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Differences in Euro-Area Household Finances and their Relevance for Monetary-Policy Transmission

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Abstract

This paper quantifies the extent of heterogeneity in consumption responses to changes in real interest rates and house prices in the four largest economies in the euro area: France, Germany, Italy, and Spain. We first calibrate a life-cycle incomplete-markets model with a liquid financial asset and illiquid housing to match the large heterogeneity of households asset portfolios, observed in the Household Finance and Consumption Survey (HFCS) for these countries. We then show that the heterogeneity in household finances implies that responses of consumption to changes in the real interest rate and in house prices differ substantially across the analyzed countries, and across age groups within these countries. The different consumption responses quantified in this paper point towards important heterogeneity in monetary-policy transmission within the euro area.

Keywords: European household portfolios, consumption, monetary policy transmission, international comparative finance, housing.

JEL-codes: D14, D15, D31, E21, E43, G11

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1 Introduction

Differences in household finances are large across the euro area. Table 1 shows that less than 20% of households are renters in Spain. In contrast, more than 50% of households rent their home in Germany. The differences in home ownership imply that the portfolios of Spanish households are much more tilted towards illiquid housing assets which are costly to adjust, increasing the country-specific exposure to housing busts.

This paper analyzes the consequences of the observed differences in household portfolios for the responses of non-housing consumption to changes in the real interest rate and relative house prices. To the best of our knowledge, we are the first to quantify the effect of household finances on these responses for the euro area in a structural model that allows to account for the observed differences in household finances within and across countries.

The size of the consumption response to changes in the real interest rate is crucial for monetary-policy transmission. For instance, a change in the nominal policy rate set by a central bank changes the real interest rate due to price rigidities in a canonical New-Keynesian representative-agent model – which would abstract from the heterogeneity of consumers we consider here. If framing monetary-policy analysis in such a canoncial model, the trade-off in the timing of aggregate consumption, as mirrored in the Euler equation of the representative consumer, will induce consumption responses resulting from intertemporal substitution.

We inspect the transmission from changes in the real interest rate to non-housing consumption in more detail by using a life-cycle incomplete-markets model, i.e., a model where heterogeneous households face uninsurable risk. This model generates endogenous distributions of consumption, asset holdings and debt positions across households in the economy, which is central to the analysis in this paper. We find that the non-housing consumption responses to unexpected changes in the real interest rate, implied by the model, are quite different across euro-area countries. A decrease of the real interest rate from 3% to 2% increases non-housing consumption by 1 percentage point more in Italy than in France, for example. The cross-country differences in consumption responses are magnified if the decrease in the real interest rate is accompanied by an increase in the relative price for housing.

We find that the difference in the consumption responses between France and Italy to changes in the real interest rate almost vanish if we control for differences in household portfolios at the time of the shock. This points to heterogeneity in monetary-policy transmission across the euro area resulting from differences in household finances and illustrates a limitation of uniform monetary policy across the euro area. Our results suggest that there is scope for beneficially complementing monetary policy with country-specific fiscal policy. Such coordination between monetary and fiscal policy may also help to address the distributional effects across age groups that we find for each of the analyzed euro-area countries.

The size of the consumption responses to changes in the relative house price have received considerable attention after the housing busts associated with the Great Recession in the U.S. and the subsequent economic crises in euro-area countries such as Spain. Our model implies that a fall of the relative house price by 10 percent, on impact, implies an elasticity of consumption with respect to the relative house-price change between 0.14 for Germany and 0.22 for Spain. These elasticities are quite similar to the model-implied elasticity of 0.2 in Kaplan et al. (2017) for the U.S. but below the range of empirical estimates for the U.S. of 0.25 to 0.4 obtained in Kaplan et al. (2016a) or 0.6 to 0.8 in Mian et al. (2013).

We use a model for computing the consumption responses to price changes because the Household Finance and Consumption Survey (HFCS) contains very detailed information on household balance sheets but only information on food consumption. Furthermore, the HFCS is a recent survey for the euro area whose structure largely follows the Survey of Consumer Finances (SCF) in the U.S. The HFCS currently only has two waves so that its panel component is still quite limited and empirical estimation of consumption responses would be problematic. Our approach is thus to build a model that captures the observed heterogeneity in household finances, on which we have detailed data. Using the model we have built, we then infer consumption responses.

Our analysis proceeds in the following steps. In Section 2, we construct a model of households' portfolio choices, allowing for a liquid financial asset and an illiquid housing asset. Our model captures key dimensions of heterogeneity observed in the HFCS

	Germany	France	Italy	Spain
Wealth composition				
Housing wealth (main residence)	66,655	92,192	117,298	116,016
+ Financial assets	83,250	81,506	69,261	76,839
= Net worth	149,905	173,698	186,559	192,855
Rental rate (percent)	53.6	41.7	32.1	17.2
Labor income (incl. transfers)	24,596	20,731	19,011	15,854

Table 1: Household finances in the euro area
Notes: Means for households aged 26-75. Units for wealth and income are euro per adult equivalent.
Source: Authors' calculation based on the first wave of the Household Finance and Consumption Survey (HFCS), 2007–2010.

for euro-area countries. In the solution of our model we allow for continuous portfolio choices to accurately capture the portfolio positions for the liquid financial asset and illiquid housing, which is important for computing the implied consumption responses.

In Section 3, we calibrate the model accounting for cross-country differences in pay-as-you-go pensions, taxation and social transfers, age profiles and risk of labor income, and demographics. The calibration ensures that we match the observed means for financial assets, housing and the rental rate (i.e., the complement of the homeownership rate) for the four largest euro-area countries displayed in Table 1: France, Germany, Italy and Spain. These countries account for three quarters of GDP in the euro area and are characteristic examples for the observed heterogeneity in household finances across the euro area.

In Section 4, we then compute the non-housing consumption response after an unexpected change in the real interest rate or the relative house price for these four countries. We consider different scenarios, in some of which we allow both the real interest rate and the relative house prices to change jointly. An important contribution is that we quantify the extent to which cross-country differences in household finances affect the transmission of unexpected changes in the real interest rate and the relative house price to non-housing consumption.

1.1 Related literature

Our paper contributes to the literature on differences in household finances and consumption responses to unexpected changes in real interest rates or relative house prices. Heterogeneity in household finances arises in our model because markets are incomplete so that agents cannot fully insure shocks to their earnings. In such an economic environment, for example Carroll et al. (2017) have demonstrated that agents with different wealth have very different marginal propensities to consume. Aggregate responses of consumption to shocks thus depend on the distribution of wealth.

In our paper we account for further heterogeneity in the composition of wealth because the data reveals substantial heterogeneity in home ownership across euro-area countries (see Table 1). Kaplan and Violante (2014) have shown that the marginal propensity to consume crucially depends on the extent to which wealth consists of illiquid (housing) wealth or liquid (financial) assets. The marginal propensity to consume out of changes in income determines the size of the consumption response to changes in the interest rate and in relative house prices. See Auclert (2017) and Berger et al. (2017), respectively. Thus, differences in household finances, which change the marginal propensity to consume, also change the consumption responses to price shocks.

Auclert (2017), Kaplan et al. (2016b) and Wong (2018) have investigated the distributional and aggregate effects of unexpected changes in the *nominal* interest rate on consumption for the U.S. Cloyne et al. (2015) compare the respective consumption responses in the U.S. and the U.K., and Jappelli and Scognamiglio (2018) provide evidence for Italy. We contribute to this literature by analyzing the consumption responses to changes in the interest rate for the euro area. We are particularly interested in how the observed differences in household finances across the euro area shape the transmission of unexpected changes in the interest rate to consumption. An important difference is that we focus on consumption responses to the *real* interest rate.

This response is an important part of monetary-policy transmission in general. For our special focus on cross-country and within-country heterogeneity, this is the key part. It separates the effects of cross-country heterogeneity in consumer finances from the potential influence of cross-country differences in expected inflation. In the case of open economies within a monetary union, country-specific price dynamics would need to be aligned with features such as cross-country flows of goods and capital, country-specific labor market institutions, and country-specific reactions of fiscal policies. Such differences and their explanation are beyond the scope of the present paper.

Our finding that the consumption responses to changes in the real interest rate are larger for younger agents in the euro area, is qualitatively similar to results in Wong (2018) for the U.S. An unexpected fall of the real interest rate thus reduces consumption inequality in our model, consistent with the empirical finding by Coibion et al. (2017) for the U.S. who show that contractionary monetary policy increases consumption inequality.

Beraja et al. (2017) uncover regional heterogeneity in the transmission of changes in the interest rates to consumption for the U.S. They show that a lower interest rate in the Great Recession benefited those regions more in which households held higher home equity. These households were able to take advantage of the lower interest rates by refinancing the mortgage while this option was not available to households with low or even negative home equity. This channel is also present in our analysis of the euro area. Because mortgage lending has been much more restrictive in the euro area with loan-to-value ratios below 80%, households have positive home equity and potentially can take advantage of refinancing. An important difference to the U.S. is, however, that refinancing is more costly in the euro area. We abstract from modeling this in our current analysis and plan to investigate it in future research.

The quantitative analysis of Hedlund et al. (2016) for the U.S provides further evidence that the transmission of monetary policy depends on the distribution of housing and debt. Based on a New Keynesian model with heterogeneous agents, they find that the transmission of monetary policy depends on the leverage of households because households with high loan-to-value ratios have higher marginal propensities to consume. They further show that the effect of changes in interest rates on consumption are amplified by their effect on house prices. In our experiments we also find amplification of the consumption responses in the considered euro area countries if, for example, a decrease in the real interest rate is accompanied by an increase in the relative house price. Our analysis of the consumption response to changes in relative house prices builds on the work by Berger et al. (2017) and Kaplan et al. (2017) who analyze the consumption response to changes in house prices in the U.S. stimulated by the seminal empirical analysis of Mian and Sufi (2011) and Mian et al. (2013).

Recent empirical work by Calza et al. (2013) and Corsetti et al. (2018) reveals heterogeneity in the monetary policy transmission to aggregate consumption and house prices across countries in the euro area. The heterogeneity is associated with differences in the housing market.[1] We build a structural model that allows us to inspect parts of the monetary-policy transmission in detail. We focus on how the differences in household finances within and across the considered four euro-area countries shape the transmission of changes in the real interest rate and the relative house price to consumption.

An important related literature has tried to uncover the determinants for the large observed differences in household finances. Guiso et al. (2003) document and analyze the differences in stock-market participation between the U.S. and European countries. Christelis et al. (2013) decompose the observed differences in household finances across the U.S. and European countries into differences resulting from the economic environment and from population characteristics. They find that differences in the economic environment are important to explain the observed differences in household finances across European countries which we try to capture in our calibration. Arrondel et al. (2016) and Bover et al. (2016) have performed similar decompositions based on the HFCS to understand the heterogeneity of assets and liabilities of households in the euro area. Adam and Zhu (2016) and Adam and Tzamourani (2016) build on the seminal paper by Doepke and Schneider (2006) for the U.S. and assess empirically the distributional effects of inflation and asset-price changes resulting from the heterogeneity in wealth across euro-area countries observed in the HFCS.

Taking a more structural approach based on a calibrated quantitative model with heterogeneous agents, Pham-Dao (2016) investigates the effect of differences in the social security systems across euro-area countries on wealth inequality. Kindermann and Kohls (2016) analyze the extent to which differences in rental-market efficiency in the euro area can explain differences in home ownership where higher homeownership rates imply lower wealth inequality. Kaas et al. (2017) argue that lower transaction costs for housing in the U.S. compared with Germany are an important factor for explaining the higher

[1] Calza et al. (2013) also provide a New-Keynesian DSGE model with two types (borrowers and savers) to interpret their empirical findings. See their paper for further references to the literature on housing markets within this framework.

homeownership rates in the U.S. Our structural approach is similar to these papers but we focus on the question of what the observed differences in household finances imply for the transmission of price changes to consumption. In our calibration of the model we find, as Kindermann and Kohls (2016) and Kaas et al. (2017), that differences in transaction costs and rental efficiency are important to match the differences in home ownership across the four analyzed euro-area countries. In line with Pham-Dao (2016), we account for differences in the design of social security across euro-area countries in the calibration.

2 The model

The model we use for our analysis is an instance of the common reference model for European household finances suggested by Hintermaier and Koeniger (2016). Our description here is organized according to the generic structure proposed there. This section describes all building blocks of the model and its features. The specific choices of parameters used for the quantitative analysis – and, in particular, country-specific differences in the relevant parameters – are discussed in Section 3.

Preferences

This building block specifies the time horizon and the preferences over consumption streams. The relevant consumption items for our analysis are nondurable consumption and housing services obtained by choosing either to own or to rent housing. We use a life-cycle model with J periods, indexed by $j = 1, \ldots, J$. Households maximize their expected utility over the life cycle. Expected lifetime utility is

$$\mathbb{E}_0\left[\Sigma_{j=1}^{J}\beta^{j-1}\sigma_j u(c_j, \hat{s}_j)\right]$$

with β denoting the discount factor, σ_j the probability of surviving up to age j and c_j the nondurable consumption at age j. The flow of housing services for owners of a house of size h_{j+1} is

$$\hat{s}_j = \phi \hat{h}_{j+1} \ .$$

If choosing to rent a house, the service flow is related to the rented housing quantity $\hat{f}_j$ by

$$\hat{s}_j = \phi_R \hat{f}_j \ .$$

We assume a utility function that is log-separable in non-housing consumption and housing services:

$$u(c_j, \hat{s}_j) = \theta \log c_j + (1-\theta) \log\left(\hat{s}_j\right) \ .$$

Earnings and Portfolio items

For the purpose of introducing the model, it is useful to present these two building blocks jointly. They are visible in the following budget constraints, relying on the previously mentioned distinction of renters and homeowners.

An important difference between rented and owned housing is that the quantity of owned housing can only be adjusted at a cost. To generate inaction ranges and lumpy adjustment patterns, we specify an adjustment cost function that has a fixed-cost component[2] (needed for lumpiness) and a variable component that is proportional to the stock sold or bought with p_t denoting the relative price of housing:

$$\alpha_{p,j}(\hat{h}_j, \hat{h}_{j+1}) = \alpha_{0,j} + \alpha_1 p_t \hat{h}_j + \alpha_2 p_t \hat{h}_{j+1},$$

if the household adjusts to a new quantity of owned housing at age j, coded in terms of a discrete decision as $d_j = 1$. This cost structure is motivated by two components: $\alpha_1 p_t \hat{h}_j$ from selling $\hat{h}_j$, and $\alpha_{0,j} + \alpha_2 p_t \hat{h}_{j+1}$ from purchasing $\hat{h}_{j+1}$. In any situation where a household decides to adjust his quantity of owned housing, such an adjustment will always result in a positive quantity $\hat{h}_{j+1}$. This is a consequence of the utility function specified above. Accordingly, when deciding to adjust to a new quantity of owned housing, such a decision will always entail triggering both the selling and the purchasing components of adjustment costs.

If the household decides not to adjust the existing quantity of owned housing, coded as $d_j = 0$, he does not incur adjustment cost.

If the household decides to rent, coded as the discrete decision $d_j = 2$, this precludes owning (a positive quantity of) housing, meaning that $\hat{h}_{j+1} = 0$. Accordingly, when making such a choice, the household faces the adjustment cost component of the selling branch but is inactive on the purchasing branch, resulting in an adjustment cost of the form

$$\alpha_{pR}(\hat{h}_j) = \alpha_1 p_t \hat{h}_j.$$

A household starts with given initial levels of financial assets a_1 and of owned housing $\hat{h}_1$. Each period a household makes the discrete choices of renting versus owning, and of adjustment versus non-adjustment.

[2]Allowing for age-dependence of the fixed cost component $\alpha_{0,j}$ is useful for situations with real income growth over calendar time. The adjustment of fixed costs over the individual life-cycle is made to simultaneously achieve the following properties in the model: First, we want to assure that individuals from different birth cohorts face the same terms when they are active on a market at a specific point in calendar time. Second, we want to assure that a single solution of the individual life-cycle choice problem is applicable to members of any cohort, independently of the time of birth. Our approach ensures that both of these properties are obtained, once the problem is considered as normalized by different units of account across cohorts.

If the household chooses to consume housing as an **owner, not adjusting** his housing stock, coded as $d_j = 0$, the following relations apply:

$$\hat{h}_{j+1} = \hat{h}_j,$$

and the budget constraint

$$c_j + a_{j+1} = y_j(s_j) + (1+r)a_j.$$

Uncertainty of earnings is captured by a Markov process, with discrete states $s \in S$, and transition probabilities denoted by $\pi_{s,s'}$, such that for all s we have that $\sum_{s' \in S} \pi_{s,s'} = 1$. We denote the idiosyncratic (household-specific) realization of the Markov state at age j by s_j.

The budget constraint thus takes into account the exogenously given endowment of earnings $y_j(s_j)$ at age j, and the choice of financial assets a_{j+1}. Earnings in the model during working age capture labor earnings after taxes and transfers, and during retirement they capture public pensions net of taxes. During working age, labor earnings are stochastic. The idiosyncratic background risk cannot be fully insured and thus matters for the life-cycle profile of asset accumulation. To accurately capture this effect, as further explained in Section 3, we will calibrate the earnings variables for each country and obtain country-specific life-cycle profiles and risk resulting from country-specific features of pay-as-you-go pensions, taxation and social security.

Asset accumulation is also restricted by a collateral constraint that limits borrowing:

$$a_{j+1} \geq -\mu p_t \hat{h}_j - g_{y,j+1},$$

where the parameter μ represents the loan-to-value (LTV) ratio and we have used $\hat{h}_{j+1} = \hat{h}_j$ given that we consider the constraint for a household who does not adjust the housing stock. The parameter $g_{y,j+1}$ denotes those pledgeable resources which are not related to asset holdings.

If the household chooses to consume housing as an **owner, adjusting** his housing stock, coded as $d_j = 1$, the budget constraint becomes

$$c_j + a_{j+1} + p_t \hat{h}_{j+1} + \alpha_{p,j}(\hat{h}_j, \hat{h}_{j+1}) = y_j(s_j) + (1+r)a_j + p_t \hat{h}_j,$$

and the collateral constraint reads

$$a_{j+1} \geq -\mu p_t \hat{h}_{j+1} - g_{y,j+1}.$$

Note that these expressions feature the items available for portfolio choice between the financial assets a_{j+1} and the housing asset h_{j+1}, as well as the financial constraint depending on these endogenously chosen portfolio positions.

If the household chooses to consume housing as a **renter**, coded as $d_j = 2$, the budget constraint reads

$$c_j + a_{j+1} + q_t \hat{f}_j + \alpha_{pR}(\hat{h}_j) = y_j(s_j) + (1+r)a_j + p_t \hat{h}_j,$$

and the collateral constraint simplifies to

$$a_{j+1} \geq -g_{y,j+1}.$$

Rental prices are assumed to be in a constant relation to prices for ownership, which we describe by

$$q_t = kp_t,$$

where the constant fraction k is referred to as a *rent-to-price ratio*.

In Appendix A we explain how we solve this model based on its recursive formulation.

3 Calibration

We calibrate the model to match the large differences in household finances across the euro area, documented in Table 1. As shown in Table 2, we allow for differences across countries in the pension and tax systems, survival probabilities, labor-income profiles and labor-income risk, transaction costs for housing, rent-to-price ratios and three preference parameters. Table 7 in Appendix B documents all other parameters that are common across countries in the calibration.

The strategy of our calibration is to explain the differences in household finances as much as possible by differences in the economic environment that have a counterpart in our model. We then explain any remaining differences with a country fixed effect that is captured in the model by differences in the following preference parameters: the discount factor β, the weight of non-housing consumption in the consumption basket θ and the rental efficiency in retirement determined by the service-flow rate out of rental housing ϕ_R^{ret}.

We account for key differences in the economic environment that influence household finances by changing incentives for asset accumulation and portfolio choices, for example, by altering the strength of the precautionary or retirement saving motives. Details on how we implement country-specific pension and tax systems, age-income profiles, and fees on real estate transactions are contained in Appendix B.

We calibrate differences in the pay-as-you-go component of the pension systems using information on the adjustment factor for pre-retirement earnings (the valorisation rate) and the number of earning years used for the calculation of retirement benefits, the growth of benefits during retirement and the net-replacement rates at different levels of net earnings documented in OECD (2007).[3] We compute pension benefits by computing the average income for the relevant pre-retirement earning years conditional on the last pre-retirement income draw. See Hintermaier and Koeniger (2011) for further details.

We account for differences in labor-income taxes across countries by following Guvenen et al. (2014). Based on the information in the OECD tax database on tax exemptions and tax rates at different levels of labor earnings, we convert the labor earnings, including transfers that we observe in the HFCS survey, into earnings after taxes and transfers.

We compute the country-specific age profiles and standard deviations of earnings after transfers by regressing the logarithm of these earnings on a quartic age polynomial.[4] The assumption of a Markov chain with an autocorrelation of 0.95 then implies the standard deviations of the innovations reported in Table 2 to match the variance of the residuals obtained from these regressions for each country. The values are broadly in line with findings reported in table 2 of Pham-Dao (2016) who reports estimates based on the EU-SILC dataset, and with the variances of earnings based on national datasets reported by Fuchs-Schuendeln et al. (2010) for Germany, Jappelli and Pistaferri (2010) for Italy and Pijoan-Mas and Sanchez-Marcos (2010) for Spain.

We allow for country-specific transaction costs for housing and rent-price ratios which influence the portfolio choice between housing and liquid financial assets and the choice between home ownership and rental.[5] The costs also contain transaction taxes in the euro area countries we consider and are typically borne by the purchaser. The taxes imply that the values displayed in Table 2 are considerably higher than in the U.S. where housing transaction costs due to fees for real-estate agents typically amount to 2.5% of the transacted value.

All other parameters in the model are set to common values across countries. Their values are summarized in Table 7 in Appendix B. The real interest rate is set to 3% and we assume stable relative house prices. The maximal value of the loan-to-value ratio μ is set to 0.8, in line with common practice of lenders in the euro area. We restrict the loan-to-value ratio to a lower value of $\mu^{ret} = 0.2$ during retirement. This shall capture that mortgage contracts typically feature substantial amortization payments until retirement

[3]Pension savings that are contained in household-specific accounts are reported in the HFCS and thus part of the targeted net worth that we match in the model calibration.

[4]We convert the cross-sectional age profiles into life-cycle income profiles, accounting for cohort effects that result from average annual income growth of 1%.

[5]Kaas et al. (2017) emphasize the importance of transaction taxes to explain the lower home ownership rate in Germany compared to the U.S. Kindermann and Kohls (2016) find quantitatively sizable differences in the euro area for rental market efficiency. They quantify the wedge in the rental market between shelter provided by landlords and shelter received by renters that implies variation in rent-price ratios across countries.

	Germany	France	Italy	Spain
	Preferences			
β	0.9939	0.9984	0.9991	0.9959
θ	0.79	0.74	0.70	0.74
ϕ_R^{ret}	0.9	0.9	0.75	0.85
	Rent-to-price ratio			
k	0.0350	0.0353	0.0352	0.0371
	Proportional transaction cost			
α_2	0.075	0.08	0.085	0.105
	Life-cycle income process:			
	age profile			
	std.dev. of innovation			
$\sigma_{\text{innovation}}$	0.23	0.18	0.23	0.20
	Pension and tax systems			
	Survival probabilities			

Table 2: Country-specific calibrated parameters

Notes: Details on our implementation of country-specific pension and tax systems, age-income profiles, and fees on real estate transactions are contained in Appendix B. For common parameters across countries see Table 7 in Appendix B.

	Germany		France		Italy		Spain	
	Data	Model	Data	Model	Data	Model	Data	Model
Wealth composition								
Housing wealth	66,655	66,803	92,192	91,712	117,298	117,941	116,016	116,594
+ Financial assets	83,250	83,130	81,506	82,329	69,261	68,138	76,839	75,409
= Net worth	149,905	149,933	173,698	174,041	186,559	186,079	192,855	192,003
Rental rate (percent)	53.6	53.8	41.7	41.9	32.1	31.7	17.2	17.9

Table 3: Averages by country in the data and model predictions

in the euro area countries we consider, as documented in ECB (2009), p. 30, so that loan-to-value ratios are low empirically at the end of the life cycle.

The starting age in the model is age 24. Until retirement age 65, labor-income fluctuates stochastically around the deterministic age profile. Between ages 65 and age 85 agents receive a deterministic pension but have survival probabilities that are calibrated using mortality tables from Eurostat.[6] These probabilities are available until age 85 so that we let agents die after reaching that age.

We simulate the model for $120,000$ agents to compute model statistics. We draw from the initial distribution of net worth and housing wealth observed in the HFCS for households aged 20 to 30 and we draw the income shocks from the stationary distribution. We align the age composition across countries between the model and data by composing a synthetic survey for each country, based on the model solution and the weights for ages between 24 and 85 observed in the HFCS. When comparing the model with the data, we focus on agents between ages 26 and 75 because the predictions of the model become too sensitive to the certain death at age 85 for later ages. Agents between ages 26 and 75 account for 90% of the sample in the HFCS for the considered countries.

Table 3 shows that the model matches the averages of net worth, housing wealth and the rental rate very closely, given that we have complemented the key differences in the economic environment, that we have explained above, with some calibrated country-specific preference parameters and the rent-price ratio. Although the parameters are jointly calibrated, net worth is matched mostly by calibrating the discount factor β. The weight of non-housing consumption in the consumption basket θ allows to match the fraction of housing wealth in the portfolio and the rent-price ratio k helps to attain the targeted rental rate.

Table 2 shows that the model only requires notable differences in the preference parameter θ to match the country-specific data targets. The discount factor β and the rent-

[6]We use the mortality tables for the representative year 2009 which are available at http://ec.europa.eu/eurostat/web/population-demography-migration-projections/deaths-life-expectancy-data/database .

price ratio are rather similar across countries and the differences in ϕ_R^{ret} are relevant only for matching the age profiles of the rental rate, as we explain further below. Interestingly, the rent-price ratio implies values for its inverse, the price-rent ratio, between 27 and 29 across the four countries. These values are close to the empirical estimates for these countries reported in Kindermann and Kohls (2016), figure 29.[7]

Figures 1 and 2 show that the model predicts the age profiles of net worth, housing wealth, and the rental rate quite well. In order to match the age profile for the rental rate across countries, the model requires a lower ϕ_R^{ret} in Italy and Spain than in France and Germany. Without making rental less attractive during retirement for these two countries, the model would predict much more rental than empirically observed. We leave the question for further research in which way specific economic features might combine with cross-country cultural differences. The relevant combination may complement or partially substitute for the role played here by preferences in explaining why rental is seemingly less attractive in Italy and Spain during retirement.

4 Consumption responses

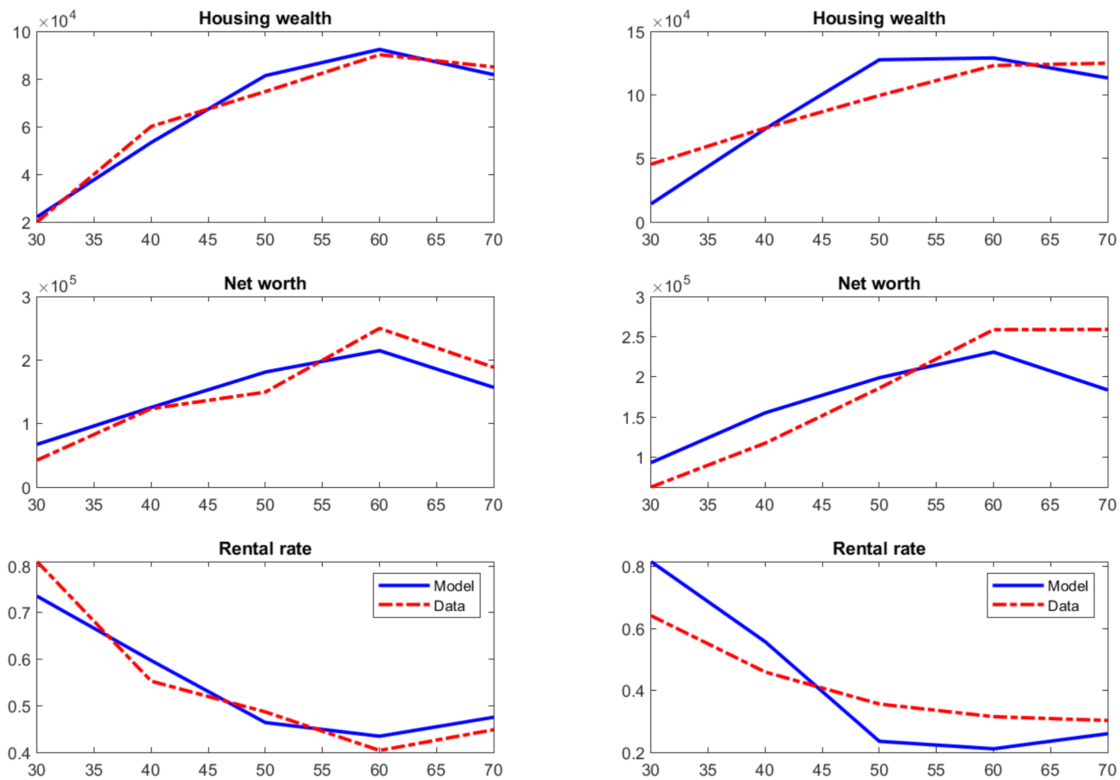
We use the model to compute responses of non-housing consumption to changes in the real interest rate and relative house prices. These responses are important for monetary-policy transmission and have received considerable attention for the U.S.[8] We find substantial heterogeneity of these responses across the major euro-area countries. This poses challenges for monetary policy that is common across these countries and suggests scope for complementing monetary policy with national fiscal policies to contain the distributional effect of changes in the real interest rate or relative house prices.

4.1 A fall in the real interest rate

Figure 3 shows the response of non-housing consumption in an experiment with a sequence of shocks, each of them being unanticipated and considered permanent while active: a reduction of the real interest rate by 1 percentage point from 3% to 2% which is reversed after five years. We assume that the reduction in the real interest rate is accompa-

[7] We have chosen to calibrate the rent-price ratio because the price comparison between rented and owned units may be confounded by quality differences. The true quality-adjusted rent-price ratio is unobserved. Nonetheless, it is comforting to see that the rent-price ratios implied by the model are in the same ballpark as their existing empirical counterparts. A rent-price ratio of 3.5% seems also plausible in our benchmark with stable relative house prices if one considers a user cost for owned housing that equals the sum of the real interest rate of 3% and a depreciation rate of 0.5%.

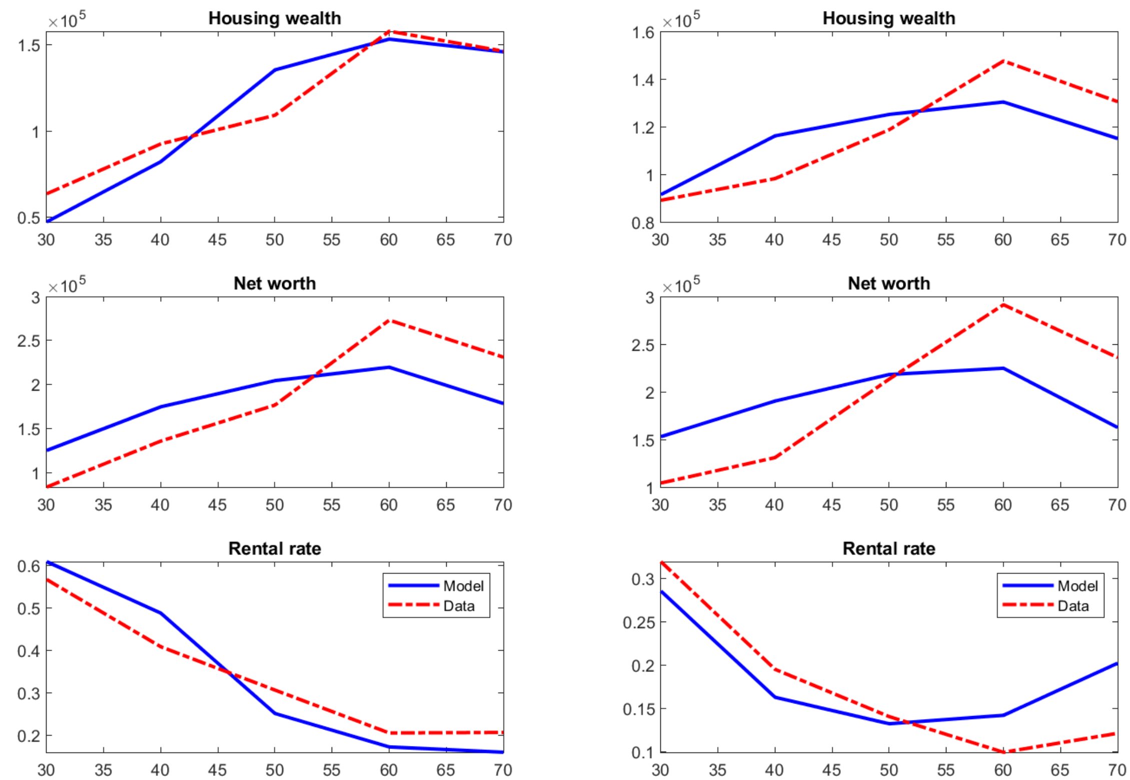
[8] See, for example, Auclert (2017), Berger et al. (2017), Beraja et al. (2017), Hedlund et al. (2016), Kaplan et al. (2017) and Kaplan et al. (2016b) for analyses on the U.S. and Cloyne et al. (2015) for evidence on the U.S. and the U.K.



(a) Germany (b) France

Figure 1: Age profiles for Germany and France: data (dashed line) and model predictions (solid line)

Notes: Averages for groups with ages 26-35, 36-45, 46-55, 56-65, 66-75. Units of net worth and housing are euro per adult equivalent.



(a) Italy (b) Spain

Figure 2: Age profiles for Italy and Spain: data (dashed line) and model predictions (solid line)
Notes: see notes for Figure 1.

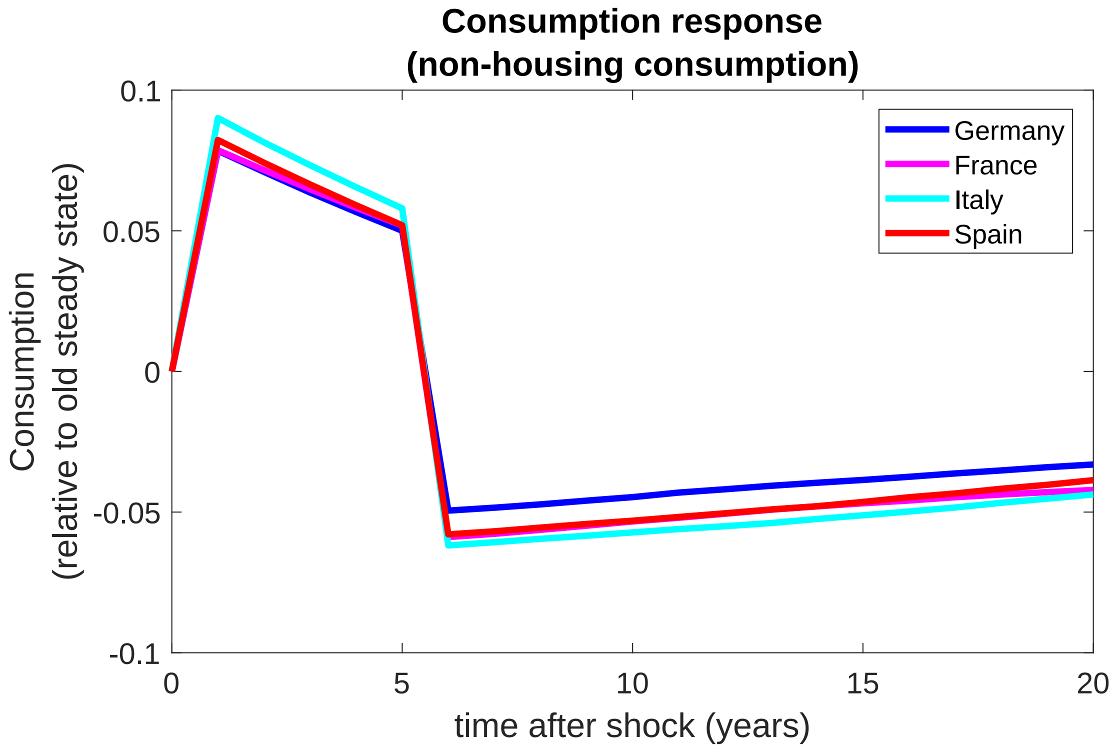


Figure 3: Unexpected fall of the real interest rate from 3% to 2%, with a contemporaneous reduction of the rent-to-price ratio by 1 percentage point (reversed after 5 years)

nied by an analogous reduction of the rent-to-price ratio by 1 percentage point, supposing that the lower user cost for housing is fully passed on to renters while the relative house price remains stable. For the responses displayed in Figure 4 we make the alternative assumption that the reduction of the rent-to-price ratio is driven by an increase of the relative house price. This then implies an increase of the relative house price between 35% and 40% across the considered countries.[9]

Figure 3 shows that a fall in the real interest rate by 1 percentage point increases non-housing consumption on impact between 7.9% in France and Germany and 9% in Italy. If accompanied by the relative house price increase between 35% and 40%, Figure 4 shows that the responses become larger and are between 14.2% in Germany and 18.6% in Italy.

The responses of non-housing consumption are large, possibly because the way the changes are implemented in the presented experiments implies that the changes in the real interest rate are expected to last forever – which, for real interest rates may be an extreme scenario. We also implicitly assume that borrowing households benefit from a lower interest rate, for example by refinancing their loan without cost. While this assumption is plausible for Italy and Spain where households have options to refinance loans at lit-

[9]The result of these two alternative experiments provide bounds for intermediate scenarios in which rents fall and house prices increase in response to a fall in the real interest rate. Such movement of prices is suggested by the empirical evidence for the euro area in Corsetti et al. (2018) who find that house prices fall and rents increase after an unexpected *increase* of the nominal interest rate.

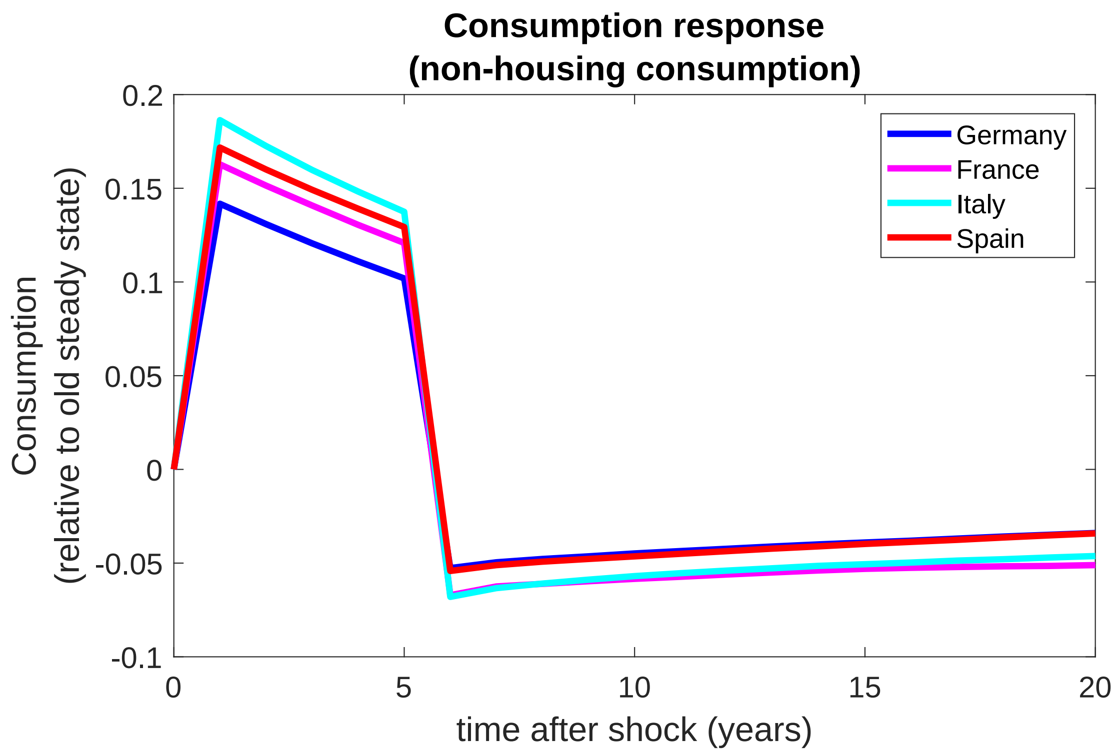


Figure 4: Unexpected fall of the real interest rate, with a contemporaneous reduction of the rent-to-price ratio by 1 percentage point and the implied maximal increase of the relative house price (reversed after 5 years)

tle cost and many mortgage contracts have variable interest rates, most households in France and Germany have mortgage contracts with fixed rates and have to make penalty payments when they refinance their mortgage (see ECB (2009), Calza et al. (2013) and Jappelli and Scognamiglio (2018)). The quantitative importance of these differences in mortgage finance across countries for the reported consumption responses is not obvious. The higher incidence of fixed-rate mortgages together with the higher cost of refinancing may dampen the response of (non-housing) consumption in France and Germany relative to Italy and Spain and thus may further increase the cross-country heterogeneity in consumption responses to changes in the real interest rate. We plan to investigate the quantitative importance of these assumptions in future work.

The experiments deliver interesting insights. The change in non-housing consumption is asymmetric when the changes are reversed after five years. Non-housing consumption then falls *below* its initial value. The reason is that the fall of the real interest rate induces large portfolio shifts from the financial asset, whose return has fallen, into housing (see Figure 5 for an illustration). Since housing can only be adjusted at a cost, this portfolio shift is not fully reversed at the time when the real interest rate returns to its initial value. As visible in Figures 3 and 4, non-housing consumption returns to its initial value very slowly. If we plotted the response for a longer time period after the shocks, it would

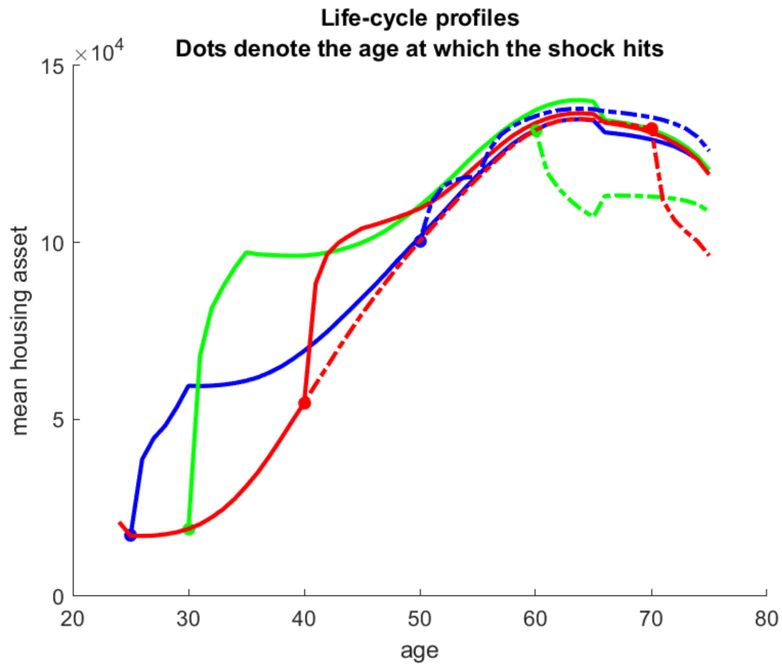


Figure 5: Life-cycle profiles of the housing asset in Germany for ages 26-75. Notes: profiles for different cohorts include age-specific responses after an unexpected fall of the real interest rate from 3% to 2%, with a contemporaneous reduction of the rent-to-price ratio by 1 percentage point (reversed after 5 years)

become apparent that consumption is close to its initial value only after more than 50 years.

The lesson from the experiments is that a fall in the real interest rate induces portfolio shifts towards the illiquid housing asset. This increases the responsiveness of non-housing consumption to changes in the real interest rate and thus can exacerbate the slump in non-housing consumption when a period with a low real interest rate comes to an end unexpectedly.

The experiments also reveal interesting differences across the age dimension. Figure 5 illustrates for Germany that while young agents shift their portfolio into housing wealth after the decrease in the real interest rate, older agents do the opposite and become renters. The intuition is that the lower real interest rate is accompanied by a lower rent-to-price ratio and owned housing has less collateral value during retirement because the loan-to-value ratio is restricted at 0.2 during retirement instead of 0.8 during the working age. Table 4 shows how the fall in the real interest rate translates into larger changes of non-housing consumption for younger agents in all considered euro-area countries. Age matters for the consumption response not only because young agents have a longer horizon but also because their asset positions vary with age. For example, the income effect on consumption after a fall in the real interest rate is positive for a borrower and negative

	Age				
	25	40	50	60	70
Consumption response on impact					
Germany	0.138	0.125	0.088	0.055	0.034
France	0.162	0.131	0.097	0.048	0.021
Italy	0.183	0.125	0.101	0.072	0.059
Spain	0.162	0.125	0.081	0.059	0.039

Table 4: Age-specific responses of (non-housing) consumption. Notes: response on impact after an unexpected fall of the real interest rate from 3% to 2%, with a contemporaneous reduction of the rent-to-price ratio by 1 percentage point.

for a saver, and younger agents borrow more on average.

We find that the distributional effects of a reduction in the real interest rate imply less consumption inequality. This result is robust to whether inequality is measured by the standard deviation of log consumption, the Gini coefficient or the ratio of consumption at the 90th percentile over consumption at the 10th percentile. The size of the effect after one year, for example, is a reduction of the standard deviation of log consumption by 1.4 log points for Germany, 2.7 log points for Italy, 2.9 log points for Spain and 3.4 log points for France. These quantitative results are of a similar magnitude as the change in inequality resulting from a change in the *nominal* interest rate for the U.S. reported by Coibion et al. (2017).[10]

4.2 A fall in the relative house price

Figure 6 shows the non-housing consumption responses after a 10% drop in house prices that is reversed in two steps within five years. Again, this is implemented as a sequence of unanticipated and supposedly permanent changes. The responses are intuitively larger in those countries in which home ownership rates are higher. Non-housing consumption falls by 2.2% in Spain, 2.1% in Italy, 1.9% in France and 1.4% in Germany. These responses imply elasticities between 0.14 and 0.22 and thus encompass the model-implied elasticity of 0.2 in Kaplan et al. (2017) obtained for the U.S.[11]

The drop in house prices also has heterogeneous effects on consumption across the age dimension. Table 5 shows that in all considered euro-area countries non-housing

[10] We compare the changes of consumption inequality implied by our model for the considered euro-area countries to the values contained in the confidence interval for the impulse response of the standard deviation of log consumption after four quarters in Figure 3 of Coibion et al. (2017).

[11] The overshooting of consumption after the relative price for housing has returned to its initial level results from accumulation of cheaper housing during the period with a lower relative price which allows agents to afford more non-housing consumption.

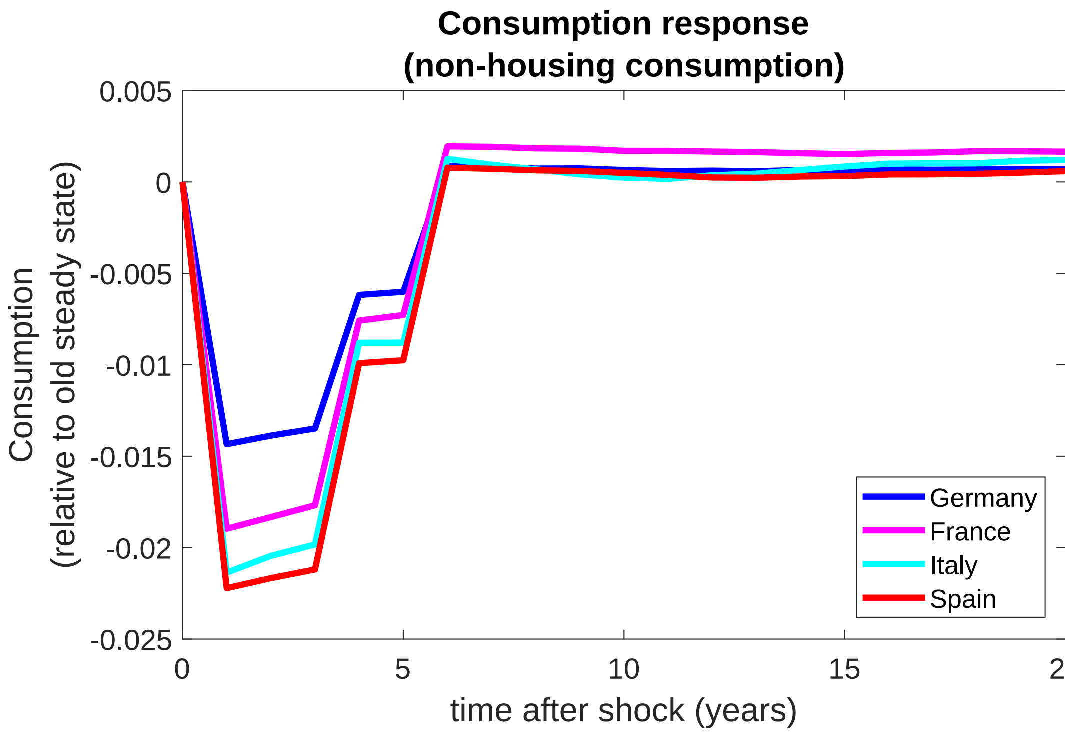


Figure 6: Unexpected fall of the relative house price by 10%, reversed in two steps within 5 years

	Age				
	25	40	50	60	70
Consumption response on impact					
Germany	-0.006	-0.008	-0.013	-0.016	-0.021
France	-0.005	-0.007	-0.018	-0.024	-0.031
Italy	-0.011	-0.011	-0.020	-0.025	-0.025
Spain	-0.013	-0.018	-0.023	-0.023	-0.026

Table 5: Age-specific responses of (non-housing) consumption. Notes: response on impact after an unexpected fall of the relative house price by 10%.

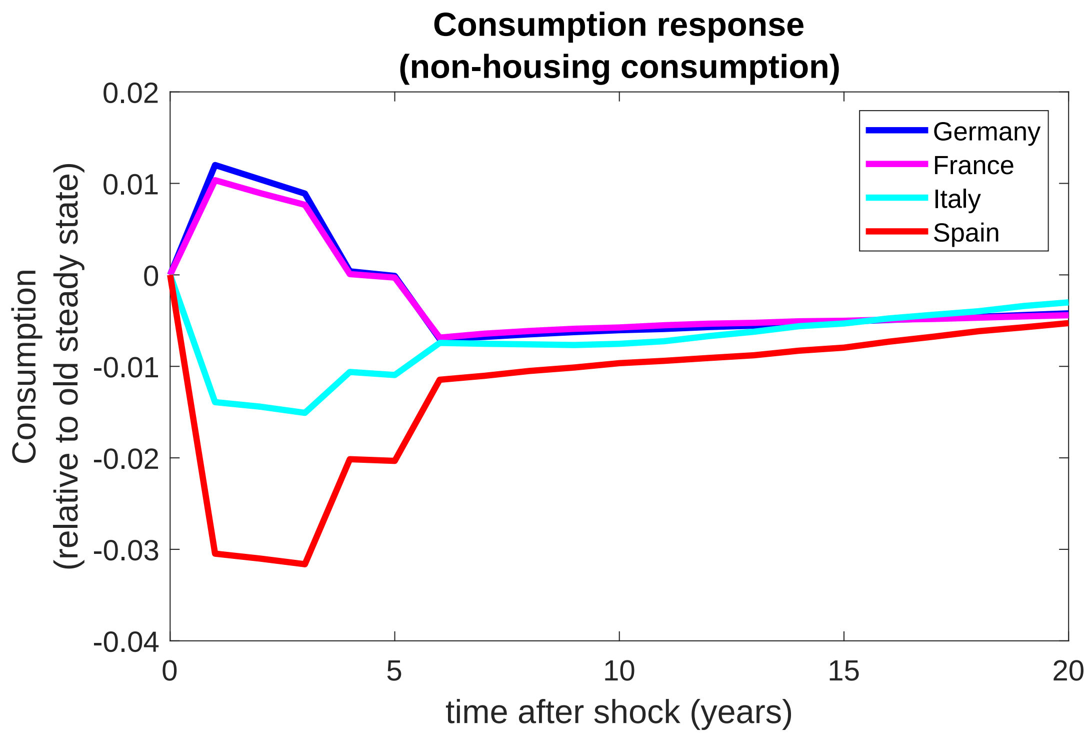


Figure 7: Observed country-specific fall of the relative house price accompanied by a reduction of the real interest rate by 25 basis points, reversed in two steps within 5 years

consumption of older agents decreases relatively more because these agents own more housing.

4.3 A fall of both the relative house price and the real interest rate

We perform an experiment in which we illustrate policy challenges in the euro area that arise due to the heterogeneity of consumption responses across euro-area countries. We feed a drop of relative house prices into the model whose size corresponds to the fall in the relative house price observed within a five-year period during the last recession for each of the four euro-area countries. Based the deflated house-price index for 2006 to 2016 from Eurostat, we let the relative price for housing drop by 5% in Germany and France, by 15% in Italy and by 20% in Spain.[12] At the same time we suppose that a central bank engineers a reduction of the real interest rate by 25 basis points. These unexpected changes are then reversed in two steps within five years.

Figure 7 shows the consumption responses for this experiment. For Germany and France, the fall in the real interest rate by 25 basis points more than compensates the negative effect on consumption resulting from the fall in the relative house price. For Italy and Spain instead, the fall in the real interest rate does not suffice to compensate the

[12]The index is available at http://ec.europa.eu/eurostat/web/macroeconomic-imbalances-procedure/house-price-index-deflated .

negative effect on consumption resulting from the housing bust. Not only is the fall in the relative house price larger for these countries but also, as we have seen in Figure 6, a given drop of the relative house price triggers a larger negative response of consumption. The stronger positive consumption response to a fall in the real interest rate in Italy than in Germany or France, visible in Figure 3, does not overturn this result for Italy. For Spain the consumption response to a fall in the real interest rate, shown in Figure 3, is quantitatively similar to France and Germany so that the effect of the fall in the relative house price certainly dominates.[13]

The results for the experiments suggest that there are trade-offs if one attempts to stabilize consumption in the euro area not only because of heterogeneous shocks but also because of the heterogeneity in the transmission from changes in real interest rates and relative house prices to consumption. We now try to uncover the role of differences in household finances for the transmission in more detail.

4.4 The role of differences in household finances

In Table 6 we disentangle the effect of country-specific household finances on consumption responses. We compare the consumption response (on impact), presented in subsections 4.1 and 4.2, with the consumption response that would obtain if, at the time of the shock, households in France, Italy and Spain had the *same* distribution of household finances as in Germany.

Table 6 shows that the responses to a fall in the real interest rate (top panel) or the relative house price (bottom panel) would become smaller in absolute value if households in France, Italy and Spain had the German distribution of household finances. This seems intuitive given that the portfolio of German households has a smaller share of illiquid housing.

The bottom panel of Table 6 further shows that eliminating differences in household finances at the time of the shock makes the consumption response to a fall in the relative house price more similar across countries. Spain, for example, then has nearly the same consumption response to a fall in the relative house price as Germany.

The effect of household finances on the cross-country differences in the consumption response is less clear cut for a decrease in the real interest. The results in the top panel of Table 6 show that differences in household finances can explain almost all of the 1.1 percentage point difference in the response between Italy and France. If both countries have the same distribution of household finances (as Germany) at the time of the shock, the consumption response only differs by 0.1 percentage points. For the differences between

[13] We have also performed an experiment in which we computed the consumption response to a decrease of the maximal loan-to-value ratio from 80% to 70%. We found rather small effects on non-housing consumption, possibly because few agents in our model simulations are close to the borrowing limit.

	Germany	France	Italy	Spain
*Consumption response on impact to fall of the **real interest rate** from 3% to 2%*				
... with observed differences in household finances at time of shock				
	0.079	0.079	0.090	0.082
... with same household finances as in Germany at time of shock				
	0.079	0.057	0.056	0.065
*Consumption response on impact to fall of the **relative house price** by 10%*				
... with observed differences in household finances at time of shock				
	-0.014	-0.019	-0.021	-0.022
... with same household finances as in Germany at time of shock				
	-0.014	-0.016	-0.018	-0.015

Table 6: Consumption responses and differences in household finances

the responses of Germany and Spain instead, the opposite is true. While the consumption response to the fall in the real interest rate is nearly the same if the distribution of household finances differs at the time of the shock (as observed in the data), the consumption response in Spain is 1.4 percentage points smaller if the differences in household finances compared to German households are eliminated at the time of the shock.

Putting these results together, we compute how the consumption response in the experiment illustrated in Figure 7 changes if we eliminate the cross-country differences in household finances at the time of the shock. In that experiment, the empirically observed fall in the relative house price in each of the considered countries is accompanied by a reduction of the real interest rate by 25 basis points. As can be seen from this figure, the largest difference in the impact consumption responses occurs between Germany and Spain. We find that differences in household finances explain a third of the difference in these responses.

Our quantitative framework allows us to rationalize this cross-country difference in reactions. The results in Table 6, where we have analyzed the effects of differences in household finances separately for changes in the interest rate and in house prices, provide a benchmark for the interpretation of an interest rate change which is accompanied by house price reactions.

The bottom panel of Table 6 reveals why cross-country differences in household finances between Germany and Spain are an important driver of differences in consumption responses. This is because consumption in Spain falls much less after the fall in the relative house price if Spanish households are (for the sake of the experiment) considered as starting from the same composition of household finances as German households, a composition that is much less tilted towards illiquid housing. Overall, this effect operating through house prices turns out to dominate the effect operating through changes in interest rates.

These results suggest that differences in household financial positions at the time of a shock are quantitatively important, explaining a part (one third, in this experiment) of cross-country differences in consumption responses. Heterogeneous household decisions after a shock explain the other part (two thirds, in this experiment) of cross-country differences. These household financial decisions are determined by the country-specific environment, augmenting the importance of household finances in shaping the transmission of price shocks to consumption across euro-area countries.

5 Conclusion

We have analyzed the consumption responses to changes in the real interest rate and in house prices for the four largest euro-area countries: France, Germany, Italy and Spain. Our quantitative analysis has revealed sizable differences in the transmission from changes in the real interest rate and relative house prices to consumption.

Our quantitative framework allows us to separate the role of household heterogeneity for the transmission mechanism in the euro area. The heterogeneity of households by age, income and wealth translates into heterogeneity of household financial positions, depending on country-specific characteristics, such as pension and tax systems, income risk, and fees on real estate transactions.

In a quantitative experiment we find that controlling for pre-existing differences in household financial positions across the considered euro-area countries reduces the maximum extent of cross-country differences in consumption responses by a third. Thus, two thirds of the effects are explained by differences in household financial decisions, that depend on the country-specific environment. This underlines the importance of a structural approach of modeling financial decisions of heterogeneous households when analyzing the transmission mechanism of monetary policy.

The differences in the consumption responses illustrate a challenge for a uniform monetary policy in the euro area. Our analysis also suggests that there is beneficial scope for country-specific fiscal policy. National taxes or within-country transfers may serve as complementary policy instruments to mitigate not only the asymmetric effects of monetary policy across countries but also the distributional effects across age groups that we find for each of the analyzed euro-area countries.

A Appendix on the recursive solution

This appendix relies on the description of the model presented in Section 2 and explains its solution based on the recursive formulation.

First we **normalize** the household problem such that neither the price level p_t nor the rental price level q_t enter as separate state variables. We define *price-transformed variables* in the following way.

$$\bar{s}_j = p_t \hat{s}_j,$$

$$h_{j+1} = p_t \hat{h}_{j+1},$$

$$f_j = p_t \hat{f}_j.$$

The normalization uses the assumption of a constant price-growth factor

$$\Pi = \frac{p_t}{p_{t-1}}.$$

Normalizing the objective function

In the log-separable case we have that

$$u(c_j, \hat{s}_j) = \theta \log c_j + (1-\theta) \log\left(\hat{s}_j\right)$$

such that in terms of price-transformed units, $\bar{s}_j = p_t \hat{s}_j$, the utility function is expressed as

$$u(c_j, \hat{s}_j) = \theta \log c_j + (1-\theta) \log\left(\frac{1}{p_t} p_t \hat{s}_j\right) = \theta \log c_j + (1-\theta) \log\left(\bar{s}_j\right) - (1-\theta) \log p_t$$

Therefore, utility is equivalently[14] described by

$$U(c_j, \bar{s}_j) = \theta \log c_j + (1-\theta) \log\left(\bar{s}_j\right)$$

For the log-separable case, the formulation in terms of valued units does not require any adjustment of the discount factor. We can use

$$\widetilde{\beta} = \beta$$

for having a clearly distinct notation of the discount factor in the normalized problem.

In the following we are going to show that, for any possible discrete choice d_j, also the constraint sets can equivalently be expressed in terms of price-transformed variables.

[14] For the equivalence in terms of the forward-looking objective function, also the time-separability of discounted utility plays a role.

Normalizing the constraints for each discrete choice

Ownership choice, not adjusting

If the household chooses to consume housing as an **owner, not adjusting** his housing stock, we code this as $d_j = 0$. We first make precise what non-adjustment means in terms of valued units. Non-adjustment of housing is naturally defined in terms of having the same *physical* (i.e., utility generating) quantity in two consecutive periods, meaning that

$$\hat{h}_{j+1} = \hat{h}_j \ .$$

Multiplying by p_t and using the definition of Π,

$$p_t \hat{h}_{j+1} = p_t \hat{h}_j = p_t \frac{1}{p_{t-1}} p_{t-1} \hat{h}_j = \Pi p_{t-1} \hat{h}_j \ .$$

In terms of price-transformed units, **physical non-adjustment** therefore implies that

$$h_{j+1} = \Pi h_j \ .$$

Ownership of housing implies that rented physical housing units $\hat{f}_j = 0$ and hence $p_t \hat{f}_j = 0$. Therefore

$$f_j = 0 \ .$$

For the physical service flow in the non-adjustment case we have $\hat{s}_j = \phi \hat{h}_j$, implying $p_t \hat{s}_j = \phi p_t \hat{h}_j$, and therefore

$$\bar{s}_j = \phi \Pi h_j \ .$$

The budget constraint is

$$c_j + a_{j+1} = y_j(s_j) + (1+r) a_j ,$$

and the collateral constraint $a_{j+1} \geq -\mu p_t \hat{h}_j - g_{y,j+1}$ can be expressed as

$$a_{j+1} \geq -\mu \Pi h_j - g_{y,j+1} .$$

Ownership choice, adjusting

If the household chooses to consume housing as an **owner, adjusting** his housing stock, coded as $d_j = 1$, $\hat{f}_j = 0$ implies

$$f_j = 0 \ .$$

The physical service flow $\hat{s}_j = \phi \hat{h}_{j+1}$ implies $p_t \hat{s}_j = \phi p_t \hat{h}_{j+1}$, and therefore

$$\bar{s}_j = \phi h_{j+1}.$$

The adjustment cost function can be written as

$$\begin{aligned} \alpha_{p,j}(\hat{h}_j, \hat{h}_{j+1}) &= \alpha_{0,j} + \alpha_1 p_t \hat{h}_j + \alpha_2 p_t \hat{h}_{j+1} \\ &= \alpha_{0,j} + \alpha_1 \frac{p_t}{p_{t-1}} h_j + \alpha_2 h_{j+1} \\ &= \alpha_{0,j} + \alpha_1 \Pi h_j + \alpha_2 h_{j+1} \ . \end{aligned}$$

Denoting

$$\alpha_j(h_j, h_{j+1}) = \alpha_{0,j} + \alpha_1 \Pi h_j + \alpha_2 h_{j+1} \ ,$$

the budget constraint

$$c_j + a_{j+1} + p_t \hat{h}_{j+1} + \alpha_{p,j}(\hat{h}_j, \hat{h}_{j+1}) = y_j(s_j) + (1+r)a_j + p_t \hat{h}_j$$

becomes

$$c_j + a_{j+1} + h_{j+1} + \alpha_j(h_j, h_{j+1}) = y_j(s_j) + (1+r)a_j + p_t \frac{p_{t-1}}{p_{t-1}} \hat{h}_j \ ,$$

which, using the price growth factor, can be written as

$$c_j + a_{j+1} + h_{j+1} + \alpha_j(h_j, h_{j+1}) = y_j(s_j) + (1+r)a_j + \Pi h_j \ .$$

The collateral constraint $a_{j+1} \geq -\mu p_t \hat{h}_{j+1} - g_{y,j+1}$ can be expressed as

$$a_{j+1} \geq -\mu h_{j+1} - g_{y,j+1}.$$

Rental choice

If the household chooses to consume housing as a **renter**, coded as $d_j = 2$, the choice of non-ownership of housing $\hat{h}_{j+1} = 0$ implies $p_t \hat{h}_{j+1} = 0$, and therefore

$$h_{j+1} = 0 \ .$$

The physical service flow $\hat{s}_j = \phi_R \hat{f}_j$ implies $p_t \hat{s}_j = \phi_R p_t \hat{f}_j$, and therefore

$$\bar{s}_j = \phi_R f_j \ .$$

The adjustment cost function can be expressed as

$$\begin{aligned}\alpha_{pR}(\hat{h}_j) &= \alpha_1 p_t \hat{h}_j \\ &= \alpha_1 \frac{p_t}{p_{t-1}} h_j \\ &= \alpha_1 \Pi h_j \ .\end{aligned}$$

Denoting

$$\alpha_R(h_j) = \alpha_1 \Pi h_j \ ,$$

and using the constant rent-to-price ratio k in $q_t = kp_t$, the budget constraint

$$c_j + a_{j+1} + q_t \hat{f}_j + \alpha_{pR}(\hat{h}_j) = y_j(s_j) + (1+r)a_j + p_t \hat{h}_j$$

becomes

$$c_j + a_{j+1} + kp_t \hat{f}_j + \alpha_R(h_j) = y_j(s_j) + (1+r)a_j + p_t \frac{p_{t-1}}{p_{t-1}} \hat{h}_j \ ,$$

which, using $f_j = p_t \hat{f}_j$ and the price growth factor, can be written as

$$c_j + a_{j+1} + kf_j + \alpha_R(h_j) = y_j(s_j) + (1+r)a_j + \Pi h_j \ .$$

The collateral constraint is

$$a_{j+1} \geq -g_{y,j+1}.$$

The recursive formulation

We denote

$$V_j(a_j, h_j, s_j) = \max_{d_j, c_j, f_j, a_{j+1}, h_{j+1}} \{U(c_j, \bar{s}_j) + \widetilde{\beta} \underset{s_{j+1}|s_j}{E} V_{j+1}(a_{j+1}, h_{j+1}, s_{j+1})\} \ ,$$

where the maximization is subject to the above-mentioned collection of discrete-choice-specific constraints, and where the expectation operator $\underset{s'|s}{E} f(\cdot, s') = \sum_{s' \in S} \pi_{s,s'} f(\cdot, s')$.

Conditional on a discrete choice, we denote

$$v_j(a_j, h_j, s_j | d_j) = \max_{c_j, f_j, a_{j+1}, h_{j+1}} \left\{U(c_j, \bar{s}_j) + \widetilde{\beta} \underset{s_{j+1}|s_j}{E} V_{j+1}(a_{j+1}, h_{j+1}, s_{j+1})\right\} \ ,$$

where the maximization is subject to the constraint set specific to the discrete choice d_j.

We handle the discrete-choice options in the recursive problem according to the approach suggested by Iskhakov et al. (2017), keeping for simplicity the same notation for functions $V(\cdot)$ and $v(\cdot)$. More specifically, we consider the addition of a random component to the valuation of discrete-choice options, and assume that this component is distributed according to an extreme-value (type I) distribution so that

$$V_j(a_j, h_j, s_j, \eta_j) = \max_{d_j \in D_j} \{v_j(a_j, h_j, s_j | d_j) + \eta_{d_j}\} \ ,$$

where η_{d_j} denotes the realization of the random component specific to a discrete choice d_j, and the vector η_j contains the collection of all realizations at age j for the set of all available discrete choices D_j. This randomness is considered for the discrete-choice-specific value functions so that

$$\begin{aligned} v_j(a_j, h_j, s_j | d_j) &= \max_{c_j, f_j, a_{j+1}, h_{j+1}} \left\{ U(c_j, \bar{s}_j) + \widetilde{\beta} \underset{s_{j+1}|s_j}{E} \left[\underset{\eta_{j+1}}{E} V_{j+1}(a_{j+1}, h_{j+1}, s_{j+1} \eta_{j+1}) \right] \right\} \\ &= \max_{c_j, f_j, a_{j+1}, h_{j+1}} \left[U(c_j, \bar{s}_j) + \widetilde{\beta} \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{v}_{j+1}(a_{j+1}, h_{j+1}, s_{j+1} | d_{j+1}), D_{j+1}; \sigma) \right] \end{aligned}$$

with[15]

$$\lambda(\left(\mathbf{x}|d_{j+1}\right), D_{j+1}; \sigma) = \sigma \log \left[\Sigma_{d_{j+1} \in D_{j+1}} \exp \frac{\left(x|d_{j+1}\right)}{\sigma} \right].$$

Ownership choice, not adjusting

In the case of non-adjustment, we use $h_{j+1} = \Pi h_j$ and the budget constraint conditional on this discrete choice so that

$$v_j(a_j, h_j, s_j | d_j = 0) = \max_{a_{j+1}} \left[U(y_j(s_j) + (1+r)a_j - a_{j+1}, \phi \Pi h_j) + \widetilde{\beta} \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{v}_{j+1}(a_{j+1}, \Pi h_j, s_{j+1} | d_{j+1}), D_{j+1}; \sigma) \right] \ ,$$

subject to the collateral constraint

$$a_{j+1} \geq -\mu \Pi h_j - g_{y,j+1} \ .$$

Ownership choice, adjusting

Inserting the budget constraint and the adjustment cost function, the recursive problem in the case of adjustment is

[15] The notation with a boldface variable $\mathbf{x}$ in the expression $\left(\mathbf{x}|d_{j+1}\right), D_{j+1}$ is shorthand for denoting the corresponding collection of discrete-choice-specific variables by $\left\{\left(x|d_{j+1}\right) : d_{j+1} \in D_{j+1}\right\}$

$$v_j(a_j, h_j, s_j | d_j = 1) = \max_{a_{j+1}, h_{j+1}} [U(y_j(s_j) + (1+r)a_j + \Pi h_j - a_{j+1} - h_{j+1} - \alpha_{0,j} - \alpha_1 \Pi h_j - \alpha_2 h_{j+1}, \phi h_{j+1})$$
$$+ \widetilde{\beta} \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{v}_{j+1}(a_{j+1}, h_{j+1}, s_{j+1} | d_{j+1}), D_{j+1}; \sigma)]$$

The next-period asset positions need to satisfy the collateral constraint

$$a_{j+1} \geq -\mu h_{j+1} - g_{y,j+1}$$

Rental choice

Using the budget constraint for the renters, considering the service flow $\bar{s}_j = \phi_R f_j$, and taking into account non-homeownership for the next-period state $h_{j+1} = 0$, we have

$$v_j(a_j, h_j, s_j | d_j = 2) = \max_{f_j, a_{j+1}} [U(y_j(s_j) + (1+r)a_j + \Pi h_j - a_{j+1} - k f_j - \alpha_1 \Pi h_j, \phi_R f_j)$$
$$+ \widetilde{\beta} \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{v}_{j+1}(a_{j+1}, 0, s_{j+1} | d_{j+1}), D_{j+1}; \sigma)]$$

The collateral constraint in this case is

$$a_{j+1} \geq -g_{y,j+1}.$$

We implement the solution of the maximization operations present in the recursive formulation by exploiting the implied first-order and envelope conditions. This lets us take advantage of the method for solving portfolio choice problems suggested by Hintermaier and Koeniger (2010), identifying candidates for optimal portfolio choice combinations in a first step, and then using them to determine optimal policy functions for all continuous decision variables.

B Appendix on the calibration

Table 7 shows the parameters that are common across countries in the calibration. For this set of parameters we try to keep the values close to values typically calibrated in the existing quantitative literature. We briefly explain the values for those parameters that have not been discussed already in the main text in Section 3.

The fixed adjustment cost α_0 is 5,000 euro and the proportional adjustment cost for sellers α_1 is 2.5% of the housing value. This approximates the illiquidity of housing and is inspired by Diaz and Luengo-Prado (2008), for example. As displayed in Table 2 in

	Adjustment costs
α_0	5,000
α_1	0.025
	Loan-to-value ratio before and after retirement
μ	0.8
μ^{ret}	0.2
	Pledgeable share of income
ξ	0.6
	Autocorrelation of income shocks
ρ	0.95
	Real interest rate
r	0.03
	Price growth factor
Π	1.0
	Taste shocks for discrete choice
σ_ϵ	0.01
	Service-flow rate out of rental housing quantity before retirement
ϕ_R	0.965

Table 7: Common parameters across countries
Notes: Country-specific parameters are contained in Table 2.

Section 3, we calibrate a higher country-specific cost for the purchaser α_2 because in the considered euro-area countries buyers typically pay the transaction taxes. These taxes differ across countries.

We allow agents to borrow up to a fraction $\xi = 0.6$ of the smallest possible labor earnings draw. Given that the fraction $\mu = 0.8$ of the housing value can be collateralized during working life, this plausibly implies that housing has a much larger collateral value than labor earnings.

In our benchmark we assume that housing has a stable value ($\Pi = 1$) and labor income is risky. We estimate differences in labor income risk across countries (see the different standard deviations of the innovations reported in Table 2). Given that the cross-sectional nature of the HFCS data does not allow direct estimation of the persistence of the income shocks, we set the autocorrelation of the shocks to $\rho = 0.95$ for all countries. This value is within the range of values for the persistence of income shocks typically assumed in quantitative analyses.

We assume a rental efficiency $\phi_R = 0.965$ during working life. This implies a service flow derived from a square meter of rented housing that is 3.5% lower than the service flow from an owned square meter. As is common in the literature, this captures foregone utility of renters, for example, due to hold-up problems which are left unmodeled.

	Germany	France	Italy	Spain
Pension parameters				
Earnings years	35	25	35	15
Valorisation rate (in percent)	1	0	1	0
Benefit growth rate (in percent)	0	0	0	0
Net replacement rate (in percent) at following multiples of mean income				
0.5	53.4	78.4	81.8	82.0
0.75	56.6	64.9	78.2	83.9
1	58.0	63.1	77.9	84.5
1.5	59.2	58.0	78.1	85.2
2	44.4	55.4	79.3	72.4

Table 8: Country-specific parameters for the pay-as-you-go pensions
Source: Authors' compilation based on the country studies, Table I.2 on pp. 28-30 and the net replacement rate reported on p. 35 in OECD (2007).

The standard deviation of taste shocks for the discrete choice, σ_ϵ, is set to a small value that adds smoothness to the discrete-choice part of the problem but prevents us from adding too much noise to the decision problem. See Iskhakov et al. (2017).

B.1 Pensions

Table 8 displays the country-specific pension parameters that we use as inputs when we calibrate the pay-as-you-go component of the pension systems based on the information available in OECD (2007). The first row shows the number of earning years used for the computation of the pension benefits. For Germany and Italy, we use 35 years to approximate the lifetime average earnings in our model. In France and Spain, pension benefits are computed based on a smaller number of highest earning years or final years before retirement, respectively. Since labor earnings grow over the life cycle in our model and reach their peak not long before retirement, the final 25 years in France are on average also the years with the highest earnings.

The valorisation rate in the second row shows how pre-retirement earnings are adjusted when pensions are computed at the time of retirement. In Germany and Italy, earnings are adjusted at the growth rate of (real) earnings which we set to 1% annually. In France and Spain, pre-retirement earnings are inflation indexed but are not adjusted for real earnings growth so that the valorisation rate is 0% in real terms.

The benefit growth rate in the third row of Table 8 captures how pension benefits are adjusted during retirement. In practice, benefits have been adjusted for inflation so that we set the growth rate of (real) benefits to zero. For Germany and Italy this calibration of (real) benefit growth deserves further discussion. In Germany, the *Rentenanpassungsformel* (pension benefit adjustment formula) seems to imply a more complicated adjustment of pension benefits than just an inflation indexation. Deflating the *de facto* nominal benefit growth since 2000 however, documented at https://www.deutsche-rentenversicherung.de, shows that the nominal benefit growth in Germany just has compensated retirees for inflation. This has been the time period in which households, surveyed in the HFCS, have made their savings decisions based on their expectations about the pay-as-you-go pension system. We thus set the (real) benefit growth rate to zero which implies indexation to inflation and no changes of benefits in real terms. We do the same for Italy, albeit high pensions in Italy are not fully inflation indexed currently so that they decrease in real terms. We abstract from modeling this detail because this seems only a transitory measure to decrease the liability resulting from the pension system in real terms.

The bottom of Table 8 displays the net replacement rate for different multiples of mean earnings. We apply these net replacement rates according to how past earnings of agents (based on the relevant earnings years for each country) compare to the mean of past earnings when we compute the pension benefits.

B.2 Taxation of labor income

In order to convert gross labor earnings including transfers into net labor earnings, we follow Guvenen et al. (2014). Based on the OECD Tax Database that reports average tax rates and social security contributions at various multiples of mean labor earnings as well as tax exemptions and tax credits, we fit parametric approximations for the schedules of taxes and social security contributions for each country. Specifically we use the information on the average tax rates and social security contributions in table i5 of the OECD Tax Database, the information on the top marginal tax rate, the earnings threshold above which it applies, the mean labor earnings in table i7, and the information on tax exemptions in table i1. We estimate the parameters of the non-linear tax schedule under the restriction that taxes are paid only above an earnings threshold that is obtained from information on tax exemptions and tax credits. In the approximation of social security contributions we capture that contributions are roughly a constant fraction of income below a maximum earnings threshold in France, Germany and Spain and become an ever decreasing fraction of income above that threshold. For Italy, we assume no maximum earnings threshold for social security contributions because such a threshold has been introduced only for labor market entrants after 1996 and this threshold is very high at 100,000 euro (see https://www.ssa.gov/policy/docs/progdesc/ssptw/2016-2017/europe/italy.html for a documentation in English language). For the estimation, we match the year in the OECD

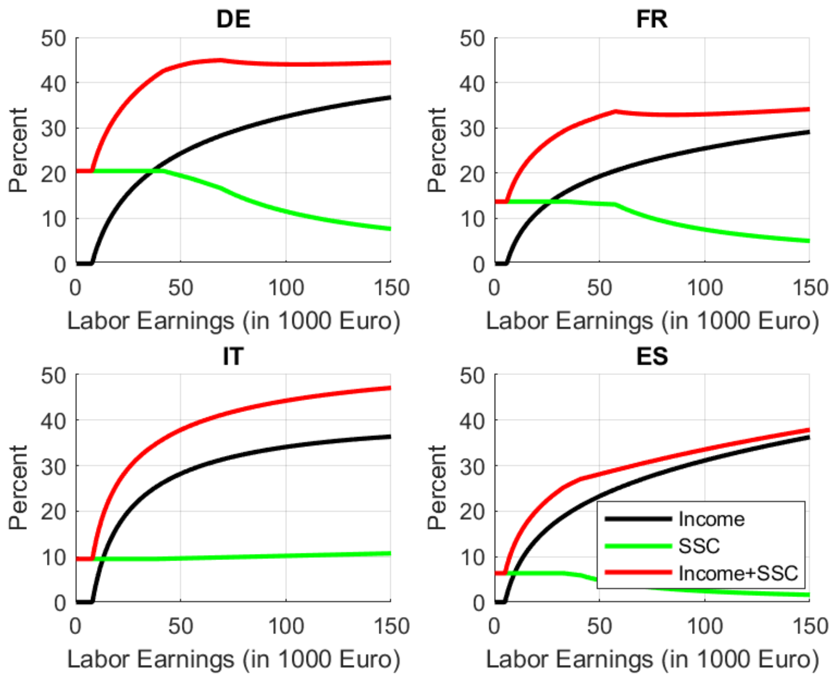


Figure 8: Country-specific schedules for average income taxes and social security contributions. Source: Authors' computation based on the OECD Tax Database, Tables i1, i5 ad i7.

Tax Database with the respective year for which households are asked about their income in the first wave of the HFCS, i.e. 2007 for Spain, 2009 for Germany and France and 2010 for Italy. Figure 8 illustrates the schedules used in our calibration.

B.3 Estimation of the income age profile and calibration of income risk

We regress the logarithm of labor earnings in adult equivalents, including transfers, on a quartic age polynomial for the ages 25 to 65 that correspond to working life in our model. Table 9 shows the results of the estimation for the age income profile and the variance of

	Germany	France	Italy	Spain
$ln(y) = \delta_0 + \delta_1 age + \delta_2 age^2 + \delta_3 age^3 + \delta_4 age^4 + u$				
δ_0	1.548	1.820	4.074	4.122
δ_1	0.701	0.790	0.575	0.610
δ_2	−0.022	−0.028	−0.021	−0.024
δ_3	3×10^{-4}	4×10^{-4}	3×10^{-4}	4×10^{-4}
δ_4	-2×10^{-6}	-3×10^{-6}	-2×10^{-6}	-2×10^{-6}
Variance of residual	0.525	0.325	0.532	0.401

Table 9: Country-specific age profile and residual variance of earnings
Source: Authors' computation based on the HFCS.

the residuals in each country. We convert the age profile into a life-cycle profile, assuming a growth rate of real income of 1% to account for cohort effects. The variance of the residual is used to compute the standard deviation of the innovation reported in Table 2, that is implied by the assumption of an AR(1)-process with persistence $\rho = 0.95$.

B.4 Transaction taxes

For Germany we add the 5% *Grunderwerbsteuer* to fees of 2.5% for real-estate agents. The *Grunderwerbsteuer* varies between 3.5% and 6.5% across regions. Unfortunately, we cannot exploit this variation because we do not have information about regions in the HFCS. We thus choose the median value across regions.

In France transaction taxes (*frais de mutation*) consist of a municipal and departmental tax and usually amount to 5.5% of the value of property. We thus set the proportional transaction cost for the purchaser to 8%, including fees for real-estate agents.

In Italy the buyer has to pay a registration tax (*imposta di registro*) of at least 3% for purchase of the main residence or alternatively VAT, depending on the seller. Furthermore, the purchaser has to pay a cadastral tax of 1% and land registry taxes of 2% (*imposte ipotecarie e catastali*). We thus set the transaction cost, including real-estate agent fees, to 8.5%.

In Spain home buyers typically have to pay 7 – 8% of value added tax and a documentation fee of 0.5% (*impuesto sobre actos jurídicos documentados*). Hence, we set transaction costs in Spain to 10.5%, including real-estate agent fees.

The website https://www.angloinfo.com contains some useful first information in English language on differences in transaction taxes and fees across countries.

B.5 Variable definitions

We provide information on how we construct variables of interest based on the HFCS. For information on the survey, its methodology and descriptive statistics we refer to Eurosystem Household Finance and Consumption Network (2013a) and Eurosystem Household Finance and Consumption Network (2013b).

We interpret the asset data in the survey as end-of-period information at the time when the survey is carried out because the questions in the survey refer to income in the previous year and agents have made their consumption and portfolio choices conditional on this income. We construct all variables for as many observations as possible. While information on net worth, home ownership, the value of the main residence with the corresponding mortgages, non-mortgage debt and gross income is available (if applicable) for more than 62,000 households in the euro area, information on mortgage payments per month (if applicable) is less complete, for example, and available for around 55,000 households.

When computing the statistics in the tables, we use the sampling weights provided in the HFCS to account for the oversampling of wealthy households, we account for the survey structure with five implicates per household (to capture the variance introduced by the imputation of values for some observations) and we use the replicate weights provided by the HFCS to account for sampling error. The variables are defined as follows (variable names in the HFCS dataset are in brackets):

Labor income (incl. transfers) is total gross household income from employment (di1100) and self-employment (di1200), income from pensions (di1500) and from social transfers except pensions (di1600).

Net worth is the consolidated net wealth position of a household (dn3001).

Housing wealth is defined as the value of the household's main residence (da1110).

Financial assets contain financial assets, other real estate and durables, net of outstanding debt. It is defined as the difference between net worth and housing wealth.

Home ownership is defined as the ownership of the household's main residence, i.e., this variable shows for which hosueholds housing wealth is positive (da1110> 0). The *rental rate* is defined as 1− *home ownership rate*.

We convert variables that are reported in euro for households into adult equivalents by giving a weight of 1 to the first adult, 0.34 to each additional adult and 0.3 to each additional child. See also the last column in Fernández-Villaverde and Krueger (2007), Table 1.

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