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 1.9 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 mortgage interest rates. Finally, including house prices into the euro area price index stabilizes output at the cost of higher 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. Following a policy rate increase, it is well documented that aggregate consumption in Spain decreases more severely than in Germany.[1] Recent evidence suggests that housing wealth effects are an important driver of the heterogeneous consumption responses to monetary policy (Slacalek, Tristani, and Violante (2020)), but the literature still lacks an understanding of what the specific sources are behind the differential cross-country responses. In this paper, I investigate and quantify the role of the housing and mortgage market institutions in shaping the monetary transmission mechanism across the euro area. I do so empirically and in a quantitative model that pays particular attention to institutional details for the eurozone country-specific markets. I focus on the role of adjustable-rate mortgage (ARM) shares and homeownership rates (HoR), two features that are extremely different across European countries and that I show drive the empirical responses to monetary policy shocks[2].

To this end, I perform an econometric analysis of monetary policy shocks across euro area countries using local projection methods (Jordà (2005)). Because I am particularly interested in studying the aggregate effects of mortgage interest rates across countries, I use high-frequency movements at longer ends of the Overnight Indexed Swap (OIS) rates around policy announcements as identified monetary policy shocks. An expansionary monetary policy shock makes 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 monetary policy effectiveness (as measured by peak or trough 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

[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.

practice, and not all of them.

To disentangle the relative importance of ARM share and the HoR, I turn to a quantitative currency-union two-agents New Keynesian (TANK) 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, house size, and rental service choices as in Greenwald (2018). The population is made of borrowers and savers: the former are impatient and constrained by a loan-to-value constraint, while the latter are patient and unconstrained. A family of landlords provides rental units to the borrowers, and I introduce nominal rigidities in the form of sticky-wage frictions. To close the model, I assume a monetary authority that employs a Taylor rule at the Euro-Area-level and equalize the short interest rates across countries. The advantage of such a unified currency-union framework with rich country-level housing and mortgage market institutions is that it allows me to analyze and compare the effects of specific features of the aforementioned markets in the transmission mechanism of monetary policy across the different euro area countries.

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. The way I rationalize in the model the fact that a country has a higher homeownership rate than another one is by assuming that households are on average happier to own. This difference in the distribution of owning utility across countries stands in for the quality of the rental market and ownership subsidies. Secondly, I assume that in each country households hold an exogenous fraction of fixed-rate mortgages (FRM) and ARM. While the mortgage type choice is in principle an endogenous household decision, I model it as exogenous because it is in practice influenced by country-specific housing finance regulation[3]. An important equilibrium feature of the model is the pass-through of the policy rate to the mortgage interest rate. I show that countries with a higher ARM share display a larger pass-through to 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. To do so, I make use of the second wave of the Eurosystem Household Finance and

[3]In Section 4.2 I argue that the quantitative results would change little if I modeled the mortgage type decision to be endogenous.

Consumer Survey, which was administered around 2014 and contains harmonized data across European countries on household balance sheets. I calibrate Spain to have a 90% share of ARM and 80% HoR, with the proportion of homeowners with mortgages being 30%. Similarly, I calibrate the euro area to have a 45% share of ARM 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.

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 mortgage interest rate on the outstanding stock of mortgages in Spain reacts about 2.2 times more than the euro area relative to 1.8 in the data. Spanish households pay less mortgage interest payments and also rush to lock in lower rates, so that newly issued mortgages in Spain increase by 2.7 times as much as in the euro area (2.8 in the data). These effects combined deliver an aggregate consumption response in Spain which is 1.9 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. To do so, I consider a counterfactual economy in which Spain has the correct ARM share but the Euro-Area-level HoR. This counterfactual economy displays exactly the same quantitative effects on mortgage interest rates as the baseline economy. This is because the presence of a higher ARM share in Spain determines a stronger pass-through to the mortgage interest rate in equilibrium – a result which I also discuss analytically. Conversely, when I consider a counterfactual economy in which Spain has the correct HoR but the Euro-Area-level share of ARM, a different scenario emerges. I find that mortgage interest rates respond in line with the euro area but newly issued mortgages respond slightly more. This is because Spain features more mortgaged homeowners who can actively increase their mortgage stock. Furthermore, given that the size of the borrower family is smaller in Spain, there is a stronger redistribution among borrowers so that more renters can change tenure status and become homeowners. As a consequence, the movements in the price-to-rent ratio in Spain are mostly determined by the higher HoR.

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, which in turn allows more renters to become homeowners and make use of the reduced mortgage interest rates. This situation lead the borrowers to spend more on their non-durable consumption. Therefore, housing and mortgage market institutions interact to amplify the potency of monetary policy on economic activity.

The last set of findings concerns the analysis of two counterfactuals. In the first experiment, I study how different forms of banking union alter the stabilization properties of the monetary authority. I find that a banking union, which I model as a Euro-Area-wide mortgage market, is successful in decreasing the heterogeneous transmission mechanism of monetary policy – especially so when the ARM share in Spain is lowered to equate that of 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 the second experiment, I build on the recent European Central Bank (ECB) monetary policy strategy review to discuss the consequences of including house prices into the euro area price index. I show that reacting to house prices reduces the volatility of output but increases the volatility of inflation. This trade-off is qualitatively robust but quantitatively different depending on the nature of the monetary shock and the inclusion of rents instead than of house prices into the price index.

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 is related to papers studying monetary policy and exchange rates in small open economy 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). I complement these models 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 with different housing institutions.

The work also relates to the class of New Keynesian models featuring housing and mortgage debt such as Iacoviello (2005), Iacoviello and Neri (2010), Calza, Monacelli, and Stracca (2013), and Greenwald (2018). Relative to these papers, I study the dynamics to monetary policy shocks across countries in a currency union, where a common interest rate is set by the central bank and countries with different characteristics display heterogeneous effects to monetary policy[4].

Overview. The rest of the paper is organized as follows. Section 2 shows the relevance of ARM shares and of the HoR to account for heterogeneous effects of monetary policy shocks across euro area countries. Section 3 introduces the model and describes the calibration. Section 4 provides the model results on the interest rate transmission, and Section 5 analyzes policy-relevant counterfactuals. Section 6 concludes.

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 country-specific monetary policy effectiveness 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. Given the long-term nature of mortgage contracts, movements in longer rates are going to be more effective drivers of macroeconomic fluctuations. 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[5].

[4]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.

[5]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.

2.1 Identification

My empirical analysis relies on high frequency identification of monetary policy shocks (an approach first started with Kuttner (2001)) and leverages on 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[6]. 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 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[7].

Given that the focus of this paper is on the role of mortgages in the transmission mechanism, I make use of the unexpected movements in the longer end of the yield curve in the main monetary policy experiment. I therefore pick the 2-year OIS changes, which is the longest high frequency term available since the early 2000s. As a robustness exercise, I show that the results are very similar when I run a conventional monetary policy analysis using changes in the shorter term OIS.

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[8]. For completeness, I also include the euro area aggregates. I use quarterly data on country-specific aggregate consumption, price-to-rent ratios, newly issued

[6]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).

[7]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.

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

mortgages, and mortgage interest rates. I also make use of a few Euro-Area-level variables, such as 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. To construct monetary policy shocks at the quarterly level, I sum up the OIS changes within quarters as in Slacalek, Tristani, and Violante (2020). As discussed in the previous section, I use the 2-year OIS changes as identified monetary policy shocks[9]. My results are robust to a conventional monetary policy analysis, as I argue in Appendix A.3. Data sources are outlined in Appendix B.

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

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

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 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

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, with some countries reacting much more severely than others. In particular, while a few countries such as Spain, Portugal, Italy, and the Netherlands increase their flow of new mortgages by about 5%, some others are far less reactive. For example, the euro area peaks at around 1.8% and Germany below 1%. The results on newly issued mortgages are echoed in the mortgage

[9]Even though most of the variation in the 2-year OIS changes happens between 2008 and 2012, the results in this section change very little if I run the analysis starting from 2003 Q1 (when mortgage interest rate data starts) instead of from 2007 Q1.

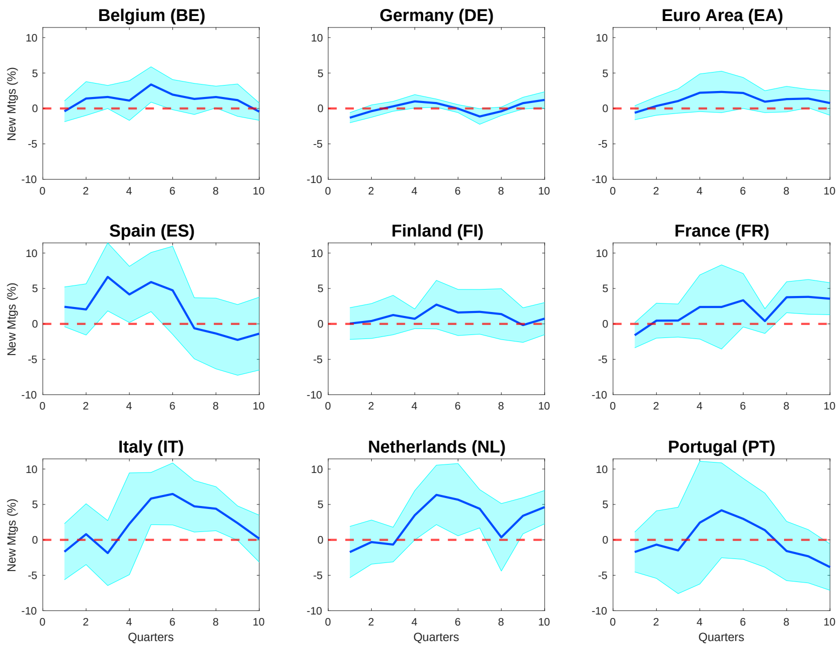


Figure 1: Impulse response functions of newly issued mortgages to an expansionary monetary policy shock of one standard deviation.

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.

interest rate responses. mortgage interest 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%.

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.

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,

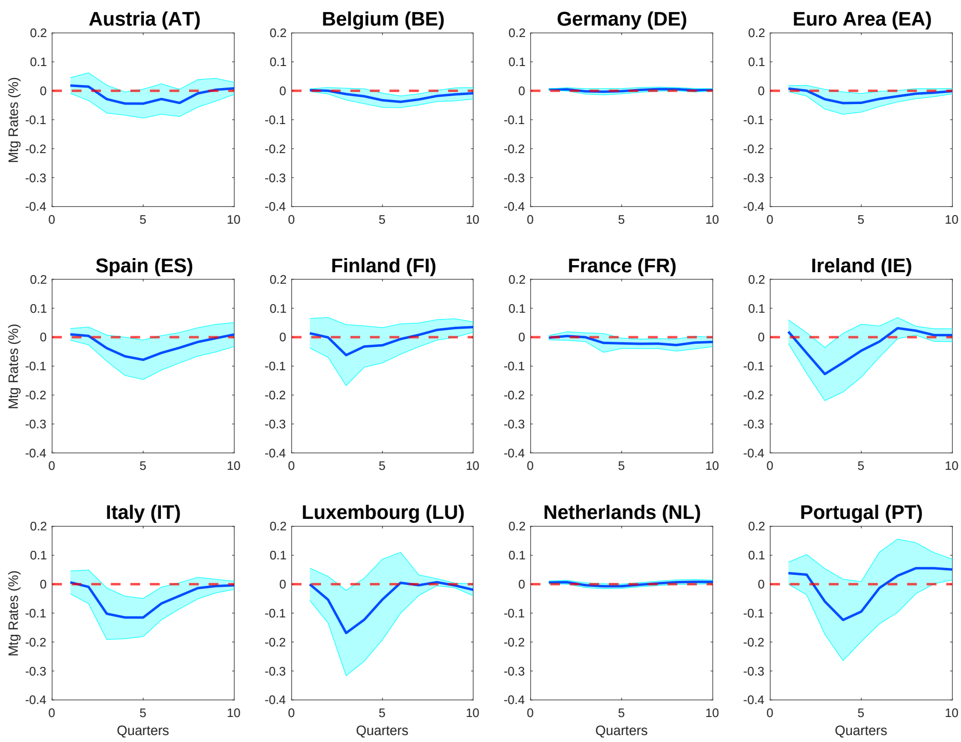


Figure 2: Impulse response functions of outstanding mortgage interest rates to an expansionary monetary policy shock of one standard deviation.

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.

my analysis provides evidence of heterogeneous responses in mortgage market variables (figures 1 and 2). Through the lenses of the model I present in Section 3, I show that the aforementioned heterogeneity is essential to explain the differential responses in aggregate consumption across euro area countries.

2.4 The Role of Housing and Mortgage Markets

In this section I correlate the country-specific monetary policy effectiveness discussed in the previous section with key housing and mortgage market institutions. To do so, I make use of the Eurosystem Household Finance and Consumption Survey (HFCS).

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, and I rely on the second wave which was administered between 2013 and 2015 and contains around 75 thousands families.

I compute a few measures which have a direct mapping with the model I present in

Section 3. To start with, for each country I compute the share of ARM over the total outstanding mortgage stock. There are striking differences in this measure across euro area countries. Most notably, while in Ireland, Spain, Finland and Portugal about 90% of outstanding mortgages are adjustable-rate, in Germany and France the counterpart figure is of about 10%. I also compute homeownership rates[10]. I further distinguish between two related measures. I define "outright homeowners" the fraction of households who own their main residence with no outstanding mortgages on it. Finally, I compute the fraction of households who have mortgages on their main residence. Obviously, in each country the sum of the latter two measures defines the HoR.

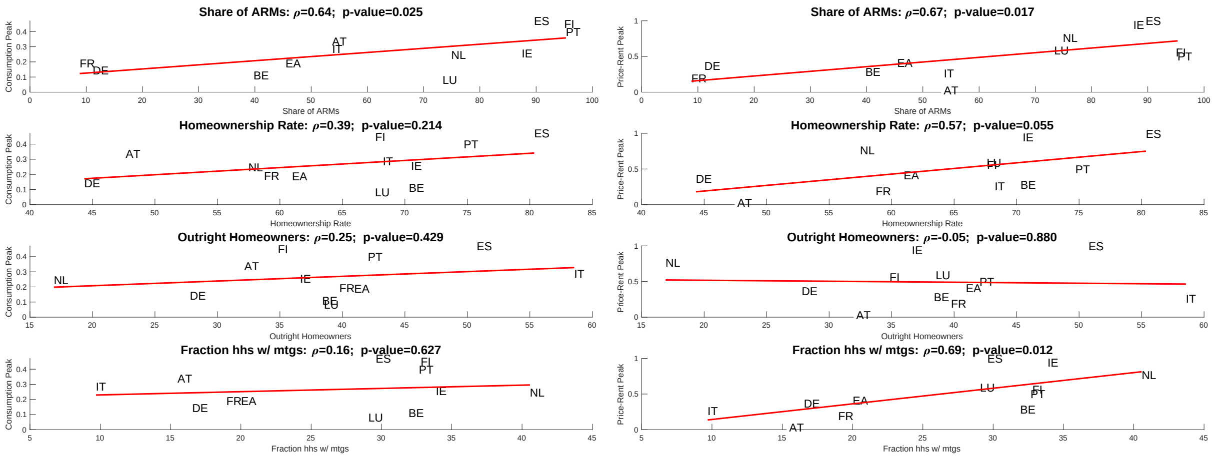
In figures 3 and 4 I plot the relationships between monetary policy effectiveness to an expansionary policy shock and the previously discussed measures of housing and mortgage market characteristics. Similarly to Almgren et al. (2019), I measure the strength of monetary policy transmission in each country by the peak response of the impulse response functions. For the mortgage interest rate responses, I consider the trough responses given the pass-through from policy rates (recall Figure 2). Before I proceed in analyzing the results of my correlation analysis, a word of caution is necessary. Because I only consider the early adopters of the euro, this analysis is meant to motivate the main futures of the currency-union TANK model I present in Section 3 rather than to uncover strong empirical relationships between the 12 data points.

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 than 11) are considered.

Secondly, it is interesting to disaggregate the correlations with the HoR into its components. For example, reactions 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 reactions of mortgage market variables are not only strikingly different between

[10]I define the homeownership rate as the fraction of households who own their main residence.



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

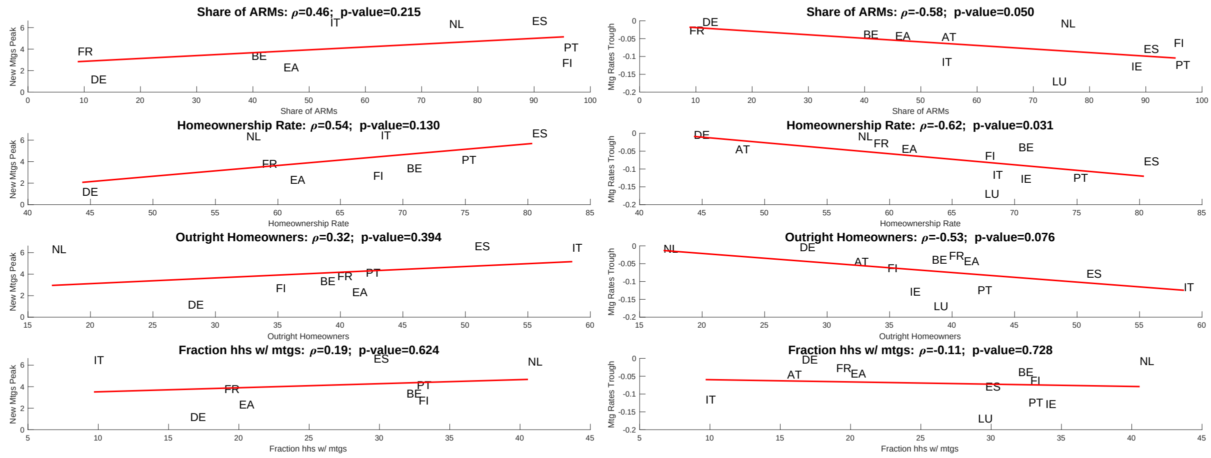
Figure 3: Scatter plots of impulse response function intensities and housing and mortgage market characteristics.

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 shares of ARM and 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. Calculations of housing and mortgage market characteristics are based on the Eurosystem Household Finance and Consumption Survey.

countries, but strongly correlate 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[11].

The main takeaway from all the correlations shown in figures 3 and 4 is that monetary policy effectiveness to the macroeconomy is strongly related to a few housing and mortgage market characteristics. These latter country-specific features, 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 bigger ARM shares, higher fraction of households holding mortgages, and higher fraction of outright homeowners. Therefore, an identification problem arises whereby it might well be that only one of those features explain the heterogeneous monetary transmission mechanism in practice, and not all of them. Section 3 builds a quantitative TANK model with the purpose of providing intuitions of the mechanisms at work as well as of quantifying the relative importance of

[11] 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 captured by the outright homeowners.



(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 shares of ARM and 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.

each of the previously mentioned country-specific housing features.

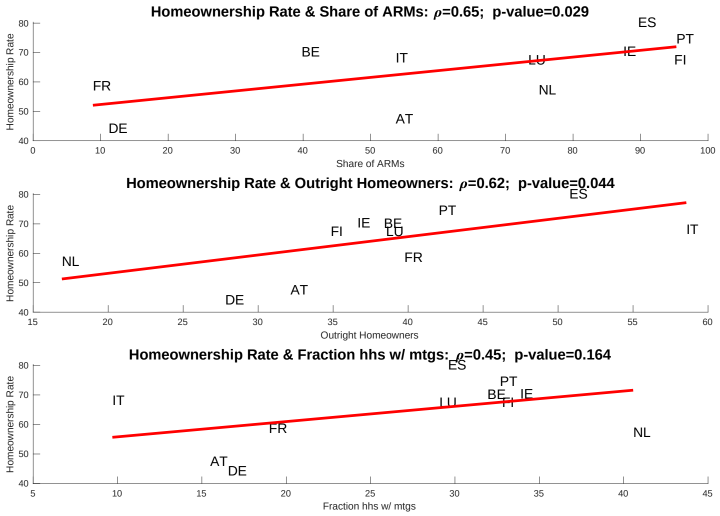


Figure 5: Scatter plots of the ARM shares and various measures of HoR.

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 (TANK) model. The main contribution of the paper is to complement the Home-Foreign type of model (Faia and Monacelli (2008)) with rich within-country housing and mortgage market institutions (Greenwald (2018)). The advantage of such a unified framework lies in the possibility to analyze the role of the housing and mortgage market institutions into the heterogeneous transmission mechanism of monetary policy highlighted empirically in Section 2. This model also 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[12].

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 aggregate up to a representative firm, which it is owned by the savers of the economy[13].

Mortgage contract. The only source of borrowing in the model economy is 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[14].

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 $(1-\alpha)$ of adjustable-rate ones[15]. This allows me to differentiate the Home and Foreign country in the model based on their ARM share, and allows me to study the dynamic effects of changes in the share in each economy. While the mortgage type choice is in principle an endogenous household decision, I model it as exogenous because it is in practice influenced by country-specific housing finance regulation[16]. 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 $(1-\nu)^k(\alpha q_t + (1-\alpha)q_{t+k})$€ at time $t+k$, for all $k>0$, where ν is the fraction of principal paid each period and q_t is the mortgage interest rate.

[12]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.

[13]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.

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

[15]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.

[16]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 ARM, as they couldn't hedge the interest rate risk.

In this economy, the mortgage debt is refinanced with an exogenous probability ρ. This means that in each period, a fraction ρ of borrowers repays the outstanding balance on their loan in order to refinance. Once they refinance, they can 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.

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. I additionally assume that the 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, $j \in \{b, s, l\}$. 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 to $\bar{H}$[17].

Borrowers have the option of renting or owning. I follow Greenwald and Guren (2019) and assume that every period they receive a service flow (positive or negative) from owning housing. In particular, if a borrower i owns one unit of housing, she receives $\omega_{b,t}^i$ of the numeraire, where $\omega_{b,t}^i \sim \Gamma_{\omega,b}$ 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, the most important reason for which Germany has the lowest homeownership rate of the euro area (40%) is thought to be its extensive social housing sector (see Voigtländer (2009) for

[17] 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.

a qualitative analysis and Kaas et al. (2021) for a quantitative one). Furthermore, German households did not benefit from high subsidies the way households in other European countries such as Spain and the Netherlands did (see also Van den Noord (2005) for a related analysis of tax treatments).

Similarly to borrowers, landlords also receive a 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[18]. 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 disccused, 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:

$$\pi^W_t(\pi^W_t - 1) = \frac{\varphi}{\psi} N_t \left(u^N(N_t) - \frac{\varphi - 1}{\varphi}(1-\tau)\frac{W_t}{P_t}\tilde{u^c} \right) + \tilde{\beta}\pi^W_{t+1}(\pi^W_{t+1} - 1). \tag{3}$$

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

[18]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 – because there are some fixed-rate mortgages in the economy – 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:

$$\begin{aligned} C_{b,t} \leq \; & \underbrace{(1-\tau)\frac{W_t}{P_t}N_{b,t}}_{Labor Income} + \underbrace{\rho(m_{b,t} - (1-\nu)\pi_t^{-1}M_{b,t-1})}_{Net Mortgage Issuance} - \underbrace{\rho p_{h,t}(h_{b,t} - H_{b,t-1})}_{Net Housing Purchases} \\ & - \underbrace{\pi_t^{-1}\nu M_{b,t-1}}_{Principal Payment} - \underbrace{\pi_t^{-1}(1-\tau)[\alpha X_{b,t-1} + (1-\alpha)q_{t-1}M_{b,t-1}]}_{Interest Payment} - \underbrace{\delta p_{h,t} H_{b,t-1}}_{Maintenance} \\ & - \underbrace{p_{r,t}(s_{b,t} - H_{b,t-1})}_{Rent} + \underbrace{\left(\int_{\bar{\omega}_{b,t-1}} \omega d\Gamma_{\omega,b}\right) A_{b,t-1}}_{Owner Surplus} + \underbrace{T_{b,t}}_{Rebates}, \end{aligned}$$

where W_t/P_t is the real wage, π_t is the inflation rate, $p_{h,t}$ is the house price, q_t is the mortgage interest rate, $p_{r,t}$ 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:

$$\begin{aligned} M_{b,t} &= \underbrace{\rho m_{b,t}}_{New Loans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}M_{b,t-1}}_{Old Loans} \\ X_{b,t} &= \underbrace{\rho q_t m_{b,t}}_{New Loans} + \underbrace{(1-\rho)(1-\nu)\pi_t^{-1}X_{b,t-1}}_{Old Loans} \\ H_{b,t} &= \underbrace{\rho h_{b,t}}_{New Housing} + \underbrace{(1-\rho)H_{b,t-1}}_{Old Housing}. \end{aligned}$$

The landlords belong to a family whose purpose is to buy housing $h_{l,t}$ and rent it out to borrowers. 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:

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

where $T_{l,t}$ rebates 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. 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:

$$\begin{aligned} C_{s,t} \leq \; & \underbrace{(1-\tau)\frac{W_t}{P_t} N_{s,t}}_{LaborIncome} - \underbrace{\rho(m_{s,t} + (1-\nu)\pi_t^{-1} M_{s,t-1})}_{NetMortgageIssuance} - \underbrace{\rho p_{h,t}(h_{s,t} - H_{s,t-1})}_{NetHousingPurchases} + \underbrace{\pi_t^{-1} \nu M_{s,t-1}}_{PrincipalPayment} + \underbrace{T_{s,t}}_{Rebates} \\ & + \underbrace{\pi_t^{-1}[\alpha X_{s,t-1} + (1-\alpha) q_{t-1} M_{s,t-1}]}_{InterestPayment} - \underbrace{(R_t^{-1} B_t - \pi_t^{-1} B_{t-1})}_{NetBondPurchases} - \underbrace{\delta p_{h,t} \bar{H}_s}_{Maintenance} + \underbrace{F_t}_{ProfitsLandlord}, \end{aligned} \tag{4}$$

The lump sum rebates $T_{s,t}$ includes 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:

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

Finally, the savers (at Home as well as in Foreign) have access to internationally traded claims. These have not been explicitly introduced in the budget constraint (4) to reduce clutter.

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: $\pi_t \equiv P_t/P_{t-1} = \pi_t^W \equiv W_t/W_{t-1}$.

The world economy is composed of two countries – Home and Foreign. The world economy has unitary measure, with Home having measure n and Foreign $(1-n)$. I follow the limit-case approach, as in Faia and Monacelli (2008), and assume that the Home economy is small relative to Foreign, that is $n \to 0$. This assumption implies in equilibrium that Home does not affect Foreign's dynamics, while the opposite is not true.

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:

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

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

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 $Q_t = \frac{\zeta_t P_t^*}{P_t}$.

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

$$Y_t(i) \quad = \quad nC_{H,t}(i) + (1-n)C_{H,t}^*(i),$$

and in Appendix C.3 I show that this implies:

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

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 shown 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.

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. Formally, I defined 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 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: $R_t = R_t^*$. To do so, the central bank makes the nominal exchange rate across countries equal to a constant ($\zeta_t = \bar{\zeta}$) which paired with uncovered interest parity leads to the equalization of the nominal interest rates.

A competitive equilibrium is a sequence of prices and aggregate variables 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: $M_{b,t} + M_{s,t} = 0$;
- 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-FRM mix in any given economy. The remaining optimality 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 mortgages that are FRM (α) and the remaining fraction of ARM ($1-\alpha$). Firstly, define $\Omega^m_{s,t}$ as the marginal continuation benefit to the savers of an additional euro of issued mortgage debt:

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

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 ARM, $(1-\alpha)q_t$, 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:

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

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 the mortgage interest rate at time t because the saver locks in that specific mortgage interest rate for the whole duration of the mortgage contract (but only on the FRM share).

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 $\Omega^m_{s,t} = 1$. Hence the saver optimality condition for new mortgages reduces to:

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

Recall that savers can also invest in a one-period bond, with the related optimality condition 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 ARM, there is perfect pass-through between the short rate and the mortgage interest rate: $R_t = q_t + 1$. Intuitively, in an ARM-only economy, 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 $q_t + 1$ next period). This also tells us that the further away we are from the full adjustable case scenario, the lower the pass-through. This is because as α increases away from zero towards one, $\Omega^x_{s,t}$ becomes quantitatively more important relative to $\Omega^m_{s,t}$ which shrinks towards zero making equation (12) further away from holding.

Assume now an FRM-only economy ($\alpha = 0$). 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. The pass-through is lowest: $\Omega^m_{s,t}$ is furthest away from unity and $\Omega^x_{s,t}$ is positive and furthest away from zero. In this scenario, the savers lock in the mortgage interest rate at time t on the whole euro invested in newly issued mortgages.

To summarize, the ARM-FRM mix in any given economy is crucial for the equilibrium pass-through from the nominal interest rate to the mortgage interest rate. Specifically, the higher the ARM share, the stronger the pass-through.

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). Some other parameters

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		
Share of ARMs	$1-\alpha^*$	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	EA Median LTV
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).

which are more standard in the New Keynesian literature are calibrated externally. As a general calibration strategy, whenever I need to assign parameters that to the best of my knowledge have never been calibrated or estimated to 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

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		
Share of ARMs	$1-\alpha$	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).

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 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 accounting for 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 parameters 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[19]. Accordingly, I internally calibrate the household disutility of

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

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:

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

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. 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 determines the equilibrium pass-through of nominal interest rate to the 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. 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). I compute and describe the impulse responses to a monetary policy shock ($\epsilon_{MP,t}$) introduced in the Taylor rule (8) in Appendix A.4.

4.1 Heterogeneous Monetary Transmission

My main result is that, 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 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. The first visible result lies in the pass-through to mortgage interest rates on new mortgages: a 1% decline of the short rate leads to a fall in mortgage interest rates applied to new mortgages of 0.75% in ES but only of 0.55% in the EA. The pass-through mechanism is pinned down by the mortgage optimality condition of savers, as discussed in Section 3.2. Furthermore, the mortgage interest rate on new mortgages takes 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. As a consequence, the average mortgage interest rate in the EA barely moves on impact but gradually declines as new mortgages are issued at the lower mortgage interest rate. 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 mortgage interest rate on new mortgages.

The lower mortgages rates in ES lead 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 a peak of 0.35% in ES, which is twice as much as the peak experienced by the EA.

Figure 7 summarizes the monetary policy effectiveness as measured by relative peaks (or troughs for the mortgage interest rate) across countries, both from the data (Section 2.3) and from the model. The model slightly overshoots the data in terms of the mortgage interest rate relative responses: ES reacts 1.8 times more than the EA in the data, but 2.2 times more in the model. In terms of newly issued mortgages and price-to-rent ratios, the model aligns very closely to the data. The aggregate consumption response in ES is 1.9 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

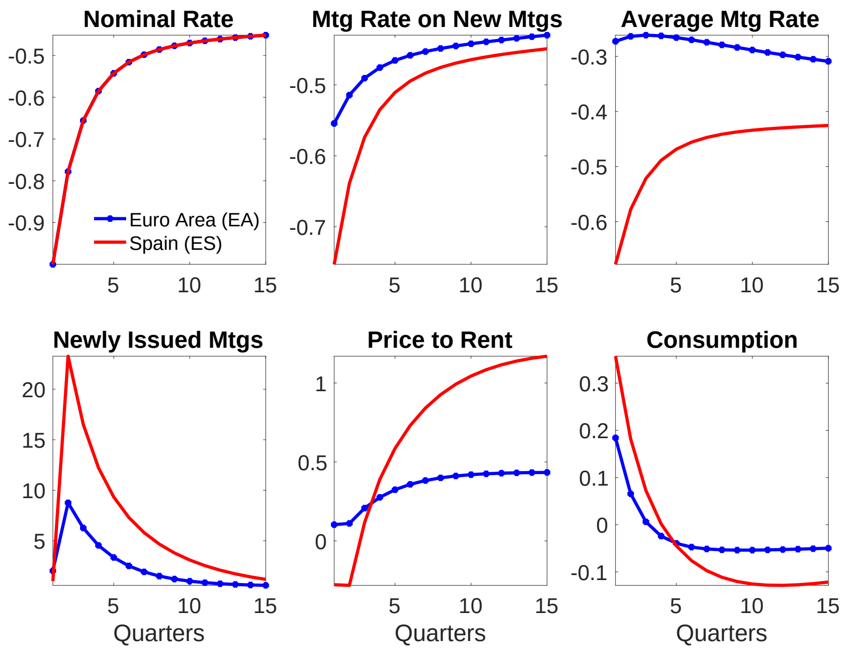


Figure 6: Impulse response functions to an inflation target shock affecting both the euro area and Spain.

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.

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

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 share of ARM, 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. Under this distinction, the movements displayed by ES-HoR can all be attributed to the HoR, while the movements associated to ES-ARM can be attributed to the ARM share.

To begin with, the center top panel shows that the pass-through to the mortgage interest rate is exclusively dictated by the differential ARM share. In other words, ES-ARM explains all the movements in mortgage interest rates, while ES-HoR features the same EA pass-through. This is in line with the derivations and intuitions provided in Section

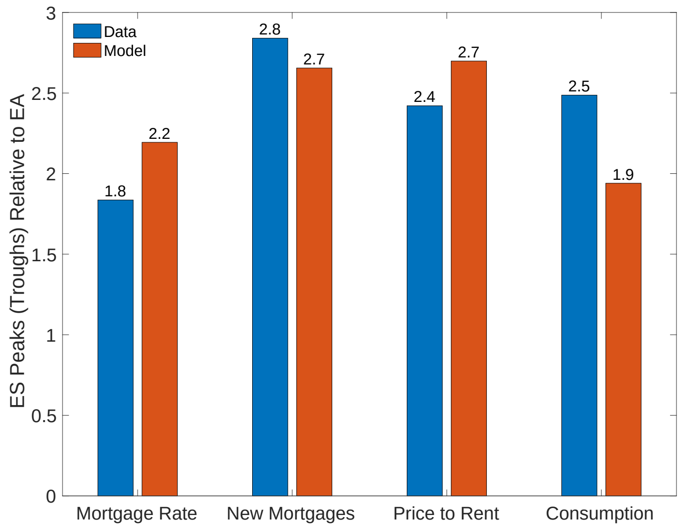


Figure 7: Bar plots of monetary policy effectiveness both in the data and in the model for Spain (ES) relative to the euro area (EA).

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.

3.2. I then focus on the borrower balance sheets. Interest payments in ES fall up to three times as much as those in the EA, an effect entirely driven by the differential mortgage interest rate pass-through. The subsequent boost in fiscal capacity makes it easier for the indebted households to take on more newly issued mortgages. 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. To understand the reasons behind, it is useful to recall how the ES-HoR economy differs from the EA economy. Firstly, the ES-HoR economy displays a higher borrower average utility from owning housing ($\mu_{\omega,b}$), 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. At the same, there are also less renters in the family, and 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 instead. I call this the "borrower redistribution effect".

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

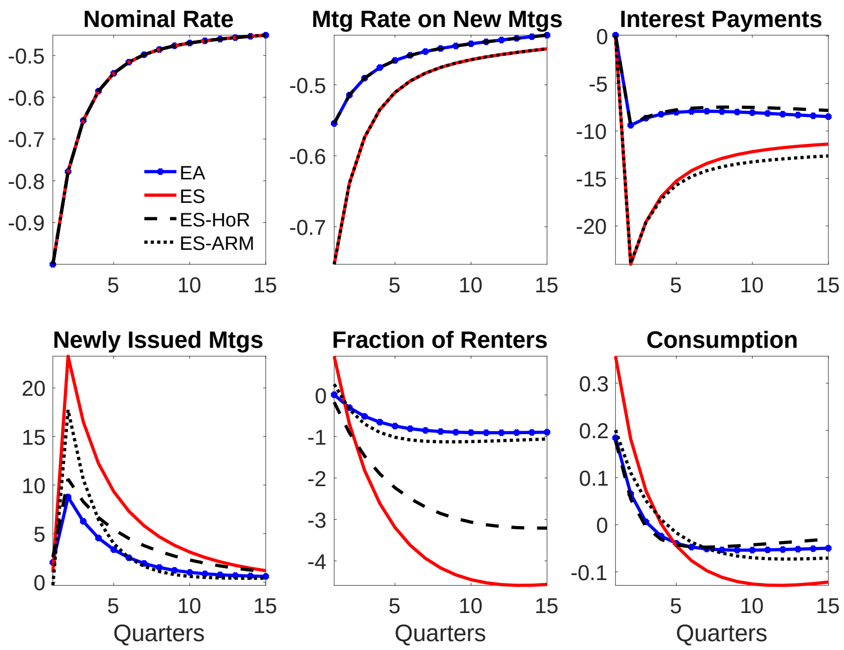


Figure 8: Impulse response functions to an inflation target shock. Decomposition of the housing and mortgage market institutions.

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 rate which is measured in percentage points. The x-axes measure time in quarters. The nominal interest rate, the mortgage interest rate, and the measure of renters are annualized.

mortgages in the aggregate. This effect is visible from the fact that a) the response of newly issued mortgages in ES-HoR is an upward shift of the EA response; and b) in the ES-HoR economy the fraction of renters decreases following the nominal interest rate shock.

Turning to aggregate consumption, it turns out that neither the ARM share nor the HoR alone contribute to a visible increase in economic activity of ES relative to the EA. This suggest a non-linear interaction whereby the ARM share and the HoR interact to amplify the potency of monetary policy on economic activity. This is because 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) which increases even further during the transition (borrower redistribution effect). 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.

I then 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

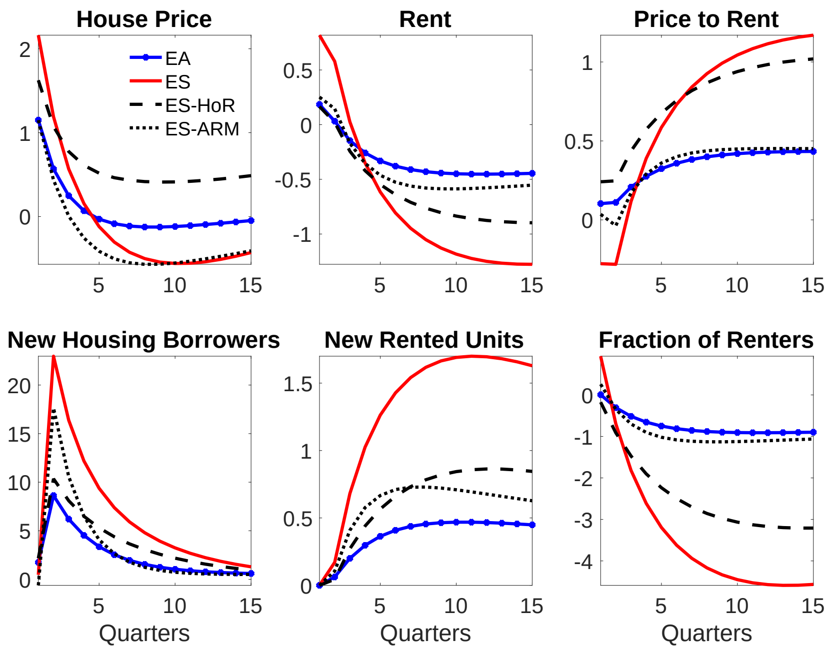


Figure 9: Impulse response functions to an inflation target shock. Decomposition of the housing and mortgage market institutions.

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.

most strongly linked to the new housing units purchased by the borrowers: house prices 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 – as discussed earlier – is 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 found for Italy and Switzerland in Koeniger, Lennartz, and Ramelet (2021), as well as with the evidence for the US in Dias and Duarte (2019).

Finally, I discuss what would change if I allowed borrowers to endogenously choose the ARM share on newly issued mortgages. Following an expansionary shock of the type analyzed in this paper, the pass-through in the EA would still be mostly pinned down by the steady-state ARM share. Even if only modest, the decrease in the mortgage interest rate makes it more convenient for borrowers to demand ARM rather then FRM. This contributes to actually increase the ARM share in the economy which, as discussed in this section, determines a stronger monetary transmission to the economy. Hence, aggregate consumption in EA would increase more than the benchmark response. This would be true but less so in ES, which already features a high ARM share and so cannot increase it much further. All in all, the difference in the transmission would be reduced but by a quantitatively small amount, because in both economies only a ρ fraction of borrowers are active in the mortgage market every period.

5 Model Counterfactuals

The model presented in Section 3 is a useful laboratory to study how changes in the housing and mortgage markets alter the stabilization properties of the euro area monetary policy. In this section, I perform two counterfactuals. In the first experiment, I introduce two different forms of 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 experiment, 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 a European fiscal integration and a banking union could bring to its member states (for a recent overview, see Bilbiie, Monacelli, and Perotti (2021)). At its current stage, the banking union is fairly limited: it is made 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.

I start off my analysis with a "weak" banking union (BU1), in which mortgages can be offered across countries. A no-arbitrage condition must hold between savers of the different countries and, as a consequence, they all offer the same mortgage interest rate on newly issued mortgages at equilibrium. In terms of equations, the first order condition for newly issued mortgages for the savers (equations (9)-(11)) only holds in the EA but not in ES, meaning that the mortgage interest rate is pinned down in the EA. Notice that under this scenario, ES still has a high ARM share. I then move to a stronger banking union (BU2), in which the BU1 is augmented so that the ARM share of ES is changed to the one of the EA[20].

Figure 10 shows the interest rate transmission results under the two different forms of banking unions. Both banking arrangements lead to a smaller pass-through to mortgage interest rates, but only the BU2 is successful in making ES average mortgage interest rate respond as much as the EA one. This is because, while in BU1 ES has a high ARM share, ES has the EA level of ARM share under the BU2[21]. A consequence of the weakened pass-through to mortgage interest rates is that borrowers in ES ask for a smaller amount of mortgages, particularly so under the BU2. In terms of economic activity, BU2 is the most effective at reducing the cross-country heterogeneity, as it brings down the ES response in aggregate consumption to the EA level. Most notably, the BU1 actually determines an increase of aggregate consumption of ES relative to the baseline for the first quarter. This very temporary increase in aggregate consumption is all driven by borrowers, who work more in equilibrium and spend the labor income in non-durable consumption. Under BU1, the savers do not optimize on newly issued mortgages. This distorted environment implies a higher marginal utility of labor relative to the marginal utility of consumption, leading to higher wage inflation dictated by the wage Phillips curve (equation (3)). In the face of an increase in nominal wage changes, the equilibrium labor goes up and borrowers are forced to supply more labor. They optimally re-balance the lower utility from working more with the higher non-durable consumption, leading the aggregate economy to temporarily shoot up relative to the baseline economy.

In terms of redistribution of resources between households, savers clearly win from the banking unions relative to the borrowers. Given the strong pass-through in the baseline ES economy, savers are forced to give up non-durable consumption in order to provide borrowers with the resources they want in terms of new mortgages. However, under the banking arrangements, borrowers ask for less funds (therefore consuming less) allowing the savers to consume more relative to the baseline economy. This redistribution of resources between households poses a trade-off to the monetary authority between a weakened heterogeneous transmission mechanism and a redistribution of resources towards the wealthier households.

[20]While in practice BU1 could be quickly arranged by imposing to all the banks of the EA to issue mortgages at the same mortgage interest rate, BU2 would take longer to implement as mortgages of a specific type can only be replaced after the end date of the contract.

[21]Effectively, BU2 is equivalent to the case discussed in Section 4.2 where ES has the EA level of ARM share. The fact that savers do not maximize their mortgage issuance under the BU2 is not consequential to the dynamics of the mortgage interest rate, since the savers in the EA face the same actual problem and so choose the same mortgage interest rate those in ES would have chosen if they could.

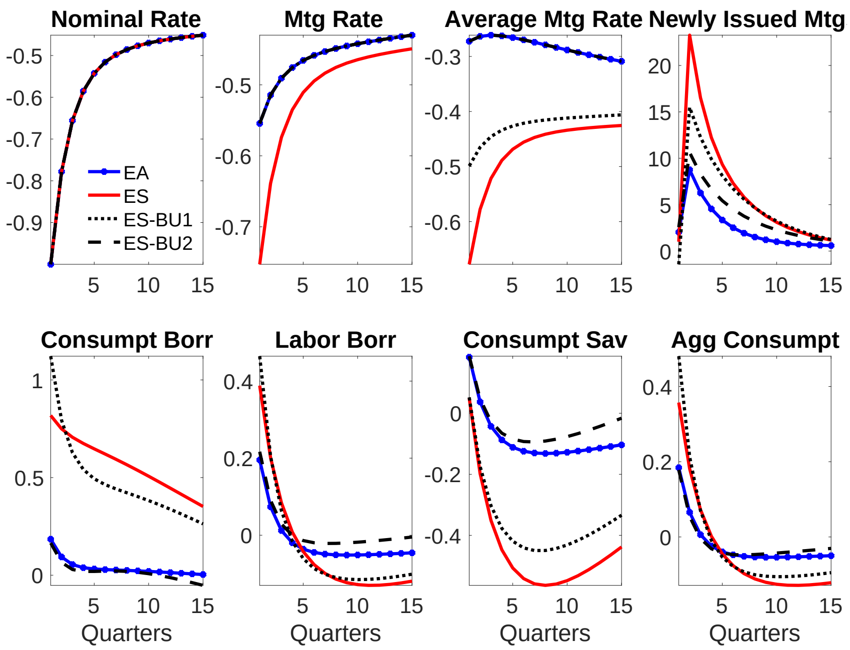


Figure 10: Impulse response functions to an inflation target shock under two different forms of banking unions.

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 nominal interest rate and mortgage interest rate are annualized.

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 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 align with using implicit costs[22]. As a consequence, the ECB has decided to include in the years to come the housing transaction prices as owner-occupied expenditures. I thereby explore the inflation-output trade-offs for different constructed price index definitions, one which

[22]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.

includes the house price (as suggested by the strategy review) and one which includes the rental price (which approximates imputed rents) as an alternative.

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 $p_{h,t}^*$ or the rental price $p_{r,t}^*$. 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 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 11 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 ($\gamma = 0$). 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.

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. In particular, including house prices or rents into the price index leads the monetary authority to react less strongly to the shock, as the weight on the goods inflation is now smaller and the housing prices do not react as much. As a consequence, the economy gets expanded less leading to smaller responses in the house price, in rent, and in output. 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 the monetary authority stabilizes more effectively the economy when responding to rent inflation relative to house price inflation. This is because rent inflation picks up more after the monetary policy shock relative to house price inflation, meaning that for the Taylor rule to hold the equilibrium interest rate responds less stimulating the economy more weakly.

In Figure 12 I repeat the exercise but assume that the monetary authority reacts to Spain house price and rent instead. That is, the relevant inflation index used in the Taylor

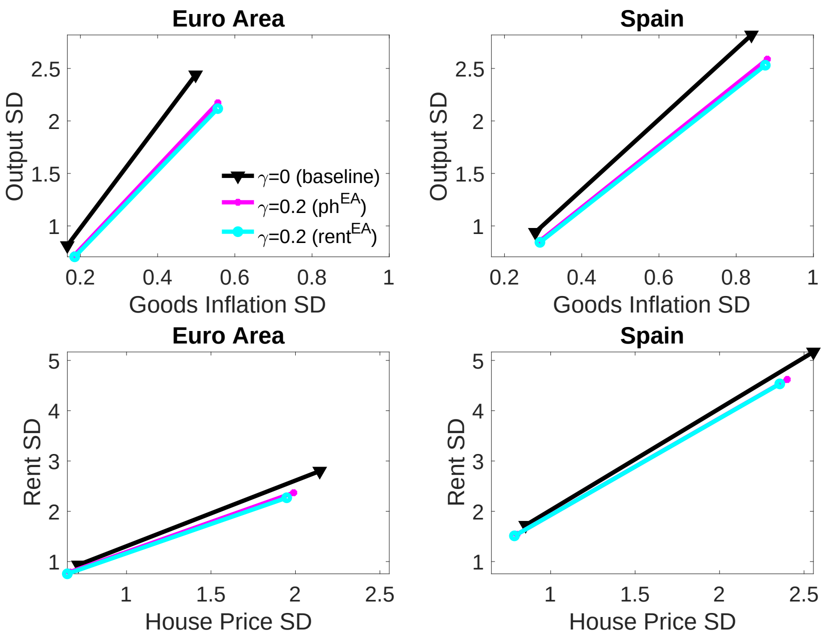


Figure 11: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (8) that include the term in equation (14) under expansionary monetary policy shocks of different sizes.

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 ($\gamma = 0$).

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 strong 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 more effectively.

In Appendix A.5 I repeat the same exercises but for the inflation target shock of the Taylor rule (7). Differently from the monetary policy shock, in this case the monetary authority faces a less favorable trade-off between output and prices. Output does not necessarily get stabilized relative to the baseline case, but goods inflation always increases its volatility. At the same time, while house price and rent inflation get stabilized (not shown), the house price and rent actually increase their volatility. Furthermore, responding

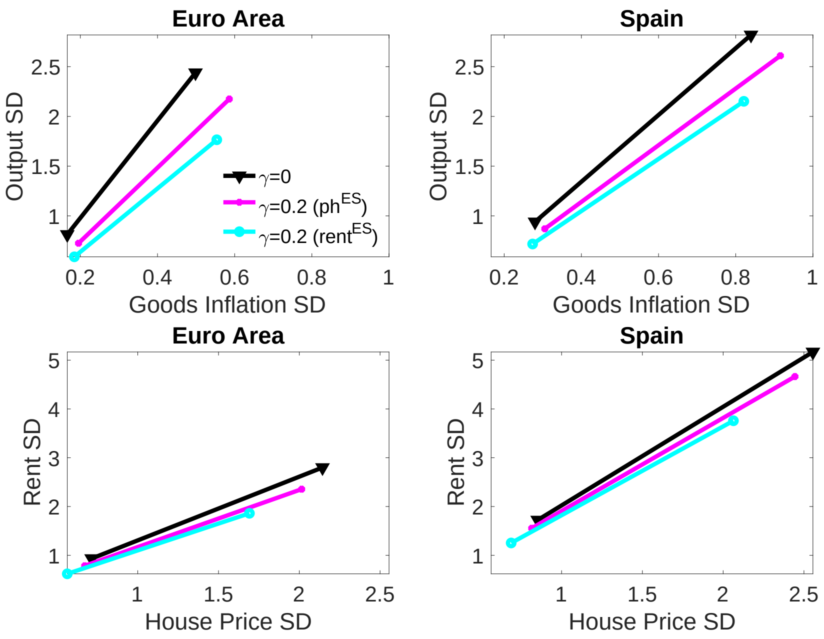


Figure 12: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (8) that include the term in equation (15) under expansionary monetary policy shocks of different sizes.

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 ($\gamma = 0$).

to house prices instead than to 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.

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 understand the volatility of house price and rent inflations for monetary shocks of different nature. For example, a conventional monetary policy shocks 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 relative to 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 relative to 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, it is far less obvious how they might matter for the 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 ARM shares and HoR for the transmission to aggregate economic activity.

The model built in the paper is a useful laboratory to analyze policy-relevant counterfactuals. I show that different forms of banking union weaken the monetary transmission mechanism, especially so if countries share similar mortgage market institutions such as the ARM share. 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 (subsidies, 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.

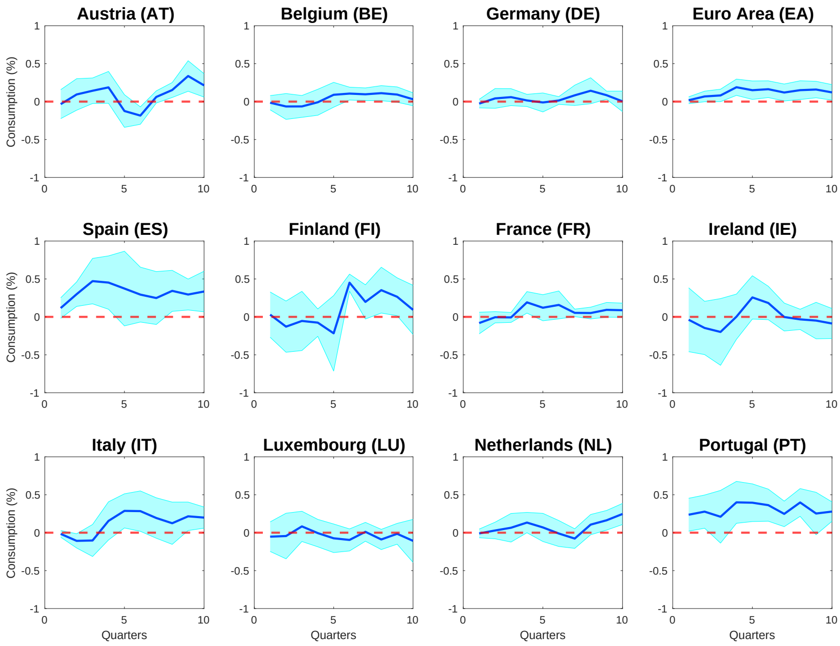


Figure A.1: Impulse response functions of aggregate consumption to an expansionary monetary policy shock of one standard deviation.

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.

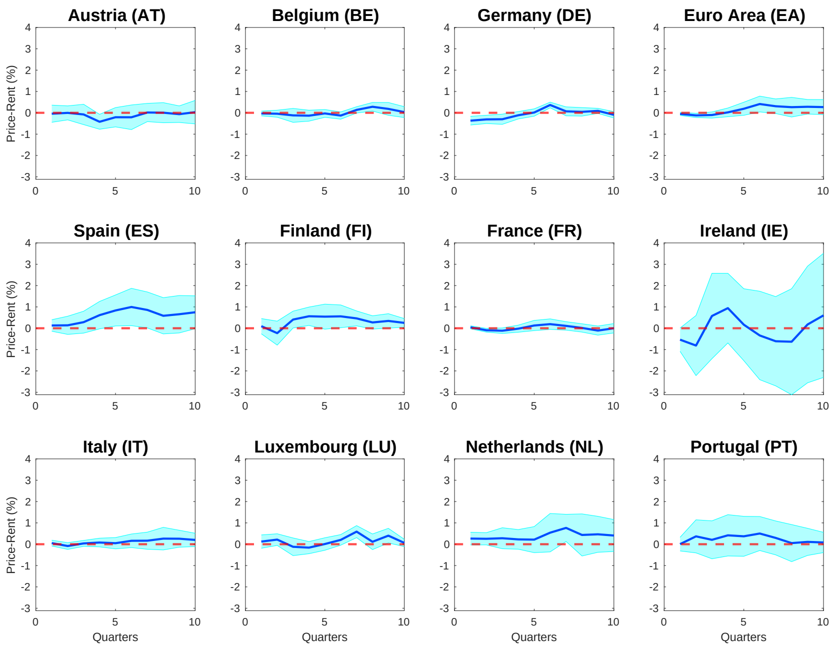


Figure A.2: Impulse response functions of price-to-rent ratios to an expansionary monetary policy shock of one standard deviation.

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.

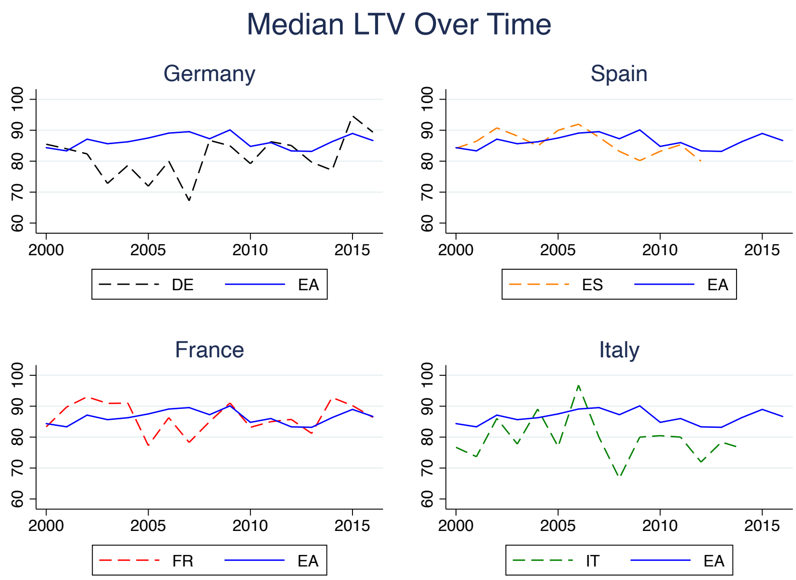


Figure A.3: Median Loan-to-Value ratios for four euro area countries since the early 2000s. *Note*: Calculations are based on the Eurosystem Household Finance and Consumption Survey.

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[23][24]. 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 severely. Comparing the reactions to the conventional analysis of this section with the reactions to the unconventional analysis of Section 2.2 shows some differences in

[23]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.

[24]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 higher terms of OIS changes.

magnitudes. In particular, countries react more following conventional policy shocks, which can be observed by comparing reactions to newly issued mortgages in Figure A.6 to those of Figure 1. 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 share of ARM as well as HoRs.

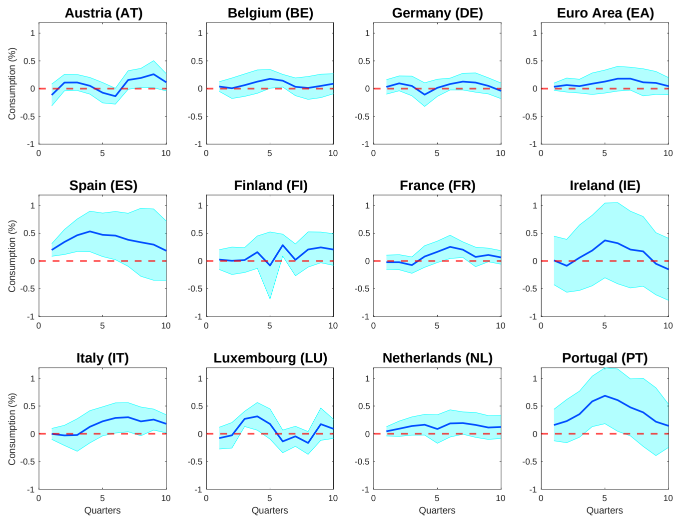


Figure A.4: Impulse response functions of aggregate consumption to an expansionary monetary policy shock of one standard deviation.

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.

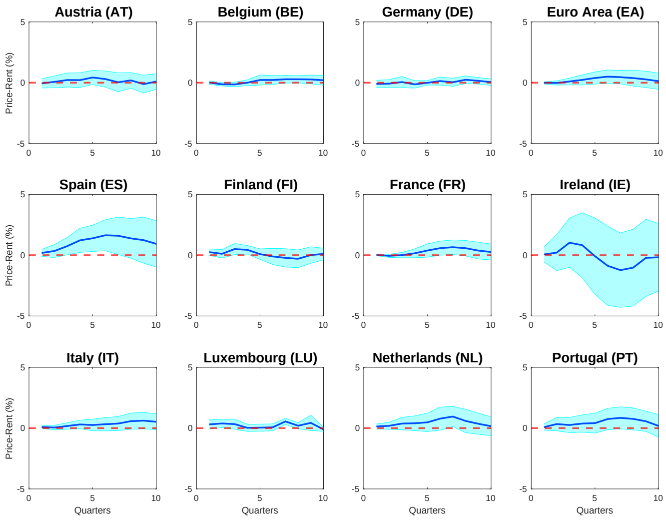


Figure A.5: Impulse response functions of price-to-rent ratios to an expansionary monetary policy shock of one standard deviation.
Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard errors. The estimation is performed over the period 2000 Q1 to 2016 Q4, with the 1Y OIS changes as identified monetary policy shocks.

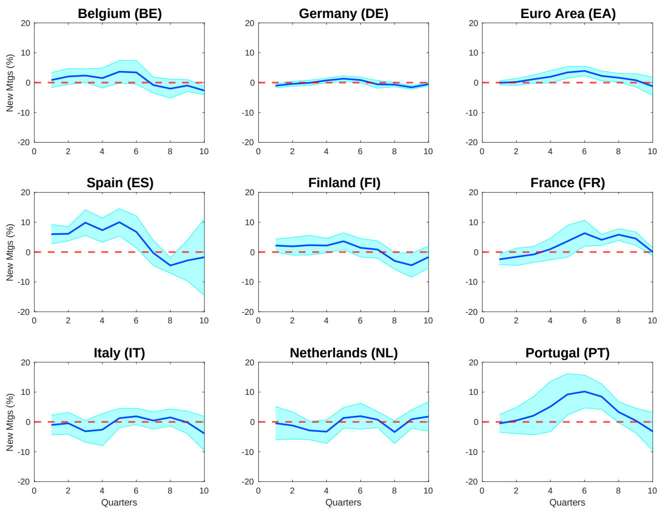


Figure A.6: Impulse response functions of newly issued mortgages to an expansionary monetary policy shock of one standard deviation.
Note: For each country, the response is estimated using equation (1). The light blue shaded areas represent the 95% confidence intervals constructed using Newey-West standard 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.

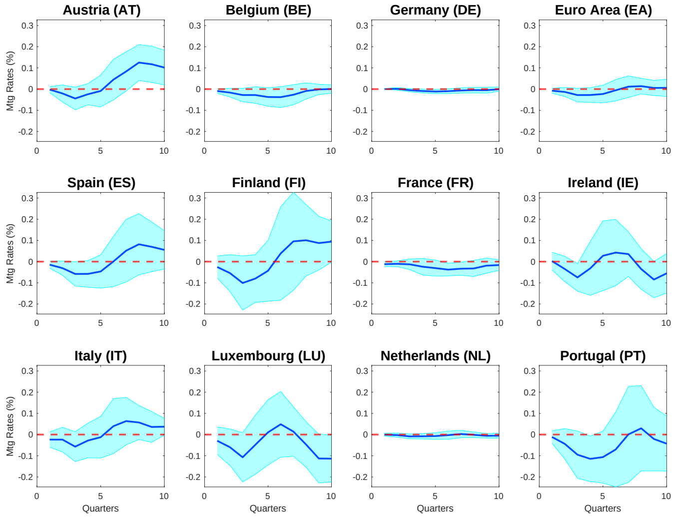
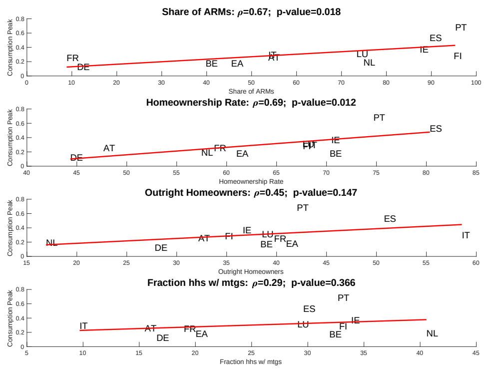
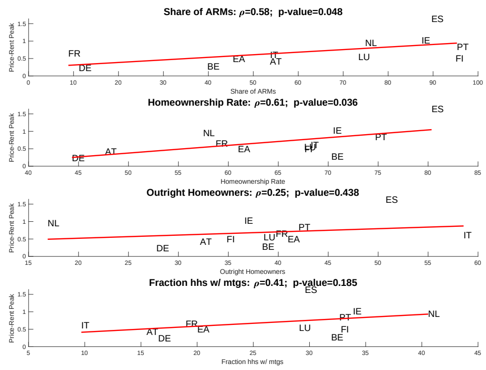


Figure A.7: Impulse response functions of outstanding mortgage interest rates to an expansionary monetary policy shock of one standard deviation.

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.



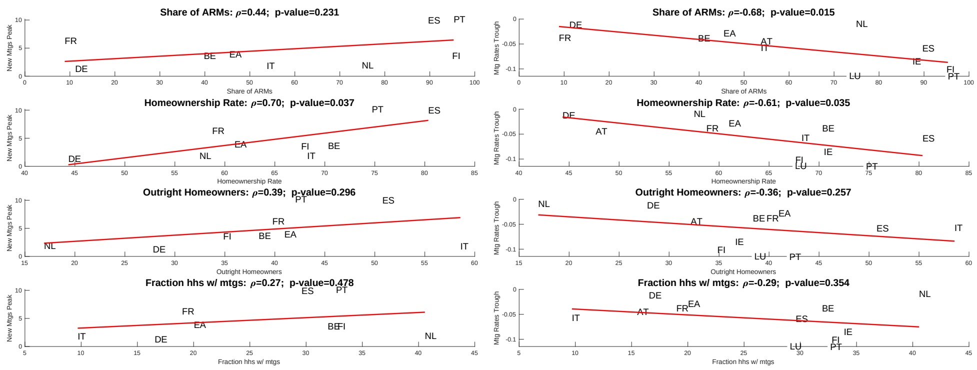
(a) Consumption Peaks



(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 shares of ARM and 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 shares of ARM and 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). The main consideration to draw from this exercise is that, 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 mortgage interest rate on new mortgages is weak even in ES, where most of the mortgages are adjustable-rate. Therefore, the average mortgage interest rate moves very little, reaching a peak of less than 0.1% on impact on the EA.

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 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.

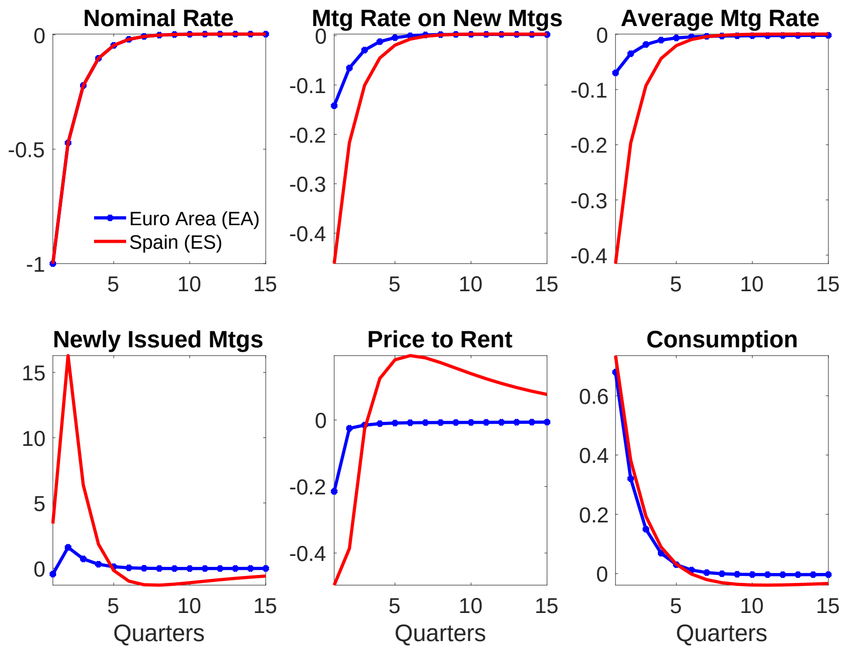


Figure A.10: Impulse response functions to a monetary policy shock normalized to a 1% fall in the nominal interest rate, both for the euro area (EA) and Spain (ES).

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

A.5 Trade-Offs Under Inflation Target Shocks

Figure A.11

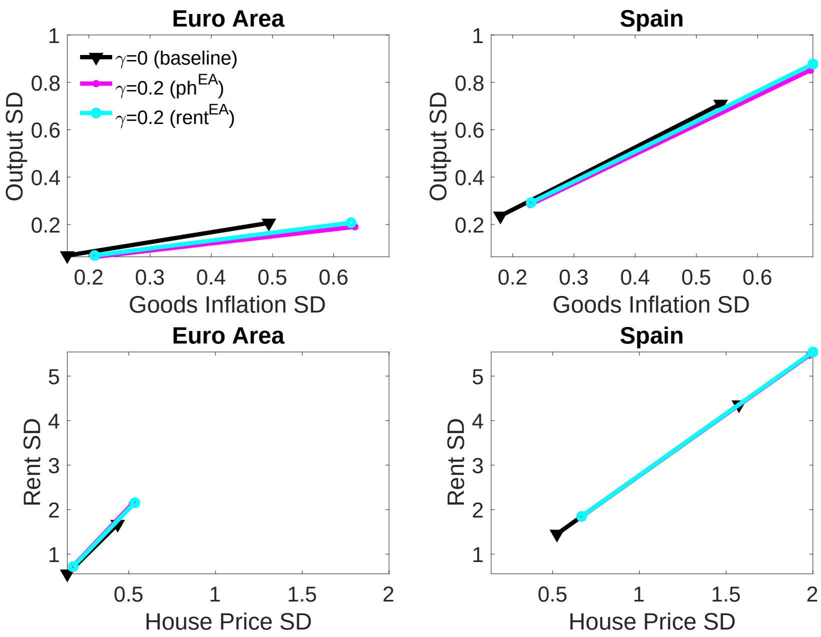


Figure A.11: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (7) that include the term in equation (14) under expansionary inflation target shocks of different sizes.

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*

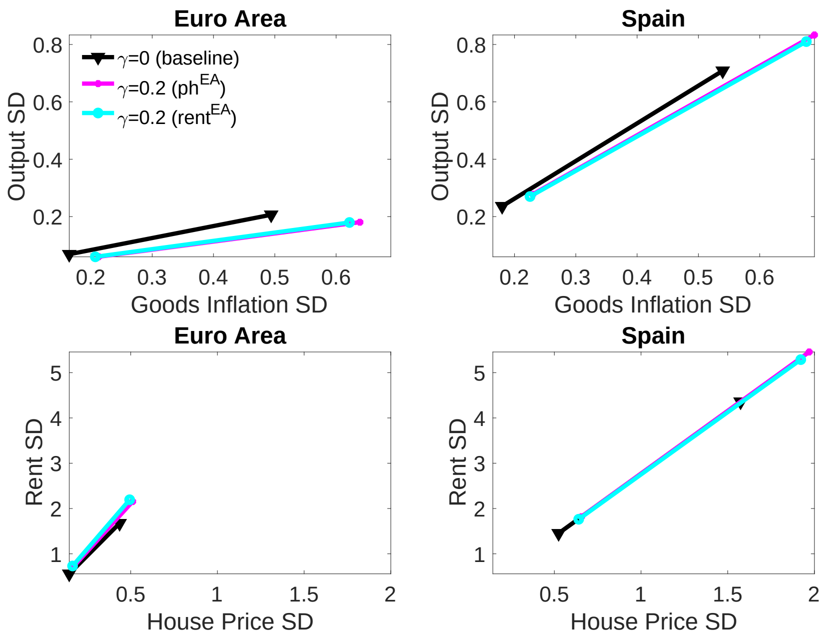


Figure A.12: Trade-offs between output, goods inflation, house price, and rent for different Taylor rules (7) that include the term in equation (15) under expansionary inflation target shocks of different sizes.

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 ($\gamma = 0$).

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 $\mathcal{C}_t = \mu_t \theta_{LTV}$, 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:

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

Finally, the assumption that the savers of both economies have access to international complete markets for state-contingent assets leads to the standard formula of international risk sharing:

$$u^{*,c}_{s,t} = u^c_{s,t} Q_t \tag{C.7}$$

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.

C.1.3 Landlord Solution

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

$$p_{h,t} = E_t \Lambda^s_{t,t+1}[p_{r,t+1} + \bar{\omega}_{l,t} + p_{h,t+1}(1-\delta)] \tag{C.8}$$

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:

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

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 full proof will be made available in the next draft.

C.3 The Home-Foreign Structure

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:

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

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

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).