assumptions and derives the price indices for the consumption bundles as well as the equilibrium relationship between Home and Foreign aggregate output:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \left[(1-\lambda)Y_t + \lambda Q^{\eta}_t Y^*_t\right]. \tag{5}$$

Equation (5) shows that Foreign aggregate output Y^*_t as well as the real exchange rate Q_t affect Home aggregate output Y_t. As argued in Appendix C.3, however, the opposite does not hold true: the Foreign economy is not affected by movements in Home output or movements in the real exchange rate.

The monetary authority operates in a currency union and therefore follows a Taylor rule at the Foreign country level (the monetary union). I focus on two different shocks, which I present sequentially as follows.

[26] The state-contingent assets they trade have not been explicitly introduced in the budget constraint (3) to reduce clutter. For a similar treatment see Gali and Monacelli (2005), Gali and Monacelli (2008), Faia and Monacelli (2008), and De Paoli (2009) among others.

The first shock I consider is an inflation target (IT) shock as in Garriga, Kydland, and Šustek (2017), Greenwald (2018), and Garriga, Kydland, and Šustek (2021). This shock is highly persistent and shifts the whole level of the yield curve while making the real rate move very little. This is the sense in which the IT shock is a *nominal* shock, which makes it very convenient to study movement in the nominal interest rate in isolation. This shock stands for expected and persistent changes in the stance of the monetary authority, like the one started in 2008 in the euro area when the European Central Bank persistently reduced the policy rates.

Formally, I define the IT shock as a white noise process $\epsilon_{\bar{\pi},t}$ so that the persistent inflation target is:

$$\log \bar{\pi}_t^* = \phi_{\bar{\pi}} \log \bar{\pi}_{t-1}^* + \epsilon_{\bar{\pi},t}, \tag{6}$$

and the Taylor rule takes the form:

$$\log(R_t^*/R_{ss}^*) = \log \bar{\pi}_t^* + \phi_R[\log(R_{t-1}^*/R_{ss}^*) - \log \bar{\pi}_{t-1}^* + \log \bar{\pi}_t^*] + \phi_\pi[\log \pi_t^* - \log \bar{\pi}_t^*]. \tag{7}$$

The second shock I consider is a white noise monetary policy shock $\epsilon_{MP,t}$, the standard shock used in the New Keynesian literature. Differently from the previously considered nominal shock, the monetary policy shock is fairly temporary and moves the real interest rate in the same direction as and quantitatively similarly to the nominal short rate. The relevant Taylor rule becomes:

$$\log(R_t^*/R_{ss}^*) = \phi_R \log(R_{t-1}^*/R_{ss}^*) + \phi_\pi \log \pi_t^* + \epsilon_{MP,t}. \tag{8}$$

Finally, being in a currency union, the monetary authority sets the nominal interest rates to be the same across countries: $R_t = R_t^*$.[27]

A competitive equilibrium is a sequence of endogenous state variables ($H_{b,t-1}$, $H_{s,t-1}$, $H_{l,t-1}$, $M_{b,t-1}$, $M_{s,t-1}$, $X_{b,t-1}$, $X_{s,t-1}$, $B_{s,t-1}$), borrower controls ($C_{b,t}$, $m_{b,t}$, $h_{b,t}$, $s_{b,t}$), saver controls ($C_{s,t}$, $m_{s,t}$, $h_{s,t}$, B_t), landlord controls ($h_{l,t}$), and prices (R_t, q_t^A, q_t^F, W_t/P_t, $p_{h,t}$, $p_{r,t}$, π_t, π_t^W, $P_{H,t}/P_t$, Q_t) such that: (i) households and firms maximize their objective values, and (ii) the following markets clear:

- Bonds are in zero net supply: $B_t = 0$;
- The labor market clears: $N_{b,t} + N_{s,t} = N_t$;
- The mortgage market clears: $M_{b,t} + M_{s,t} = 0$;

[27] To do so, the central bank makes the nominal exchange rate across countries equal to a constant: $\zeta_t = \bar{\zeta}$ in the notation of Appendix C.3. Because uncovered interest parity holds, nominal interest rates are equalized across countries.

- The housing market clears: $H_{b,t} + H_{s,t} + H_{l,t} = \bar{H}$;
- Housing services: $s_{b,t} = H_{b,t-1} + H_{l,t-1}$;
- The goods market clears: $C_{b,t} + C_{s,t} + \delta p_t^h \bar{H} = Y_t$.

3.2 Equilibrium Mortgage Interest Rate Pass-Through

I now present the optimality condition of newly issued mortgages for the savers, which determines the pass-through from the nominal interest rate to the mortgage interest rates and highlights the importance of the ARM share in any given economy. The remaining equilibrium conditions are detailed in Appendix C.1.

Before showing the first order condition of the savers with respect to newly issued mortgages, I introduce some notation. When savers invest one euro in new mortgages, they receive future payments on both the fraction of those mortgages that are fixed-rate (α) and the remaining fraction of ARMs $(1-\alpha)$. Firstly, define $\Omega^m_{s,t}$ as the marginal continuation benefit to the savers of an additional euro of issued mortgage debt:

$$\Omega^m_{s,t} = E_t \Lambda^s_{t,t+1} \pi^{-1}_{t+1} [(1-\alpha) q^A_t + \rho(1-\nu) + \nu + (1-\rho)(1-\nu)\Omega^m_{s,t+1}], \tag{9}$$

where $\Lambda^s_{t,t+1} = \beta_s \frac{u^c_{s,t+1}}{u^c_{s,t}}$ is the saver stochastic discount factor with $u_{s,t}$ denoting the saver marginal utility of consumption at time t. The continuation value of equation (9) involves receiving from the borrowers a) the mortgage interest rate on the fraction of ARMs, $(1-\alpha)q^A_t$, b) the constant fraction of the principal paid ν, and c) the whole net euro issued $(1-\nu)$ in the states of the world where the borrowers refinance (with probability ρ). These quantities will be received again each future period in the states of the world where the borrowers do not refinance (with probability $1-\rho$).

Secondly, define $\Omega^x_{b,t}$ as the marginal continuation benefit to the savers of an additional euro of promised initial payments:

$$\Omega^x_{s,t} = E_t \Lambda^s_{t,t+1} \pi^{-1}_{t+1} [\alpha + (1-\rho)(1-\nu)\Omega^x_{s,t+1}], \tag{10}$$

which entails receiving the FRM share α in the states of the world where the borrowers don't refinance (with probability $1-\rho$).

We can finally turn to the first order condition for newly issued mortgages of the savers, which reads as:

$$\Omega^m_{s,t} + q^F_t \Omega^x_{s,t} = 1, \tag{11}$$

and states that the marginal benefit of issuing one euro worth of mortgage debt (the left-hand-side) equals its cost (the right-hand-side). Notice that the marginal benefit is composed of the marginal continuation benefit of an additional euro of issued mortgage debt ($\Omega^m_{s,t}$) as well as of the marginal continuation benefit of an additional euro of promised initial payments ($\Omega^x_{s,t}$). The latter component is multiplied by q^F_t because the savers lock-in that specific mortgage interest rate for the whole duration of the mortgage contract (but only on the FRM share).

3.2.1 Perfect Pass-Through to Interest Rate on ARMs

To see how the pass-through from the short-term nominal interest rate to the mortgage interest rate works, assume that there are no fixed-rate mortgages ($\alpha = 0$). Equation (10) implies $\Omega^x_{s,t} = 0$ and equation (11) reduces to $\Omega^m_{s,t} = 1$. The saver optimality condition for new mortgages thus reduces to:

$$E_t[\Lambda^s_{t,t+1}\pi^{-1}_{t+1}(q^A_t + 1)] = 1. \tag{12}$$

Recall that savers can also invest in a one-period bond, with the related optimality condition (the Euler equation) being:

$$E_t\left[\Lambda^s_{t,t+1}\pi^{-1}_{t+1}R_t\right] = 1. \tag{13}$$

Comparing equations (12) and (13) makes it clear that in an economy with only ARMs, there is perfect pass-through between the short rate and the mortgage interest rate: $R_t = q^A_t + 1$. Intuitively, a no-arbitrage condition must hold whereby the savers are indifferent between investing 1 euro in the bond (yielding R_t next period) and issuing 1 euro worth of mortgages (yielding $q^A_t + 1$ next period). I therefore impose this equilibrium condition to hold also when the economy features a positive FRM share (i.e., whenever $\alpha > 0$). Indeed, in euro area countries, the mortgage rate on ARMs is typically linked to the ECB reference interest rate (the Euribor).

3.2.2 Imperfect Pass-Through to Interest Rate on FRMs

Assume now an FRM-only economy ($\alpha = 1$). Then the continuation value equations reduce to the ones considered in Greenwald (2018), which he uses to analyze the debt dynamics in the United States:

$$\Omega^m_{s,t} = E_t\Lambda^s_{t,t+1}\pi^{-1}_{t+1}[\rho(1-\nu) + \nu + (1-\rho)(1-\nu)\Omega^m_{s,t+1}],$$

$$\Omega^x_{s,t} = E_t\Lambda^s_{t,t+1}\pi^{-1}_{t+1}[1 + (1-\rho)(1-\nu)\Omega^x_{s,t+1}],$$

and which pin down the mortgage interest rate on FRMs: $q^F_t = (1 - \Omega^m_{s,t})/\Omega^x_{s,t}$. The savers choose q^F_t and lock it in for the whole duration of the mortgage contract, and thus by the expectations hypothesis q^F_t moves less than the nominal interest rate in equilibrium.[28]

[28] Guren, Krishnamurthy, and McQuade (2021) also formalize this idea in a quantitative life-cycle model and show that, because of the stronger pass-through to mortgage rates, ARMs are better suited than FRMs to stabilize a housing crisis.

The extent of the pass-through depends on the refinancing probability ρ, the fraction of principal paid ν, and the inflation-adjusted stochastic discount factor $\Lambda^s_{t,t+1}\pi^{-1}_{t+1}$.[29] The latter component is the same across countries (i.e., $\Lambda^s_{t,t+1}\pi^{-1}_{t+1} = \Lambda^{*,s}_{t,t+1}\pi^{*,-1}_{t+1}$), because the Euler equation (13) holds in each country and the nominal interest rates are the same ($R_t = R^*_t$). In the calibration of Section 3.3, I assume $\rho = \rho^*$ and $\nu = \nu^*$ given the lack of microdata which would allow me to estimate them separately. Therefore, the pass-through from the nominal rates to the mortgage interest rate on FRMs is exactly the same across countries, that is $q^F_t = q^{*,F}_t$.

3.2.3 Pass-Through to Average Mortgage Interest Rates

Country-level household responses to monetary policy shocks are determined by the average mortgage interest rate on newly issued mortgages $\bar{q}^{new}_t$ and the average mortgage interest rate on outstanding mortgages $\bar{q}^{out}_t$. The former affects household demand of newly issued mortgages, the latter relates to the interest payment on outstanding mortgages.

Following a shock to the nominal interest rate, countries with higher ARM shares feature stronger pass-through to the average mortgage interest rates. This is because the rate on ARMs – which moves one-to-one with the nominal interest rate – is weighted relatively more than the rate on FRMs – which moves less than the nominal interest rate. This mechanism turns out to be quantitatively important for the model results presented in Section 4.

3.3 Calibration

The model period is one quarter, and the world economy is calibrated in two steps. In the first step, I calibrate the Foreign economy to the euro area (EA). As the Home economy is assumed to be small, the Foreign economy block of the model is completely independent from the details of the Home economy. The results from the first step are illustrated in Table 1. In the second step, I calibrate the Home economy to Spain (ES). In steady state, the influence of the Foreign economy on the Home economy is visible from equation (5). Hence, the Home economy needs to be calibrated together with the Foreign economy. The results from this second step are reported in Table 2.

Most of the parameters relating to the housing and mortgage markets are calibrated internally to hit moments from the Eurosystem Household Finance and Consumption Survey (HFCS). The parameters that are standard in the New Keynesian literature are calibrated externally. As a general calibration strategy, whenever I need to assign

[29] In particular, a higher refinancing rate ρ or a higher fraction of principal paid each period ν imply a stronger equilibrium pass-through because q^F_t is locked-in for a smaller period of time.

Parameter	Name	Value	Internal	Target/Source
		Demographics and Preferences		
Borrower discount factor	β_b^*	0.96	N	Greenwald (2018)
Saver discount factor	β_s^*	0.993	N	Avg. EA 10Y rate, 2007-2019
Borrower measure	χ_b^*	0.591	N	2014 EA fraction of renters & mortgaged homeowners
Labor disutility	ι^*	0.838	Y	$N_{SS}^* = 1$
Inverse Frisch elasticity	ϕ^*	0.5	N	Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010)
Housing preference	ξ^*	0.407	Y	$M_{SS}^*/Y_{SS}^* = 0.428$
Landlord het. (location)	$\mu_{\omega,l}^*$	-0.002	N	Greenwald and Guren (2019)
Landlord het. (scale)	$\sigma_{\omega,l}^*$	0.020	N	Greenwald and Guren (2019)
Borrower het. (location)	$\mu_{\omega,b}^*$	-0.0155	Y	2014 EA home ownership rate
Borrower het. (scale)	$\sigma_{\omega,b}^*$	0.008	N	Greenwald and Guren (2019)
		Housing and Mortgages		
ARM Share	$1-\alpha^*$	0.529	N	2014 EA share of adjustable rate mortgages
Mortgage amortization	ν^*	0.435%	N	Greenwald (2018)
Income tax rate	τ^*	0.24	N	Christoffel, Coenen, and Warne (2008)
Max LTV ratio	θ_{LTV}^*	0.85	N	See text
Housing depreciation	δ^*	0.005	N	Standard
Refinancing rate	ρ^*	0.034	N	Greenwald (2018)
Housing stock	$\bar{H}^*$	21.727	Y	$p_{SS}^{*,h} = 1$
		Labor Market		
Elasticity subst. tasks	φ^*	21	N	Auclert, Rognlie, and Straub (2018)
Disutility wage changes	ψ^*	250.64	Y	Implies standard value for wage flexibility: 0.1
		Monetary Policy		
Taylor rule (inflation)	ϕ_π	1.5	N	Standard
Taylor rule (smoothing)	ϕ_R	0.865	N	Christoffel, Coenen, and Warne (2008)
Inflation target (pers.)	$\phi_{\bar{\pi}}$	0.994	N	Garriga, Kydland, and Šustek (2017)

Table 1: Calibration for the euro area (Foreign economy).
Note: The model is calibrated at steady state at quarterly frequency. The "Internal" column indicates whether the parameters are calibrated to match a targeted moment internally (Y) or in closed form (N).

parameters that to the best of my knowledge have never been calibrated to (or estimated for) euro area countries and for which I have no relevant microdata for, I use US values and assign them to be the same across the EA and ES.

Demographics and preferences. To determine the borrower population share, I make use of the second wave of the HFCS, which I discussed in Section 2.4 and that was administered around 2014. In the model, the borrowers are both renters and mortgaged homeowners. Conversely, the savers are outright homeowners. In the data, I find the fraction of borrowers to be 59% in the EA (39% renters and 20% mortgaged homeowners) and 50% in ES (20% renters and 30% mortgaged homeowners).

As the focus of the paper is on long rates, I calibrate the saver discount factor to yield the average EA long-term (10Y) rate over 2007-2019 (2.64%). This is imposed in both economies. I set the borrower discount factor externally in both economies to the

Parameter	Name	Value	Internal	Target/Source
		Demographics and Preferences		
Borrower discount factor	β_b	0.96	N	Same as Euro Area
Saver discount factor	β_s	0.993	N	Same as Euro Area
Borrower measure	χ_b	0.492	N	2014 ES fraction of renters & mortgaged homeowners
Labor disutility	ι	0.752	Y	$N_{SS} = 1$
Inverse Frisch elasticity	ϕ	0.5	N	Same as Euro Area
Housing preference	ξ	0.407	N	Same as Euro Area
Landlord het. (location)	$\mu_{\omega,l}$	-0.002	N	Same as Euro Area
Landlord het. (scale)	$\sigma_{\omega,l}$	0.020	N	Same as Euro Area
Borrower het. (location)	$\mu_{\omega,b}$	0.015	Y	2014 ES home ownership rate
Borrower het. (scale)	$\sigma_{\omega,b}$	0.008	N	Same as Euro Area
		Housing and Mortgages		
ARM Share	$1-\alpha$	0.896	N	2014 ES share of adjustable rate mortgages
Mortgage amortization	ν	0.435%	N	Same as Euro Area
Income tax rate	τ	0.24	N	Same as Euro Area
Max LTV ratio	θ_{LTV}	0.85	N	ES Median LTV
Housing depreciation	δ	0.005	N	Same as Euro Area
Refinancing rate	ρ	0.034	N	Same as Euro Area
Housing stock	$\bar{H}$	21.727	N	Same as Euro Area
		Labor Market		
Elasticity subst. tasks	φ	21	N	Same as Euro Area
Disutility wage changes	ψ	279.135	Y	Implies standard value for wage flexibility: 0.1
		International Finance		
Home bias	λ	0.187	N	Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010)
Elasticity subst. consumpt.	η	7.671	N	Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010)

Table 2: Calibration for Spain (Home economy).
Note: The model is calibrated at steady state at quarterly frequency. The "Internal" column indicates whether the parameters are calibrated to match a targeted moment internally (Y) or in closed form (N).

value calibrated in Greenwald (2018) (i.e., 0.96). Increasing this value to the one used in Iacoviello and Neri (2010) (i.e., 0.97) or decreasing it further does not affect the results of the paper.

I calibrate the labor disutility in both economies (ι^* and ι) so that aggregate labor (and so output) in steady state is equal to unity. This makes it easier and more accurate the comparison of aggregate variables across economies following an aggregate shock. Next, I calibrate the Frisch elasticity in both economies to 2, the value estimated in Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010) for Spain. I also calibrate the housing preference parameters in the EA (ξ^*) to hit the 2014 target of total mortgage stock to GDP from Hypostat (2019), which is 0.428. I set the ES housing preference parameter (ξ) to the same EA value so to make sure I do not introduce cross-country differences in household valuation of housing services.

Finally, I calibrate the heterogeneity in the benefits to borrower and landlord homeownership closely following Greenwald and Guren (2019). In particular, the ownership distributions are specified as logistic with c.d.f.:

$$\Gamma_{\omega,j}(\omega) = \left[1 + \exp\left\{-\left(\frac{\omega - \mu_{\omega,j}}{\sigma_{\omega,j}}\right)\right\}\right]^{-1} \qquad j \in \{b, l\}$$

These distributions determine the position and the slopes of the demand and supply curves in the price-to-rent and homeownership space. In both economies, I calibrate the scale parameters as well as the landlord location parameter to Greenwald and Guren (2019). However, I calibrate internally the borrower location parameter $\mu_{\omega,b}$ to match the HoRs among "borrowers" from the HFCS (20% in the EA, 29.6% in ES). Given that the savers are homeowners in the model, this procedure provides the correct country-level HoR (61% in the EA, 80% in ES). As argued earlier on, I interpret differences in the average owning utility $\mu_{\omega,b}$ between the EA and ES as reflecting the quality of the rental market and ownership subsidies. $\mu_{\omega,b}$ is a key parameter in the paper and I vary it to study the role of the HoR in the monetary transmission mechanism.

Housing and mortgages. I calibrate the ARM share in each country $(1-\alpha)$ and $(1-\alpha^*)$ from the HFCS. This leads to a share of 53% in the EA, and a share of 90% in ES. This is the second main parameter of the model which I vary throughout the paper to analyze its effects on the monetary transmission mechanism as well as to study different forms of banking unions. Turning to the maximum LTV ratio parameters θ_{LTV} and θ^*_{LTV}, I find no quantitatively important differences across euro area countries in the HFCS data. Indeed, Figure A.3 in Appendix A.2 shows that the median LTV ratio has been very similar across euro area countries and very stable over time at around 85%. For this reason, I assign that value to both the Home and Foreign economies and decide therefore to not generate cross-country differences in this way.

Next, I internally calibrate the total housing stock in the EA ($\bar{H}^*$) to normalize the real house price to one. I assign that same value to the total housing stock parameter in ES ($\bar{H}$). I calibrate the refinancing rate (ρ^* and ρ) and the mortgage amortization rate (ν^* and ν) to the levels calibrated for the US by Greenwald (2018). I set the income tax rate to the value computed by Christoffel, Coenen, and Warne (2008) for the EA, and I assume it to be the same in ES.

Labor Market. I closely follow Auclert, Rognlie, and Straub (2018) and set, for both economies, the elasticity of substitution of tasks from labor packers (φ^* and φ) to the value they use for the US.[30] Additionally, I internally calibrate the household disutility of nominal wage changes (ψ^* and ψ) so that the implied wage flexibility parameters equal the standard value of 0.1. The wage flexibility parameters are defined as:

$$\kappa_w = \frac{\varphi}{\psi N u^N(N)}; \qquad \kappa^*_w = \frac{\varphi^*}{\psi^* N^* u^{*,N}(N^*)}$$

[30] This in turn is the same value used in Christiano, Eichenbaum, and Evans (2005).

where $u^N(N)$ and $u^{*,N}(N^*)$ are the marginal utilities of labor evaluated at the aggregate levels of labor, N and N^*. In practice, wage rigidities might not be the same across euro area countries. However, since the focus of this paper is on housing and mortgage markets, I do not generate cross-country differences based on the labor markets.

Monetary Policy. The monetary authority in the EA follows the Taylor rules (7) and (8). The parameter on the inflation response is standard, while the one determining the interest rate smoothing has been estimated by Christoffel, Coenen, and Warne (2008) in the context of the euro area. For the inflation target process (equation (6)), I use the persistence parameter estimated for the US by Garriga, Kydland, and Šustek (2017), who also study the impact of this type of shock on long-term mortgages.

International Finance. Burriel, Fernández-Villaverde, and Rubio-Ramirez (2010) estimate a DSGE model for Spain, and I make use of their estimated parameter values for both the home bias (λ) and the elasticity of substitution between Foreign and Home consumption bundles (η). It is worth noticing that the presence of home bias implies that Foreign output as well as the real exchange rate affect aggregate output at Home (equation (5)). This effect is, however, quantitatively small. When I re-calibrate the model assuming a zero degree of trade openness ($\lambda = 0$), I find virtually identical results for both the steady state and the dynamics of the Home economy.

Summary. There are three parameters that crucially differentiate the EA from ES. Firstly, the ARM shares $(1-\alpha)$ and $(1-\alpha^*)$. These parameters determine the equilibrium pass-through of nominal interest rate to the average mortgage interest rate as discussed in Section 3.2. Secondly, the shares of outright homeowners (that is, the savers) χ_s and χ_s^* which control the relative size of each family. Thirdly, the average owning utility $\mu_{\omega,b}$ and $\mu^*_{\omega,b}$ which control the fraction of housing that goes to borrowers relative to landlords in steady state. I study how changing these parameters affect the monetary transmission mechanism next.

4 Model Results

This section shows the effects that the ARM shares and the HoR play in the transmission mechanism of monetary policy in the euro area. I linearize the model equations to first-order around the deterministic steady state and plot the relevant impulse response functions to an inflation target shock ($\epsilon_{\bar{\pi},t}$) introduced in the Taylor rule (7).[31]

[31] Impulse response functions to a monetary policy shock ($\epsilon_{MP,t}$) introduced in the Taylor rule (8) are displayed and described in Appendix A.4.

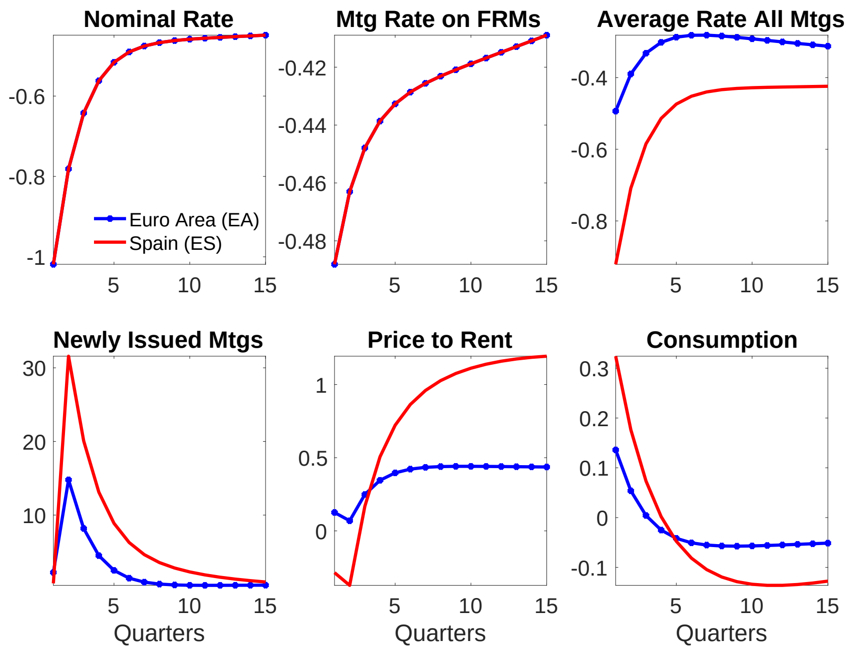


Figure 6: Impulse response functions to an inflation target shock affecting both the euro area and Spain.

Note: The shock is normalized to a 1% fall in the nominal interest rate. The y-axes measure a 1% deviation relative to steady state, except for the mortgage interest rates which are measured in percentage points. The x-axes measure time in quarters. The nominal interest rate and the mortgage interest rates are annualized.

4.1 Heterogeneous Monetary Transmission

As in the data, a shock to the long end of the yield curve, captured through an inflation target shock, leads Spain to react more strongly than the euro area. I discuss the differential responses of the two countries as follows, and then turn to Section 4.2 to unravel the sources behind them.

In Figure 6 I plot the impulse response functions to an inflation target shock inducing the nominal interest rate (and so the interest rate on ARMs) to fall by 1% on impact. Given that Spain belongs to the currency-union, it inherits the nominal interest rate set by the euro area monetary policy authority. Because savers across countries price the FRMs in the same way as argued in Section 3.2, the pass-through to interest rates on FRMs is the same in the EA and ES: a 1% decline of the short nominal rate leads to a fall in mortgage interest rate on FRMs of 0.49%. Furthermore, the mortgage interest rate on new mortgages takes more time to transmit to the average mortgage interest rate on outstanding mortgages in the EA, as this economy is characterized by a relatively higher FRM share with previously locked-in rates. To the contrary, most mortgages in ES are adjustable-rate and therefore the average mortgage interest rate in the economy closely follows the dynamics of the nominal interest rate.

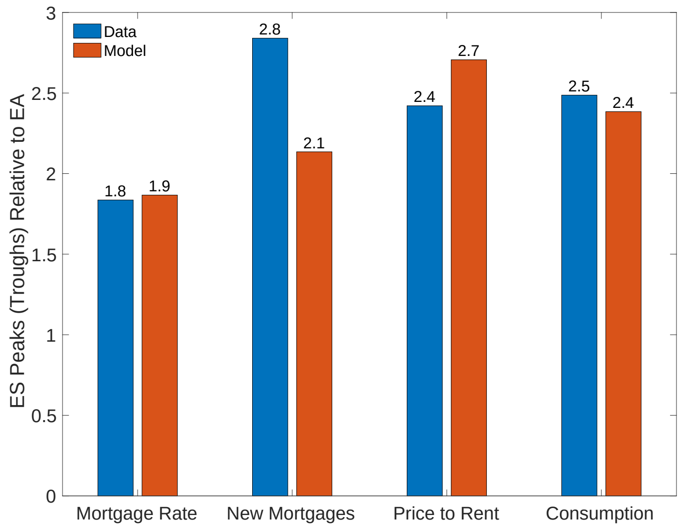


Figure 7: Bar plots of monetary policy effectiveness in the data and model for Spain (ES) relative to the euro area (EA).

Note: For each variable, the y-axis measures the peak (trough for the average mortgage interest rate) response to a monetary policy shock of ES relative to the EA.

The lower average mortgage interest rate in ES pushes more borrowers to increase the amount of mortgages they require on their housing stock. In other words, it is a better time to be a homeowner in ES relative to the EA, as also indicated by the higher price-to-rent ratio. Turning to aggregate consumption, my results show the the ES peak response is approximately 2.4 times as big as the peak experienced by the EA.

Figure 7 summarizes the monetary policy effectiveness as measured by relative peaks (or troughs for the average mortgage interest rate) across countries, both from the data (Section 2.3) and from the model. Overall, the model closely aligns to the data in terms of average mortgage interest rates, price-to-rent ratios, and aggregate consumption while not generating enough relative response in newly issued mortgages. Most importantly, the aggregate consumption response in ES is 2.4 times stronger than the EA in the model relative to 2.5 times in the data. Therefore, while I only target key cross-sectional housing and mortgage market institutions such as the ARM share and the HoR, the model is able to quantitatively match the dynamic monetary policy effectiveness across countries.

4.2 Decomposing the Effects of ARM Shares and the HoR

Because there is value in a uniform transmission of monetary policy (Cœuré (2019)), understanding the sources behind the stronger ES responses is crucial for policy. I therefore investigate how much of the aforementioned results are determined by the ARM share and how much are determined by the HoR.

Figure 8 shows the responses of two more economies: the economy "ES-HoR" is calibrated to hit all the targets described in Table 2 except the ARM share, which is instead set at the euro area level; on the contrary, the economy "ES-ARM" is calibrated to hit all the targets described in Table 2 with the exception of the HoR, which is calibrated to the euro area level. Therefore, the movements displayed by ES-HoR can all be attributed to the HoR, while the movements associated with ES-ARM can be attributed to the ARM share.

4.2.1 Transmission to Mortgage Interest Rates

The top panels of Figure 8 show that the pass-through to the average mortgage interest rates is exclusively determined by the differential ARM share. The average mortgage interest rates in ES respond more to the shock because more weight is assigned to the interest rate on ARMs, which is the nominal interest rate. The average rate on new mortgages is more responsive than the rate on outstanding mortgages because it includes the mortgage rate on FRMs, which gets locked-in only on newly issued mortgages.[32]

4.2.2 Transmission to Mortgage Volume

I then focus on the borrower balance sheets. Interest payments in ES fall up to two times as much as those in the EA, an effect entirely driven by the differential mortgage interest rate pass-through on outstanding mortgages. Indebted households in ES can take on more newly issued mortgages than those in the EA because a) they face lower overall mortgage payments, and b) newly mortgages are issued at lower interest rates. As a consequence, the ES-ARM economy displays an increase of new mortgages of about 100% relative to the EA.

In contrast, new mortgages in the ES-HoR economy increase by about 20% relative to the EA even though the mortgage interest rates in these two economies are the same. This happens because the ES-HoR economy displays a higher borrower average utility from owning housing (higher $\mu_{\omega,b}$), with the corresponding effects of increasing the fraction of the housing stock that goes to mortgaged homeowners in steady state. The upshot is that (more) borrowers demand even more mortgages on their housing, an effect which I call the "borrower level effect".[33]

[32] Recall from Section 3.2 and Figure 6 that the interest rate on newly issued FRMs responds in the same way across countries following aggregate shocks.

[33] Relative to the EA, the ES-HoR economy also features a higher share of outright homeowners (higher χ_s), which has the effect of shrinking the size of the family of borrowers. As a consequence, the within-family risk sharing makes it easier for the mortgaged homeowners to distribute resources towards the renters who can now afford to switch tenure status and buy housing through newly issued mortgages. I quantify this effect to be small in Appendix A.5.

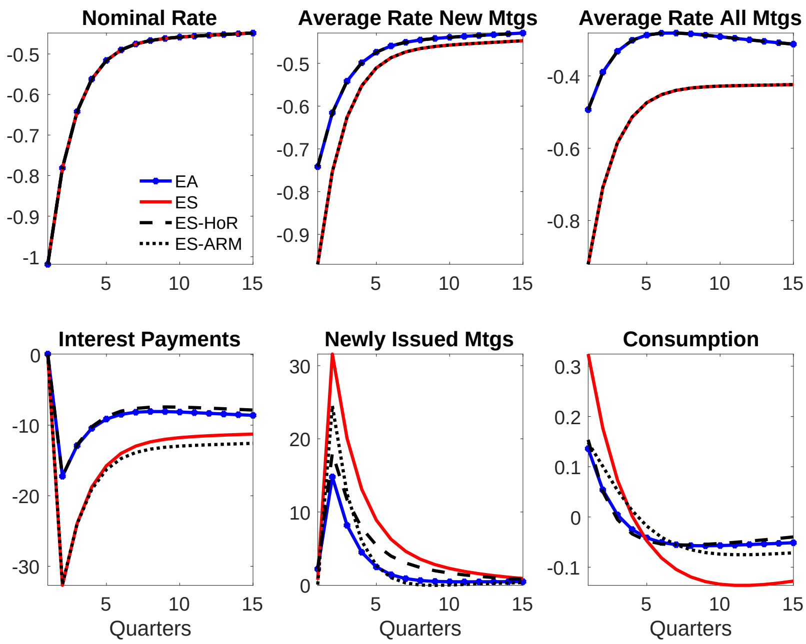


Figure 8: Impulse response functions to an inflation target shock. Decomposition of the housing and mortgage market institutions.

Note: The shock is normalized to a 1% fall in the nominal interest rate. I show results for the euro area (EA), Spain (ES), Spain re-calibrated to the EA share of ARM "ES-HOR", and Spain re-calibrated to the EA HoR "ES-ARM". The y-axes measure a 1% deviation relative to steady state, except for the mortgage interest rates which are measured in percentage points. The x-axes measure time in quarters. The interest rates are annualized.

4.2.3 Transmission to Aggregate Consumption

Turning to aggregate consumption, neither the ARM share nor the HoR alone contribute to a visible increase in economic activity of ES relative to the EA. This suggests a non-linear effect whereby the ARM share and the HoR interact to amplify the potency of monetary policy on economic activity. Both channels are active simultaneously: on one hand, it is a good time to borrow because mortgage interest rates and interest payments are low; on the other hand, the economy features a higher fraction of mortgaged homeowners (borrower level effect) who are active in the mortgage market. ARM share and HoR together allow for a stronger and more persistent increase in newly issued mortgages, which maps to a stronger increase in non-durable consumption and economic activity.

4.2.4 Transmission to Housing and Rental Markets

I finally turn to the housing markets in Figure 9 to understand the sources behind the movements in price-to-rent ratios. House prices move to clear the housing markets, where borrowers, landlords, and savers buy and sell housing units. I find that house prices are most strongly linked to the new housing units purchased by the borrowers: house prices

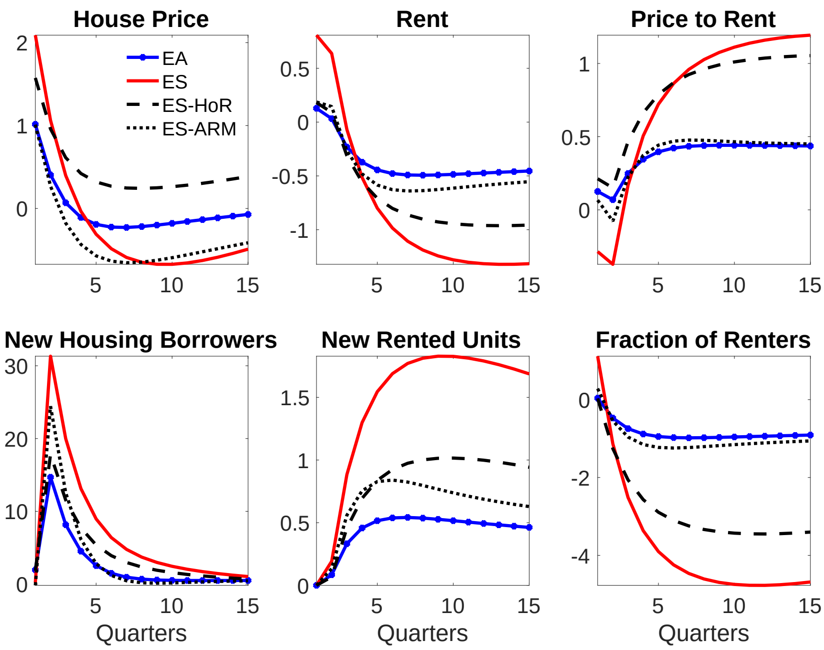


Figure 9: Impulse response functions to an inflation target shock. Decomposition of the housing and mortgage market institutions.

Note: The shock is normalized to a 1% fall in the nominal interest rate. I show results for the euro area (EA), Spain (ES), Spain re-calibrated to the EA share of ARM "ES-HOR", and Spain re-calibrated to the EA HoR "ES-ARM". The y-axes measure a 1% deviation relative to steady state. The x-axes measure time in quarters. The measure of renters is annualized.

increase the most when mortgaged homeowners increase more heavily their housing stock.

A similar picture emerges from the rental market, which is cleared through the rental price. Economies featuring a stronger increase in newly rented units also experience a stronger increase in rental prices. All in all, the price-to-rent ratio is tightly linked to the movements in the fraction of renters which are mostly dominated by movements in the HoR.

Figure 9 also shows that while house prices mostly increase after the expansionary shock, rents in both ES and the EA quickly become negative after a few quarters. This is consistent with the evidence provided by Koeniger, Lennartz, and Ramelet (2021) for Italy and Switzerland, as well as with the evidence provided by Dias and Duarte (2019) for the US.

5 Model Counterfactuals

My two country New Keynesian model with housing and long-term mortgages is a useful laboratory: In this section I study how changes in the housing and mortgage market institutions alter the stabilization properties of the euro area monetary policy. In a first

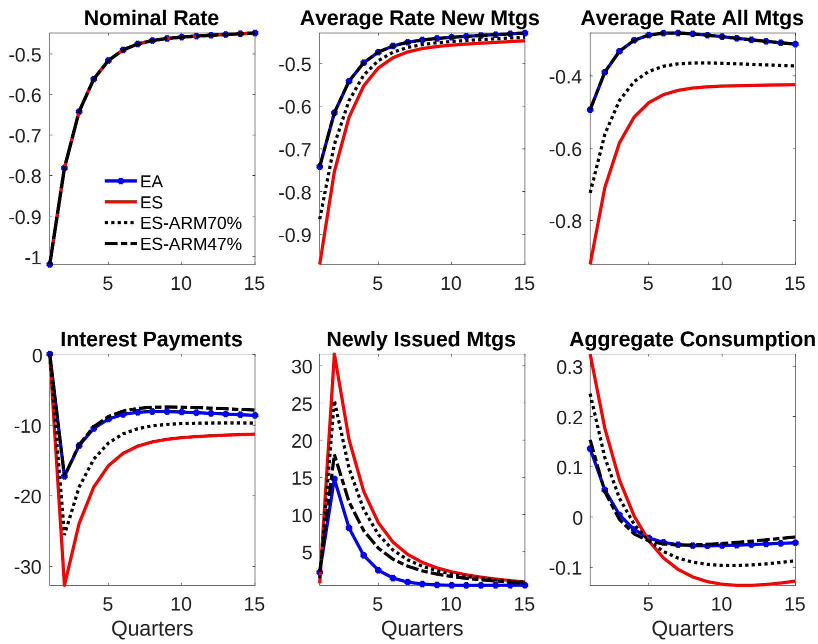


Figure 10: Impulse response functions to an inflation target shock under two different forms of banking unions.

Note: The shock is normalized to a 1% fall in the nominal interest rate. I show results for the euro area (EA), Spain (ES), Spain under a weak banking union "ES-BU1", and Spain under a stronger banking union "ES-BU2". The y-axes measure a 1% deviation relative to steady state, except for the mortgage interest rates which are measured in percentage points. The x-axes measure time in quarters. The interest rates are annualized.

counterfactual, I introduce a banking union in the form of a common design for the mortgage markets in the euro area countries. While a banking union formally already exists, it is in practice very limited (see Garicano (2019) for an analysis of the problems and potential ways forward to build a stronger union). In a second counterfactual, I build on the recent strategy review (ECB (2021)) and explore the inflation-output trade-off the ECB faces when weighting for housing costs in the price index.

5.1 Towards a Banking Union

There is a lot of discussion in both academic and policy circles about the potential benefits of a European fiscal integration and a banking union (for a recent overview, see Bilbiie, Monacelli, and Perotti (2021)). At its current stage, the banking union is fairly limited: it consists of a common bank supervision (Single Supervisory Mechanism) and of a common resolution procedure for failing banks (Single Resolution Mechanism). One of the features that are missing is a risk-sharing arrangement through which funding costs for banks (and households) equalize across the different countries of the euro area.

My model allows to study the interest rate transmission mechanism in a currency-union with a more integrated financial system. A banking union in the form of a EA-wide mortgage market is one where the mortgage contract types (ARMs and FRMs) are issued in the same (or at least in a more similar) proportion. I contrast ES and the EA with two additional economies: the economy "ES-ARM70%" is calibrated to hit all the ES targets described in Table 2 except the ARM share, which is instead decreased from 90% to 70%; on the contrary, the economy "ES-ARM47%" is calibrated to hit all the targets described in Table 2 with the exception of the ARM, which is calibrated to the euro area level (47%).[34]

Figure 10 displays the results of the inflation target shock in this environment. In the "ES-ARM70%" economy, the aggregate consumption response differential between Spain and the euro area drops by around 40%. This driven by a weaker pass-through to average mortgage interest rates, which determines a small cash-flow effect to borrowers who cannot leverage up as much anymore. The aggregate consumption response differential vanishes completely in the "ES-ARM47%" economy, where Spain is required to share the same mix of ARMs and FRMs as the euro area. This is because, in this economy, the pass-through to average mortgage interest rates is the same as the euro area one. Spanish borrowers can leverage up only slightly more than euro area borrowers, an effect driven by the higher homeownership rate. However, the level effect alone is not enough to meaningfully increase aggregate consumption relative to the euro area.

In terms of redistribution of resources between households, Figure 11 shows that savers win from the banking union relative to the borrowers. This is because the more FRMs the savers issue, the more interest rate risk they bear – which is advantageous during an expansion. On the other hand, borrowers in economies with a lower ARM share are forced to give up on non-durable consumption because the mortgage interest payments do not fall as much. This redistribution of non-durable consumption between borrowers and savers consequently leads to a redistribution of welfare. This poses a trade-off to the monetary authority between a weakened heterogeneous transmission mechanism and a redistribution of resources towards the wealthier households of the economy.

5.2 The Inflation-Output Trade-Off

On July 2021, the ECB published a new strategy review to assess whether new measures were needed in the face of the challenges the euro area endured during the previous two decades. One of the main decisions has been to enhance the representativeness of the Harmonized Index of Consumer Prices (HICP) to include owner-occupied housing

[34]Effectively, "ES-ARM47%" is equivalent to the "ES-HoR" economy discussed in Section 4.2 where ES has the EA level of ARM share. For the intermediate case ES-ARM70%, I choose the exact number of 70% because it is the midpoint between the ES ARM share and the EA ARM share.

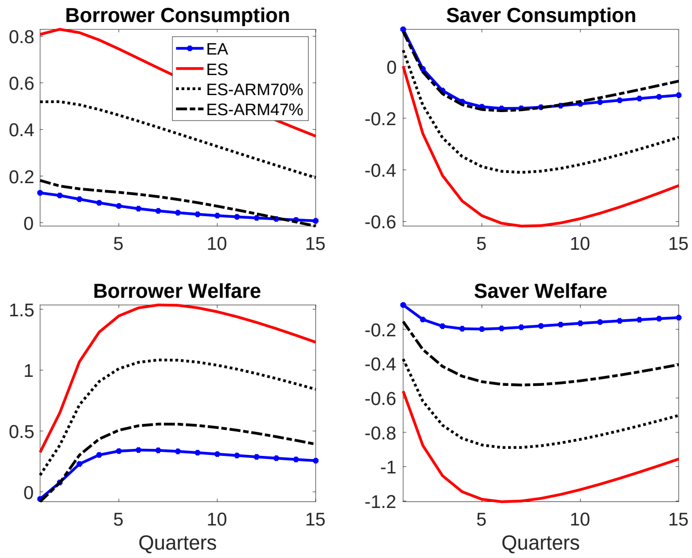


Figure 11: Impulse response functions to an inflation target shock under two different forms of banking unions.

Note: The shock is normalized to a 1% fall in the nominal interest rate. I show results for the euro area (EA), Spain (ES), Spain under a weak banking union "ES-BU1", and Spain under a stronger banking union "ES-BU2". The y-axes measure a 1% deviation relative to steady state, except for the mortgage interest rates which are measured in percentage points. The x-axes measure time in quarters.

expenditures. In the United States, such expenditures are accounted for in the CPI through "imputed rents", the implicit rent home owners would need to pay if they were instead renting their homes. While some European countries also use such a method to include owner-occupied housing costs into the national price indices, the European Statistical System producing the HICP uses a methodology which does not use implicit costs.[35] As a consequence, the ECB has decided to include in the years to come the housing transaction prices as owner-occupied expenditures.

My model with endogenous country-level house prices and rents allows me to quantify the inflation-output trade-offs for different euro area price index definitions. I define the euro area strategy review price index $P^{*,SR}$ as follows:

$$P_t^{*,SR} = p_{k,t}^{*,\gamma} P_t^{*,1-\gamma}$$

where $p^*_{k,t}$ is either the house price $p^*_{h,t}$ (as suggested by the strategy review) or the rental price $p^*_{r,t}$ (which approximates imputed rents). With $\gamma = 0$, the strategy review price collapses to the model price index of Section 3; with a positive γ, the ECB weights the housing cost into the strategy review price index. The euro area Taylor rule now includes

[35] The HICP can only capture expenditures involving movements of money from hand to hand. Therefore, imputed rents, own production of goods, and remuneration in kind are excluded. Furthermore, mortgage interest payments are also excluded because they are considered a distributive transaction and not consumption.

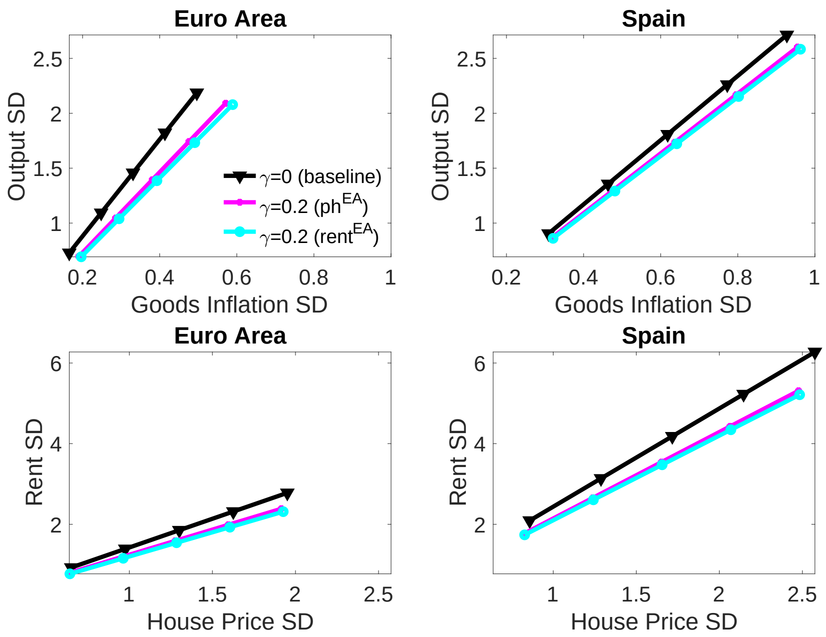


Figure 12: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (8) that include the term in equation (14) under expansionary monetary policy shocks of different sizes.

Note: The axes measure the standard deviation of the impulse response functions over 20Q and are all multiplied by 100. The shocks considered move the nominal interest rate on impact between -1.5% and -0.5% under the baseline Taylor rule ($\gamma = 0$).

the strategy review inflation index which accounts for either the house price inflation $\pi^*_{h,t}$ or the rent inflation $\pi^*_{r,t}$:

$$\pi_t^{*,SR} = \pi_{k,t}^{*,\gamma} \pi_t^{*,1-\gamma} \tag{14}$$

Figure 12 plots the trade-offs between output, goods inflation, rent, and house price for an expansionary monetary policy shock affecting both the euro area and Spain. I follow Kaplan, Moll, and Violante (2018) in plotting the frontiers for different shock sizes, which are normalized to lead to a decrease of the nominal interest rate on impact of between -1.5% and -0.5% under the baseline Taylor rule ($\gamma = 0$).[36]

Each frontier represent a trade-off under different types of equation (14) in the Taylor rule (8). On the axes, I plot the standard deviation of the impulse response functions over 20Q. Notice that Spain displays bigger standard deviations in each of the outcomes of interest, in line with the main results of the paper (Section 4). I plot the results for $\gamma = 0$ and $\gamma = 0.2$, and results for a smaller γ would be monotonically decreasing so that the specific value of 0.2 is picked only for illustrative purposes.

[36]This exercise is different in nature from the one performed by Iacoviello (2005). He assumes that the central bank responds to the house price level (not house price inflation) separately from the other Taylor rule components. Under that specification, he finds no significant gains in terms of output-inflation stabilization.

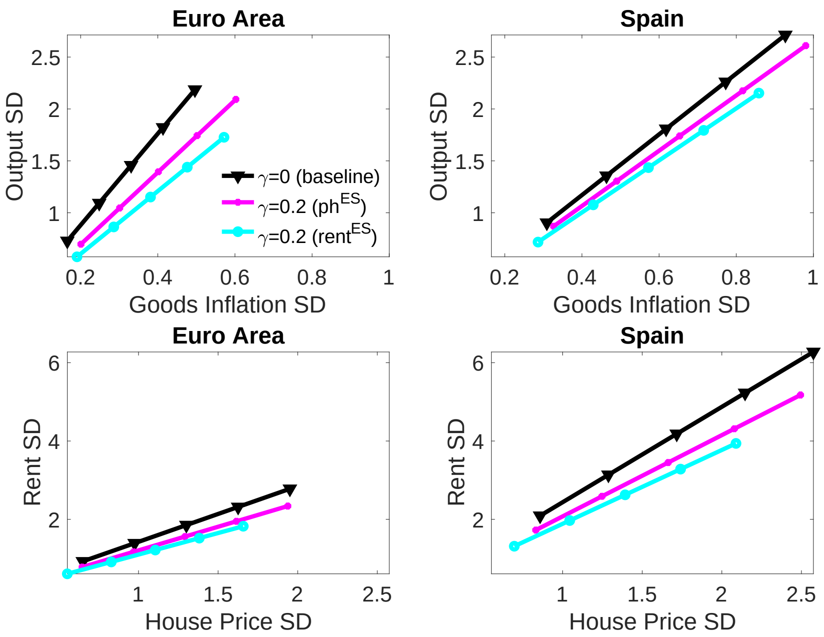


Figure 13: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (8) that include the term in equation (15) under expansionary monetary policy shocks of different sizes.

Note: The axes measure the standard deviation of the impulse response functions over 20Q and are all multiplied by 100. The shocks considered move the nominal interest rate on impact between -1.5% and -0.5% under the baseline Taylor rule ($\gamma = 0$).

The results show that whenever the monetary authority considers expanding the price index to include housing costs, it faces a trade-off between stabilizing output and prices. The idea behind is that if the central bank wants to control prices that are more volatile than goods prices, then to keep them under control it cannot move the interest rate as much. Both house prices and rents in the model are more volatile than goods price following a monetary policy shock. As a consequence, the monetary authority has reduced space of action when $\pi_t^{*,SR}$ includes housing prices, and it optimally decreases the nominal interest rate by less. This determines smaller responses in the house price, in rent, and in output both in the EA and in ES. The downside of it is that the goods inflation reacts more, exactly because it is weighted less in the Taylor rule.

One additional point to highlight is that in doesn't matter whether the monetary authority includes EA house prices or rents in $\pi_t^{*,SR}$: They are equally volatile.[37]

In Figure 13 I repeat the exercise but assume that the monetary authority reacts to ES house price and rent instead. That is, the relevant inflation index used in the Taylor

[37]In Appendix A.6 I repeat the same exercises but for the inflation target shock of the Taylor rule (7). The main difference is that following an inflation target shock, house price inflation is more volatile than rent inflation. Therefore, the monetary authority react less strongly when weighting house prices and is therefore able to better stabilize the economy.

rule is:

$$\pi_t^{*,SR} = \pi_{k,t}^{\gamma} \pi_t^{*,1-\gamma} \tag{15}$$

where $\pi_{k,t}$ is either the Spain house price inflation $\pi_{h,t}$ or the Spain rent inflation $\pi_{r,t}$. The idea underlying the exercise is that the monetary authority might consider weighting more aggressively housing prices of the countries that react the most to monetary policy shocks (such as Spain). The results show that by doing so, the monetary authority actually stabilizes the economy more both in Spain and in the whole euro area. This is particularly true when weighting rent inflation, which responds more strongly to monetary policy shocks triggering a weaker interest rate reaction from the monetary authority. This exercise therefore suggests that by weighting more the housing prices of the most responsive countries, the monetary authority is able to stabilizes the economy of all countries more effectively.

Putting together the previous results points to an important policy lesson. When deciding to include housing prices into the price index, the monetary authority faces a trade-off between stabilizing output and stabilizing prices. Moreover, it is crucial to quantify the volatility of house price and rent inflations for monetary shocks of different nature. For example, a conventional monetary policy shock leads to a bigger increase in rent inflation relative to house price inflation, making it more convenient for the monetary authority to respond to rents instead of house prices. However, an inflation target shock has the opposite effect, thereby making it more convenient for the monetary authority to respond to house prices instead of rents.

6 Conclusion

Heterogeneous institutions across euro area countries can impair the uniform transmission of monetary policy (Cœuré (2019)). While it is clear that housing and mortgage markets are very different across countries, the literature has not yet established their role in the monetary transmission mechanism. In this paper, I document strong correlations between the degree of cross-country heterogeneity of monetary policy effectiveness and key housing and mortgage market institutions, namely the ARM share and the HoR. I introduce these institutions into a quantitative currency-union two-agents New Keynesian model, which I calibrate to Spain and the euro area. As in the data, the model results show that Spain reacts more strongly than the euro area in terms of aggregate consumption, price-to-rent ratios, mortgage interest rates, and newly issued mortgages. My results point to the importance of the interaction between the ARM share and the HoR for the monetary transmission to aggregate economic activity.

My model is a useful laboratory to analyze policy-relevant counterfactuals. I show that a banking union sharing more similar financial regulations is able to weaken the heterogeneous impact of monetary policy in the currency union. I also show that adding house prices to the HICP lead the ECB to face a trade-off between output and inflation stabilization. Looking ahead, my model additionally suggests that policies that homogenize the homeownership rate across countries (in terms of subsidies and improvements to rental markets) lead to a more uniform transmission mechanism of monetary policy.

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Appendix A Additional Figures

A.1 Main Empirical Experiment: More Impulse Response Functions

In this appendix I provide the impulse response functions for aggregate consumption (Figure A.1) and price-to-rent ratios (Figure A.2) from the main empirical experiment of Section 2. The results uncover important heterogeneity across euro area countries. An expansionary monetary policy shock of one standard deviation leads to an increase in aggregate consumption in Spain of about 0.5%, which is more than double the response of the euro area. The results point instead to a subdued response in Belgium, Germany, and Luxembourg. Portugal and Finland react almost as much as Spain.

Turning to price-to-rent ratios of Figure A.2, the results are similar overall. The magnitudes of the impulse response functions are stronger, revealing that house prices react more severely than aggregate consumption. Confidence intervals are also wider, however, pointing to higher uncertainty associated with these responses.

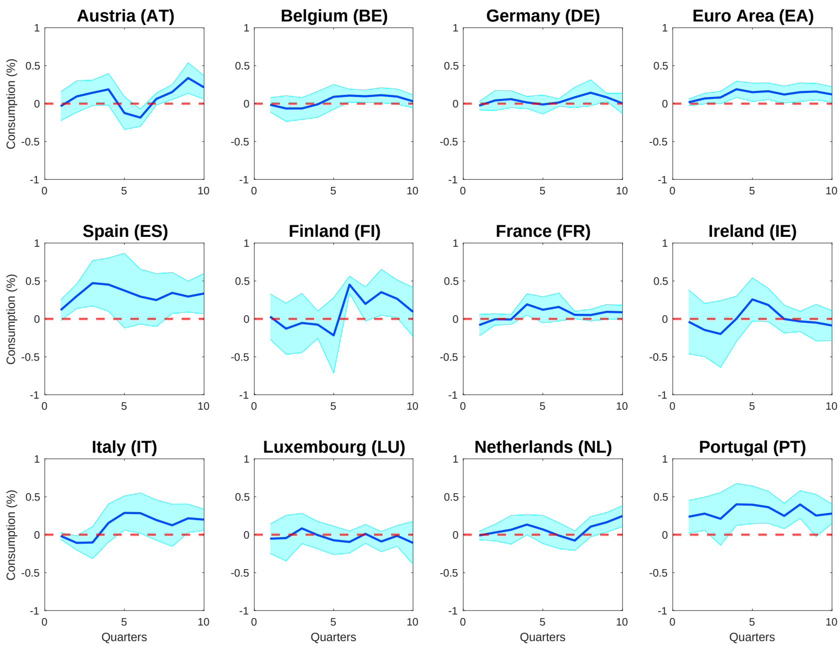


Figure A.1: Impulse response functions of aggregate consumption to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2007 Q1 to 2019 Q3, with the 2Y OIS changes as identified monetary policy shocks.

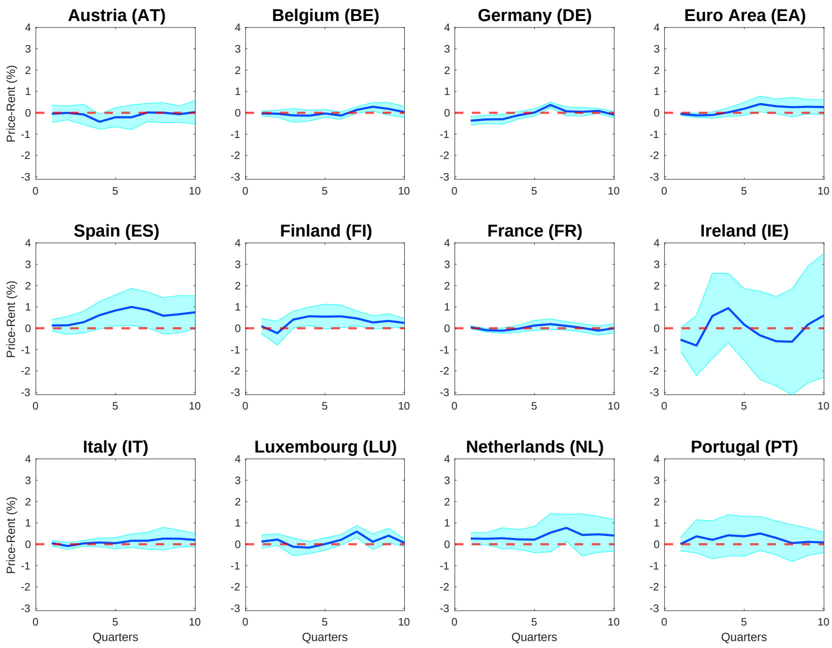


Figure A.2: Impulse response functions of price-to-rent ratios to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2007 Q1 to 2019 Q3, with the 2Y OIS changes as identified monetary policy shocks.

A.2 Calibration Figures

Previous literature investigating LTV ratio differences across countries has reached mixed results. Based on a survey of banks, ECB (2009) report a list of "typical" LTV ratios across euro area countries. These values have then been used by Calza, Monacelli, and Stracca (2013) to show empirically that countries with higher LTV ratios react more in terms of residential investment and house prices (but not consumption) to monetary policy shocks. On the other hand, Corsetti, Duarte, and Mann (2021) find that those same LTV ratios do not correlate with cross-country monetary policy effectiveness.

In figure A.3 I plot the loan-to-value (LTV) ratios across the four biggest euro area countries since the early 2000s. I aggregate all household-level mortgages at each year of origination from the HFCS at the country level. The results show that LTV ratios have been quite stable over time and also very similar across countries. In the quantitative model, I therefore avoid to generate cross-country differences based off LTV ratios.

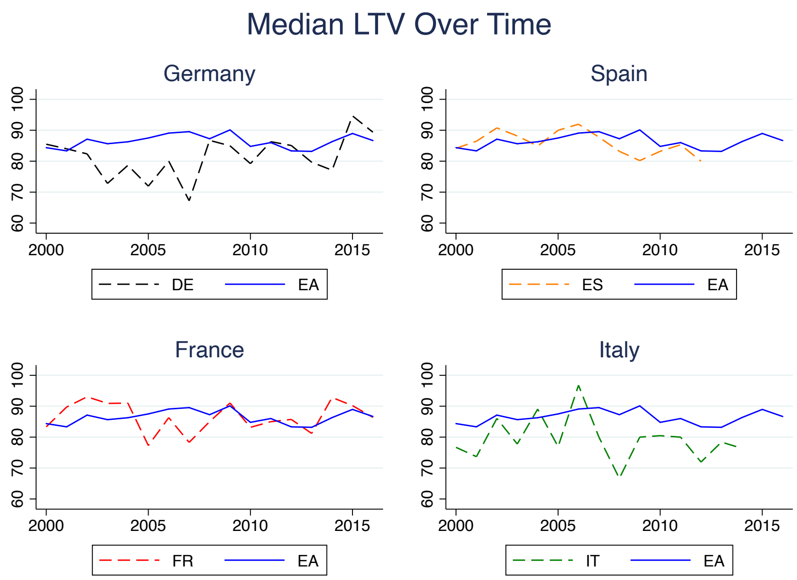


Figure A.3: Median Loan-to-Value ratios for four euro area countries since the early 2000s. *Note*: Calculations are based on the Eurosystem Household Finance and Consumption Survey.

A.3 Empirical Analysis of Conventional Monetary Policy

This appendix extends the empirical exercise performed in Section 2.2 by considering a more standard conventional monetary policy analysis. In this regard, I follow the identification of Corsetti, Duarte, and Mann (2021). They run their analysis from 2000 Q1 to 2016 Q4 and make use of a shorter term OIS instrument than the one I use in my main analysis, namely the 1-year OIS rates.[38][39] Additionally, I use the 3-month short rate as the policy rate instead of the euro area-wide mortgage interest rate which I instead employ in the main policy experiment run in Section 2.2. I then estimate impulse response function using equation (1).

Figure A.4 displays results for aggregate consumption, Figure A.5 for price-to-rent ratios, Figure A.6 for newly issued mortgages, and Figure A.7 for mortgage interest rates. The results are overall similar to the ones in Section 2.3. Impulse response functions are heterogeneous across countries, with countries like Spain and Portugal always reacting more strongly. Comparing the reactions to the conventional analysis of this section with

[38] In their appendix, Corsetti, Duarte, and Mann (2021) show that for a small monthly VAR the best instrument strength is provided by the 3-month OIS, while for the quarterly VAR counterpart the best instrument is the 1-year OIS.

[39] Different scholars have used different OIS rate changes as their instrument for a conventional monetary policy analysis. For example, Slacalek, Tristani, and Violante (2020) use the 1-month OIS, while Almgren et al. (2019) use the 3-month OIS. Results are similar when I assume different terms of OIS changes except for mortgage interest rates, which display higher pass-through for OIS changes to the longer end of the yield curve.

the reactions to the unconventional analysis of Section 2.2 shows some differences in magnitudes. In particular, countries react more following conventional policy shocks. This is true for all variables considered except mortgage interest rates, which instead tend to react more following shocks to the longer end of the yield curve.

Finally, Figures A.8 and A.9 show scatter plots of the relationship between the previously mentioned impulse response functions and the housing and mortgage market characteristics. The results line up with those of Section 2.4, uncovering strong correlations between impulse response function peaks (or troughs for mortgage interest rates) and the ARM shares as well as HoRs.

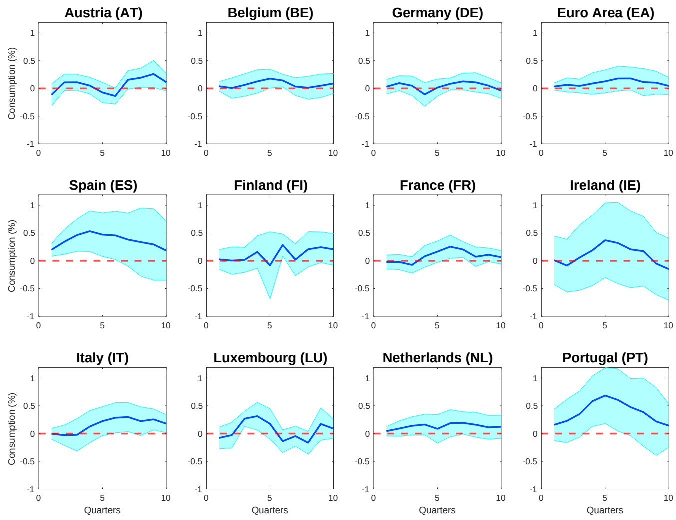


Figure A.4: Impulse response functions of aggregate consumption to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2000 Q1 to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks.

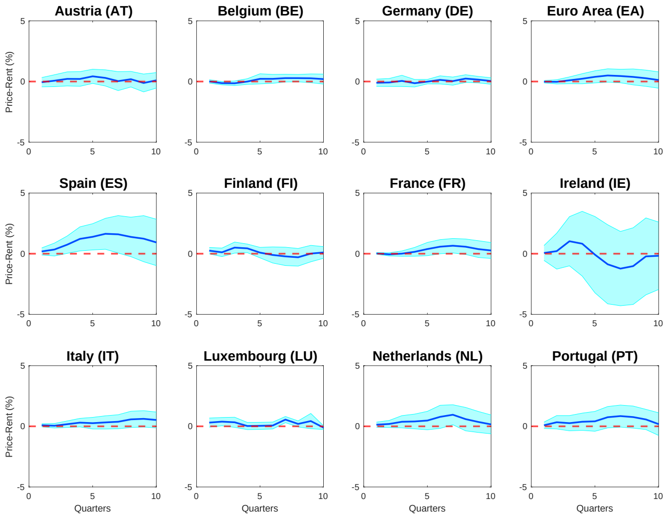


Figure A.5: Impulse response functions of price-to-rent ratios to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2000 Q1 to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks.

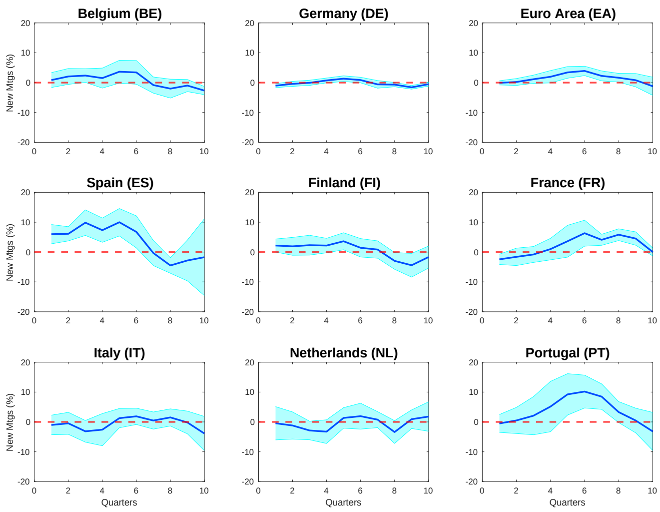


Figure A.6: Impulse response functions of newly issued mortgages to an expansionary monetary policy shock of one standard deviation.

Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2007 Q1 to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks. Notice I start the estimation in 2007 Q1 and not in 2000 Q1 because that is when the data starts.

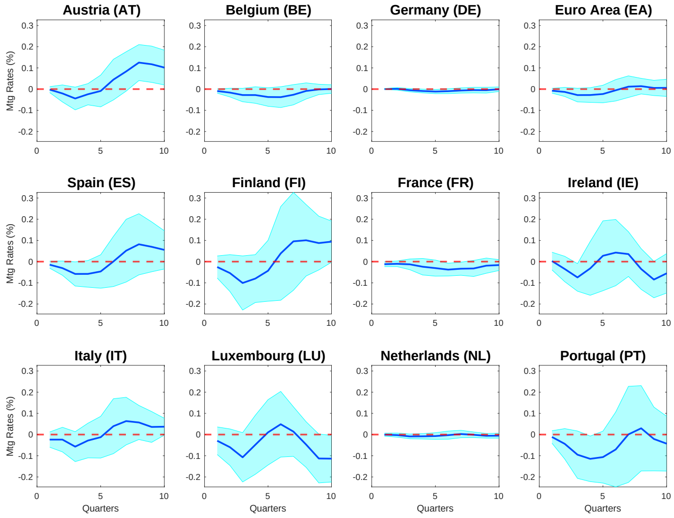
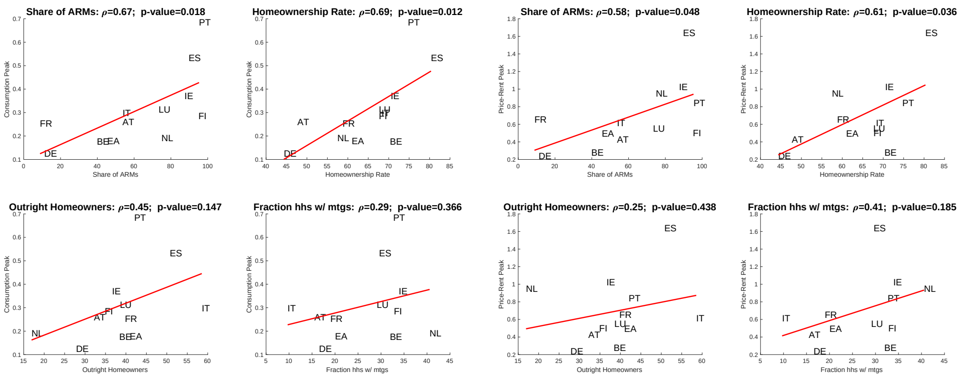


Figure A.7: Impulse response functions of outstanding mortgage interest rates to an expansionary monetary policy shock of one standard deviation.

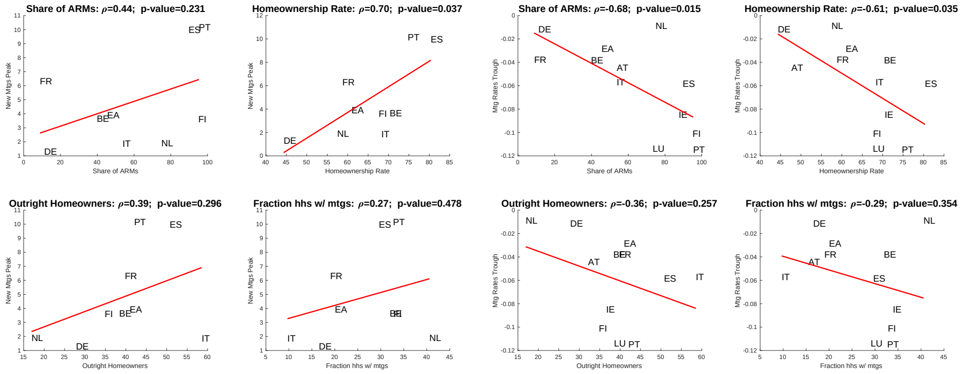
Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2003 Q1 to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks. Notice I start the estimation in 2003 Q1 and not in 2000 Q1 because that is when the data starts.



(a) Consumption Peaks **(b)** Price-to-Rent Peaks

Figure A.8: Scatter plots of impulse response function intensities and housing and mortgage market characteristics.

Note: On the y-axis, I measure the strength of monetary policy by means of peak responses for both aggregate consumption and price-to-rent ratios. On the x-axis of each subplot, I make use of ARM shares and of various homeownership measures. For each country, the impulse response functions are estimated using equation (1) over the period 2000 Q1 to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks. Calculations of housing and mortgage market characteristics are based on the Eurosystem Household Finance and Consumption Survey.



(a) New Mortgages Peaks **(b)** Mortgage Interest Rate Troughs

Figure A.9: Scatter plots of impulse response function intensities and housing and mortgage market characteristics.

Note: On the y-axis, I measure the strength of monetary policy by means of peak responses for newly issued mortgages, and trough responses for mortgage interest rates. On the x-axis of each subplot, I make use of ARM shares and of various homeownership measures. For each country, the impulse response functions are estimated using equation (1) over the period 2003 Q1 (2007 Q1 for newly issued mortgages) to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks. Calculations of housing and mortgage market characteristics are based on the Eurosystem Household Finance and Consumption Survey.

A.4 Model Results to a Monetary Policy Shock

In this section, I show the results of a standard monetary policy shock to the Taylor rule (8). I normalize the shock to a 1% fall in the nominal interest rate, and plot in Figure A.10 the impulse responses for both Spain (ES) and the euro area (EA). Notice that for this exercise, and contrary to the inflation target shock considered in Section 4, the standard monetary policy shock is short-lived. The nominal interest rate quickly reverts to zero, with the real rate (not shown) displaying the same exact dynamics. Most notably, the pass-through to the average mortgage interest rate on new mortgages is weak even in ES, where most of the mortgages are adjustable-rate.

The magnitudes of the housing and mortgage market-related variables are smaller than the counterparts in the target shock experiment. This suggest that the monetary policy shock is too temporary for it to have an effect to the aggregate macroeconomy through the housing and mortgage markets. On the other hand, the standard inter-temporal substitution effects are now at play, whereby the savers increase their consumption as dictated by the Euler equation (13). Consequently, aggregate consumption reacts more strongly and in line with standard economic activity responses as found in the literature. However, given the lack of sizable effects coming through the housing and mortgage markets highlighted in this paper, there is very little difference between ES and the EA in terms of consumption, as shown in the far right bottom panel of Figure A.10.

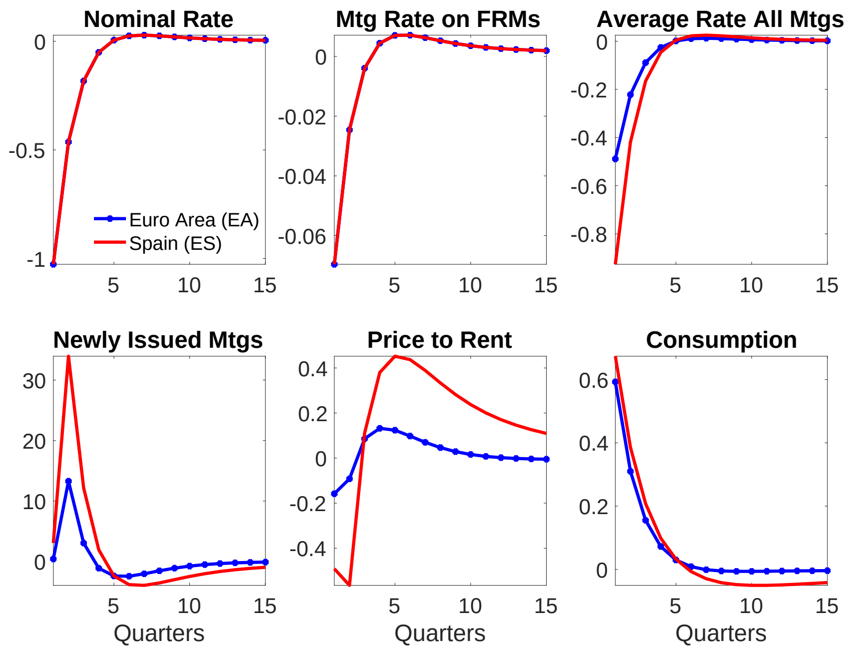


Figure A.10: Impulse response functions to a monetary policy shock normalized to a 1% fall in the nominal interest rate, both for the euro area (EA) and Spain (ES).
Note: The y-axes measure a 1% deviation relative to steady state, except for the mortgage interest rates which are measured in percentage points. The x-axes measure time in quarters. The interest rates are annualized.

A.5 The Role of Risk-Sharing in the ES-HoR Economy

As argued in Section 4.2, the ES-HoR economy differs from the EA economy in two ways. Firstly, the ES-HoR economy displays a higher borrower average utility from owning housing (higher $\mu_{\omega,b}$), with the corresponding effects of increasing the fraction of the housing stock that goes to mortgaged homeowners in steady state. This implies that more borrowers can ask for even more mortgages on their housing, an effect which I call the "borrower level effect". Secondly, the ES-HoR economy features a higher share of outright homeowners (higher χ_s), which has the effect of shrinking the size of the family of borrowers. As a consequence, the within-family risk sharing makes it easier for the mortgaged homeowners to distribute resources towards the renters who can now afford to switch tenure status and buy housing through newly issued mortgages. I call this effect the "borrower redistribution effect".

In Figure A.11 I show that the borrower level effect and the borrower redistribution effect reinforce each other so that the mortgaged homeowners in the ES-HoR economy – who are already in a greater proportion relative to the EA – actually increase in number and ask for even more mortgages in the aggregate. Relative to the EA, the ES-χ_b economy features a smaller family of borrowers but the same measure of mortgage homeowners. On the other hand, the ES-MR economy features the same size family of borrowers but the

ES-level measure of mortgage homeowners. Therefore, the former economy provides the quantification of the borrower level effect, while the latter economy quantifies the borrower redistribution effect.

Most importantly, Figure A.11 shows that most of ES-HoR effect on higher newly issued mortgages and on the lower fraction of renters comes from the ES-MR economy. This speaks to the greater quantitative importance of the borrower level effect.

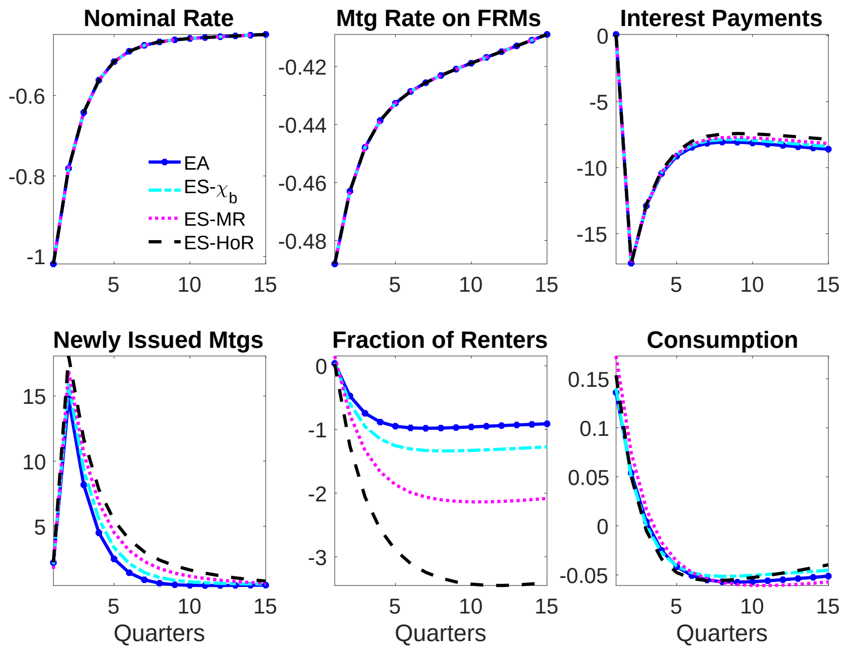


Figure A.11: Impulse response functions to an inflation target shock. Decomposition of the homeownership rate.

Note: The shock is normalized to a 1% fall in the nominal interest rate. I show results for the euro area (EA), Spain re-calibrated to the EA share of ARM "ES-HOR", Spain re-calibrated to the EA share of ARM and the EA measure of mortgage homeowners "ES-χ_b", and Spain re-calibrated to the EA share of ARM and the EA measure of borrowers "ES-MR". The y-axes measure a 1% deviation relative to steady state, except for the mortgage interest rate on FRMs which is measured in percentage points. The x-axes measure time in quarters. The interest rates and the measure of renters are annualized.

A.6 Trade-Offs Under Inflation Target Shocks

Figure A.12 displays the output-inflation trade-off under an inflation target shock (Taylor rule (7)). Differently from the monetary policy shock analyzed in Figure 12 , in this case the monetary authority faces a less favorable trade-off between output and prices. Output is less stable in ES relative to the baseline policy, but goods inflation always increases its volatility. At the same time, while house price and rent inflation display less volatility (not shown), the house price and rent actually increase their volatility. Furthermore, responding to house prices instead then goods inflation is actually better because house prices are more volatile under inflation target shocks, thereby triggering the monetary authority to react less strongly and better stabilize the economy.

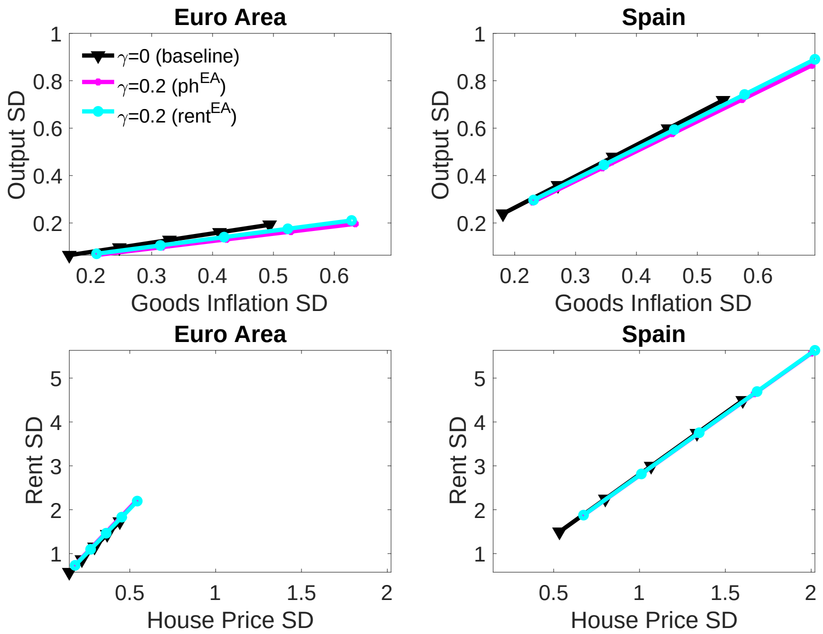


Figure A.12: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (7) that include the term in equation (14) under expansionary inflation target shocks of different sizes.

Note: The axes measure the standard deviation of the impulse response functions over 400Q and are all multiplied by 100. The shocks considered move the nominal interest rate on impact between -1.5% and -0.5% under the baseline Taylor rule ($\gamma = 0$).

Appendix B Data Sources

The following is a list of all of the data sources used in the aggregate-level empirical analysis.

Aggregate Consumption: *Household and NPISH final consumption expenditure, Chain linked volumes.* Seasonally adjusted, quarterly frequency. Source: Eurostat.

Aggregate Output: *Gross Domestic Product at market prices, Chain linked volumes.* Seasonally adjusted, quarterly frequency. Source: Eurostat.

Harmonized Index of Consumer Prices (HICP): *All-items HICP.* Seasonally adjusted, quarterly frequency. Source: Eurostat.

Real House Prices/Rents/Price-to-Rents: Seasonally adjusted, quarterly frequency. Source: OECD.

Newly Issued Mortgages: *Total amount of residential loans advanced during the period. Gross lending includes new mortgage loans and external remortgaging (i.e. remortgaging with another bank) in most countries.* Units are million euros, quarterly frequency. I deflate each country-level series by the HICP and I deseasonalize them leveraging the X-13-ARIMA-SEATS procedure. Source: European Mortgage Federation.

Mortgage Interest Rates: *Annualised agreed rate (AAR) / Narrowly defined effective rate (NDER), Credit and other institutions (MFI except MMFs and central banks) reporting sector - Lending for house purchase, Total original maturity, Outstanding amount business coverage, Households and non-profit institutions serving households (S.14 and S.15) sector, denominated in Euro.* Monthly frequency, which I average to quarterly. Source: ECB SDW.

3-Month Short Rate: *Euro area (changing composition) - Money Market - Euribor 3-month - Historical close, average of observations through period - Euro, provided by Reuters.* Monthly frequency, which I average to quarterly. Source: ECB SDW.

OIS Changes: *Change in the median quote from the window 13:25-13:35 before the press release to the median quote in the window 15:40-15:50 after the press conference (Monetary Event Window).* Dates of policy event frequency (roughly monthly), which I sum up to quarterly. Source: Euro Area Monetary Policy event study Database (EA-MPD).

Appendix C Model Derivations and Solution

This appendix is organized as follows. Section C.1 lists the optimality conditions of the agents of the model economy. I derive the wage Phillips curve in Section C.2, and the main equations of the Home-Foreign structure in Section C.3.

C.1 Optimality Conditions

C.1.1 Borrower Solution

Optimality with respect to housing services implies that the rental price equals the marginal rate of substitution between housing services and consumption:

$$p_{r,t} = \frac{u^h_{b,t}}{u^c_{b,t}} \tag{C.1}$$

Optimality with respect to new mortgages reads as:

$$\mu_t + \Omega^m_{b,t} + q_t \Omega^x_{b,t} = 1 \tag{C.2}$$

where μ_t is the multiplier on the LTV constraint. $\Omega^m_{b,t}$ and $\Omega^x_{b,t}$ are, respectively, the marginal continuation costs to the borrower of taking an additional euro of face value debt, and of promising an additional euro of initial payments:

$$\Omega^m_{b,t} = E_t \Lambda^b_{t,t+1} \pi^{-1}_{t+1} [(1-\tau)(1-\alpha)q_t + \rho(1-\nu) + \nu + (1-\rho)(1-\nu)\Omega^m_{b,t+1}] \tag{C.3}$$

$$\Omega^x_{b,t} = E_t \Lambda^b_{t,t+1} \pi^{-1}_{t+1} [(1-\tau)\alpha + (1-\rho)(1-\nu)\Omega^x_{b,t+1}] \tag{C.4}$$

Notice the differences with the corresponding first order condition for new mortgages of the saver, equations (9)-(11). Firstly, the borrowers are constrained by the LTV so that the rate at which they value the relaxation (μ_t) shows up in the optimality trade-off. Secondly, the borrowers deduct their mortgage payments at rate τ, decreasing all their future continuation costs.

Furthermore, the borrowers optimize with respect to new house size:

$$p^h_t = \frac{\mathbb{E}_t \Lambda^b_{t,t+1} \{p_{r,t+1} + \bar{\omega}_{b,t} + p_{h,t+1}[(1-\delta) - (1-\rho)\mathcal{C}_{t+1}]\}}{1 - \mathcal{C}_t}. \tag{C.5}$$

The term $\mathcal{C}_t$ is the marginal collateral of housing, representing the benefit to the borrowers from investing into housing thus relaxing the LTV constraint. Notice that $\mathcal{C}_t \equiv \mu_t \theta_{LTV}$, where μ_t is the multiplier on the LTV constraint. The term $\Lambda^b_{t,t+1} = \beta_b \frac{u^c_{b,t+1}}{u^c_{b,t}}$ is the borrower stochastic discount factor.

Equation (C.5) states that the marginal benefits from investing one more euro in housing includes the foregone rental cost next period $p_{r,t+1}$, the utility benefit from owning $\bar{\omega}_{b,t}$ as in Greenwald and Guren (2019), and the housing value next period.

Finally, the relevant normalization for the ownership utility term in the borrower budget constraint is: $A_{b,t} = \frac{(H_{b,t}+H_{l,t})^2}{H_{l,t}}$.

C.1.2 Saver Solution

In Section 3.2 I discuss the optimality conditions of the savers with respect to bonds (the Euler equation (13)) and with respect to newly issued mortgages (equations (9)-(11)). The optimality with respect to house size implies:

$$p_{h,t} = \frac{u^h_{s,t}}{u^c_{s,t}} + E_t\left[\Lambda^s_{t,t+1} p_{h,t+1}(1-\delta)\right] \tag{C.6}$$

C.1.3 Landlord Solution

The landlords only optimize with respect to new house size, leading to:

$$p_{h,t} = E_t \Lambda^s_{t,t+1}[p_{r,t+1} + \bar{\omega}_{l,t} + p_{h,t+1}(1-\delta)] \tag{C.7}$$

where the relevant normalization for the ownership utility term in the landlord budget constraint is: $A_{l,t} = \frac{(H_{b,t}+H_{l,t})^2}{H_{b,t}}$.

C.2 The Labor Market and The Wage Phillips Curve

In deriving the wage Phillips curve, I follow Auclert, Rognlie, and Straub (2018) and extend their result to households with different discount factors.

Each household i provides hours of work n_{ikt} to a continuum of unions indexed by $k \in [0,1]$. Therefore, household i provides a total of $n_{it} \equiv \int_k n_{ikt} dk$ hours of work. Unions aggregate hours of work into tasks: $N_{kt} = \int n_{ikt} di$. A competitive labor packer packages these tasks into aggregate labor demand using the technology:

$$N_t = \left(\int_k N_{kt}^{\frac{\varphi-1}{\varphi}} dk\right)^{\frac{\varphi}{\varphi-1}}$$

and sell these services to perfectly competitive producers in the final good sector introduced in Section 3 at price W_t.

Next, each union k that adjusts the nominal wage W_{kt} determines a quadratic utility cost to households. Specifically, each household utility (2) features an additive cost $\frac{\psi}{2}\int_k \left(\frac{W_{kt}}{W_{kt-1}} - 1\right)^2 dk$. In a symmetric equilibrium, unions set equal wages and ask households to supply the same hours of labor, implying:

$$\frac{N_{b,t}}{\chi_b} = \frac{N_{s,t}}{\chi_s} = N_t$$

Finally, I follow the derivation in Auclert, Rognlie, and Straub (2018) and show that in my setting the wage Phillips curve takes the form:

$$\pi^W_t(\pi^W_t - 1) = \frac{\varphi}{\psi} N_t \left(u^N(N_t) - \frac{\varphi-1}{\varphi}(1-\tau)\frac{W_t}{P_t}\tilde{u^c}\right) + \tilde{\beta}\pi^W_{t+1}(\pi^W_{t+1} - 1)$$

where $\tilde{u^c} = \chi_b u^c(C_{b,t}/\chi_b) + \chi_s u^c(C_{s,t}/\chi_s)$ is the average marginal utility, and $\tilde{\beta} = \chi_b * \beta_b + \chi_s * \beta_s$ is the average discount factor in the economy.

C.3 The Home-Foreign Structure

The world economy has unitary measure, with Home having measure n and Foreign $(1-n)$. The Home-Foreign structure closely follows Faia and Monacelli (2008) with some adjustment related to housing expenditures.

Aggregate consumption in the Home economy (which includes non-durables as well as expenditures on housing) is described by the following index of domestic and imported bundles of goods:

$$AC_t \equiv \left[(1-\gamma)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

where $\eta > 0$ is the elasticity of substitution between domestic and foreign goods, and $\gamma \equiv (1-n)\lambda$ denotes the weight of imported goods in the Home consumption. This weight depends on $(1-n)$, the relative size of Home, and on λ, the degree of trade openness of Home. Analogously, consumption preferences in Foreign are defined as:

$$AC_t^* \equiv \left[(1-\gamma^*)^{\frac{1}{\eta}} C_{F,t}^{*\frac{\eta-1}{\eta}} + \gamma^{*\frac{1}{\eta}} C_{H,t}^{*\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}.$$

where $\gamma^* \equiv n\lambda^*$.

Each consumption bundle $C_{H,t}$ and $C_{F,t}$ is composed of imperfectly substitutable varieties:

$$C_{H,t} \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}; \quad C_{F,t} \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}};$$

$$C_{H,t}^* \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}^*(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}; \quad C_{F,t}^* \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}^*(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}.$$

where $\epsilon > 1$ is the elasticity of substitution across the differentiated products.

The consumption-based price indices that correspond to the above specifications of preferences are given by:

$$P_t = \left[(1-\gamma)P_{H,t}^{1-\eta} + \gamma P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}; \quad P_t^* = \left[(1-\gamma^*)P_{F,t}^{*1-\eta} + \gamma^* P_{H,t}^{*1-\eta}\right]^{\frac{1}{1-\eta}}.$$

$P_{H,t}$ is the price sub-index for home-produced goods expressed in the domestic currency, $P_{F,t}$ is the price sub-index for foreign-produced goods expressed in the domestic currency, $P_{H,t}^*$ is the price sub-index for home-produced goods expressed in the foreign currency, and $P_{F,t}^*$ is the price sub-index for foreign-produced goods expressed in the foreign currency. The price sub-indices are defined as follows:

$$P_{H,t} = \left[\left(\frac{1}{n}\right) \int_0^n P_{H,t}(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}; \quad P_{F,t} = \left[\left(\frac{1}{1-n}\right) \int_n^1 P_{F,t}(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}};$$

$$P_{H,t}^* = \left[\left(\frac{1}{n}\right) \int_0^n P_{H,t}^*(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}; \quad P_{F,t}^* = \left[\left(\frac{1}{1-n}\right) \int_n^1 P_{F,t}^*(i)^{1-\epsilon} di\right]^{\frac{1}{1-\epsilon}}.$$

For notational convenience, I impose the goods-market clearing conditions of each country: $AC_t \equiv C_t + \delta p_t^h \bar{H} = Y_t$; $AC_t^* \equiv C_t^* + \delta p_t^{*,h} \bar{H}^* = Y_t^*$. We can additionally express the consumption bundles $C_{H,t}$ and $C_{F,t}$ as function of aggregate country-level output:

$$C_{H,t} = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} (1-\gamma) Y_t; \quad C_{F,t} = \left(\frac{P_{F,t}}{P_t}\right)^{-\eta} \gamma Y_t;$$

$$C_{H,t}^* = \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\eta} \gamma^* Y_t^*; \quad C_{F,t}^* = \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\eta} (1-\gamma^*) Y_t^*;$$

Finally, we can derive the intermediate good-level demand of each consumption bundle:

$$C_{H,t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon} \left(\frac{1}{n}\right) C_{H,t}; \quad C_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon} \left(\frac{1}{1-n}\right) C_{F,t};$$

$$C_{H,t}^*(i) = \left(\frac{P_{H,t}^*(i)}{P_{H,t}^*}\right)^{-\epsilon} \left(\frac{1}{n}\right) C_{H,t}^*; \quad C_{F,t}^*(i) = \left(\frac{P_{F,t}^*(i)}{P_{F,t}^*}\right)^{-\epsilon} \left(\frac{1}{1-n}\right) C_{F,t}^*;$$

Law of one price. I assume that the law of one price holds, meaning that $P_{H,t}(i) = \zeta_t P_{H,t}^*(i)$ and $P_{F,t}(i) = \zeta_t P_{F,t}^*(i)$, where ζ_t is the nominal exchange rate. Notice that by plugging the previous expressions into the corresponding price-subindices formulae, we can derive that $P_{H,t} = \zeta_t P_{H,t}^*$ and $P_{F,t} = \zeta_t P_{F,t}^*$. That is, the law of one price also holds at the price of the consumption bundles. However, given the presence of home bias, purchasing power parity does not hold, that is, $P_t \neq \zeta_t P_t^*$. Hence, I denote the real exchange rate as $Q_t \equiv \frac{\zeta_t P_t^*}{P_t}$.

Total variety demands. Market clearing for domestic variety i must satisfy:

$$\begin{aligned} Y_t(i) &= nC_{H,t}(i) + (1-n)C_{H,t}^*(i) \\ &= \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon} \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} \left[(1-\gamma)Y_t + \frac{1-n}{n}\gamma^* Q_t^\eta Y_t^*\right] \end{aligned}$$

Accordingly, market clearing for foreign variety i must satisfy:

$$\begin{aligned} Y_t^*(i) &= nC_{F,t}(i) + (1-n)C_{F,t}^*(i) \\ &= \left(\frac{P_{F,t}^*(i)}{P_{F,t}^*}\right)^{-\epsilon} \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\eta} \left[\frac{n}{1-n}\gamma^* Q_t^{-\eta} Y_t + (1-\gamma^*)Y_t^*\right] \end{aligned}$$

Next, we substitute in the expressions $\gamma \equiv (1-n)\lambda$ and $\gamma^* \equiv n\lambda^*$. Further, to portray our small open economy we take $n \to 0$ to get:

$$Y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\epsilon} \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} [(1-\lambda)Y_t + \lambda^* Q_t^\eta Y_t^*]$$

$$Y_t^*(i) = \left(\frac{P_t^*(i)}{P_t^*}\right)^{-\epsilon} Y_t^*$$

It is clear from these latter equations that while consumption of the Foreign economy affects the Home economy, the opposite does not hold true. At the same time, changes in the real exchange rate do not affect Foreign aggregate demand.

In a symmetric equilibrium, each producer charges the same price and produces the same level of output. For the Foreign economy, this means $P_t^*(i) = P_t^*$ and $Y_t^*(i) = Y_t^*$. Similarly for the Home economy, this means $P_{H,t}(i) = P_{H,t}$ and $Y_t(i) = Y_t$. Furthermore, assuming $\lambda = \lambda^*$ implies:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} [(1-\lambda)Y_t + \lambda Q_t^\eta Y_t^*]$$

which is equation (5).