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ABSTRACT

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

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 financial asset and 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 countries, and within countries by household characteristics such as age, housing tenure, and asset positions. The different consumption responses quantified in this paper point towards important heterogeneity in monetary-policy transmission in the euro area.

JEL Classification: D14, D15, D31, E21, E43, G11

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

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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 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 consumption to changes in the real interest rate and the house price. 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 matches the observed differences in household finances across and within countries. For the empirical counterpart in this match we use the household-level micro data provided by the euro-area Household Finance and Consumption Survey (HFCS).

The size of the consumption response to changes in the real interest rate is crucial for the effect of monetary policy on aggregate demand, as a change in the nominal policy rate set by the central bank changes the real interest rate due to price rigidities in common models of monetary-policy transmission. We inspect the heterogeneity of the transmission from changes in the real interest rate to consumption across countries, and within countries across consumers with different ages, housing tenure and asset positions.

For this purpose, we use 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. This allows us to characterize the heterogeneity of consumption responses while using the information available in micro-level survey data on the heterogeneity of household financial positions as an empirical counterpart.

Using this model to infer the aggregate consumption response to an unexpected fall of the real interest rate by 25 basis points, we find that this response is between 0.27% in Germany and 0.29% in Spain.[1] The cross-country differences in consumption responses are amplified up to fivefold if the decrease in the real interest rate does not have a pass-through effect on the cost of rented housing, or if it is accompanied by an increase in the house price. Regarding within-country differences explained by household characteristics, we find that the consumption responses to changes in the real interest rate, and their contribution to the aggregate consumption response, are largest at ages 35 – 54.[2]

If we account for differences in household portfolios at the time of the shock, the dif-

[1] These numbers are in line with recent time series estimates for the euro area reported by Corsetti et al. (2018).

[2] For the U.S., where half of the young are homeowners with higher levels of leverage than in the euro area, Wong (2019) finds that the response is largest at young ages 25 – 34.

ferences in the aggregate consumption responses to changes in the interest rate across the considered countries increase to 7 basis points compared to 2 basis points in the benchmark. This points to asymmetries in monetary-policy transmission across the euro area shaped by differences in the economic environment. For stabilization policy such asymmetries imply challenges, which we illustrate considering a scenario of a housing bust accompanied by accommodative monetary policy. In our illustration, the resulting consumption boom in Germany and France together with the consumption slump in Italy and Spain highlights trade-offs for stabilizing consumption in the euro area not only because of heterogeneous shocks across countries but also because of the cross-country heterogeneity in the responses to changes in real interest rates and house prices.

The size of the consumption responses to changes in the 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 house price between 0.10 for Germany and 0.22 for Spain. These elasticities are quite similar to the model-implied elasticity of 0.2 in Kaplan et al. (2019) 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. (2016) or 0.6 to 0.8 in Mian et al. (2013).

Our analysis proceeds in the following steps. In Section 2, we construct a model with a financial asset and a housing asset that can be rented or owned. In the solution of our model we allow for continuous portfolio choices to accurately capture the portfolio positions, 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 targets include the observed means and age profiles for net worth, housing, and rental rate for the four largest euro-area countries displayed

	Germany	France	Italy	Spain
Wealth composition				
Housing wealth (main residence)	66,660	92,192	117,298	116,016
+ Financial assets	83,250	81,505	69,261	76,839
= Net worth	149,910	173,697	186,559	192,855
Rental rate (percent)	53.6	41.7	32.1	17.2

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

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 consumption response after changes in the real interest rate and the house price for these four countries. We consider different scenarios, in some of which we allow both the real interest rate and the house price to change jointly.

1.1 Related literature

Our paper contributes to the literature on differences in household finances and consumption responses to changes in real interest rates and house prices. The relationship between heterogeneity in wealth and heterogeneity in marginal propensities to consume has been analyzed in environments with uninsurable idiosyncratic risk, as for example in Carroll et al. (2017). The marginal propensity to consume determines the size of the consumption response to price changes, as shown by Auclert (2019) for changes in the interest rate and by Berger et al. (2018) for changes in the house price.

Kaplan and Violante (2014) have shown that the marginal propensity to consume crucially depends on wealth composition, distinguishing liquid and illiquid assets. In our paper we account for the substantial heterogeneity in home ownership across euro-area countries (see Table 1), distinguishing financial assets and housing in household portfolios. In this framework differences in household finances, which change the marginal propensity to consume, also change the consumption responses to price shocks.

Auclert (2019), Kaplan et al. (2018) and Wong (2019) have investigated the distributional and aggregate effects of unexpected changes in the *nominal* interest rate on consumption for the U.S. Cloyne et al. (2019) 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 dependence of these responses on the observed differences in household finances across the euro area.

We focus on the consumption response to changes in the *real* interest rate. This response is an important part of monetary-policy transmission in general. For our emphasis on cross-country and within-country heterogeneity, this is the key part. Such a focus separates the effects of cross-country heterogeneity in consumer finances from the potential influence of cross-country differences in inflation. In the case of open economies within a monetary union, country-specific inflation 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.

Beraja et al. (2018) 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. A difference to the U.S. is that refinancing is more costly in some of the considered countries of the euro area. We provide suggestive evidence that this cost would increase the cross-country differences in the consumption responses even further.

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 relates to work by Berger et al. (2018) and Kaplan et al. (2019) who analyze the consumption response to changes in house prices in the U.S., and the 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 transmission of monetary policy to aggregate consumption and house prices across countries in the euro area. The heterogeneity is associated with differences in the housing market.[3] 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

[3] 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.

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 structural approach based on a life-cycle model with one asset and heterogeneous agents, Pham-Dao (2019) investigates the effect of differences in the social security systems across euro-area countries on wealth inequality. We perform our analysis in a framework with household portfolio choice, also accounting for differences in the design of social security across euro-area countries. Kindermann and Kohls (2018) 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 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 (2018) 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.

2 The model

We use a life-cycle incomplete-markets model with household portfolio choice for our quantitative analysis. This section describes the features of all building blocks of the model. 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. In Appendix A we provide formal details of the recursive formulation and explain how we solve the model.

We implement a version of the life-cycle model which combines discrete choices and continuous choices. For a realistic account of household decisions, we allow for discrete choices in owning versus renting a house and in adjusting versus not adjusting one's house size. Based on these discrete choices the remaining choices of nondurable consumption, of financial assets, and of relevant housing quantities are continuous.

Preferences

This building block specifies the time horizon and the preferences over consumption streams. We use a life-cycle model with J periods, indexed by $j = 1,\ldots,J$. Households maximize their expected discounted utility over the life cycle. They apply a discount factor β on future period utilities. Expectations take into account survival probabilities, idiosyncratic risk in earnings, and aggregate risk in future returns on financial assets.

The relevant consumption items for our analysis are nondurable consumption c_j and housing services $\hat{s}_j$, obtained by choosing either to own or to rent housing. We assume a period utility function that is log-separable in non-housing consumption and housing services:[4]

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

The flow of housing services for owners of a house of size $\hat{h}_{j+1}$ 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

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

In the calibration $\phi > \phi_R > 0$ allows to capture a smaller per-unit utility flow from housing for renters compared to owners, as a commonly used reduced form for utility losses resulting from moral-hazard or hold-up problems in the rental market.

For the event of death, households consider a warm-glow bequest motive with utility $\Psi(\mathfrak{b})$ from bequeathing an amount of resources $\mathfrak{b}$, whose relation to the bequeather's asset positions is specified in the section on portfolio items below. The bequest utility function takes the form

$$\Psi(\mathfrak{b}) = \psi_0 \log(\psi_1 + \mathfrak{b}) .$$

This standard functional form captures the strength of the bequest motive with the parameter $\psi_0 > 0$, and the extent to which bequests are a luxury good with the parameter $\psi_1 > 0$.

[4] The notation with hats used here distinguishes physical housing as a utility-generating quantity from its valuation, which will be used for the recursive formulation of the model, as is explained in Appendix A.

Earnings

Uncertainty in the model is captured by a Markov process. We denote the realization of the Markov state at age j by s_j, and the implied household earnings by $y_j(s_j)$.

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 subject to stochastic variation each period. During retirement age, they are determined by household-specific working-age earnings. These sources of idiosyncratic background risk cannot be fully insured against and thus matter for the life-cycle profiles of asset accumulation and portfolio composition. 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 taxation, social security, and pay-as-you-go pensions.

Portfolio items: costs, returns, constraints

An important difference between rented and owned housing is that the quantity of owned housing can only be adjusted at a cost, reflecting the illiquidity of housing as an asset. To generate inaction ranges and lumpy adjustment patterns, we specify an **adjustment cost function** that has a fixed-cost component[5] (needed for lumpiness) and variable components proportional to the quantities sold or bought with p_t denoting the relative price of housing:

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

These costs have to be paid if the household chooses **to adjust** to a new quantity of owned housing at age j. The 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 chooses **not to adjust** the existing quantity of owned housing, such that $\hat{h}_{j+1} = \hat{h}_j$, no adjustment costs are incurred.

[5]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 participating in 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 rent** 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[6] of renting versus owning, and of adjustment versus non-adjustment, subject to the applicable versions of the budget constraint and the collateral constraint specified in the following.

If the household chooses to consume housing as an **owner adjusting** his housing stock, the **budget constraint** at age j is

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

where r_{t-1} denotes the safe interest rate promised at calendar time $t-1$, when the decision maker was of age $j-1$ and invested in the financial asset position a_j, and current age earnings are denoted by $y_j(s_j)$.

If the household chooses to consume housing as an **owner not adjusting** his housing stock, such that $\hat{h}_{j+1} = \hat{h}_j$, the budget constraint becomes

$$c_j + a_{j+1} = y_j(s_j) + (1 + r_{t-1})a_j.$$

If the household chooses to consume housing as a **renter**, the following budget constraint applies

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

Rental prices q_t are specified in relation to prices for ownership as

$$q_t = k_t p_t,$$

where the fraction k_t is referred to as the *rent-to-price ratio*. We allow for time variation of the rent-to-price ratio by considering it as the sum of a non-interest component $\underline{k}$ and the interest rate r_t prevailing at time t

$$k_t = \underline{k} + r_t,$$

and we refer to this specification as *pass-through* (of interest rates to the rent-to-price

[6]In the quantitative application we allow for the consideration of some degree of noise in decisions among discrete choices, as explained in the recursive formulation in Appendix A.

ratio). If r_t in the previous specification is replaced by the unconditional mean interest rate, we call this a situation with *no pass-through*.

Portfolio choices, and in particular debt positions, are also restricted by a **collateral constraint** that limits borrowing:

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

where the parameter μ represents the loan-to-value (LTV) ratio. The parameter $g_{y,j+1}$ denotes those pledgeable resources which are not related to asset holdings. For those households who choose to own and not to adjust their house size, meaning that $\hat{h}_{j+1} = \hat{h}_j$, this collateral constraint becomes $(1+r_t)a_{j+1} \geq -\mu p_t \hat{h}_j - g_{y,j+1}$. For households who choose to be renters, and therefore get a housing position of $\hat{h}_{j+1} = 0$, this implies the borrowing constraint $(1+r_t)a_{j+1} \geq -g_{y,j+1}$.

Finally, given the previous description of portfolio items, costs, and returns, we are in a position to specify the amount of resources bequeathed in the event of death as

$$\flat = (1+r_t)a_{j+1} + (1-\alpha_1)p_{t+1}\hat{h}_{j+1},$$

which can be interpreted as liquidable wealth from the portfolio existing at the time of death.

3 Calibration

Our approach is to build a model that captures the observed heterogeneity in household finances, on which we have detailed data. We use the Household Finance and Consumption Survey (HFCS), a recent survey for the euro area whose structure largely follows the Survey of Consumer Finances (SCF) in the U.S. The survey contains detailed information on household balance sheets but no information on consumption other than food.[7] Thus, we use a model, calibrated to match the household balance sheets, to infer the consumption responses.

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 capture 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 some preference parameters. We describe the essential cross-country differences in this section, and refer to Appendix B for details. Table 7 in that Appendix B documents all other parameters

[7] Even for food consumption, the HFCS waves have a limited panel component and the survey is only conducted at a frequency of three years. This would not allow to estimate responses to those types of changes we analyze, namely responses to *aggregate* changes at the frequency relevant for monetary policy.

that are common across countries.

The aim of our calibration is to explain the differences in household finances by observable cross-country differences. The economic environment in a country influences household finances by affecting motives for asset accumulation and portfolio choice, for example, the motives for precautionary and retirement saving. Any remaining part, unexplained by the economic environment, is captured with the following preference parameters: the discount factor β, the weight of non-housing consumption in the consumption basket θ, the rental efficiency before and during retirement determined by the service-flow rates out of rental housing ϕ_R and ϕ_R^{ret}, the bequest motive and the extent to which bequests are a luxury good captured by parameters ψ_0 and ψ_1. Such unobservable preference heterogeneity corresponds to a country fixed effect.

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).[8] We calculate 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.[9] The assumption of an AR(1) process 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.[10] The values are broadly in line with findings reported in table 2 of Pham-Dao (2019) 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 capture country-specific transaction costs for housing and rent-price ratios which

[8]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.

[9]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%.

[10]We use the Rouwenhourst method to approximate the Markov chain with seven income states. Together with the five states of the interest-rate process discussed below, this implies 35 stochastic states in the model economy.

	Germany	France	Italy	Spain
		Preferences		
β	0.969	0.982	0.996	0.970
θ	0.79	0.73	0.79	0.82
ϕ_R	0.864	0.930	0.908	0.999
ϕ_R^{ret}	0.66	0.68	0.74	0.90
ψ_0	50.23	35.56	9.49	47.81
ψ_1^*	4.13	0.06	2.45	2.49
	Non-interest component of rent-to-price ratio			
$\underline{k}$	0.0019	0.0023	0.0030	0.0089
		Proportional transaction cost		
α_2	0.075	0.08	0.085	0.105
		Life-cycle income process		
	country-specific age profiles			
	country-specific pension and tax systems			
		std.dev. of innovation		
$\sigma_{\text{innovation}}$	0.23	0.18	0.23	0.20
		Life expectancy		
	country-specific 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. ψ_1^* expresses ψ_1 in relation to earnings at the beginning of the life-cycle.

influence the portfolio choice between housing and liquid financial assets and the choice between home ownership and rental.[11] 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.

Those parameters in the model set to common values across countries are summarized in Table 7 in Appendix B. For all four euro-area countries considered, we calibrate the stochastic process of the interest rate using the five-year German government bond to approximate the common financial asset in the model. The average rate $\bar{r}$ is thus 2%, which corresponds to the return net of inflation in the pre-crisis 2000s. We approximate the stochastic process of the interest rate by a Markov chain with five states, based on our estimates of the standard deviation of the innovation $\sigma_r = 0.0064$ and persistence $\rho_r = 0.39$.[12] We assume stable expected relative house prices as a benchmark. The maximum 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 by retirement 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 mean age profile. Between ages 65 and age 85 agents receive their earnings-dependent pension, calculated as explained above, and have survival probabilities that are calibrated using mortality tables from Eurostat.[13] These probabilities are available until age 85, which coincides with the terminal age in our model. The interest rate r of the financial asset is stochastic over the whole life cycle.

We simulate the model for 120,000 agents to compute model statistics. To obtain the initial distribution, we draw from the empirical 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. For each country we build a synthetic survey by sampling households at various ages of their simulated life-cycle profiles. The age-

[11] 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 (2018) 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.

[12] We estimate an AR(1)-process on quarterly data for the five-year German government bond series available from the Bloomberg database for the pre-crisis period 1999Q1-2008Q3, and then convert the standard deviation and persistence to annual values.

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

	Germany		France		Italy		Spain	
	Data	Model	Data	Model	Data	Model	Data	Model
Wealth composition								
Housing wealth	66,660	66,780	92,192	93,418	117,298	116,946	116,016	111,768
+ Financial assets	83,250	87,303	81,505	79,663	69,261	67,741	76,839	79,810
= Net worth	149,910	154,083	173,697	173,081	186,559	184,687	192,855	191,578
Rental rate (percent)	53.6	55.0	41.7	40.7	32.1	33.6	17.2	16.1
Fraction of homeowners with debt	17.7	21.3	16.6	25.1	9.5	25.9	23.2	33.8
LTV, conditional on debt	45.4	32.3	39.2	28.1	32.0	17.4	44.4	40.6
LTV > 0.5, conditional on debt	34.0	23.0	32.1	14.0	23.9	3.4	23.0	37.6

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

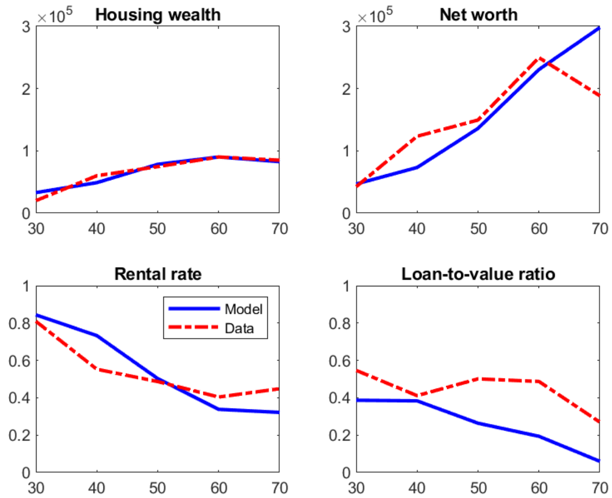
specific sampling weights match the demographic composition of the micro data set for the corresponding country. When comparing the model with the data, we focus on agents between ages 26 and 75 who account for more than 80% of the sample in the HFCS for the considered countries.

We calibrate the model by targeting the set of moments reported in Table 3 and Figures 1 and 2. These moments capture the extensive and intensive margin of household balance sheets in terms of housing tenure and the associated leverage. We also target the fraction of highly levered households with a loan-to-value (LTV) ratio larger than 50 percent because the model predicts that these households have higher propensities to consume.[14] Table 3 and Figures 1 and 2 show that the life-cycle model manages to match most of the targets well by accounting for key differences in the economic environment, that we have explained above, and by calibrating some country-specific preference parameters and the rent-price ratio.[15] Although the parameters are jointly calibrated, some targets are tightly related to certain parameters. The discount factor β and the parameters ψ_0 and ψ_1 for the bequest motive allow to match average net worth and its age profile. The weight of non-housing consumption in the consumption basket θ together with the non-interest component of the rent-price ratio $\underline{k}$ and the parameters for the rental efficiency ϕ_R and ϕ_R^{ret} allow to match average housing wealth, the rental rate and their age profiles.[16] Within the set

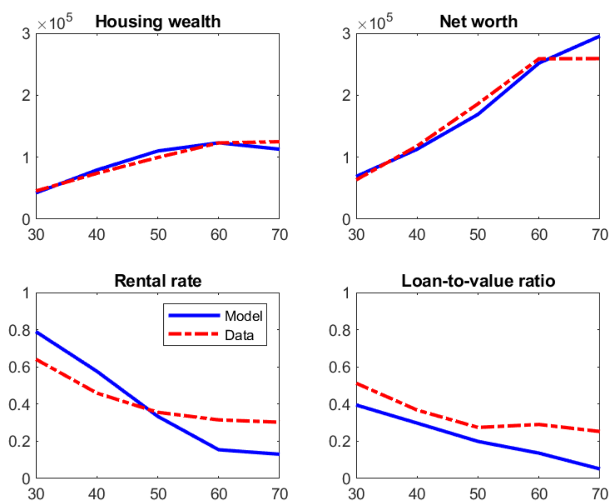
[14]Given the importance of housing wealth and housing tenure for the consumption responses, we attach a tenfold weight to the targets of net worth, housing and the rental rate in the objective function to minimize the Euclidean distance from the targets in percentage points or percent, depending on the target.

[15]We calibrate the rent-price ratio because the existing data on rent-price ratios may be confounded by quality differences so that the quality-adjusted rent-price ratio is unobserved. The calibrated non-interest component of the rent-price ratio reported in Table 2 varies between 0.2 and 0.9 percent. These values have a plausible order of magnitude if one considers the rough approximation of the user cost for owned housing that equals the sum of the real interest rate and the depreciation rate, where the depreciation rate for housing is usually estimated to be small and within the ballpark of the values of the non-interest component in our calibration.

[16]It is noteworthy that the model requires a lower ϕ_R^{ret} than ϕ_R in the calibration. Without making rental less attractive during retirement, the model would predict more rental than empirically observed. We leave the question for further research in which way specific economic features might combine with cross-country

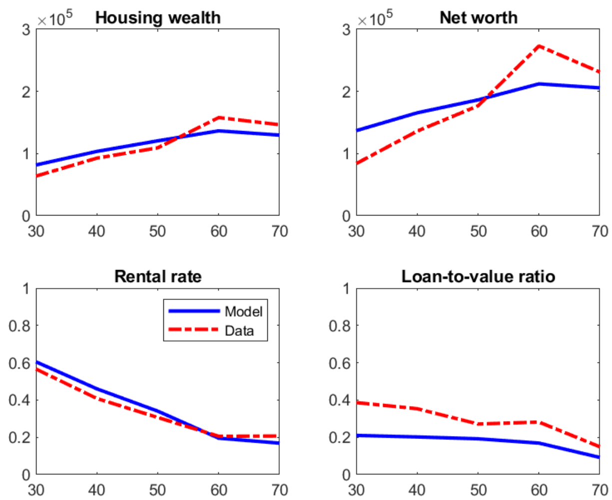


(a) Germany

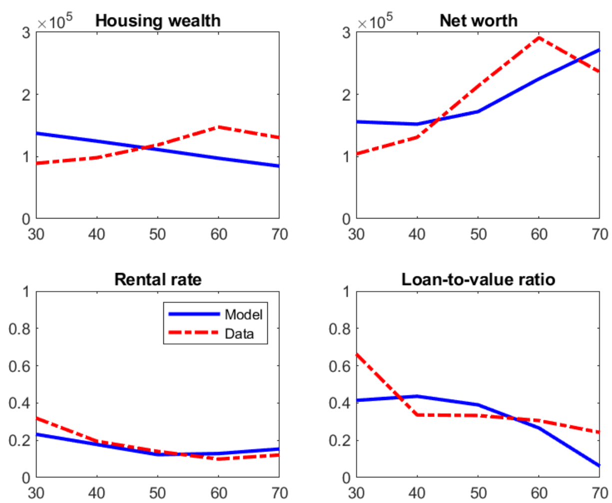


(b) France

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.

of parameters that match these targets well, we search for parameter combinations that align as much as possible the extensive and intensive margin of indebtedness associated with home ownership predicted by the model with the data.[17]

Figures 1 and 2 reveal the trade-offs implied by our multi-dimensional objective function. The calibration implies lower LTV ratios of homeowners at all ages than in the data in France and Italy. This deviation is related to the model generating too many homeowners with household debt compared to the data, particularly for Italy (see Table 3). In Spain the age profile of housing wealth, plotted in Figure 2, is rather flat and peaks within the youngest age group whereas the age profile is also flat in the data but peaks at age 60. Our extensive search in the parameter space during the calibration has confirmed that these deviations from the data targets could only be reduced at the cost of increasing deviations from other data targets such as net worth or the rental rate. Hence, further research may explore additional features to improve the model performance in these dimensions, which, however, may come at the cost of having to abandon a uniform modeling framework for the euro-area countries.

Table 2 shows that the model also requires differences in the preference parameters to match the country-specific data targets. In Appendix B.5, Tables 10, 11 and 12 show that the country-specific model inputs in Table 2 and the differences in the initial asset distributions of young households are quantitatively important for explaining the cross-country differences in household finances. The existing differences in the age composition across countries in the HFCS instead contribute little.

4 Consumption responses

We use the model to compute the aggregate response of non-housing consumption to a change in the real interest rate and in the house price. This type of response is important for monetary-policy transmission and has received considerable attention for the U.S.[18]

4.1 A fall in the real interest rate

Figure 3 shows the response of non-housing consumption for a specific path of the interest rate chosen for illustrative purposes, where the real interest decreases by 25 basis points for 4 years and then increases back to its initial value. In the benchmark, we assume

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 during retirement.

[17] The leverage of renters is targeted implicitly by matching average net worth, its age profile and the rental rate.

[18] See, for example, Auclert (2019), Berger et al. (2018), Beraja et al. (2018), Hedlund et al. (2016), Kaplan et al. (2019) and Kaplan et al. (2018) for analyses on the U.S. and Cloyne et al. (2019) for evidence on the U.S. and the U.K.

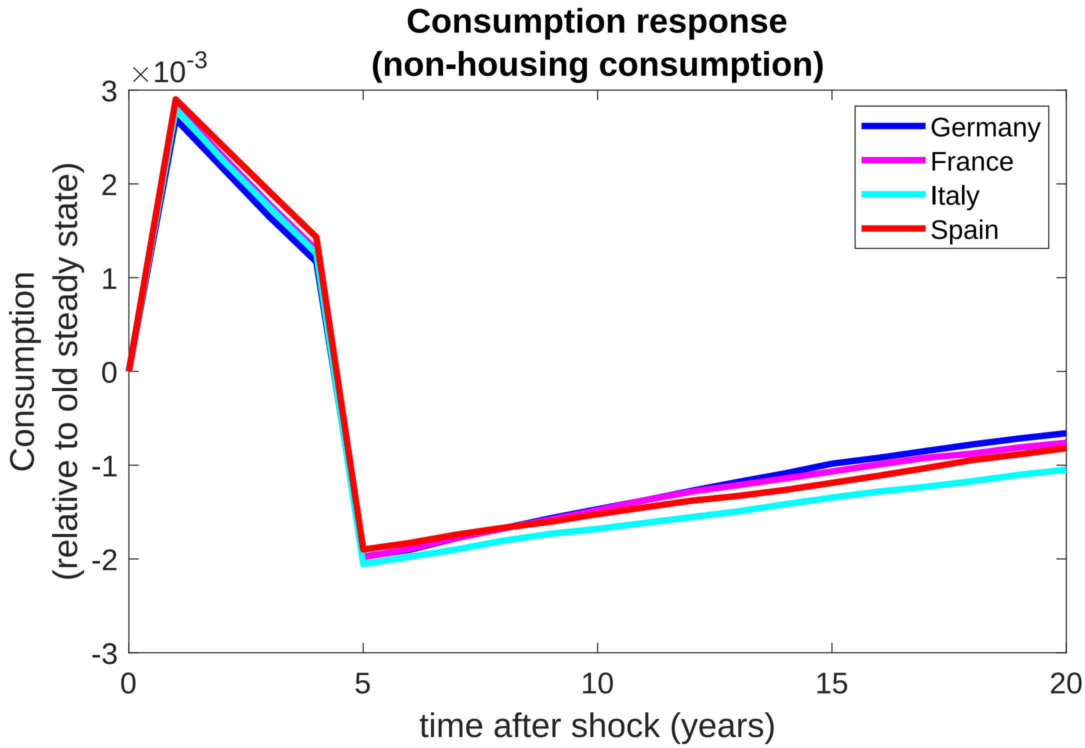


Figure 3: Unexpected fall of the real interest rate from 2% to 1.75%, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points (reversed after 4 years)

that the reduction in the real interest rate is accompanied by an analogous reduction of the rent-to-price ratio by 25 basis points, supposing that the lower user cost for housing is fully passed on to renters while the relative house price remains stable. In Appendix C.1 we show how the response changes if we assume no pass-through of the interest-rate change to the rent-price ratio, if we make the alternative assumption that the reduction of the rent-to-price ratio is driven by an increase of the relative house price and not by a decrease in rents, if the decrease of the interest rate is (expected to be) permanent and not transitory, and if the real interest rate increases to check for possible asymmetries in the consumption response. We will comment below on the similarities and differences in these alternative experiments compared to the benchmark.

Figure 3 shows that a fall in the real interest rate by 25 basis points increases non-housing consumption on impact between 0.27% in Germany and 0.29% in Spain. As we document in Appendix C.1, the cross-country differences in consumption responses are amplified up to fivefold if the decrease in the real interest rate does not have a pass-through effect on the cost of rented housing, or if it is accompanied by an increase in the house price.

The size of the consumption responses is in the ballpark of the empirical estimate for the response to a monetary-policy shock of 25 basis points in the euro area over an annual horizon, as reported in recent evidence by Corsetti et al. (2018), Figure 4, based on high-frequency identification of monetary policy shocks. The consumption responses generated by our model are at the upper end of the confidence interval of estimates reported in Corsetti et al. (2018). This is to be expected because we compute the consumption response to changes of the *real* interest rate whereas Corsetti et al. (2018) estimate the consumption response to changes of the *nominal* rate, and only part of the change of the nominal rate translates into a change of the real rate. In line with Corsetti et al. (2018), Figure 6, we find that the consumption response is largest in Spain and smallest in Germany. The larger quantitative differences in the responses across countries in Corsetti et al. (2018) suggest that there are additional channels through which monetary-policy shocks affect consumption beyond the changes in the real rate captured in our model.

The responses in Figure 3 deliver interesting insights. The consumption response is largest on impact and then decreases because the real rate is expected to be mean reverting. As the interest rate remains below its initial level for a longer time, consumers with financial assets loose more capital income and thus reduce consumption.[19] After year 4, when the interest rate increases back to its initial level at the mean of 2%, consumption falls below its initial level. As visible in Figures 3, non-housing consumption returns slowly to its initial level, as eventually the economy is populated only by households who at no point of their life cycle were affected by the temporary change. The deviation of consumption from its initial level falls below 10^{-3} after 15 years. We thus find that there is a persistent slump in non-housing consumption when a period with a low real interest rate comes to an end unexpectedly. Further note that the change of consumption after year 4 in Figure 3 is of similar size in absolute terms as the change of consumption after the initial increase of the real rate, illustrating that the effect of increases and decreases of the interest rate on consumption is approximately symmetric at the aggregate level.[20]

Appendix C.1 shows that the qualitative features of the consumption response are robust. We show in Appendix C.1.1, Figure 7, that the quantitative size of the response increases by an order of magnitude if the reduction in the rent-price ratio, which accompanies the drop in the real interest rate, is attributed to an increase in relative house prices. In this case, as discussed further in subsection 4.2 below, the higher relative house price increases consumption partly through the endowment effect recently emphasized by Berger et al. (2018).

In Appendix C.1.2, Figure 8, we further show that the size of the consumption response increases tenfold if the change of the real interest rate is expected to be permanent in the experiment with a sequence of unanticipated, measure-zero and thus supposedly permanent changes, sometimes called MIT-shocks. This relates to the discussion of

[19]In Appendix C.1.2, Figure 8, we show that the consumption response decreases much less in percentage terms if consumers expect the drop in the interest rate to be permanent.

[20]See Figure 10 in Appendix C.1.4 for the consumption response after a positive change of the real interest rate.

forward guidance as it illustrates the scope for larger consumption responses if interest changes are expected to last for a longer time period. The results reported in Figure 8 provide an upper bound on the consumption response given that consumers expect the change of the interest rate to be permanent.

If we assume instead in the model that there is no pass-through from the interest rate to the rent-price ratio, Figure 9 in Appendix C.1.3 shows that the consumption responses have a similar order of magnitude as in the benchmark but they become more heterogeneous across countries. The maximum cross-country difference in the consumption responses on impact, after a fall in the real interest rate by 25 basis points, then is 7 basis points compared to 2 basis points in the benchmark. Results that are not reported for brevity show that, without pass-through from the interest rate to the rent-price ratio, the effects of monetary policy on rental expenditures and portfolio choices change substantially compared to the benchmark. In the benchmark, the effect of the decrease in the real interest rate on the portfolio of financial assets and housing as well as the rental rate is small. Rental expenditures increase moderately given that the rent-price ratio decreases. If the rent-price ratio remains unchanged instead, consumers shift their portfolio towards housing and the rental rate decreases. The size of the portfolio shift differs across the four euro-area countries that have very different home ownership rates and portfolio compositions at the time of the shock. This generates more heterogeneous consumption responses than in the benchmark. The analysis suggests that, in future research, it is important for the understanding of the transmission of monetary policy to model the pass-through of interest-rate changes to the rent-price ratio in more detail and to collect data that allow to estimate this pass-through for the euro-area countries.

The aggregate consumption response hides substantial heterogeneity across households. Some households increase their housing stock after the fall of the interest rate and *reduce* their non-housing consumption. Other households have a marginal propensity to consume well above 20%. Table 4 illustrates some of the heterogeneity in the consumption responses after the fall of the interest rate for Germany, focussing on observable group characteristics at the time of the shock that have received interest in (empirical) analyses of consumption responses for the U.S. or U.K. by Cloyne et al. (2019) or Wong (2019), for example. The results for the other euro-area countries considered are qualitatively similar, except for the aspects highlighted in the discussion below, and are contained in Appendix C.2.

Table 4 shows that consumers between ages 35 to 54, outside the bottom quartile of the net-worth distribution, where they tend to have positive assets, contribute most to aggregate consumption response. 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

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
	Aggregate response on impact = 0.0027			
	Composition of impact response across age groups			
Ages 25 – 34	0.0027	0.1529	0.1790	0.0005
Ages 35 – 44	0.0031	0.2166	0.2485	0.0008
Ages 45 – 54	0.0031	0.2468	0.2582	0.0008
Ages 55 – 64	0.0024	0.1784	0.1607	0.0004
Ages 65 – 74	0.0017	0.1871	0.1407	0.0002
	Composition of impact response across net-worth distribution			
Percentiles 0 – 25	0.0023	0.2500	0.1973	0.0005
Percentiles 25 – 50	0.0035	0.2500	0.2219	0.0008
Percentiles 50 – 75	0.0031	0.2500	0.2255	0.0007
Percentiles 75 – 90	0.0026	0.1500	0.1799	0.0005
Percentiles 90 – 95	0.0021	0.0500	0.0752	0.0002
Percentiles 95 – 99	0.0017	0.0400	0.0737	0.0001
Percentiles 99 – 99.9	0.0014	0.0090	0.0235	0.0000
Percentiles 99.9 – 100	0.0011	0.0010	0.0031	0.0000
	Composition of impact response across housing-tenure types			
Homeowners	0.0026	0.4485	0.5426	0.0014
... with positive assets	0.0023	0.3463	0.4268	0.0010
... with debt	0.0038	0.1022	0.1157	0.0004
Renters	0.0028	0.5515	0.4574	0.0013
... with positive assets	0.0030	0.4546	0.3934	0.0012
... with debt	0.0012	0.0970	0.0640	0.0001

Table 4: Germany: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the real interest rate from 2% to 1.75% for 4 years, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points.

is positive for a borrower and negative for a saver, and younger agents borrow more on average. Indeed, the bottom panel of the table shows in the first column that the consumption response of indebted homeowners is higher. Because indebted homeowners in Germany account for a small share of aggregate consumption, as reported in the third column, the contribution of their response to the aggregate response is relatively small. Column 4 in the table shows that indebted homeowners account for an aggregate increase in consumption of 0.04%, which is small when compared to the aggregate response of 0.27%.[21] Appendix C.2 shows that, among the considered euro-area countries, the contribution of indebted homeowners to the aggregate consumption response is largest in Spain. Indebted homeowners in Spain account for 30% of the population, for a quarter of consumption and thus they contribute three times as much to the aggregate consumption response compared to indebted homeowners in Germany.

The results on consumption responses across different household types also allow us to gauge the importance of the assumption that borrowing households benefit from a decline in the interest rate. While this assumption is plausible for Italy and Spain where households have options to refinance loans at little cost or 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. As a rough check of this conjecture, we compute the aggregate consumption response under the assumption that the consumption response of borrowing homeowners is zero in Germany and France because of fixed-rate mortgage contracts and large penalty payments for refinancing. This adjustment likely provides an upper bound for the reduction of the consumption response in these countries because we do not only eliminate the income effect but also the substitution effect of the interest change, which are both positive for borrowers, and any further effects, possibly due to precautionary savings and the occasionally binding collateral constraint. The bottom panel of Table 4 shows that

[21] Note that the consumption response of indebted renters is smaller than the consumption response of renters with positive assets. This is because indebted renters have negative net worth and their consumption response is more strongly affected by the collateral constraint. See also the consumption response of consumers in the bottom quartile of the net worth distribution which is lower than the response of consumers in the second quartile. Note further that the contribution to the aggregate consumption response by households in the top percentiles of the net-worth distribution is relatively small in our calibrated economy. As pointed out by Kaplan et al. (2018), p. 701, high liquid wealth households do not react much to an interest-rate cut due to uninsurable income shocks and possibly binding liquidity constraints in the future.

the consumption response of indebted homeowners accounts for 4 basis points of the aggregate response in Germany. Abstracting from the consumption response of indebted homeowners hence reduces the consumption response on impact from 0.27% to 0.23% in Germany and, analogously based on the results reported in Table 13 of Appendix C.2, from 0.28% to 0.22% in France, thus increasing the difference to the consumption responses in Italy and Spain.[22]

We find substantial heterogeneity in the direct effect of changes in the interest rate on consumption across the four euro-area countries. We have also illustrated that this heterogeneity is amplified if relative house prices are negatively correlated with changes in the real interest rate, as standard asset pricing theory predicts. It would be interesting in further research to investigate whether general equilibrium effects through the labor market or fiscal policy, as emphasized by Kaplan et al. (2018), reduce or further amplify the differences in the consumption responses across countries. The national pecularities in labor market institutions and in the conduct of fiscal policy across euro-area countries suggest that they are additional sources of heterogeneity in the transmission of real-interest rate changes to consumption.

4.2 A fall in the house price

Figure 4 shows the non-housing consumption responses after a 10% drop in house prices that is reversed in two steps within four years. The house-price changes are implemented as a sequence of MIT shocks, i.e., 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% in Italy, 1.4% in France and 1% in Germany. These responses imply elasticities between 0.1 and 0.22 and thus encompass the model-implied elasticity of 0.2 in Kaplan et al. (2019) obtained for the U.S.[23]

Figure 11 in Appendix C.3.1 shows that there is some asymmetry in the consumption response to house price changes. The collateral constraint entails a consumption response that is larger for price decreases than for increases, albeit only by a small amount given that on average households in the euro area are not that highly leveraged. The increase in consumption after a 10% house-price increase is between 0.97% in German and 1.91% in Spain.

[22]In further research it would be desirable to check the robustness of this result if we modeled fixed-rate and variable-rate mortgage contracts explicitly to account for changes in consumer behavior. This extension is non-trivial because it adds additional discrete choices and state variables to the problem.

[23]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.

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
	Aggregate response on impact = −0.0101			
	Composition of impact response across age groups			
Ages 25 – 34	-0.0056	0.1529	0.1770	-0.0010
Ages 35 – 44	-0.0071	0.2166	0.2472	-0.0018
Ages 45 – 54	-0.0103	0.2468	0.2588	-0.0027
Ages 55 – 64	-0.0139	0.1784	0.1619	-0.0022
Ages 65 – 74	-0.0159	0.1871	0.1420	-0.0023
	Composition of impact response across net-worth distribution			
Percentiles 0 – 25	-0.0000	0.2500	0.1919	-0.0000
Percentiles 25 – 50	-0.0049	0.2500	0.2221	-0.0011
Percentiles 50 – 75	-0.0132	0.2500	0.2271	-0.0030
Percentiles 75 – 90	-0.0179	0.1500	0.1815	-0.0032
Percentiles 90 – 95	-0.0166	0.0500	0.0758	-0.0013
Percentiles 95 – 99	-0.0155	0.0400	0.0747	-0.0012
Percentiles 99 – 99.9	-0.0147	0.0090	0.0237	-0.0003
Percentiles 99.9 – 100	-0.0133	0.0010	0.0031	-0.0000
	Composition of impact response across financial positions of homeowners			
Homeowners	-0.0192	0.4361	0.5294	-0.0101
... with positive assets	-0.0173	0.3407	0.4226	-0.0073
... with debt	-0.0267	0.0954	0.1067	-0.0028

Table 5: Germany: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the relative house price by 10%.

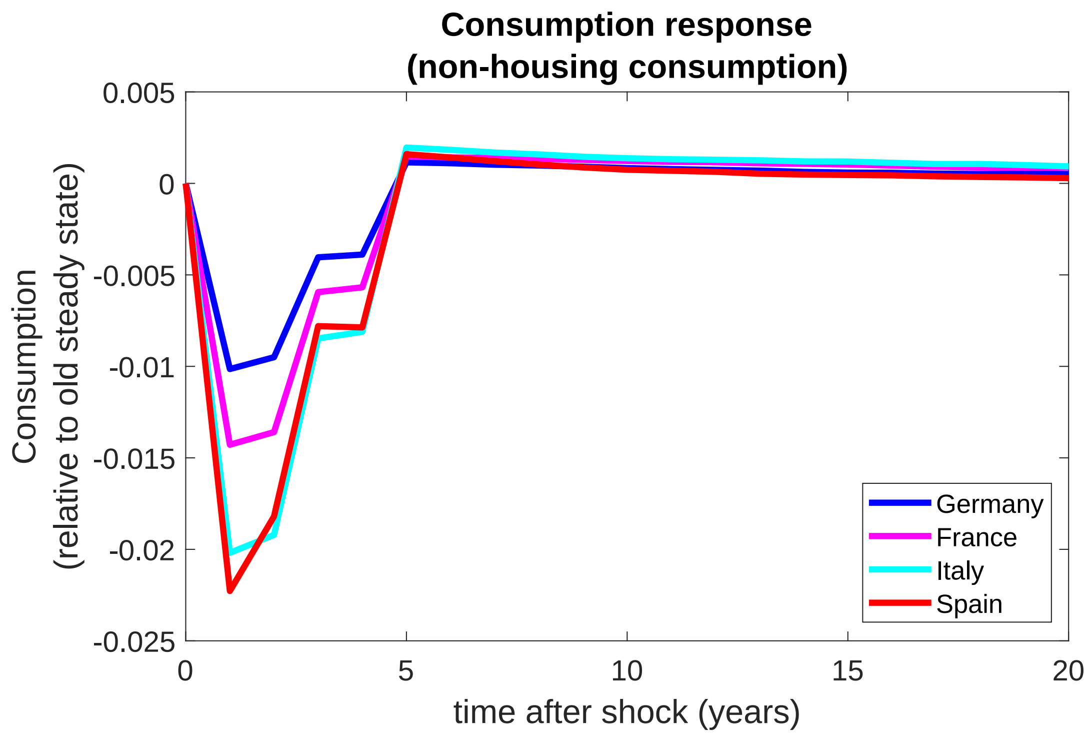


Figure 4: Unexpected fall of the relative house price by 10%, reversed in two steps within 4 years

Changes in house prices affect consumers quite differently depending on their age and portfolio positions. Table 5 illustrates the heterogeneity for Germany. Appendix C.4 contains the results for the other countries and we will refer to the main differences in the findings across countries below.

Table 5 shows that non-housing consumption of older households decreases relatively more after a drop in house prices because more of these households own housing and conditional on ownership their housing stock is larger. Agents with ages between 35 and 54 consume half of aggregate consumption and the consumption responses of this age group account for half of the aggregate response. In Appendix C.4 we show that this pattern is similar for Spain while for France and Italy older age groups contribute more to the aggregate consumption response. The difference is particularly strong quantitatively for Italy where the households aged 65 to 74 contribute a third to the aggregate consumption response.

Table 5 further shows that the consumption response is quite similar across different percentiles in the top half of the net-worth distribution. Since housing wealth and its ownership is concentrated among wealthier households, the top half of the distribution also accounts for most of the aggregate consumption response. Appendix C.4 shows that this is quantitatively less so in Italy in Spain where housing wealth is less concentrated.

The bottom panel of Table 5 shows that indebted homeowners in Germany have a larger consumption response than homeowners with positive financial assets but they account for less of the aggregate consumption response because their share of aggregate consumption is smaller. Appendix C.4 shows that this pattern is similar for France and Italy and quantitatively less so in Spain where indebted homeowners account for a quarter of aggregate consumption. Note that the consumption response of homeowners to house price changes equals the aggregate consumption response because the experiment we consider abstracts from equilibrium feedback effects on renters from house-price changes.[24] The extensive margin of home ownership is thus particularly important to understand the aggregate consumption response to house price changes.

We find that the consumption response to relative house price changes is approximated less well than for the U.S., in particular for Italy, by the rule of thumb proposed by Berger et al. (2018). The rule of thumb is based on the consumption response in a frictionless model which nests our preferences and shares the specification of the collateral constraint. In this case, the consumption response is determined by the endowment effect, while the substitution, income and collateral-constraint effects cancel. To gauge whether the rule of thumb is approximately true in our model with frictions, we proceed as Berger et al. (2018) and calculate the correlation between the actual consumption response in the model with frictions and the rule-of-thumb response. We find that the correlation is 0.74 in Germany, 0.61 in France, 0.56 in Spain and 0.46 in Italy compared to a correlation of 0.964, corresponding to an R^2 statistic of 0.93, for the U.S. in Berger et al. (2018). The difference to the U.S. is partially explained by the different adjustment cost function compared to Berger et al. (2018) and the interest-rate risk in our model. If we eliminate the interest-rate risk in the model calibrated for Germany, as an example without recalibrating the model, the correlation increases to 0.79. If we additionally use the same adjustment cost function as Berger et al. (2018), the correlation increases further to 0.84, quite close to the correlation that Berger et al. (2018) obtain for the U.S.

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 countries. For each country we apply the model to a scenario with a fall of the house price that is expected to be permanent, and whose size corresponds to the fall in the house price within a five-year

[24] If the price drop causes the rent-price ratio to increase instead, the consumption responses are amplified. To provide a bound, we make the assumption that rents remain constant after the house-price drop. The implied increase in the rent-price ratio after the house-price drop then amplifies the negative consumption response in Germany by 1 percentage point so that the response doubles in size. In Spain instead, where the share of renters is smallest among the euro-area countries considered, the additional negative consumption response of renters implies a smaller change of the aggregate consumption response by 0.4 percentage points.

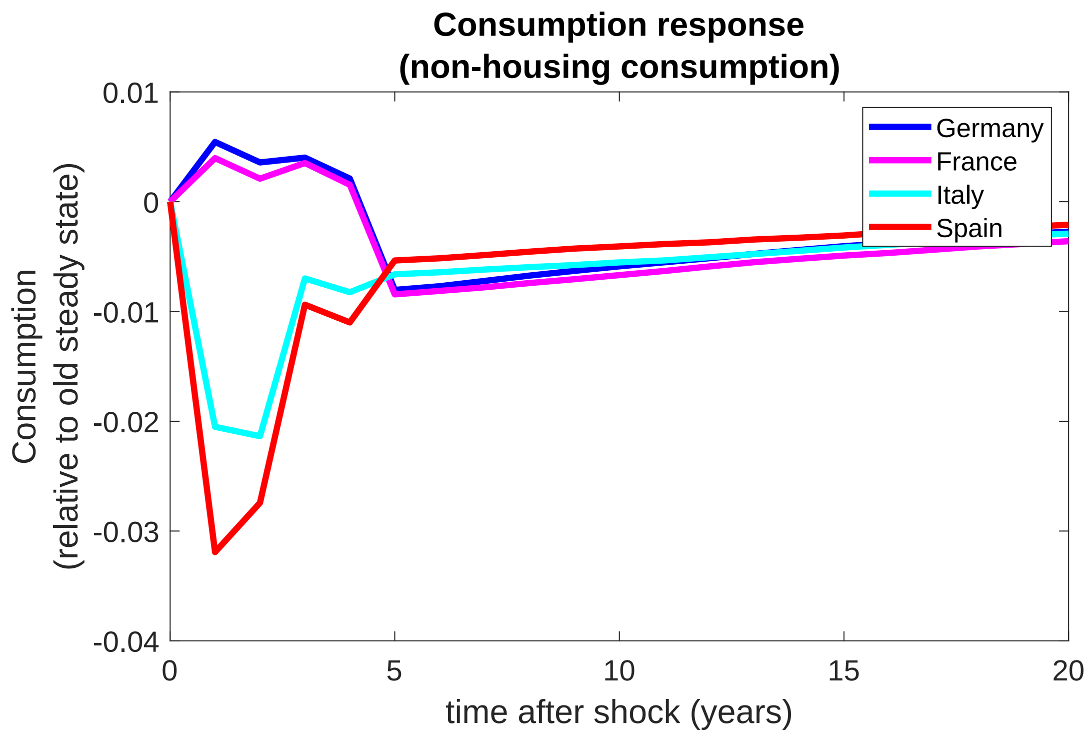


Figure 5: Observed country-specific fall of the relative house price accompanied by a reduction of the real interest rate by 1percentage point, reversed within 4 years (for price change in two steps)

period observed during the last recession. Based on the deflated house-price index for 2006 to 2016 from Eurostat, we let the house price drop by 5% in Germany and France, by 15% in Italy and by 20% in Spain.[25] At the same time we assume that a central bank engineers a temporary reduction of the real interest rate by 1 percentage point. These changes are then reversed within four years.

Figure 5 shows the consumption responses for this experiment. For Germany and France, the fall in the real interest rate by 1 percentage point 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 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 4, a given drop of the relative house price triggers a larger negative response of consumption. A stronger positive consumption response to a fall in the real interest rate in Spain compared to Germany or France, visible in Figure 3, does not overturn this result for Spain. For Italy the consumption response to a fall in the real interest rate, shown in Figure 3, is quantitatively similar to France but larger than in Germany, and the effect of the fall in

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

the relative house price also dominates.

The results for the experiments suggest that attempts to stabilize consumption in the euro area involve trade-offs. These arise 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.[26]

Table 6 shows that the responses to a fall in the real interest rate (top panel) and 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 and France then have the same consumption response to a fall in the relative house price as Germany up to the third digit. The consumption response for Italy remains rather different instead. This suggests that the endowment effect, which is captured by the rule of thumb for the consumption response in Berger et al. (2018), explains quantitatively less of the consumption response to house-price changes in Italy than in the other considered euro-area countries. Indeed, we have shown at the end of subsection 4.2 that the correlation between the actual consumption response and the rule of thumb for the response is smallest in Italy among the considered euro-area countries. It turns out that this is related to the stronger contribution of the elderly to the aggregate consumption response in Italy compared to Germany, shown in Tables 5 and 17. The reason is that the consumption response of older households, who

[26]We apply this difference-in-differences technique to the aggregate response of consumption. Given that we impose the German steady-state distribution of household finances on France, Italy and Spain, these economies converge back to their respective steady state, causing dynamic changes in consumption even without any price changes. To account for this additional effect, we construct a control group of consumers in France, Italy and Spain that start with the German distribution of household finances and that are *not* exposed to a change of the interest rate or the relative house price. We construct a treatment group of consumers in France, Italy and Spain that start with the German distribution of household finances and that are exposed to the price changes.

	Germany	France	Italy	Spain
Consumption response on impact to fall of the **real interest rate** from 2% to 1.75%				
... with observed differences in household finances at time of shock				
	0.0027	0.0028	0.0028	0.0029
... with same household finances as in Germany at time of shock				
	0.0027	0.0020	0.0023	0.0024
Consumption response on impact to fall of the **relative house price** by 10%				
... with observed differences in household finances at time of shock				
	-0.010	-0.014	-0.020	-0.022
... with same household finances as in Germany at time of shock				
	-0.010	-0.010	-0.018	-0.010

Table 6: Consumption responses and differences in household finances

are mostly non-adjusting homeowners, is less well approximated by the rule of thumb. At ages 65 to 74 the correlation coefficient between the rule of thumb and the actual consumption response is 0.58 in Germany and 0.42 in Italy compared to the correlation in the whole sample of 0.74 and 0.46, respectively. This suggests that part of the difference in the consumption response for Italy compared to Germany is accounted for by the different age composition of aggregate consumption in the two countries.

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 mask some of the underlying heterogeneity in the consumption responses across countries. If France, Italy and Spain have the same distribution of household finances (as Germany) at the time of the shock, the consumption responses after a decrease in the real interest rate differ by up to 7 basis points compared to 2 basis points in the benchmark.

Putting these results together, we compute how the consumption response in the experiment illustrated in Figure 5 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 1 percentage point. 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 58% 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 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 (58%, in this experiment) of cross-country differences in consumption responses. Heterogeneous household decisions after a shock explain the other part (42%, in this experiment) of cross-country differences. These household financial decisions are determined by the heterogeneous shocks and 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 applied a life-cycle incomplete-markets model with owned and rented housing and collateralized debt to capture key dimensions of heterogeneity in household finances in the four largest euro-area countries: France, Germany, Italy and Spain. The aggregate consumption responses generated by the model have revealed sizable differences in the transmission from changes in the real interest rate and house prices to consumption across these countries, which differ in their pension and tax systems, income risk, and fees on real estate transactions. Within countries, we have identified which population groups in terms of ages, housing tenure and asset positions quantitatively contribute most to the aggregate consumption response.

In a quantitative experiment we find that controlling for pre-existing differences in household financial positions across these four euro-area countries reduces the maximum extent of cross-country differences in consumption responses by 58%. Thus, 42% of the effects are explained by differences in household financial decisions, that depend on the country-specific environment and heterogeneous shocks. This underlines the importance of a structural approach of modeling financial decisions of heterogeneous households when analyzing the transmission mechanism of monetary policy.

Our project provides a proof of concept that a structural life-cycle model with discrete decisions on home ownership and adjustment of owned housing, and continuous portfolio choices can be optimized to fit the rich household micro data, using an appropriately designed solution method. In particular, the method implemented avoids any need to restrict the utility value of housing to positions on a coarse, discrete grid as in much of the literature. Instead we capture the portfolio positions accurately, which is important for computing the implied consumption responses.

The heterogeneity of consumption responses across and within countries illustrates the limits for what uniform monetary policy in the euro area can achieve. Our results suggest that country-specific fiscal policy through national taxes or within-country transfers is required to provide complementary policy instruments if policy makers want to mitigate not only the asymmetric effects of monetary policy across countries but also the distributional effects across consumers with different ages, housing tenure and asset positions that we find for each of the analyzed euro-area countries.

A 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 the price level p_t does not enter as a separate state variable. 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 utility function

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 described by

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

Resources relevant for bequests contain the term $p_{t+1}\hat{h}_{j+1}$, which can be expressed as Πh_{j+1}. Given the separability in discounted expected life-cycle utility, we have that the normalization extends to the forward-looking objective of the household.

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.

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

$$c_j + a_{j+1} = y_j(s_j) + (1 + r_{t-1}) a_j,$$

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

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

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

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

becomes

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

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

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

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

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

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 rent-to-price ratio k_t to express the rental price $q_t = k_t p_t$, the budget constraint

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

becomes

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

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

$$c_j + a_{j+1} + k_t f_j + \alpha_R(h_j) = y_j(s_j) + (1 + r_{t-1})a_j + \Pi h_j \ .$$

The collateral constraint is

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

The recursive formulation

Uncertainty in the dynamic optimization problem 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 realization of the Markov state at age j by s_j. Note that this Markov state represents the combination of two sources of uncertainty here: aggregate uncertainty about the evolution of the risk-free interest rate and idiosyncratic (household specific) earnings uncertainty.

We first define an auxiliary state variable, which turns out to be convenient for the solution, and rewrite all constraints using that variable. The auxiliary state variable x_j, which may be interpreted as liquidable wealth, is defined as

$$x_j = (1 + r_{t-1})\, a_j + (1 - \alpha_1)\, \Pi h_j.$$

For the two cases (not adjusting and adjusting) of ownership choice, the budget constraint is expressed in terms of the auxiliary variable as follows:

$$c_j + a_{j+1} + h_{j+1} + \mathbf{1}_{d_j=1}\ \alpha_j(h_j, h_{j+1}) = y_j\left(s_j\right) + (1 + r_{t-1})a_j + \Pi h_j,$$

where $\mathbf{1}_{d_j=1}$ denotes an indicator function which takes the value of 1 if an adjustment is made and zero otherwise.

In the case of **non-adjustment** of housing, where the discrete choice variable is $d_j = 0$, and $h_{j+1} = \Pi h_j$, we have

$$c_j = y_j\left(s_j\right) + x_j - (1 - \alpha_1)\Pi h_j - a_{j+1}.$$

In the case of **adjustment** of housing, where the discrete choice variable is $d_j = 1$, we have

$$c_j = y_j\left(s_j\right) + x_j - a_{j+1} - h_{j+1} - \alpha_{0,j} - \alpha_2 h_{j+1}.$$

In both cases, adjustment and non-adjustment, the next-period asset positions need to satisfy the collateral constraint

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

which, in terms of our auxiliary variable can be expressed as derived in the following. For the next age, the definition of the auxiliary state variable can be solved for the financial asset

$$(1 + r_t)\, a_{j+1} = x_{j+1} - (1 - \alpha_1)\, \Pi h_{j+1}\ .$$

Substituting for $(1 + r_t)\, a_{j+1}$ in the collateral constraint, we obtain

$$x_{j+1} \geq [(1 - \alpha_1)\, \Pi - \mu]\, h_{j+1} - g_{y,j+1}\ .$$

For the case of **rental choice**, where the discrete choice is $d_j = 2$, and $h_{j+1} = 0$, the budget constraint

$$c_j + a_{j+1} + k_t f_j + \alpha_R(h_j) = y_j\left(s_j\right) + (1 + r_{t-1})a_j + \Pi h_j$$

is expressed in terms of the auxiliary variable as follows

$$c_j + k_t f_j = y_j\left(s_j\right) + x_j - a_{j+1}\ ,$$

and the collateral constraint is

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

In the recursive problem we denote

$$W_j(x_j, h_j, s_j) = \max_{d_j, c_j, f_j, a_{j+1}, h_{j+1}} \{U(c_j, \bar{s}_j) + \left(1 - \iota_j\right) \beta \underset{s_{j+1}|s_j}{E} W_{j+1}(x_{j+1}, h_{j+1}, s_{j+1}) + \iota_j \Psi\left(x_{j+1}\right)\},$$

where the expectation operator $\underset{s'|s}{E} f(\cdot, s') = \sum_{s' \in S} \pi_{s,s'} f(\cdot, s')$.[27] The probability of death in period j is denoted by ι_j. We consider a warm-glow bequest motive, represented by utility from bequeathing, as captured by the function $\Psi\left(x_{j+1}\right)$, whose argument is therefore to be interpreted as liquidable wealth after death. The bequest utility function is parameterized as follows:

$$\Psi(x_{j+1}) = \psi_0 \log\left(\psi_1 + x_{j+1}\right) .$$

We require that $\psi_1 > g_{y,j+1}$ for all j, in order to ensure that the bequest utility function is well defined for borrowers in the feasible borrowing set of our model.

Henceforth we denote by β_j the product of the survival probability in age j and the discount factor β, that is

$$\beta_j \equiv \left(1 - \iota_j\right) \beta.$$

By the same token, we define

$$\Psi_j\left(x_{j+1}\right) \equiv \iota_j \Psi\left(x_{j+1}\right).$$

Conditional on the discrete choice,

$$w_j(x_j, h_j, s_j | d_j) = \max_{c_j, f_j, a_{j+1}, h_{j+1}} \left\{ U(c_j, \bar{s}_j) + \beta_j \underset{s_{j+1}|s_j}{E} W_{j+1}(x_{j+1}, h_{j+1}, s_{j+1}) + \Psi_j\left(x_{j+1}\right) \right\}.$$

So far, there is uncertainty about death, earnings, and future interest rates in the model. We handle the discrete-choice options in the recursive problem according to the approach suggested by Iskhakov et al. (2017). 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, keeping for simplicity the same notation for functions $W_j(\cdot)$ and $w_j(\cdot)$,

$$W_j(x_j, h_j, s_j, \eta_j) = \max_{d_j \in D_j} \{w_j(x_j, h_j, s_j | d_j) + \eta_{d_j}\} ,$$

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

[27] Recall that $\bar{s}$ denotes the price-transformed service flow from housing while s denotes the stochastic state.

$$w_j(x_j,h_j,s_j|d_j) = \max_{c_j,f_j,a_{j+1},h_{j+1}} \left\{ U(c_j,\bar{s}_j) + \beta_j \underset{s_{j+1}|s_j}{E} \left[\underset{\eta_{j+1}}{E} W_{j+1}(x_{j+1},h_{j+1},s_{j+1},\eta_{j+1}) \right] + \Psi_j\left(x_{j+1}\right) \right\}$$

$$= \max_{c_j,f_j,a_{j+1},h_{j+1}} \left\{ U(c_j,\bar{s}_j) + \beta_j \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{w}_{j+1}(x_{j+1},h_{j+1},s_{j+1}|d_{j+1}),D_{j+1};\sigma) + \Psi_j\left(x_{j+1}\right) \right\}$$

with[28]

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

Ownership choice, not adjusting

In the case of non-adjustment, where $h_{j+1} = \Pi h_j$, using the budget constraint for this case, we have

$$w_j(x_j,h_j,s_j|d_j=0) = \max_{a_{j+1}}\{U(y_j\left(s_j\right) + x_j - (1-\alpha_1)\Pi h_j - a_{j+1}, \phi\Pi h_j)$$
$$+ \beta_j \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{w}_{j+1}(x_{j+1},\Pi h_j,s_{j+1}|d_{j+1}),D_{j+1};\sigma) + \Psi_j\left(x_{j+1}\right)\}\ ,$$

subject to the collateral constraint

$$x_{j+1} \geq [(1-\alpha_1)\Pi - \mu]\Pi h_j - g_{y,j+1}\ .$$

Ownership choice, adjusting

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

$$w_j(x_j,h_j,s_j|d_j=1) = \max_{a_{j+1},h_{j+1}}\{U(y_j\left(s_j\right) + x_j - a_{j+1} - h_{j+1} - \alpha_{0,j} - \alpha_2 h_{j+1}, \phi h_{j+1})$$
$$+ \beta_j \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{w}_{j+1}(x_{j+1},h_{j+1},s_{j+1}|d_{j+1}),D_{j+1};\sigma) + \Psi_j\left(x_{j+1}\right)\}\ .$$

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

$$x_{j+1} \geq [(1-\alpha_1)\Pi - \mu]\, h_{j+1} - g_{y,j+1}\ .$$

Note that in this discrete-choice-specific problem any dependence on h_j is captured by its

[28]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 $\left\{\left(x|d_{j+1}\right) : d_{j+1} \in D_{j+1}\right\}$

contribution to x_j. Apart from this contribution, the problem conditional on choosing to adjust is independent of h_j, which is convenient for the numerical solution.

Rental choice

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

$$\begin{aligned} w_j(x_j, h_j, s_j | d_j = 2) = \max_{f_j, a_{j+1}} \Big[& U(y_j\left(s_j\right) + x_j - a_{j+1} - k_t f_j, \phi_R f_j) \\ & + \beta_j \underset{s_{j+1}|s_j}{E} \lambda(\mathbf{w}_{j+1}(x_{j+1}, 0, s_{j+1} | d_{j+1}), D_{j+1}; \sigma) + \Psi_j\left(x_{j+1}\right)\Big] . \end{aligned}$$

The collateral constraint in this case is

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

Note that also for this discrete-choice-specific problem any dependence on h_j is captured by its contribution to x_j. Separate from this contribution, the problem conditional on choosing to rent is independent of h_j, which conveniently simplifies the numerical solution.

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 Calibration

Table 7 shows the parameters that are common across countries in the calibration. For this set of parameters we 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 Section 3, we calibrate a higher country-specific cost for the purchaser α_2 because in the

	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
$\bar{r}$	0.02
σ_r	0.0064
ρ_r	0.39
	Price growth factor
Π	1.0
	Taste shocks for discrete choice
σ_ϵ	0.01

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

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.

The standard deviation of taste shocks for the discrete choice, σ_ϵ, is set to add a small amount of noise to the discrete-choice part of the decision problem, as discussed in Iskhakov et al. (2017). Adding smoothness through such a model feature is convenient for approximating functions in the model solution given discrete grids for the endogenous states.

	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).

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-

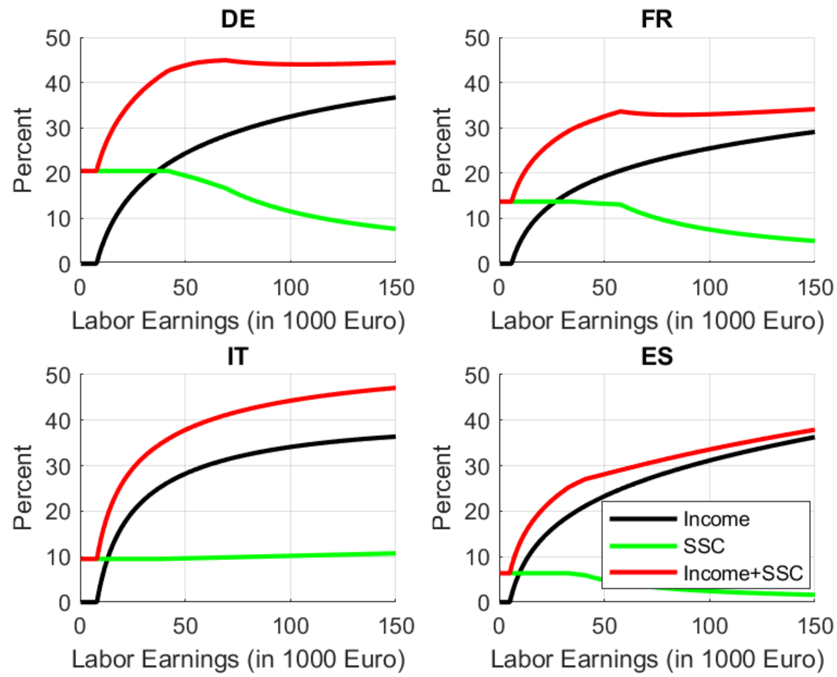


Figure 6: Country-specific schedules for average income taxes and social security contributions. Source: Authors' computation based on the OECD Tax Database, Tables i1, i5 ad i7.

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

	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	7.109	1.820	4.074	3.266
δ_1	0.159	0.790	0.575	0.689
δ_2	−0.003	−0.028	−0.021	−0.027
δ_3	2×10^{-5}	4×10^{-4}	3×10^{-4}	5×10^{-4}
δ_4	-5×10^{-8}	-3×10^{-6}	-2×10^{-6}	-3×10^{-6}
Variance of residual	0.547	0.325	0.532	0.410

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

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 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 6 illustrates the schedules used in our calibration.

B.3 Estimation of the age income 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 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% transaction tax (*Grunderwerbsteuer*) to fees of 2.5% for real-estate agents. Although the *Grunderwerbsteuer* varies between 3.5% and 6.5% across regions, we cannot exploit this variation because we do not have information about the region of the households 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 Decomposition of the effects of country-specific model inputs

Tables 10, 11 and 12 show how the cross-country differences in the target statistics in France, Italy and Spain relative to Germany, reported in Table 3, depend on the different model inputs. The results in the tables are obtained by changing the country-specific inputs mentioned in each column to the inputs of the German benchmark. The changes are implemented sequentially and, as is well known, the sequence will matter for the precise quantitative change of the respective target statistic. The main point of these tables is thus to provide an indication for the order of magnitude with which a certain country-specific model input affects the target statistics. The columns contain the relative changes in the target statistics resulting from the implemented change of the model input mentioned in the header of the respective column.

B.6 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).

	Age composition	Initial distribution of net worth and housing	Pensions/Tax/ Income profile and process	Transaction cost	Rent-price ratio	Preference parameters
Target statistics			*Relative changes*			
Housing wealth	-0.04	-0.11	0.85	-0.18	0.47	0.01
Net worth	-0.19	-0.33	-0.48	-0.00	-0.002	2.00
Rental rate	-0.08	-0.00	1.51	-0.27	0.67	0.83
Indebted homeowners	0.09	0.86	6.02	-0.42	0.50	6.06
LTV	-0.14	-0.54	-0.58	-0.49	1.02	1.73
LTV > 0.5	-0.11	-0.50	-0.21	-0.14	0.28	1.68

Table 10: France: decomposition of effects of country-specific model inputs

	Age composition	Initial distribution of net worth and housing	Pensions/Tax/ Income profile and process	Transaction cost	Rent-price ratio	Preference parameters
Target statistics			*Relative changes*			
Housing wealth	0.05	0.55	-0.16	-0.17	0.61	0.12
Net worth	0.12	0.93	-0.76	-0.00	-0.04	0.77
Rental rate	0.11	0.67	-0.15	-0.33	1.24	-0.53
Indebted homeowners	-0.01	-1.36	3.16	-2.14	6.97	-5.61
LTV	0.01	-0.04	0.02	0.30	-0.27	0.99
LTV > 0.5	0.01	-0.10	0.02	0.20	-0.08	0.95

Table 11: Italy: decomposition of effects of country-specific model inputs

	Age composition	Initial distribution of net worth and housing	Pensions/Tax/ Income profile and process	Transaction cost	Rent-price ratio	Preference parameters
Target statistics			*Relative changes*			
Housing wealth	0.01	0.89	-0.02	-0.13	1.45	-1.20
Net worth	-0.04	1.45	-0.56	-0.03	0.09	0.09
Rental rate	0.00	0.37	0.15	-0.15	1.66	-1.03
Indebted homeowners	0.08	-0.42	0.52	-0.15	0.07	0.91
LTV	0.04	-0.57	0.16	-0.17	1.32	0.21
LTV > 0.5	0.04	-0.62	0.18	-0.18	1.52	0.06

Table 12: Spain: decomposition of effects of country-specific model inputs

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 households housing wealth is positive. 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.

C Further results on the consumption responses

C.1 Consumption response to changes in the real interest rate

C.1.1 Full attribution of the change in the rent-price ratio to the relative house price

The assumption of the full attribution of the change in the rent-price ratio to house prices implies an increase of the relative house price between 10% and 13% across the considered countries. The results of the benchmark and the case, in which the fall in the rent-price ratio is fully attributed to an increase of the relative house price, provide bounds for intermediate scenarios in which the decrease of the rent-price ratio is attributed both to a fall in rents and a decrease in house prices. 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 3 shows that a fall in the real interest rate by 25 bps increases non-housing consumption on impact between 0.27% in Germany and 0.29% across countries. If accompanied by the relative house price increase between 10% and 13%, Figure 7 shows that the responses become larger and are between 1.51% in Germany and 2.54% in Italy.

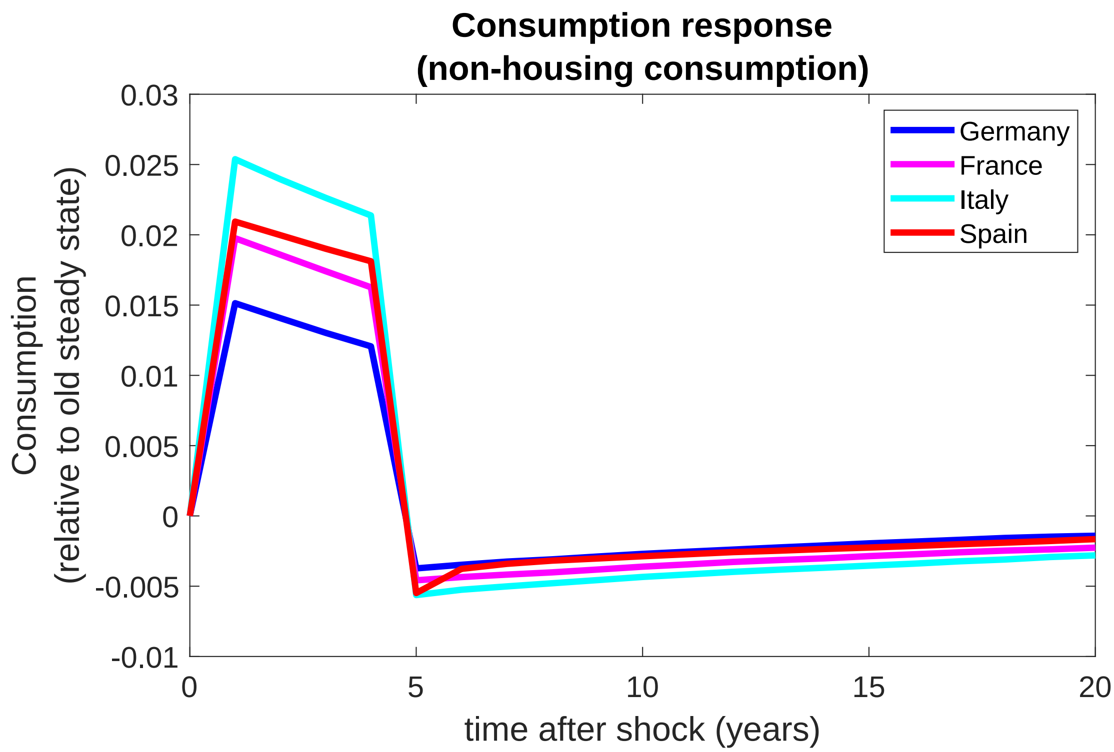


Figure 7: Unexpected fall of the real interest rate, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points and the implied maximal increase of the relative house price (reversed after 4 years)

C.1.2 Permanent reduction of the interest rate

Figure 8 illustrate that the consumption responses increase tenfold compared with the benchmark case if the shock is expected to be permanent. The responses also become more persistent, as one would expect.

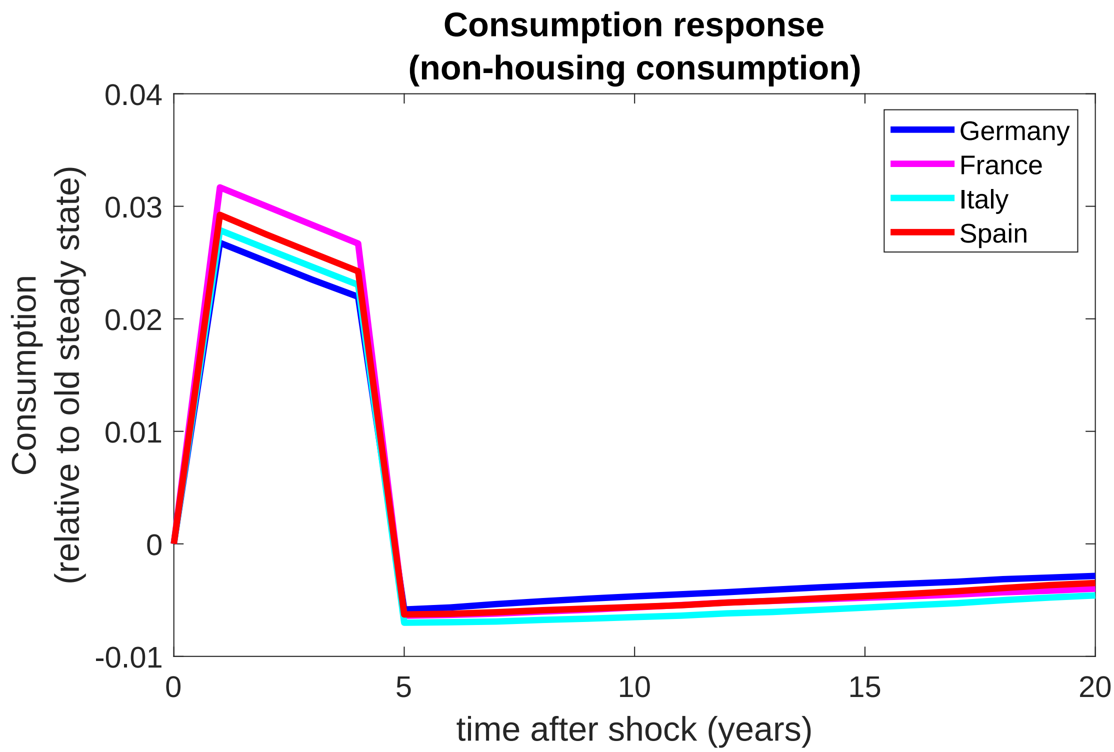


Figure 8: Unexpected fall of the real interest rate, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points. Note: Price changes reversed after 4 years but expected to be permanent.

C.1.3 No pass-through to the rent-price ratio

Figure 9 shows that, without a pass-through to the rent-price ratio, the responses of non-housing consumption are of a similar order of magnitude as in the benchmark but they are more heterogeneous across countries. See the discussion in the main text.

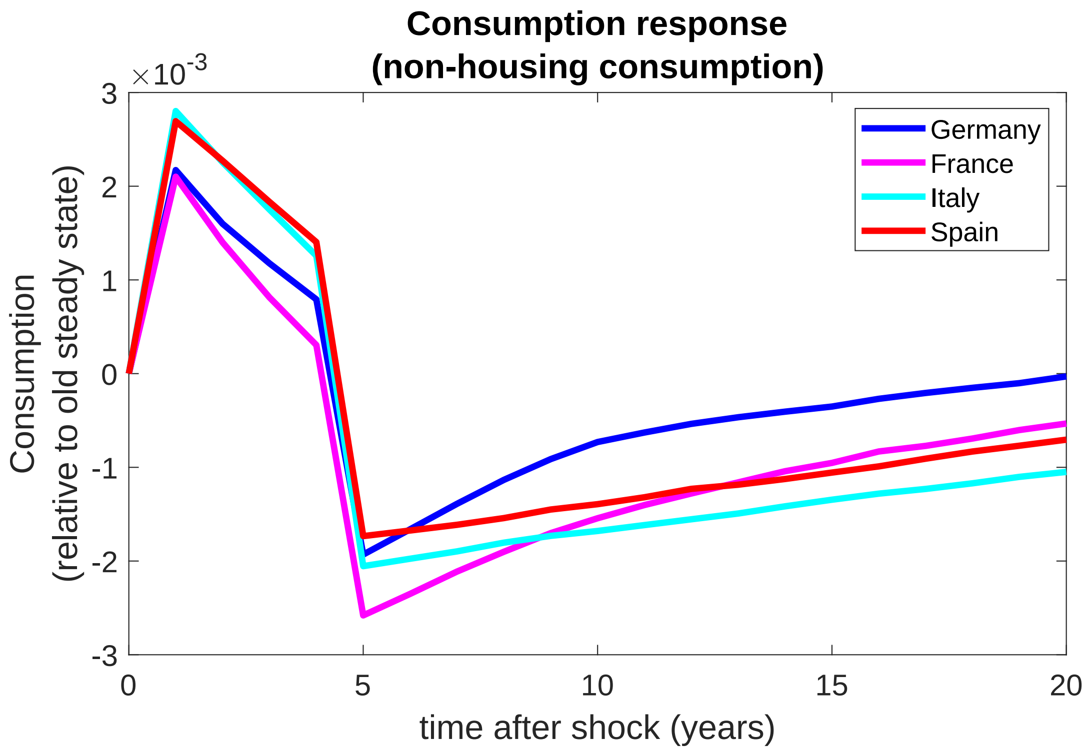


Figure 9: Unexpected fall of the real interest rate from 2% to 1.75% (reversed after 4 years), without pass-through to rent-to-price ratio

C.1.4 Asymmetry of the response?

Figure 10 shows that the absolute size of the consumption response to a positive change of the interest rate is quantitatively similar to the response to negative change of the interest rate (see Figure 3 in the main text). There are no sizable asymmetries in the response.

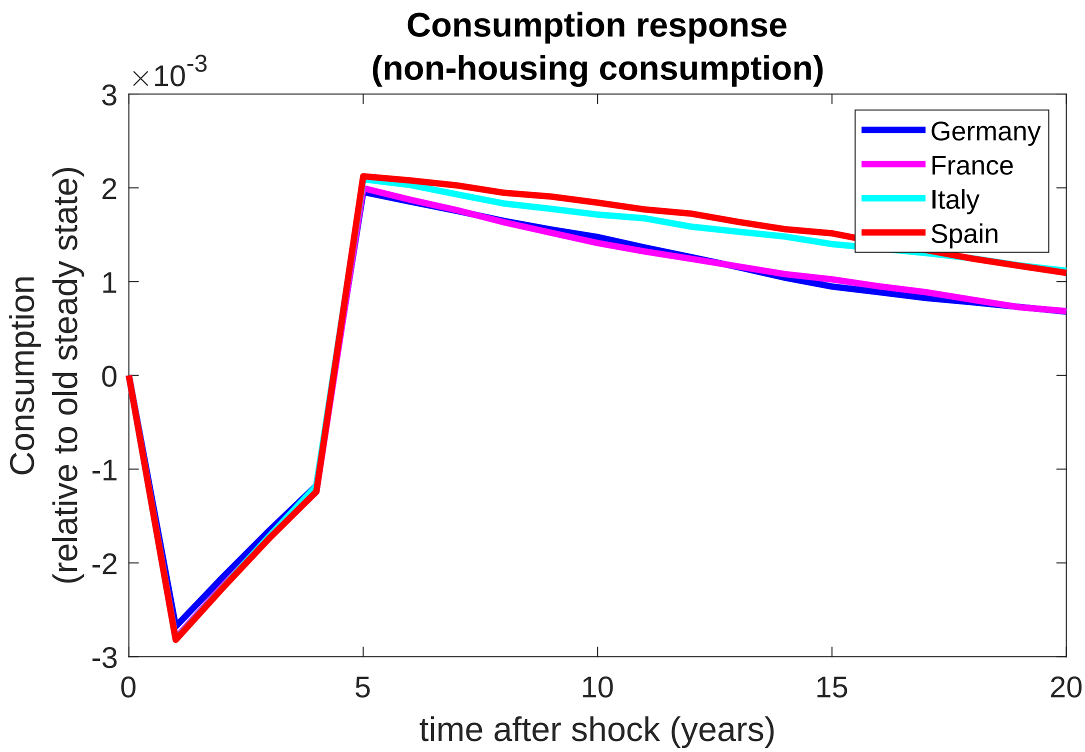


Figure 10: Unexpected increase of the real interest rate from 2% to 2.25%, with a contemporaneous increase of the rent-to-price ratio by 25 basis points (reversed after 4 years)

C.2 Results for France, Italy and Spain on the heterogeneity of the consumption response after a fall in the interest rate

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
		Aggregate response on impact = 0.0028		
		Composition of impact response across age groups		
Ages 25 – 34	0.0033	0.1685	0.1814	0.0006
Ages 35 – 44	0.0033	0.2334	0.2432	0.0008
Ages 45 – 54	0.0031	0.2100	0.2116	0.0006
Ages 55 – 64	0.0024	0.2285	0.2206	0.0005
Ages 65 – 74	0.0018	0.1443	0.1296	0.0002
		Composition of impact response across net-worth distribution		
Percentiles 0 – 25	0.0033	0.2500	0.1935	0.0006
Percentiles 25 – 50	0.0033	0.2500	0.2155	0.0007
Percentiles 50 – 75	0.0031	0.2500	0.2404	0.0007
Percentiles 75 – 90	0.0025	0.1500	0.1780	0.0005
Percentiles 90 – 95	0.0020	0.0500	0.0733	0.0002
Percentiles 95 – 99	0.0017	0.0400	0.0723	0.0001
Percentiles 99 – 99.9	0.0014	0.0090	0.0230	0.0000
Percentiles 99.9 – 100	0.0014	0.0010	0.0040	0.0000
		Composition of impact response across housing-tenure types		
Homeowners	0.0027	0.5754	0.6434	0.0018
... with positive assets	0.0024	0.4262	0.4945	0.0012
... with debt	0.0039	0.1492	0.1490	0.0006
Renters	0.0030	0.4246	0.3566	0.0010
... with positive assets	0.0030	0.4054	0.3461	0.0010
... with debt	0.0020	0.0192	0.0105	0.0000

Table 13: France: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the real interest rate from 2% to 1.75% for 4 years, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points.

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
	Aggregate response on impact = 0.0028			
	Composition of impact response across age groups			
Ages 25 – 34	0.0031	0.0927	0.0737	0.0002
Ages 35 – 44	0.0030	0.2464	0.2171	0.0007
Ages 45 – 54	0.0029	0.2349	0.2298	0.0007
Ages 55 – 64	0.0027	0.2113	0.2297	0.0006
Ages 65 – 74	0.0026	0.1973	0.2291	0.0006
	Composition of impact response across net-worth distribution			
Percentiles 0 – 25	0.0031	0.2500	0.1393	0.0004
Percentiles 25 – 50	0.0031	0.2500	0.1981	0.0006
Percentiles 50 – 75	0.0030	0.2500	0.2634	0.0008
Percentiles 75 – 90	0.0026	0.1500	0.2068	0.0005
Percentiles 90 – 95	0.0023	0.0500	0.0843	0.0003
Percentiles 95 – 99	0.0021	0.0400	0.0835	0.0002
Percentiles 99 – 99.9	0.0020	0.0090	0.0216	0.0000
Percentiles 99.9 – 100	0.0012	0.0010	0.0030	0.0000
	Composition of impact response across housing-tenure types			
Homeowners	0.0028	0.6343	0.7580	0.0021
... with positive assets	0.0026	0.4732	0.6289	0.0016
... with debt	0.0037	0.1611	0.1290	0.0005
Renters	0.0028	0.3657	0.2420	0.0007
... with positive assets	0.0028	0.3568	0.2393	0.0007
... with debt	0.0016	0.0089	0.0027	0.0000

Table 14: Italy: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the real interest rate from 2% to 1.75% for 4 years, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points.

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
		Aggregate response on impact = 0.0029		
		Composition of impact response across age groups		
Ages 25 – 34	0.0033	0.1425	0.1810	0.0006
Ages 35 – 44	0.0033	0.2543	0.2911	0.0010
Ages 45 – 54	0.0030	0.2297	0.2314	0.0007
Ages 55 – 64	0.0024	0.1836	0.1584	0.0004
Ages 65 – 74	0.0018	0.1706	0.1246	0.0002
		Composition of impact response across net-worth distribution		
Percentiles 0 – 25	0.0038	0.2500	0.1685	0.0006
Percentiles 25 – 50	0.0035	0.2500	0.2068	0.0007
Percentiles 50 – 75	0.0029	0.2500	0.2492	0.0007
Percentiles 75 – 90	0.0022	0.1500	0.1874	0.0004
Percentiles 90 – 95	0.0019	0.0500	0.0810	0.0002
Percentiles 95 – 99	0.0023	0.0400	0.0799	0.0002
Percentiles 99 – 99.9	0.0022	0.0090	0.0224	0.0001
Percentiles 99.9 – 100	0.0012	0.0010	0.0050	0.0000
		Composition of impact response across housing-tenure types		
Homeowners	0.0030	0.8357	0.9047	0.0027
... with positive assets	0.0024	0.5429	0.6432	0.0016
... with debt	0.0042	0.2928	0.2615	0.0011
Renters	0.0024	0.1643	0.0953	0.0002
... with positive assets	0.0026	0.1314	0.0796	0.0002
... with debt	0.0014	0.0329	0.0157	0.0000

Table 15: Spain: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the real interest rate from 2% to 1.75% for 4 years, with a contemporaneous reduction of the rent-to-price ratio by 25 basis points.

C.3 Consumption response to changes in the relative house price

C.3.1 Asymmetry of the response?

Compared to Figure 4 for the consumption response to a drop in house prices, Figure 11 shows that an increase in the relative house price has quantitatively smaller effects. The asymmetry of the effects is rather small as discussed in the main text.

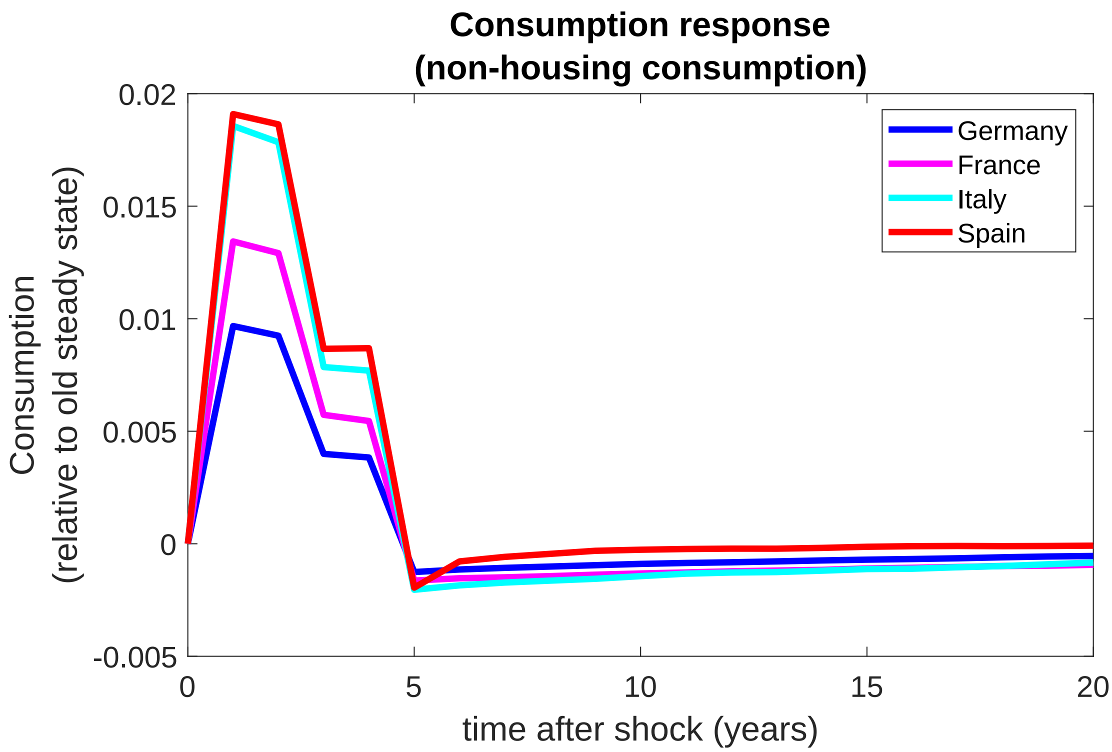


Figure 11: Unexpected increase of the relative house price by 10%, reversed in two steps within 4 years

C.4 Results for France, Italy and Spain on the heterogeneity of the consumption response after a house price drop

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
	Aggregate response on impact = −0.0143			
	Composition of impact response across age groups			
Ages 25 – 34	-0.0056	0.1685	0.1814	-0.0010
Ages 35 – 44	-0.0091	0.2334	0.2432	-0.0022
Ages 45 – 54	-0.0150	0.2099	0.2116	-0.0032
Ages 55 – 64	-0.0205	0.2285	0.2206	-0.0045
Ages 65 – 74	-0.0233	0.1443	0.1296	-0.0030
	Composition of impact response across net-worth distribution			
Percentiles 0 – 25	-0.0014	0.2500	0.1936	-0.0003
Percentiles 25 – 50	-0.0087	0.2500	0.2156	-0.0019
Percentiles 50 – 75	-0.0192	0.2500	0.2403	-0.0046
Percentiles 75 – 90	-0.0218	0.1500	0.1780	-0.0039
Percentiles 90 – 95	-0.0215	0.0500	0.0733	-0.0016
Percentiles 95 – 99	-0.0211	0.0400	0.0723	-0.0015
Percentiles 99 – 99.9	-0.0205	0.0090	0.0230	-0.0005
Percentiles 99.9 – 100	-0.0151	0.0010	0.0040	-0.0001
	Composition of impact response across financial positions of homeowners			
Homeowners	-0.0222	0.5743	0.6428	-0.0143
... with positive assets	-0.0223	0.4269	0.4950	-0.0110
... with debt	-0.0221	0.1475	0.1478	-0.0033

Table 16: France: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the relative house price by 10%.

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
	Aggregate response on impact = −0.0202			
	Composition of impact response across age groups			
Ages 25 – 34	-0.0086	0.0927	0.0737	-0.0006
Ages 35 – 44	-0.0119	0.2464	0.2170	-0.0026
Ages 45 – 54	-0.0165	0.2349	0.2298	-0.0038
Ages 55 – 64	-0.0233	0.2113	0.2298	-0.0054
Ages 65 – 74	-0.0309	0.1973	0.2292	-0.0071
	Composition of impact response across net-worth distribution			
Percentiles 0 – 25	-0.0016	0.2500	0.1392	-0.0002
Percentiles 25 – 50	-0.0168	0.2500	0.1983	-0.0033
Percentiles 50 – 75	-0.0238	0.2500	0.2635	-0.0063
Percentiles 75 – 90	-0.0259	0.1500	0.2067	-0.0054
Percentiles 90 – 95	-0.0265	0.0500	0.0842	-0.0022
Percentiles 95 – 99	-0.0262	0.0400	0.0834	-0.0022
Percentiles 99 – 99.9	-0.0234	0.0090	0.0216	-0.0005
Percentiles 99.9 – 100	-0.0243	0.0010	0.0030	-0.0001
	Composition of impact response across financial positions of homeowners			
Homeowners	-0.0266	0.6340	0.7581	-0.0202
... with positive assets	-0.0261	0.4744	0.6299	-0.0164
... with debt	-0.0293	0.1596	0.1281	-0.0038

Table 17: Italy: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the relative house price by 10%.

Group	Consumption response of group	Share of group	Consumption share of group	Contribution of group to aggregate consumption response
Aggregate response on impact = −0.0223				
Composition of impact response across age groups				
Ages 25 – 34	-0.0275	0.1425	0.1809	-0.0050
Ages 35 – 44	-0.0256	0.2543	0.2911	-0.0075
Ages 45 – 54	-0.0204	0.2297	0.2315	-0.0047
Ages 55 – 64	-0.0169	0.1836	0.1585	-0.0027
Ages 65 – 74	-0.0177	0.1706	0.1246	-0.0022
Composition of impact response across net-worth distribution				
Percentiles 0 – 25	-0.0358	0.2501	0.1695	-0.0061
Percentiles 25 – 50	-0.0184	0.2499	0.2068	-0.0038
Percentiles 50 – 75	-0.0171	0.2500	0.2492	-0.0043
Percentiles 75 – 90	-0.0149	0.1500	0.1869	-0.0028
Percentiles 90 – 95	-0.0234	0.0500	0.0807	-0.0019
Percentiles 95 – 99	-0.0354	0.0400	0.0796	-0.0028
Percentiles 99 – 99.9	-0.0258	0.0090	0.0223	-0.0006
Percentiles 99.9 – 100	-0.0144	0.0010	0.0050	-0.0001
Composition of impact response across financial positions of homeowners				
Homeowners	-0.0246	0.8362	0.9050	-0.0223
... with positive assets	-0.0188	0.5487	0.6471	-0.0121
... with debt	-0.0393	0.2874	0.2580	-0.0102

Table 18: Spain: heterogeneity of the (non-housing) consumption response across households. Notes: response on impact after an unexpected fall of the relative house price by 10%.

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