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Abstract

The housing bust in Spain was characterized by a significant and rapid drop in home ownership among the younger cohorts, a relatively homogeneous but significant decrease in consumption and significant movements in the rent-to-house price ratio. To uncover the causes of these movements, we solve and estimate an equilibrium life-cycle model with non-linear income, mortgage and housing and rental market dynamics, and simulate a series of counterfactual policy changes and macroeconomic conditions observed in Spain during the period. The lion's share of the observed drop in home ownership and consumption and the housing market dynamics can be explained by more cautious credit conditions and the major shift in income dynamics observed in Spain between the boom and bust phases.

Keywords: life-cycle models, mortgage debt, housing.

JEL classification: E21, E44.

Resumen

En España, el colapso del mercado inmobiliario se caracterizó por una disminución significativa y rápida de la propiedad de viviendas entre la población más joven, un descenso relativamente homogéneo, pero notable, del consumo y movimientos significativos en la relación entre el precio del alquiler y el precio de la vivienda. Para descubrir las causas de estos movimientos, desarrollamos y estimamos un modelo de equilibrio de ciclo de vida con dinámicas no lineales de ingresos, hipotecas, mercados de viviendas y alquileres, y simulamos los cambios políticos contrafactuales y condiciones macroeconómicas que tuvieron lugar en España durante ese período. La mayor parte de la caída observada en la propiedad de viviendas y el consumo, así como las dinámicas del mercado inmobiliario, pueden explicarse por condiciones crediticias más prudentes y el cambio significativo en las dinámicas de ingresos contemplado en España entre las fases de expansión y recesión.

Palabras clave: modelos de ciclo de vida, deuda hipotecaria, mercado de vivienda.

Códigos JEL: E21, E44.

1 Introduction

In this paper, we use detailed household panel data on assets, liabilities, income, and consumption from the Spanish Survey of Household Finances (Encuesta Financiera de las Familias, EFF) during the last leverage cycle 2002-2017 to document the change in home-ownership, leverage and consumption behavior of Spanish households of different ages, cohorts and balance-sheet positions. The granular data shows that the adjustment in the behavior of young households after 2008 significantly differed from that of older ones, especially regarding housing tenure decisions. Of course, buying and renting decisions are closely linked to consumption and saving more broadly, and this is so in the data. We also show that most of the heterogeneous behavior can be explained by the timing with which relatively young households enter the job market, i.e. a cohort effect.

The conditional age-related heterogeneity described above has been loosely linked to three central dynamics observed during the boom-bust cycle in Spain: (i) lenders becoming more cautious regarding credit access conditions, in particular, the maximum loan-to-value ratios LTVs and payment-to-income (PtI) offered by credit institutions at origination (ii) age-related worsening in labor income dynamics (lower on average and a more volatile income, higher probability of facing downside risk), and (iii) the elimination, at the end of 2012 and as part of the fiscal consolidation plan implemented by the incumbent government, of fiscal incentives to buy (mortgage payment deductions). In the second part of the paper, we build a life-cycle, heterogeneous agent model of detailed household behavior regarding tenure choice, portfolio composition, and default, where we allow for equilibrium in the housing market and a general non-linear and non-normal household income process, along the lines of Arellano et al. (2017). In line with recent contributions by De Nardi et al. (2020), we show that allowing for deviations from the standard Gaussian income process is necessary to capture the asymmetric impact of the crisis on households of different ages and positions in the income distribution. We estimate the main model parameters using simulated method of moments so that the model matches cross-sectional statistics from the Spanish Survey of Household Finances between 2002 and 2008 and then use it to provide an answer to the following counter-factual question: what has been the main driving force behind the observed dynamics of macroeconomic aggregates (house prices, consumption, homeownership rates) as well as a heterogeneous change in homeownership, consumption, and welfare for different cohorts after the crisis?

Firstly, we show that three central dynamics we identify can account jointly for three-fourths of observed drop in consumption, almost all drop in homeownership rate, and about one-third of drop in observed house prices. Secondly, we show that a more cautious supply of credit as well as changes in the labor income conditions can explain a lions-share in the age-dependent shift in housing tenure, consumption and deleveraging; although the elimination of mortgage deductibility significantly impacts the consumption decisions of middle-aged owners, it has a marginal impact on the housing tenure decisions of younger households.

As hinted above, our life-cycle model incorporates two recent methodological features that allow us to capture the rich household heterogeneity in the data, particularly along the assets, income, and age dimensions. First, we model in detail the household decision between liquid and illiquid (housing) assets and the cost and financing options associated with them. This follows recent work by, for example, Kaplan and Violante (2014). We allow for both ownership and rental decisions in the housing market, which is crucial both to capture the co-movement between house prices and credit restrictions[1], as well as capturing the heterogeneous holdings across the life-cycle. Second, following recent developments by Arellano et al. (2017), we model household labor income as a general Markov process, allowing us to capture the pervasive non-linearity and non-normality of income shocks in the data. In particular, as documented by Guvenen et al. (2014, 2021); De Nardi et al. (2020) for the U.S., the persistence and skewness of income shocks change with the age and income rank of the household. This can have important implications for households' behavior by age, which interacts with other forces in the model to capture the observed heterogeneity.

Related literature This paper is also related to the broader literature that estimates more flexible distributions of labor income and studies their implications for household behavior, including consumption and portfolio choice (Arellano et al. (2017); Guvenen et al. (2021); De Nardi et al. (2020); Paz-Pardo (2024)). We contribute to this literature by documenting nonlinear income dynamics in expansions and recessions in Spain and studying its implications for housing markets in an estimated general equilibrium model, which the first three papers do not consider.[2]. In particular, the results

[1] Kaplan et al. (2020) recently made this point; our framework is similar along the household dimension.

[2] Arellano et al. (2017) proposes a quantile-based panel data framework to estimate earnings and consumption dynamics. Guvenen et al. (2021), meanwhile, documents the countercyclicality of earnings and studies their implications for consumption. De Nardi et al. (2020) proposes a framework to discretize the nonlinear earnings process of Arellano et al. (2017) and shows their implications for consumption behavior. Relative to these papers, we consider how differences in nonlinear earnings dynamics affect consumption and housing decisions in an estimated general equilibrium model.

we obtain for the earnings process closely mirror those obtained by Paz-Pardo (2024), which studies business cycle-dependent nonlinear earnings dynamics and their implications for homeownership in an estimated partial equilibrium life cycle model for the US.

While household heterogeneity took center stage in mainstream macroeconomic research at least 25 years ago, the recent availability of detailed and granular household-level data, together with modeling and computational developments, has allowed researchers to uncover the importance of heterogeneity in balance-sheet composition and understanding the response of households to different type of economic shocks. In particular, these studies have shed light on two relevant aspects of the data which were overlooked before the crisis: (i) there is a significant share of households who, despite having a non-trivial amount of net wealth, most of it tends to be *illiquid*, and therefore their behavior is close to being hand-to-mouth[3]; and (ii) the composition of a household's balance-sheet changes throughout the life-cycle due to, among other reasons, family formation, income evolution, and shocks, consumption smoothing and precautionary motives, health shocks and education decisions. These two features imply that an economic shock will affect households of different ages differently and that different demographic structures will potentially generate different transmission and general equilibrium effects.[4]

2 Housing Market Dynamics in Spain since 2002

2.1 Aggregate dynamics

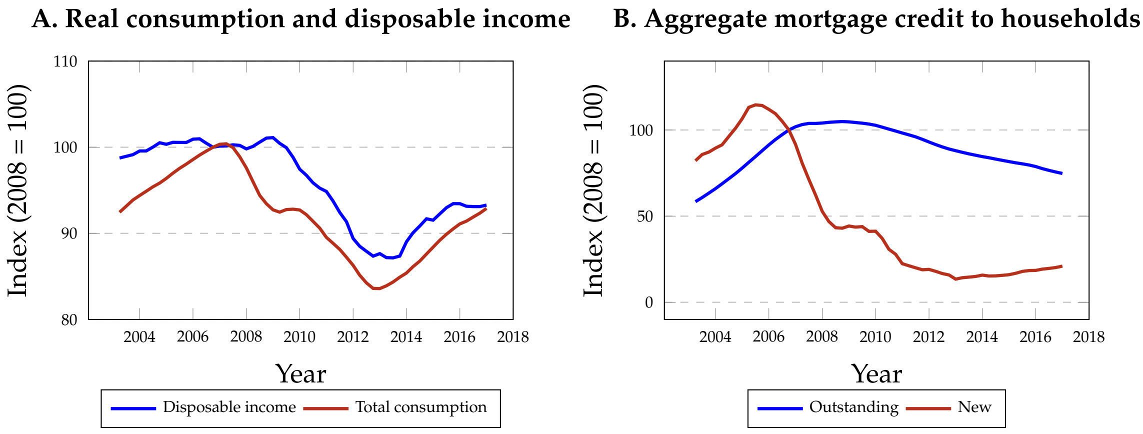
Figures 1 - 4 present the dynamics of selected aggregate variables during the housing boom and bust cycle in Spain between 2002-2018. Three patterns are worth noting. First, although the cycle in disposable income and consumption was significant (see Panel A in Figure 1), both the drop and persistence of the bust have been much more significant for housing-related variables such as mortgage credit to households (see Panel B in Figure 1) and housing construction and investment (see Figure 2).

Second, the return on buying a house/flat and renting it out, captured by housing and rental prices, has also fluctuated significantly (see Figure 3).

[3]Two recent examples of the modeling and empirical advances are Kaplan and Violante (2014) and Cloyne et al. (2020)

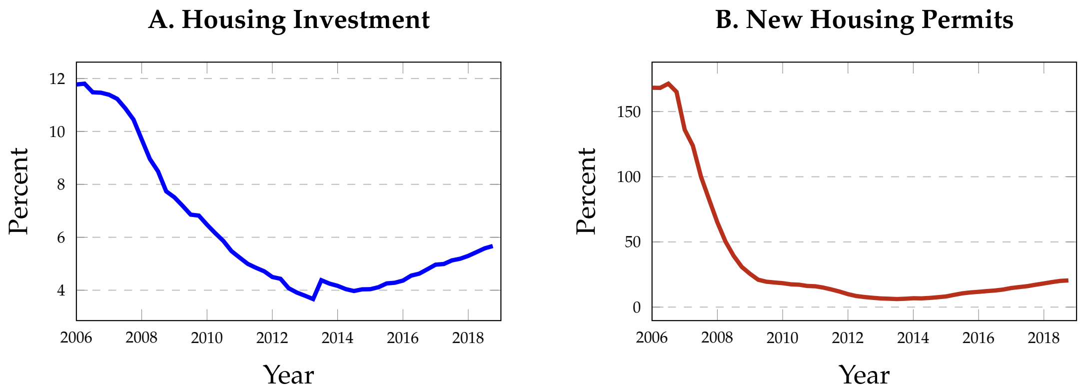
[4]See for example Wong (2021) for monetary policy shocks, Glover et al. (2020) for earnings and asset price shocks, Lisack et al. (2017) and Gagnon et al. (2021) for long run changes in demographics.

Figure 1: Consumption, Income, and Mortgage Credit



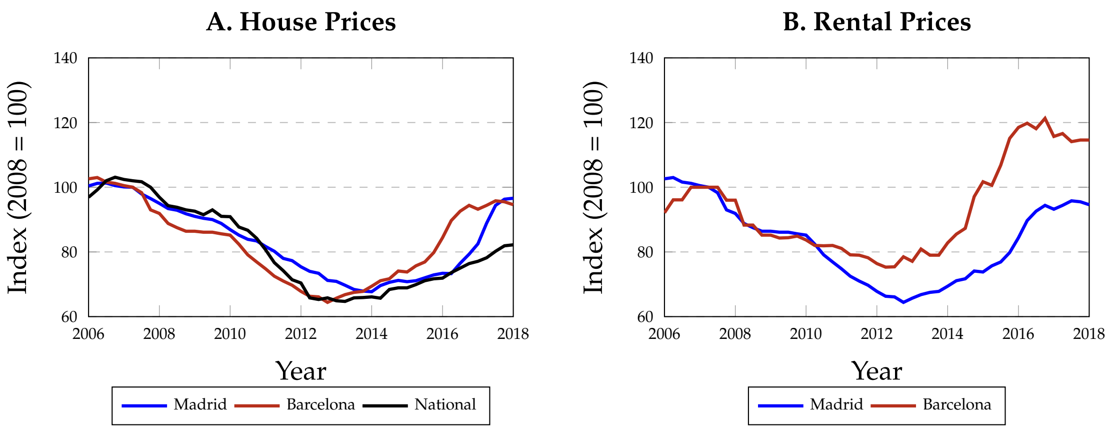
Source: National Accounts, 2002 - 2018.

Figure 2: Housing Investment and New Housing Permits



Source: National Accounts and Ministry of Transport and Sustainable Mobility, 2006 - 2018.

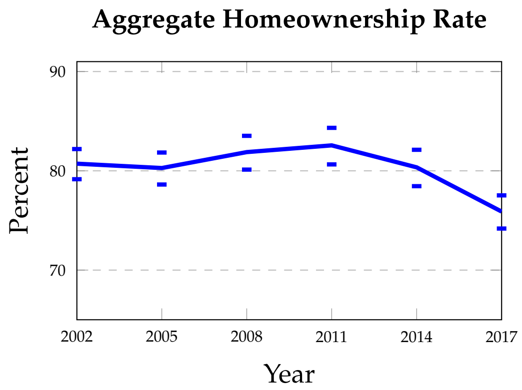
Figure 3: Housing and Rental Prices



Source: Alves and Urtasun (2019).

Third, the aggregate home-ownership rate, computed from the Spanish Survey of Household Finances, has been comparably stable across most of the cycle, with a slight decrease from 80% to around 75% between 2008 and 2017 (see Figure 4). One could interpret patterns two and three through the lens of a price-quantity framework, along the lines of a recent debate on housing market segmentation and the impact of credit shocks on consumption, portrayed in Greenwald and Guren (2021) and Kaplan et al. (2020).

Figure 4: Aggregate Homeownership Rate



Source: Survey of Household Finances (EFF), 2008 - 2017

2.2 Heterogeneity in life-cycle and cohort dynamics

Aggregate dynamics presented above hide significant heterogeneity. Using both the panel and the cross-section dimensions of the six EFF waves from 2002 to 2017, Figures 5 and 6 plot the cohort and the life-cycle behaviors for consumption, homeownership rate, and household debt.[5]

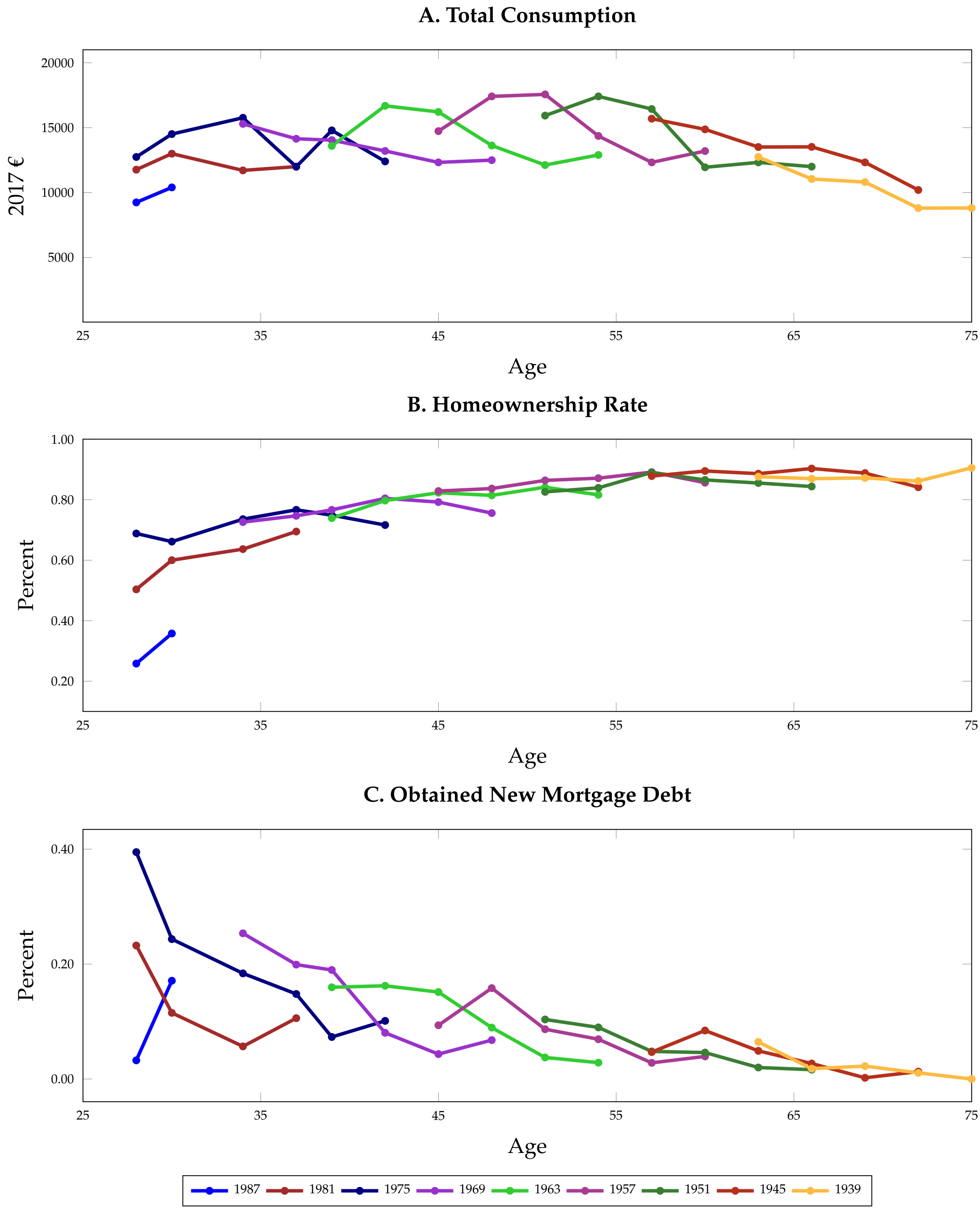
Several patterns are worth noting. First, although total consumption presents the well-known humped-shaped life-cycle profile (see Panel A in Figure 5), consumption possibilities of the youngest two cohorts appear to have been severely hampered relative to previous cohorts at the same age, as seen in the Panel A in Figure 6. Second, consistent with what has been documented using similar data, home-ownership ratios for Spanish households at different ages tends to be high relative to the average European country.[6] Again, the youngest cohorts have been disproportionally affected by the recession phase of the last cycle in Spain: home-ownership rates dropped around 50% for households whose head was below 30 years of age, or around 30% considering

[5]The EFF is a rotating-panel survey containing detailed individual and household-level information on assets, liabilities, income, and consumption. It is carried out every three years; the first wave, which covers household responses from 2001-2002, was carried out in 2002, while the last available wave was in 2020. In this paper, we use the 2002 - 2017 waves. Interestingly, these waves cover entirely the last boom-bust cycle in the Spanish housing and credit markets.

[6]See, for example, Kaas et al. (2021).

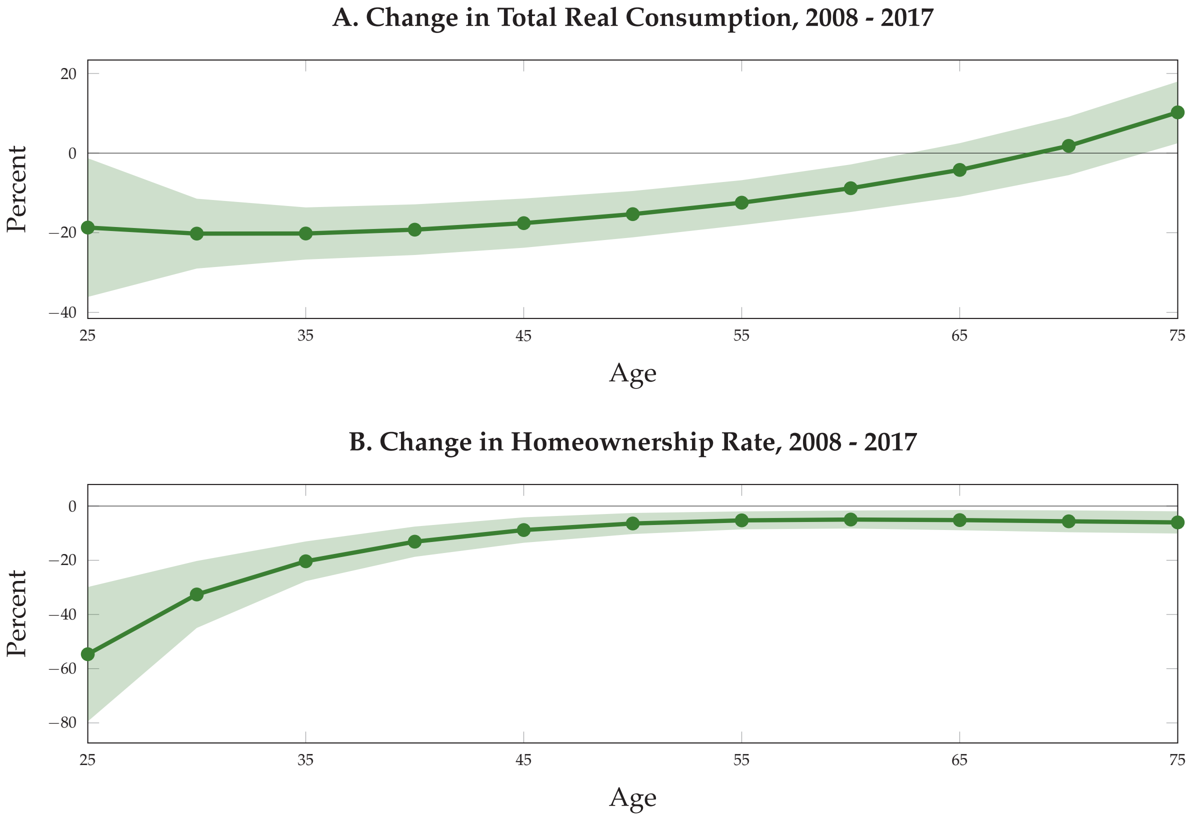
household heads below 35 y.o (see Panel B in Figure 6). Most of this effect is coming from young households (or individuals) delaying their first-time purchase (see Panel B in Figure 5). The question of how persistent this delay will be is still difficult to answer from the data alone. Third, as seen in Panel C in Figure 5, the share of households obtaining new mortgage debt presents a declining profile over the life cycle and is lower for households of the most recent cohorts.

Figure 5: Consumption, homeownership rate, and mortgage credit by birth cohorts



Source: Survey of Household Finances (EFF), 2002 - 2017

Figure 6: Changes in consumption and homeownership rates



Source: Survey of Household Finances (EFF), 2002 - 2017

Understanding what were the causes behind these aggregate and cohort dynamics is challenging. However, three particular and significant features emerged during the late boom and early part of the housing bust in Spain. These were (1) more cautious mortgage credit supply conditions, (2) a worsening in labor income prospects and dynamics, potentially asymmetric across ages and income levels; and (3) changes in property taxes as well as mortgage interest payment deductibility. Although these changes were probably both the cause and consequence of the initial bust, they were relatively unexpected from the point of view households had at the peak of the housing boom phase around 2007-2008. Our goal is to quantify their explanatory power for the dynamics presented above through the lens of an equilibrium structural model.

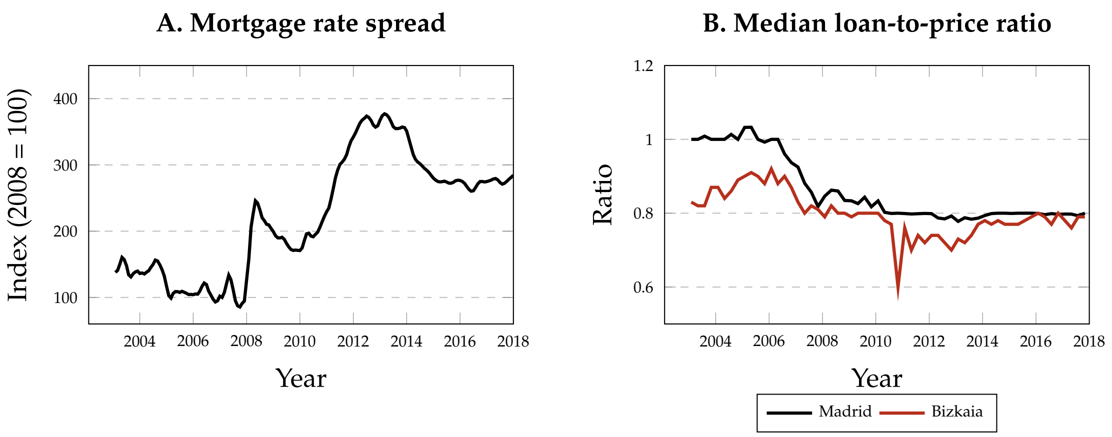
We then identify three macroeconomic channels that we test as potential explanations of the evolution of housing markets in Spain.

2.3.1 Mortgage credit market conditions

Several studies have indicated that the data on the selling prices of houses (and hence the resulting loan-to-value indicators) in Spain differs depending on the data source one uses. For example, Montalvo and Raya (2012), show that three measures of house prices (the value agreed in the transaction, the transaction price declared to the tax authority, and the appraisal value of the property) can differ. Akin et al. (2014) extends the measures used by Montalvo and Raya (2012) and compares the LTV values pre- and post-boom in Spain; they document an overall drop in the LTV ratios post-2007. García Montalvo and Raya (2018) also documented the overall issues with the LTV ratios in Spain during this period. Other noteworthy studies that have also documented the evolution of the LTV ratios (as well as other credit market conditions) in Spain are Bover et al. (2019) and Banco de España (2020). The former analyzes how the dispersion of appraisal values (and hence the LTV ratios) has varied over the business cycle (between 2004 and 2016) and documents the overall dispersion in the measurement of LTV ratios. The latter describes the main features of the Spanish housing market in the post-bust period (between 2014 and 2019).

In our analysis, we use the evidence from Bover et al. (2019) and Banco de España (2020) to construct measures of credit conditions given by the average mortgage rate spread on newly issued mortgages, Loan-to-price (LTP), and payment-to-income (PTI) ratios for pre-bust, bust, and recovery periods. We will then map median values to the structural model, first in the estimation exercise, and then in our simulation of the bust cycle. An example of those measures is displayed in Figure 7 below: according to Banco de España (2020), the median LTP ratio has fallen by around 25% between the expansion and recession period.

Figure 7: Changes in credit conditions after 2008.



Source: Bank of Spain and Banco de España (2020).

2.3.2 Income dynamics

An extensive set of literature has analyzed changes in income conditions in Spain post-2008. Among others, Anghel et al. (2018) analyze the evolution of income, consumption, and wealth inequality in Spain in the post-crisis period; Bonhomme and Hospido (2017) study the evolution of earnings inequality and employment in Spain from 1988 to 2010; Arellano et al. (2022) study income dynamics and income risk inequality in Spain between 2005 and 2018; Bentolila et al. (2021) study the evolution of youth employment in Spain during the Great Recession and Covid-19 pandemic; Felgueroso et al. (2017) document recent trends in the use of temporary contracts in Spain and its effect on aggregate employment.

One piece of evidence is clear from the studies mentioned above: the worsening of labor market conditions after 2008. However, the labor market structure could have facilitated changes in income dynamics between the boom and bust of the last cycle in Spain, which are less obvious but relevant for household decisions.

To capture this in a tractable manner, we model household labor income as a general Markov process in the spirit of Arellano et al. (2017) and De Nardi et al. (2020). The key idea is to posit a non-parametric model that allows for non-linearity, age dependence, and non-normality in income shocks. In particular, a working-age household i receives exogenous income y_{ij}. Labor income can be decomposed into a deterministic part, which is a function of demographic characteristics, and a stochastic part η_{ij}.[7]

Let $Q_\eta(q|\cdot)$ be the conditional quantile function for the variable η, and denote the qth conditional quantile for the variable η. Then, we can write the following process for the stochastic component of income:

$$\eta_{ij} = Q_\eta(v_{ij}|\eta_{ij-1}, j),\ v_{ij} \overset{\text{iid}}{\sim} U(0,1),\ j > 1. \tag{1}$$

The model can be thought of as a representation of the uncertainty that households face with respect to their future labor income, which influences their consumption and savings decisions. Intuitively, the quantile function maps random draws from the uniform distribution over (0,1) (cumulative probabilities) into corresponding quantile draws for η. As the quantile function is general, it allows for nonlinearities in persistence and conditional skewness.

In particular, the notion of persistence in this model is captured by the following function:

$$\rho(q|\eta_{ij-1}, j) = \frac{\partial Q_\eta(q|\eta_{i,j-1}, j)}{\partial \eta}, \tag{2}$$

which measures the persistence of $\eta_{i,j-1}$ when it is hit by a shock of size q. As can be observed, persistence is allowed to be a function not only of the past realization

[7] Notice that as opposed to Arellano et al. (2017), who model the stochastic component as a persistent-transitory process, we model the stochastic component of income as a one error process. This is due to the structure of the Spanish Household Finance Survey, which does not permit disentangling between the two components.

of stochastic income, $\eta_{i,j-1}$, but also of the magnitude and the sign of the realization of the income shock. Moreover, in the nonlinear model, current income shocks are allowed to wipe out the memory of past shocks, or equivalently, the future persistence of a current shock depends on future shocks.[8] This notion of income persistence is denoted by Arellano et al. (2017) as the persistence of earnings histories. The nonlinear model allows for conditional heteroscedasticity in η_{ij}, as the conditional distribution of η_{jt} given η_{jt-1} is left unrestricted. More importantly, the model allows for conditional skewness and kurtosis in η_{jt}.[9]

We use the 2002-2017 waves of the Spanish Household Finance Survey to estimate the deterministic and stochastic components of income. In this section, we provide a brief description of the sample selection and the estimation procedure. We provide a detailed description of the estimation in the Appendix A.1.

Unlike most studies that model household earnings dynamics, we estimate the labor income process for individuals from 25 to 65 years old. The rationale is that by aggregating earnings across households, we might not be able to capture the uncertainty that young workers face.[10] We take a broad definition of labor income to acknowledge that have several ways of self-insuring against labor income risk. Hence, we defined total income as the sum of labor earnings, unemployment compensation, pensions, child support, and total transfers. We remove individuals who obtain their income mainly from pensions and those with incomplete demographic information.

To estimate the deterministic component of income, we regress the logarithm of household income on a set of demographic characteristics, which include a fourth-order polynomial on age, education dummies, time dummies, marital status, family size dummies, number of children in the household, and indicators for other income earners, and if the household has children who live out of the house. We report the results of this estimation in the Appendix A.1.

We then divide the sample into "expansion" (2002-2008) and "recession" (2011-2017) and estimate the nonlinear income process on these two subsamples via quantile regressions. More details on the estimation are in the Appendix A.1. The results on conditional persistence are in Figure 8, and conditional volatility and skewness are in

[8]Notice that the random walk model is a special case of the nonlinear earnings process. In fact, in the case of a random walk, the quantile function is $Q_\eta(v_{ij}\eta_{ij-1}, j) = \rho\eta_{i,j-1} + \Phi^{-1}(v_{ij};\sigma)$, where $\Phi^{-1}(\cdot)$ is the inverse cdf of a Normal with variance σ.

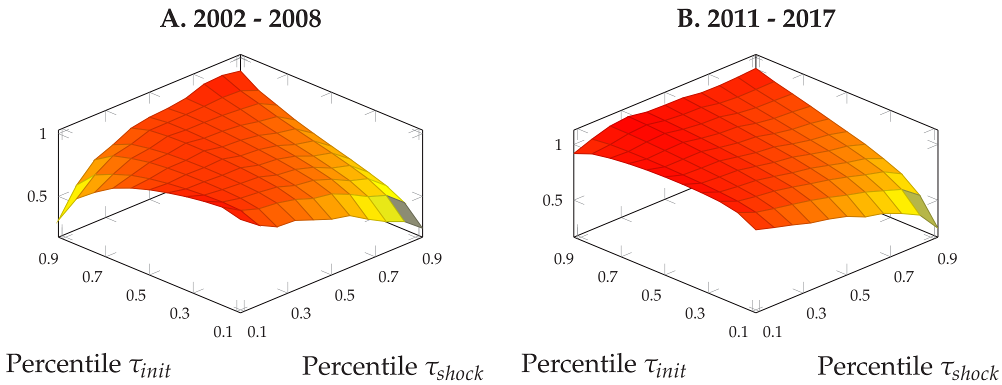
[9]A measure of conditional skewness is

$$sk_j(\eta_{i,j-1}, \tau) = \frac{Q_\eta(1-\tau|\eta_{i,j-1}) + Q_\eta(\tau|\eta_{i,j-1}) - 2Q_\eta(0.5|\eta_{i,j-1})}{Q_\eta(1-\tau|\eta_{i,j-1}) - Q_\eta(\tau|\eta_{i,j-1})}. \tag{3}$$

[10]Moreover, very few households have heads that are less than 30 years old.

Figure 9. The results on persistence and conditional skewness align with those shown in Arellano et al. (2017) and in Galvez (2019). In particular, the results indicate that both expansion and recession sub-samples exhibit nonlinear persistence (see Figure 8). Moreover, in expansions we find that persistence is high for high-income households receiving relatively good shocks, and low income households receiving relatively bad shocks, while persistence is low for high-income households receiving relatively bad shocks, and low-income households receiving relatively good shocks, which aligns with the results of Arellano et al. (2017). In contrast, the non-linearities in persistence are less pronounced in recessions.

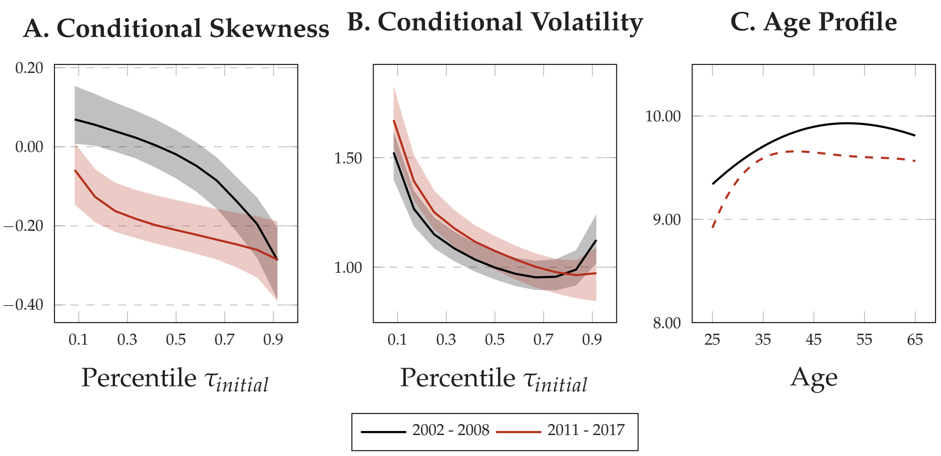
Figure 8: Conditional Persistence



Source: Survey of Household Finances (EFF), 2002 - 2017

As seen from Figure 9, we also find that both periods exhibit conditional skewness that is dependent on the position of the household in the income distribution. Moreover, conditional skewness (in levels) is higher in recessions than expansions. The results suggest that households in recessions have considerably higher probabilities of experiencing downside risk, which is in contrast to households in recessions, wherein income-poor households have some probability of facing upside risk, which could translate to movements up the job ladder. Finally, the results for conditional volatility indicate that households at the lower quantiles of the income distribution have more volatile incomes. Furthermore, we find that incomes are more volatile in recessions than in expansions. Lastly, as shown in Panel C in Figure 9, in the recession period, households income peaks around the age of 40 and stays roughly constant (compared to peak around the age of 59 during the expansion period).

Figure 9: Conditional Skewness and Volatility, and the Deterministic Age Profile



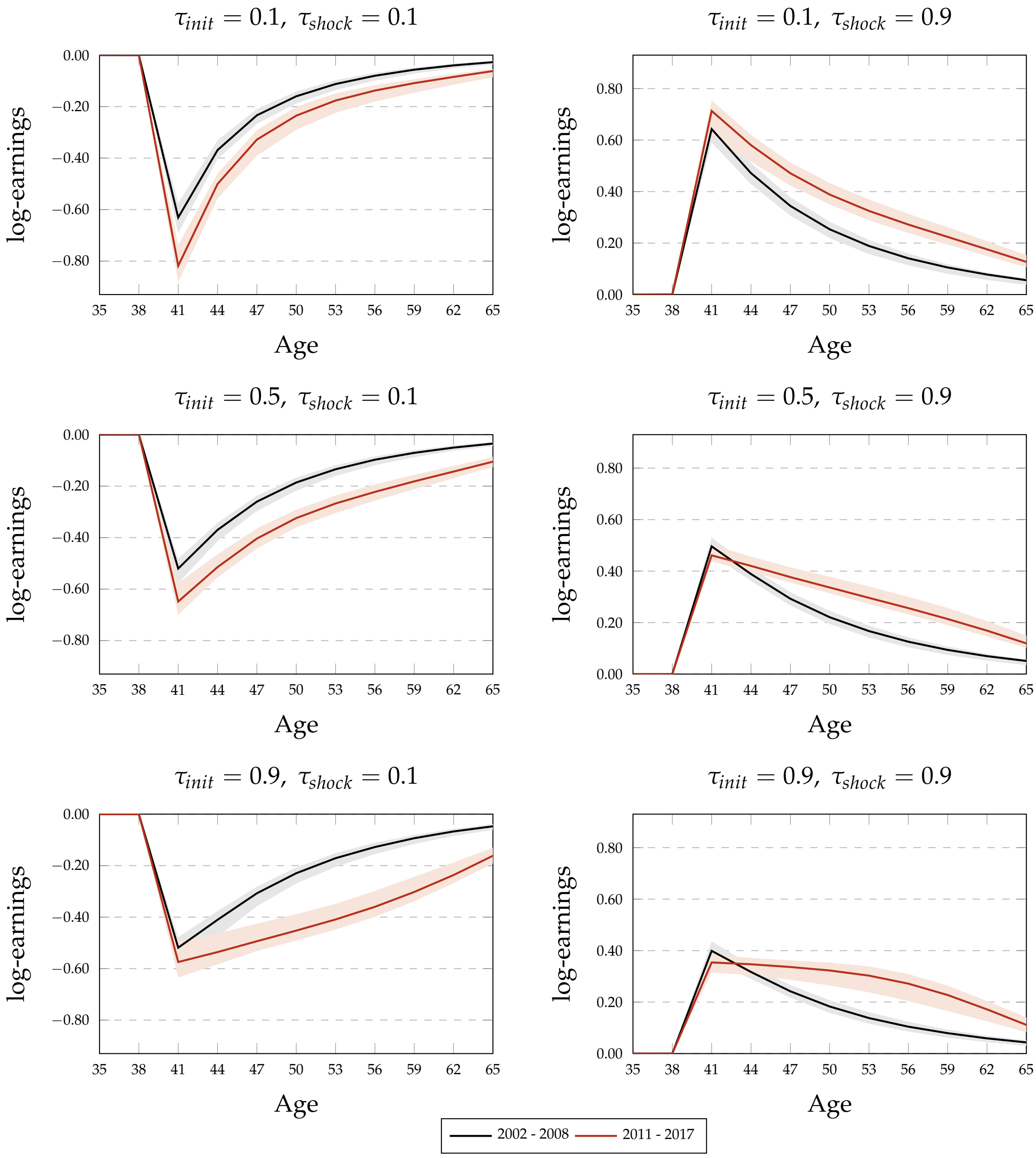
Source: Survey of Household Finances (EFF), 2002 - 2017.

To further emphasize the role of non-linearities that we uncover in the estimation of income, we simulate life-cycle earnings according to the nonlinear model, and show its evolution following a shock to income. We report the difference between the age-specific medians of two types of households: households that are hit, at age 38, by either a large positive income shock (which we denote $\tau_{shock} = 0.90$), or by a large negative income shock (which we denote $\tau_{shock} = 0.1$), and households that are hit by a median income shock (those with $\tau_{shock} = 0.5$). For that, we simulate 1,000,000 individuals and report age-specific medians. We assume that at the start of the simulation (i.e., at age 35), all households have the same initial income realization τ_{init}. With some abuse in terminology, we will call these pseudo-impulse response functions.

Figure 10 shows the earnings responses according to the estimated nonlinear income process for "expansion" (black) and "recession" (red) periods, respectively. The results of the simulation exercise indicate that the impact of large positive and negative shocks is larger (in percentage points) for relatively poor households than for relatively rich households. Moreover, the differences are statistically significant at the 95% confidence level. The figure also highlights the asymmetries in persistence across households. For instance, although low-income households receive the largest impact from large negative shocks, their recovery appears to be faster than for high-income households. Finally, looking at the difference between expansion and recession periods, the difference between the two pseudo-impulse responses is larger for relatively rich households during middle age than for relatively poor households.

We also look at how the pseudo-impulse response functions change depending on the timing of the shock. Figure 11 shows the results for households that are hit with large positive and negative shocks at age 47, well in middle age. As opposed to the

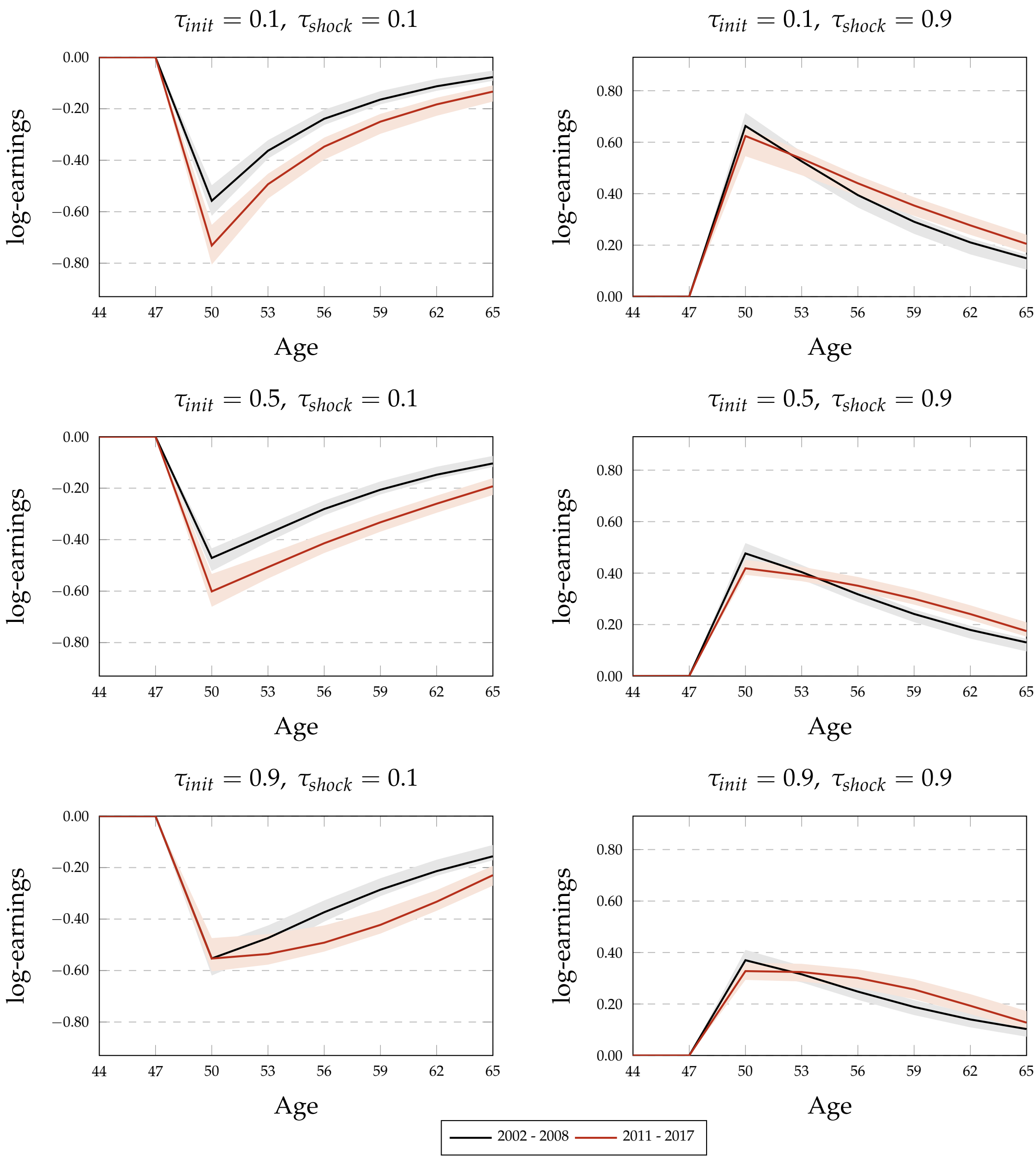
Figure 10: Pseudo-impulse responses, nonlinear income process



Note: The graphs show the difference between a household hit by a τ_{shock} at age 38, and a 0.5 shock at the same age. Age-specific medians across 1,000,000 simulations. Top row: $\tau_{init} = 0.1$, Middle row: $\tau_{init} = 0.5$, Bottom row: $\tau_{init} = 0.9$. Left columns: $\tau_{shock} = 0.1$, Right column: $\tau_{shock} = 0.9$.
Source: Survey of Household Finances (EFF), 2002 - 2017.

previous figure, while the earlier conclusions about the impact of the shock are similar (i.e., income poor households receive the largest impact, and that of asymmetries in persistence), the differences between the income paths during recession and expansion periods are less stark. In particular, the paths after a large positive shock are quite similar across both periods. While there are still differences in income paths after a large negative shock, these differences appear to be smaller than in the earlier case (they do, however, remain statistically significant).

Figure 11: Pseudo-impulse responses, nonlinear income process



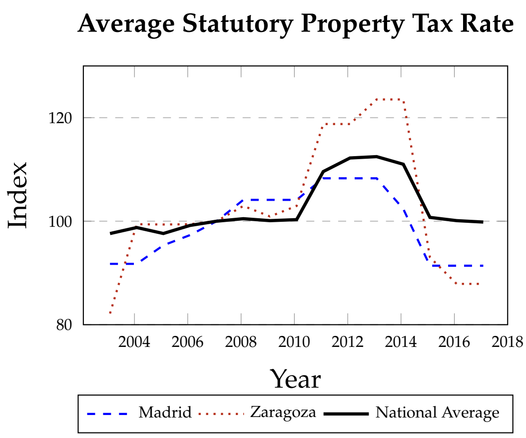
Note: The graphs show the difference between a household hit by a τ_{shock} at age 47, and a 0.5 shock at the same age. Age-specific medians across 1,000,000 simulations. Top row: $\tau_{init} = 0.1$, Middle row: $\tau_{init} = 0.5$, Bottom row: $\tau_{init} = 0.9$. Left columns: $\tau_{shock} = 0.1$, Right column: $\tau_{shock} = 0.9$.
Source: Survey of Household Finances (EFF), 2002 - 2017

2.3.3 Property taxes and mortgage deductibility

The main property tax in Spain, the IBI (Impuesto sobre Bienes Inmobiliarios), is a direct tax on the value of properties. It was introduced in 1990 by law 39/188 and has gone through several modifications since then. Tax bands are set according to the nature of the property. Total IBI depends on (1) the statutory tax rates and (2) land valuations. Both can vary between councils. These variations are often related to revaluations of land within certain areas, which makes the local governments adjust marginal min and max rates in order to avoid sudden jumps in payments for owners.[11] The global financial crisis triggered significant changes in the economic governance framework of the European Union (EU). The main argument behind these changes was that of "significant fiscal imbalances", deepened by the financial crisis. A task force was set up in March 2010 to "strengthen the EU surveillance framework, in particular budgetary and macroeconomic surveillance, and to establish a crisis management framework"[12]. Following this mandate, two important IBI reforms were introduced in 2011 (the RDL 20/2011) and 2013 (Ley 16/2013). Both stipulated a higher tax rate in those councils where the last land revaluation was done further away. In Figure 12, we plot the average statutory property tax in Spain and the evolution for two particular provinces. As can be seen, the reforms implied a tax rate increase of 13% on average. Importantly, this was relatively unexpected but transitory.

The Spanish Personal Income Tax (PIT, *Impuesto a la Renta de las Personas Fisicas*) is the tax on the income of Spanish residents. Until 2012, for the tax liability of an individual (or household, if taxes were submitted jointly), a non-refundable tax credit for a 15% of mortgage payments could be applied. This was possible as long as the house had been purchased prior to the end of 2012. Following the significant drop in GDP, the deterioration of public finances, and the economic governance reform within the Euro Area described above, the national government decided on the elimination of this tax credit (in addition to other tax increases or credit eliminations).

Figure 12: Changes in taxes after 2008



Source: Bank of Spain.

[11] Adjustment of land valuation is regulated by Real Decreto Ley 1/2004, according to two criteria: (i) collective valuation and (ii) pre-established updating coefficients. Criteria (i) cannot be applied with a frequency higher than five years. If there is a significant deviation in property values within these five years, then criteria (ii) is called.

[12] See The Reform of Economic Governance in the Euro Area

Table 1 summarizes the three changes described above into a set of values that we will be feeding into our structural model. Note that, although some of the changes have been clearly transitory (such as the property tax increase that was reversed in 2016), it is not entirely clear how transitory the rest of the shifts are going to be. By the time we are writing this paper (May 2024) mortgage size restrictions at origination similar to the ones observed during the bust, are still predominant. The tax credit for mortgage payments has not yet been brought back. Such persistence is an important input into the quantitative exercises we will carry out. We will therefore consider alternative scenarios regarding the nature of the different shocks.

Table 1: A summary of the changes in the Spanish economy between 2002 and 2017

Feature	**Before bust**	**Bust**	**Persistence**
Credit conditions			
max LTV at origination	0.95	0.7	?
max PTI at origination	0.4	0.25	?
mortgage spread at origination		$\times 3.5$	?
Income dynamics			
life-cycle component	estimated	estimated	transitory
conditional persistence	estimated	estimated	transitory
conditional skewness	estimated	estimated	transitory
Fiscal instruments			
Property tax	1%	1.13%	?
Mortgage payment deductibility	15%	0%	?

The following sections present the structure of the model, the equilibrium definition, and the steps followed for its estimation.

3 A Life-Cycle Model with Housing Market Equilibrium

Time is discrete. The economy is populated by overlapping generations of finitely-lived households who make decisions about consumption, saving, and owning or renting a house, and collateralized borrowing. House prices and rental rates are endogenously determined in equilibrium. There is a government that sets taxes and deductions which mimic the tax scheme in place in Spain.

3.1 Demographics and preferences

Demographics Age is indexed by $j = 1, \ldots, J$. Households work during the first $J_r - 1$ periods and are retired from J_r until period J. Each period, a mass of new households enters the labor market (i.e., enters the model), where the rate of population growth is assumed to be n. Households face the risk of early death in each period, but they die with certainty at age J. Let ψ_j denote the probability of surviving to age j, conditional on surviving to age $j-1$.[13]

Preferences Households maximize expected lifetime utility, which is given by

$$\mathbb{E}_0 \left\{ \sum_{j=1}^{J+1} \beta^{j-1} \left[\left(\prod_{k=1}^{j} \psi_k \right) u_j(c_j, s_j) + \left(\prod_{k=1}^{j-1} \psi_k \right) (1-\psi_j) v(a_{j+1}) \right] \right\}, \tag{4}$$

Here c_j denotes the consumption of non-durable goods at age j and s_j denotes the consumption of housing services at age j, β is the discount factor, and a_{j+1} is the amount of bequest left by a household of age j, and $\prod_{k=1}^{j} \psi_k$ is the unconditional probability an age-j agent will survive to age j. Expectations are taken with respect to idiosyncratic income shocks. Utility function u is an aggregator over consumption and housing services

$$u_j(c_j, s_j) = e_j \frac{\left[c_j^{\alpha} s_j^{1-\alpha} \right]^{1-\vartheta} - 1}{1-\vartheta} \tag{5}$$

while the bequest function v is given as in De Nardi (2004)

$$v(a) = \mathcal{B} \frac{(a + \underline{a})^{1-\vartheta} - 1}{1-\vartheta}, \tag{6}$$

where α denotes the share of consumption in the utility, and ϑ is the risk aversion, $\mathcal{B}$ measures the strength of bequest motive while $\underline{a}$ measures how luxurious is the bequest.[14] Above, e_j denotes the equivalence scale to account for the fact that household composition changes over time. Housing services can be obtained by either owning or renting. We assume that renting generates a service flow equal to the size of the house, i.e., $s = \tilde{h}$, while owning a house generates an extra utility for the household, such that $s = \omega h$, where $\omega \geq 1$ and h is the size of the owned house.

3.2 Labour Income

Households in the model do not make endogenous decisions about working. However, we do want to capture the stochastic and dynamic properties of labor income for households of different ages and positions in the income distribution, as estimated in 2.3; this is one of the main goals of this paper.

[13]Naturally, $\psi_1 = 1$ and $\psi_{J+1} = 0$. Demographic patterns are stable, so that age-j agents make up a constant fraction of the total population μ_j. In particular, we can define μ_j recursively, so that

$$\mu_{j+1} = \frac{\psi_{j+1}\mu_j}{1+n}, \quad j = 1, \dots, J-1$$

with μ_1 such that $\sum_{j=1}^{J} \mu_j = 1$.

We, therefore, map the non-parametric process for income estimated in the previous section into the structural model here. Concretely, and following a standard decomposition in the literature, labor income has a deterministic life-cycle part and a stochastic part η_{ij}

$$y_{ij} = f(x_j;\theta) + \eta_{ij} \tag{7}$$

where y_{ij} is the logarithm of labour income and $f(x_j;\theta)$ is the life-cycle component. In contrast to most of the related literature, however, household income shocks are allowed to be non-linear, age-dependent, and non-normal. As presented in section 2.3, let $Q_\eta(q|\cdot)$ be the conditional quantile function for the variable v, denote the qth conditional quantile for the variable v. Then, we can write the following process for the stochastic component of income:

$$\eta_{ij} = Q_\eta(v_{ij}|\eta_{ij-1}, j), v_{ij} \sim_{iid} U(0,1), j > 1. \tag{8}$$

with a *conditional* persistence given by

$$\rho(q|\eta_{ij-1}, j) = \frac{\partial Q_\eta(q|\eta_{ij-1}, j)}{\partial \eta}, \tag{9}$$

Here, $\rho(q|\eta_{ij-1}, j)$ is the persistence of η_{ij-1} when it is hit by a shock of size q. Crucially for our purposes, $\rho(\cdot,\cdot)$ is a function not only of the past realization of stochastic income, η_{ij-1} but also of the magnitude and the sign of the realization of the income shock.

After retirement, households receive social security benefits

$$y_{ij} = \rho_{ss} y_{iJ_r}, \quad j > J_r,$$

where ρ_{ss} is a replacement rate and y_{iJ_r} are their earnings in the last working period. The pay-as-you-go social security system is run by the government.

3.3 Housing market and mortgages

In order to obtain housing services, households can either rent or buy a house. The structure of ownership and rental units is characterized by three features. First, houses

[14] We also perform the robustness analysis when the utility function u is a CES aggregator over consumption and housing services given by

$$u_j(c_j, s_j) = e_j \frac{\left[(1-\phi)c_j^{1-\gamma} + \phi s_j^{1-\gamma}\right]^{\frac{1-\vartheta}{1-\gamma}} - 1}{1-\vartheta}$$

where ϕ denotes housing preference, $1/\gamma$ is the elasticity of substitution between non-durable consumption and housing services. The results in the paper are robust to this specification and are available upon request.

are indexed by their size, which is given by a discrete and finite set.[15] Let $\widetilde{\mathcal{H}}$ denote the set of houses available for rent, while $\mathcal{H}$ denotes the set of owner-occupied houses. Second, rental units are, on average, smaller than owner-occupied ones, although we allow for some size overlap: $\max\{\widetilde{\mathcal{H}}\} \geq \min\{\mathcal{H}\}$. Importantly, as described in section 4, these features will be estimated in equilibrium to match some observed counterparts of both markets in Spain.

3.3.1 Owning a house

Each unit in $\{\mathcal{H}\}$ can be purchased at a homogeneous price p_h. A house is an *illiquid* asset: in order to buy or sell, a household has to pay a transaction cost κ_h proportional to the house value. In addition, a home-owner has to pay, in every period, a proportional maintenance cost δ_h that fully offsets the physical depreciation of the house, as well as a tax τ_h on real estate value.

Mortgages The purchase of a house can be financed with a mortgage. A household that takes out a new mortgage with a principal balance m' receives from a lender m' units of the numeraire good. We assume all mortgages are of adjustable-rate type r_m and have to be repaid over the remaining life of the borrower. We also assume that mortgage rate r_m is exogenous to the rest of the model and is given by

$$r_m = (1 + \iota) r_a, \tag{10}$$

where ι controls the spread between r_a and r_m. That is, the spread is independent of mortgage and borrower characteristics. Importantly, interest payments can be deducted from income when computing tax liabilities. As explained in the previous section, this deductibility was eliminated in Spain during 2012, and will be part of the experiments carried out below. The downpayment for a borrower who takes out a mortgage of size m' to buy a house of size h' is then given by

$$p_h h' - m' \tag{11}$$

Mortgage origination is subject to two types of frictions. First, households need to pay a fixed origination cost κ_m. This is meant to capture fees and other costs that the lender/bank charges in order to issue the mortgage. Second, the mortgage amount is subject to two constraints. The first one is a maximum loan-to-value constraint: the initial mortgage size must be less than a fraction λ_m of the value of the house being purchased.

[15] In our model, we don't distinguish between the size and quality of a house.

$$m' \leq \lambda_m p_h h' \tag{12}$$

The amount borrowed is also subject to a maximum payment-to-income constraint: the first minimum mortgage payment must be less than a fraction λ_π of the income at the time of purchase

$$\pi_j^{min}(m') \leq \lambda_\pi y_j, \tag{13}$$

where we define the minimum payment function $\pi_j^{min}(m')$ using a constant amortization formula

$$\pi_j^{min}(m') = \frac{r_m(1+r_m)^{J-j}}{(1+r_m)^{J-j}-1} m' \tag{14}$$

which assumes that the borrower is required to make $J - j$ payments π that exceed the minimum payment requirement after mortgage origination. The remaining mortgage principle evolves according to

$$m' = m\,(1+r_m) - \pi \tag{15}$$

When selling a house, households are required to fully repay whatever outstanding mortgage balance they have, in addition to the transaction costs described above.

3.3.2 Rental market

Each unit in $\widetilde{\mathcal{H}}$ can be rented by a households at a homogeneous rental rate p_r. Renters face neither transaction nor real estate tax payments.

Rental investors and market segmentation Rental units are owned by a unit mass of homogeneous (deep-pocketed) institutional investors operating in a competitive market with a discount factor β_I. Investors transact in the ownership market in order to adjust the stock of rental units they hold, in response to rental demand from households. We assume they have to pay for the depreciation of the rental property δ_r, with $\delta_r > \delta_h$, as well as taxes on property owned.

As recently pointed out by Greenwald and Guren (2021), the structure and degree of segmentation between the ownership and rental markets (i.e., how feasible it is to convert rented units in order to sell them, and vice-versa) is a feature that has a direct impact on how shocks transmit into equilibrium price and quantities. On one extreme, if there is full segmentation such that housing units cannot be converted (and assuming no constructions sector), then a credit shock that perturbs the supply of financing will affect equilibrium prices (house prices and rents) but not quantities (the aggregate home-ownership rate). On the other extreme, when there are no segmentation and frictions, a credit shock will translate into changes in quantities rather than prices.

In terms of the question we are trying to address and the quantitative experiment proposed to provide an answer, pinning down the degree of segmentation is important. In a setting with a simplified individual tenure decision, Greenwald and Guren (2021) suggest mapping parameter(s) to the relative elasticity of prices and home ownership to an identified credit shock. As we have pointed out in Section 2.3, the housing bust in Spain was not only accompanied by changes in the credit conditions, but also by changes in fiscal policy, and, more importantly, substantial changes in income dynamics. Thus, we are lacking the kind of exogenous variation as in Greenwald and Guren (2021) to exactly identify the degree of segmentation oh the housing and rental markets. Nonetheless, aggregate movements in prices and home-ownership rates presented in figures 3 4 can guide our modeling choices. Two equilibrium outcomes observed in the data are relevant. First, as can be seen from figure 3, following the peak of the housing boom, house prices, and rents reacted significantly and in the same direction to the combination of shocks and endogenous dynamics, though house prices tended to react more strongly. Second, the aggregate home-ownership rate did react, although sluggishly. Given these two observations, we assume there are short-run frictions when converting units between both markets, though these disappear in a stationary equilibrium. We also analyse what happens under the full-segmentation scenario (i,e, infinite costs of conversion) in the Appendix.

The relationship between the rental rate and purchase price in the stationary equilibrium is governed by a standard user-cost formula, derived from a no-arbitrage condition when there is free entry of investors[16]. In a stationary equilibrium with constant house price $p_{h,t} = p_h^{SS}$, the rental rate is then given by

$$p_r^{ss} = (1 - \beta_I + \beta_I(\delta_r + \tau_h))\, p_h^{ss} \tag{16}$$

where $\beta_I = \frac{1}{1+r_a}$ is the investors discount factor.

In any given period outside the steady-state, we assume rental investors accounting is such that they mark-to-market only those units they need to acquire or sell to adjust to the demand from households. In addition, the rental rate is such that the investors earn the same return as in steady-state. These two assumptions imply a pricing relationship given by

$$p_{r,t} = (1 - \beta_I)p_{h,t} + \beta_I(\delta_r + \tau_h)p_{h,t+1} - \beta_I\,(p_{h,t+1} - p_{h,t})\ \frac{R_t - \bar{R}}{R_t} \tag{17}$$

where R_t is the demand for rental units in any period t, $\bar{R}$ is the steady-state stock of rental units. In the user cost formula above, the new third term reflects the gains and losses from the share of transacted rental stock in any period t.

3.4 Liquid asset

Households can save in one-period bonds, a, with an exogenous interest rate given by r_a. However, they are not allowed any unsecured borrowing, which means they face a constraint of the form

$$a \geq 0 \tag{18}$$

3.5 Government

In the model, the government receives revenues from the property tax τ_h and progressive income tax $\mathcal{T}(y, m)$ that depends on income y and mortgage holdings m. Interest paid on mortgages is deductible up to a predetermined percentage. We assume that tax function is progressive as in Heathcote et al. (2017) and $\mathcal{T}$ takes the form

$$\mathcal{T}(y, m) = y - \tau_y^0 \left(y - r_m \tau_m m\right)^{1-\tau_y^1} \tag{19}$$

where τ_y^0 and τ_y^1 measure the progressivity of the tax system, and τ_m denotes the mortgage interest share that is deductible. On the spending side, taxes collected are used to finance the social security system. The government runs a balanced budget, with services G (not valued by the household) adjusting to absorb any difference between government income and spending.

3.6 Dynamic Problem of the Household

We now describe the dynamic problem faced by households. At each point in time, there are two types of households in the economy: homeowners and non-homeowners. Let V_j^n denote the value function of the non-homeowner at age j and let V_j^h denote the value function of the homeowner at age j. When a non-homeowner enters the period with age j, she has two choices - either remain a non-homeowner until the next period (renting this period) or buy a house and become a homeowner. Let V_j^r and V_j^o denote the value functions of renters and buyers, respectively. Non-homeowners solve the following problem

$$V_j^n(\mathbf{x}_j^n) = \max\left\{V_j^r(\mathbf{x}_j^n), V_j^o(\mathbf{x}_j^n)\right\} \tag{20}$$

where $\mathbf{x}_j^h$ denotes the vector of state variables of the non-homeowner, described below.

When a homeowner enters the period, she has three different choices. She can either continue paying the existing mortgage if she has one (let V_i^p denote the value

[16] See Piazzesi and Schneider (2016). In every period, the marginal investor decides between (i) purchase a unit of housing at price p_h, rent it out to households at rate p_r in the current period, and selling it next period after having paid for depreciation costs and property taxes, or (ii) invest in risk-free one-period bonds with a net return r.

function of the mortgage payer), adjust the house or mortgage size (let V_j^m denote the value function of the "mover"), or repay the remaining mortgage and sell the house (let V_j^s denote the value function of the seller). The problem solved by a homeowner is, therefore

$$V_j^h(\mathbf{x}_h) = \max\left\{V_j^p(\mathbf{x}_j^h), V_j^m(\mathbf{x}_j^h), V_j^s(\mathbf{x}_j^h)\right\} \tag{21}$$

where $\mathbf{x}_j^h$ denotes the vector of state variables of the homeowner, described below. Non-homeowners of age j enter the period with a holding of liquid assets a_j and exogenous income y_j. On the other hand, homeowners of age j also enter the period with an outstanding balance on the mortgage m and house h. When $m > 0$, we refer to homeowners as the mortgagor, whereas when $m = 0$, we refer to them as outright owners. Also, in the case of "movers" we split households into actual movers (that adjust value of the house and/or mortgage balance) and refinancers (that stay in the same house but adjust the size of the mortgage). Thus

$$\mathbf{x}_j^n = \left(a_j, y_j\right) \tag{22}$$

$$\mathbf{x}_j^h = \left(a_j, m_j, h_j, y_j\right) \tag{23}$$

Assume that the state and control variables with no subscript denote the current age/period variables, i.e. $a_j = a$, while state and control variables with $'$ superscript denote the next period/age variables, i.e. $a_{j+1} = a'$.

Renters Households of age j that enter the period as non-homeowner and decide to rent choose the level of consumption today (c), the level of liquid savings to carry to the next period (a'), and the size of the rented dwelling ($\tilde{h}'$). In recursive form, their problem can be written as

$$V^r(\mathbf{x}^n) = \max_{c,a',\tilde{h}'} u(c,s) + \beta\psi'\mathbb{E}\left[V^{n'}\left(\mathbf{x}^{n'}\right)\right] \tag{24}$$

Renters solve the above problem subject to:

$$\begin{aligned} & c + p_r\tilde{h}' + a' \leq (1+r_a)a + y - T(y,0) \\ & a' \geq 0 \\ & s = \tilde{h}' \\ & y' \sim Y(y) \end{aligned} \tag{25}$$

where the equations above are budget constraint, borrowing constraint, housing services production, and income evolution, respectively. Let $\mathbb{1}^r\left(\mathbf{x}^n\right)$ denote the decision of a non-homeowner with state variables $\mathbf{x}^n$ to rent a house.

Buyers The households of age j that enter the period as non-homeowners and decide to buy a house choose the level of consumption today (c), the level of liquid savings to carry into the next period (a'), the size of the house to buy (h'), and the level of mortgage to take out. In recursive form, their problem can be written as

$$V^{o}(\mathbf{x}^{n}) = \max_{c,a',h',m'} u(c,s) + \beta\psi'\mathbb{E}\left[V^{h'}\left(\mathbf{x}^{h'}\right)\right] \tag{26}$$

subject to

$$\begin{aligned}
& c + a' + p_h h' + \kappa_m \leq (1+r_a)a + y - T(y,0) + q_m m' \qquad (27)\\
& m' \leq \lambda_m p_h h' \\
& \pi^{\min}(m') \leq \lambda_\pi y \\
& a' \geq 0 \\
& s = \omega h' \\
& y' \sim Y(y)
\end{aligned}$$

where the equations are the budget constraint, the LTV and PTI constraints, the (unsecured) borrowing constraint, housing services production, and income evolution, respectively. Let $\mathbb{1}^{o}\left(\mathbf{x}^{n}\right)$ denote the decision of non-homeowner with state variables $\mathbf{x}^{n}$ to buy a house; renting or buying are mutually exclusive such that

$$\mathbb{1}^{r}\left(\mathbf{x}^{n}\right) + \mathbb{1}^{o}\left(\mathbf{x}^{n}\right) = 1$$

Mortgage payers The households of age j that enter the period as homeowners with a given level of mortgage m and house size h, and decide to make the payment towards the mortgage balance, choose the level of consumption today (c), the level of liquid savings next period (a'), and the size of payment (π). In recursive form, their problem can be written as

$$V^{p}(\mathbf{x}^{h}) = \max_{c,a',\pi} u(c,s) + \beta\psi'\mathbb{E}\left[V^{h'}\left(\mathbf{x}^{h'}\right)\right] \tag{28}$$

Mortgage payers solve the above problem subject to:

$$\begin{aligned}
& c + a' + (\delta_h + \tau_h) p_h h' + \pi \leq (1+r_a)a + y - T(y,m) \\
& m' = (1+r_m)\, m - \pi \\
& \pi \geq \pi^{\min}(m) \\
& a' \geq 0 \qquad (29)\\
& s = \omega h', \quad h' = h \\
& y' \sim Y(y) \qquad (30)
\end{aligned}$$

where the equations are the budget constraint, mortgage balance evolution, minimum payment requirement, (unsecured) borrowing constraint, housing services production, and income evolution, respectively. When choosing the current level of mortgage payment, the household needs to satisfy the minimum payment requirement. Let $\mathbb{1}^p\left(\mathbf{x}^h\right)$ denote the decision of a homeowner with state variables $\mathbf{x}^h$ to make a payment towards the mortgage.

Sellers The households of age j that enter the period as home-owners with a given level of mortgage m and house size h, and decide to sell their house in the current period, choose the level of consumption today (c), the level of liquid savings carried into next period (a') and the size of the rented dwelling for the current period ($\tilde{h}'$), given they will remain non-home-owners until the following period.

$$V^s(\mathbf{x}^n) = \max_{c,a',\tilde{h}'} u(c,s) + \beta\psi'\mathbb{E}\left[V^{n'}\left(\mathbf{x}^{n'}\right)\right] \tag{31}$$

House sellers solve the above problem subject to:

$$\begin{aligned} & c + p_r\tilde{h}' + a' \leq a_s + y - T(y,m) \\ & a' \geq 0 \\ & s = \tilde{h}' \\ & y' \sim Y(y) \end{aligned} \tag{32}$$

where a_s denotes the current level of assets plus the proceedings from selling the house net of transaction costs and mortgage balance, given by

$$a_s = (1+r_a)a + (1-\delta_h-\tau_h-\kappa_h)p_h h - (1+r_m)\,m. \tag{33}$$

Let $\mathbb{1}^s\left(\mathbf{x}^h\right)$ denote the decision of the homeowner with state variables $\mathbf{x}^h$ to sell the house.

Movers The households of age j that enter the period as homeowners with a given level of mortgage m and house size h can decide to upgrade or downgrade the house and/or adjust the mortgage. They choose the level of consumption today (c), the level of liquid savings next period (a'), the level of new mortgage (m'), and the new house size (h). In recursive form, their problem can be written as

$$V^m(\mathbf{x}^h) = \max_{c,a',h',m'} u(c,s) + \beta\psi'\mathbb{E}\left[V^{h'}\left(\mathbf{x}^{h'}\right)\right] \tag{34}$$

Movers solve the above problem subject to:

$$
\begin{aligned}
& c + a' + p_h h' + \kappa_m \leq (1 + r_a) a_m + y - T(y, m) + q_m m' \\
& m' \leq \lambda_m p_h h' \\
& \pi^{\min}(m') \leq \lambda_\pi y \\
& a' \geq 0 \\
& s = \omega h' \\
& y' \sim Y(y)
\end{aligned} \tag{35}
$$

where the equations are the budget constraint, LTV constraint, PTI constraint, borrowing constraint, housing services production, and income evolution, respectively. As before, a_m denotes the current level of assets plus the proceedings from selling the house net of transaction costs (in case the household adjusts the house size) and mortgage balance, given by

$$
a_m = a + (1 - \delta_h - \tau_h - \mathbb{1}\left(h' \neq h\right) \kappa_h) p_h h - (1 + r_m)\, m. \tag{36}
$$

Let $\mathbb{1}^m\left(\mathbf{x}^h\right)$ denote the decision of homeowner with state variables $\mathbf{x}^h$ to move the house, with

$$
\mathbb{1}^p\left(\mathbf{x}^h\right) + \mathbb{1}^m\left(\mathbf{x}^h\right) + \mathbb{1}^s\left(\mathbf{x}^h\right) = 1
$$

3.7 Equilibrium

We give a formal definition of the equilibrium in Appendix A.2.

4 Parametrization

We parametrize the model using a combination of externally set and estimated parameters. Table 2 summarizes all the parameters used in the model. Below we describe those in detail.

4.1 Externally set parameters

Demographics and Preferences The model period is three years. Households enter the economy at age 25, retire at age 64 ($J_r = 14$) and live until age 82 ($J = 20$). We use the same strategy as Kaplan et al. (2020) and set risk aversion parameter ϑ equal to 2 so that the EIS is 0.5. The equivalence scale $\{e_j\}$ is taken directly from the data and corresponds to the OECD equivalence scale. Survival probabilities are taken from Population Mortality Tables for Spain and are available from The National Statistics

Institute. Finally, we set the share of utility from non-durable α equal to 0.75, which matches the share of non-durable consumption in total consumption expenditure in Spain.

Labor Income and Government Expenditure We set the social security replacement rate to 75%. The parameters of the tax function (19), τ_y^0 and τ_y^1, are set to 0.8823 and 0.1224, respectively and are taken from García-Miralles et al. (2019) for Spain. Parameter τ_y^0 measures the average level of taxation, and parameter τ_y^1 measures the degree of progressivity. The percentage of the mortgage that is tax-deductible, τ_m, is set to correspond to 15%.

Assets of Newborns Newborn agents are born with no liquid assets, but a proportion of households are born as homeowners. We set this initial share to 10%, corresponding to the average homeownership rate for households between 23 and 27 years old in Spain for our sample period.

Housing We fix the grid for the owner-occupied houses ($\mathcal{H}$) and rented houses ($\widetilde{\mathcal{H}}$) so that households are only allowed to choose to buy or rent the dwellings from the grid. We do, however, estimate the value of points in both grids. The depreciation rate of housing is set equal to 1.5 percent. The depreciation rate of the rental market is set such that in the steady-state, equation (16) implies a rent-to-price ratio of 13.5%. The implied value of δ_r is 5.5 percent.

Liquid Assets and Mortgages The interest rate and mortgage rate are parametrized as described above. We set the annual interest rate on liquid assets to 1.3 percent. We set the spread parameter ι equal to 35% percent, implying the annual mortgage rate of 1.75 percent. The mortgage origination cost, κ_m, is set to be equivalent to 5000 EUR, corresponding to the sum of application, attorney, appraisal, and inspection fees. As a share of three-year income, the corresponding value of κ_m is 0.059.

4.2 Parameters calibrated internally

The remaining parameters are estimated by means of the simulated method of moments (SMM), as is standard in the literature. Concretely, we estimate the discount factor β, the extra utility from home-ownership ω, the minimum rental grid point $\tilde{h}_{min}$, the gaps in the rental and ownership grids, and the transaction cost of selling a house κ_h, bequest intensity ψ and luxury of bequest $\underline{a}$ in order to minimize the weighted distance between data moments and their respective model counterparts. As our targets

Table 2: Parameter values in the estimated model

Parameter		Estimated internally	Value
	Demographics and Preferences		
J	Length of life	N	20
J_r	Length of working life	N	14
$\{e_j\}$	Equivalence scale	N	Online Appendix
$\{\psi_j\}$	Survival Probabilities	N	Online Appendix
α	Share of consumption in utility	N	0.75
ϑ	Risk aversion	N	2
β	Discount factor	Y	0.9026
$\psi, \underline{a}$	Strength and luxury of bequest	Y	(1600, 11.10)
ω	Extra ownership utility	Y	1.0
	Labor Income and Government Expenditure		
χ_j	Deterministic life-cycle profile	N	Online Appendix
τ_y^0, τ_y^1	Income tax parameter	N	(0.8823, 0.1224)
ρ_{ss}	Replacement rate	N	0.8
τ_h	Property tax	N	3%
	Housing grids, mortgages and liquid assets		
$\widetilde{\mathcal{H}}$	Rental housing grid	Y	{0.2546}
$\mathcal{H}$	Owned housing grid	Y	{0.4230, 2.8594}
δ_r, δ_h	Depreciation rate: rented & owned	N	(0.055, 0.015)
κ_h	Selling transaction cost	Y	0.2934
r_a	Real risk-free rate (annual)	N	1.3%
ι	Initial mortgage spread	N	36%
r_m	Mortgage rate (annual)	N	1.75%
κ_m	Mortgage origination cost	N	0.059
$\bar{m}$	Mortgage interest rate deduction	N	15%
λ_a	Unsecured borrowing limit	N	0.0
q_m	Down payment requirement	Y	1.0

in the estimation, we choose the average homeownership rate as well as the homeownership rate at 35, 65, and 80 years old. We also choose the average share of mortgagors, median loan-to-income, percent of transacted sq. meters, median net worth to income, and median net worth of households at age 75 relative to age 50.

4.3 Properties of the Baseline Model

In this section, we describe the properties of the baseline model. In particular, we first compare the targeted moments from the data to those implied by the model. Those are summarized in Table 3. We then plot the life-cycle profiles of income, consumption, homeownership rate, the share of households with a mortgage, and median loan-to-income by age, both for the model and for the data.

Table 3: Targeted moments in the parametrization

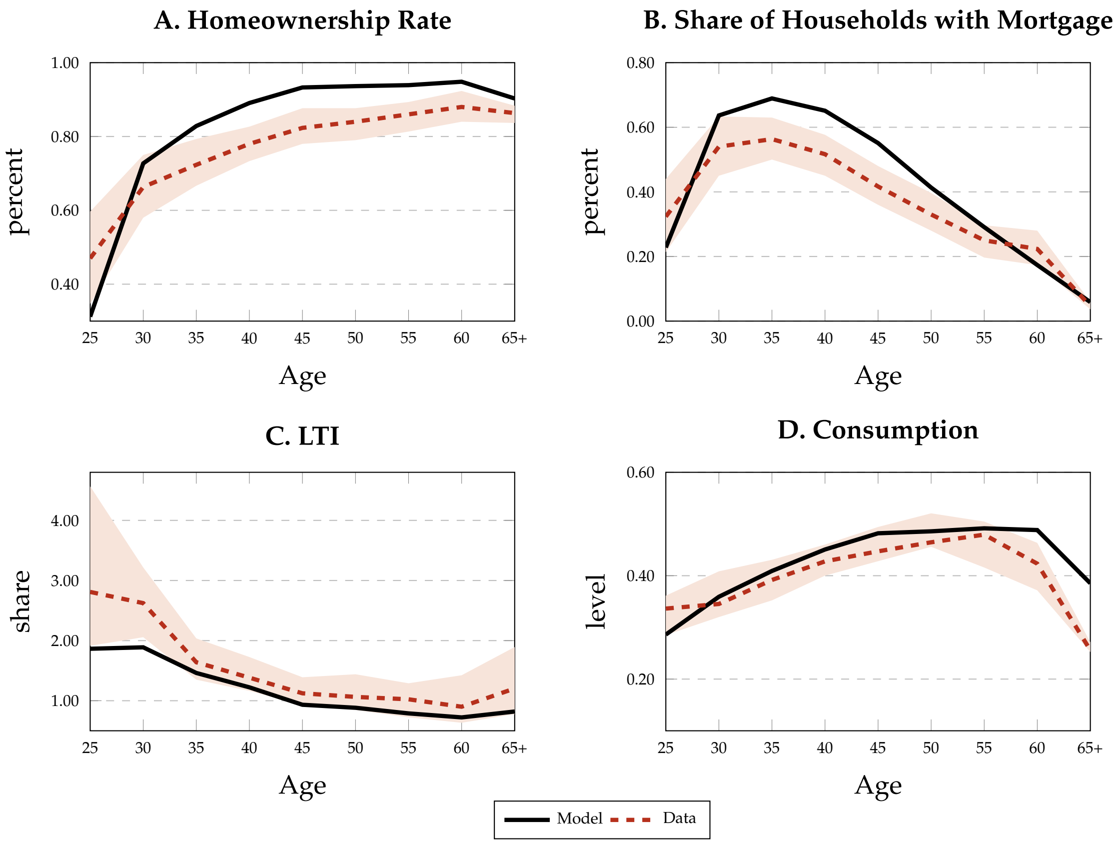
Targeted Moments		
Moment	**Model**	**Data**
Average home-ownership rate	0.80	0.81
Home-ownership rate (age 35)	0.77	0.72
Home-ownership rate (age 65)	0.95	0.89
Home-ownership rate (age 80)	0.87	0.87
Average share of mortgagors	0.33	0.35
Percent of transacted sq. meters	4%	4%
Median loan-to-income (LTI)	1.27	1.42
Median NW at 75yo / Median NW at 50 yo	1.32	1.31
Median NW / Median Income	3.91	3.67

Note: Empirical values correspond to Survey of Household Finances (EFF), averaged for 2002-2008 waves.

As can be seen from Table 3, the model captures well the targeted housing-related moments (such as homeownership rates and the share of mortgagors), as well as moments related to wealth and asset accumulation. We slightly underestimate the median loan-to-income in the estimated model (1.27 vs. 1.42 in the data).

We then analyze how well the model can match the life-cycle profiles not explicitly targeted in the estimation. Figure 13 plots both the model-implied profiles (black solid line) along with those in the data (red dashed line). As can be seen from Panel A, the model generates an increase in the average homeownership rate for households of young ages (until the age of 40) and a relatively stable homeownership rate later on in life. While we slightly overestimate the values for middle-aged households, the overall pattern is consistent with the data. Similarly, while we only target the average share of households with a mortgage in our identification, as can be seen from Panel B, the model reproduced the hump-shaped life-cycle profile of households with a mortgage. Panel C plots the median loan-to-income (LTI) in the data and in the model. Overall, we capture the life-cycle profile of the median LTI, but we slightly underestimate the value of the LTI both at the aggregate level as well as for all ages (as mentioned above). Panel D plots the life-cycle profile of non-durable consumption. The model reproduces the increase in non-durable consumption up to retirement and the drop (while not as large as in the data) at the end of the lifetime.

Figure 13: Life-cycle profiles in the baseline model



Note: The top left panel displays the mean homeownership rate. The top right panel displays the mean share of households with a mortgage. The bottom left panel plots the median loan-to-income. The bottom right panel plots the consumption profile. The black solid line corresponds to model-generated life-cycle profiles, while the red dashed line corresponds to data-generated profiles. Shaded areas represent the data bootstrap confidence intervals.

5 Modelling Bust Dynamics in Spanish Housing Market

In our main experiment, we simulate the bust cycle in the model that mimics the evolution of a bust cycle in Spain. In our simulations, we model the crisis as being determined by three factors: (i) severe contraction in credit supply, (ii) contraction in the labor market, and (iii) elimination of fiscal incentives to own the house. We conduct several sets of experiments. The full experiment is described in Table 4.

In particular, we model the change in credit conditions as a combination of three exogenous policy changes: a temporary (but persistent) drop of maximum LTV at origination from a baseline value of 0.95 to a value of 0.7 (change in the parameter λ_m), a drop of maximum PTI at the origination from 0.4 to 0.25 (change in the parameter λ_π) and an increase of mortgage spread by a factor of 3.5 (change in the parameter ι). In terms of the changes in the income dynamics, as discussed in section 2.3.2, we estimate

Table 4: Bust dynamics in Spain

Feature	Before bust	Bust	Persistence
Credit conditions			
max LTV at origination	0.95	0.7	persistent
max PTI at origination	0.4	0.25	persistent
mortgage spread		$\times$3.5	persistent
Income dynamics			
life-cycle component	estimated	estimated	transitory
conditional persistence	estimated	estimated	transitory
conditional skewness	estimated	estimated	transitory
Fiscal instruments			
Property tax	1%	1.13%	persistent
Mortgage payment deductibility	15%	0%	persistent

the exogenous income process separately for the pre-bust period and for the bust period. Therefore, in our main experiment, we model the change in income dynamics as a temporary change in the estimated income process - this includes the changes in the deterministic life-cycle profile and changes in conditional persistence and skewness. Finally, we also model the change in the homeownership fiscal incentives. In particular, we model them as an increase in the property tax (parameter τ_h) by 1.3pp and removal in mortgage payment deduction (parameter τ_m).

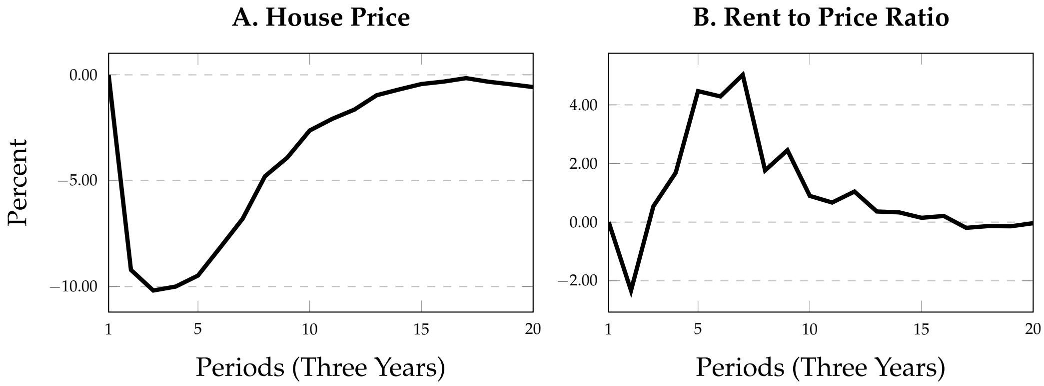
We then proceed to analyze the model-implied dynamics following the experiment described above. First, we analyze the behavior of aggregate prices as well as aggregate variables, such as homeownership rate, consumption, and aggregate mortgage credit. We then proceed to analyze the dynamics for different cohorts. Second, we look at the welfare implications of the analyzed policies, both on the aggregate and cohort levels. Finally, we break down the analysis into a series of partial experiments to analyze the role of each change in Table 4. In the Appendix, we then analyze a set of alternative experiments: the higher persistence of the credit and fiscal shocks, the permanent nature of those shocks, the role of equilibrium prices, and the role of segmentation of the housing and rental markets.

We assume that in the initial period, the economy is in a steady state, characterized by the behavior described in section 4.3 and a set of initial policy parameters (second column in Table 4). We then model the bust episode as a temporary (but persistent) change in the policy and income parameters (third column in Table 4), with the economy fully reverting to the initial steady state after a number of periods.

5.1 Aggregate dynamics

In our benchmark scenario, following the change in credit, income, and fiscal conditions, the model produces a drop in house prices of around 10% at the peak and an increase in the rent-to-price ratio of around 4% (see Figure 14). While smaller in magnitudes, the changes in house prices and rental rates are in line with the data (see Figure 3). In particular, the model generates about a third of the observed house price drop in the data.[17]

Figure 14: Evolution of house price and rent to price ratio



Note: The figure depicts the evolution of owner-occupied house price (left panel) and rent-to-price ratio (right panel) in the benchmark scenario.

Given the set of shocks in our benchmark scenario and the endogenous response in prices observed in Figure 14, we proceed to analyze the response of the set of other macroeconomic aggregates, namely total housing market indicators (aggregate homeownership rate and the average size of owner-occupied home), the share of households with mortgage debt, aggregate consumption, and aggregate liquid savings. Those are indicated as black solid lines in Figure 15.

While in the benchmark scenario, the house prices have fallen (as indicated in Figure 14), the simultaneous decrease in income and the contraction in the credit conditions led to an overall decrease in the aggregate homeownership rate of about 10% (see Panel A in Figure 15) and the share of households with the mortgage (see Panel B). In

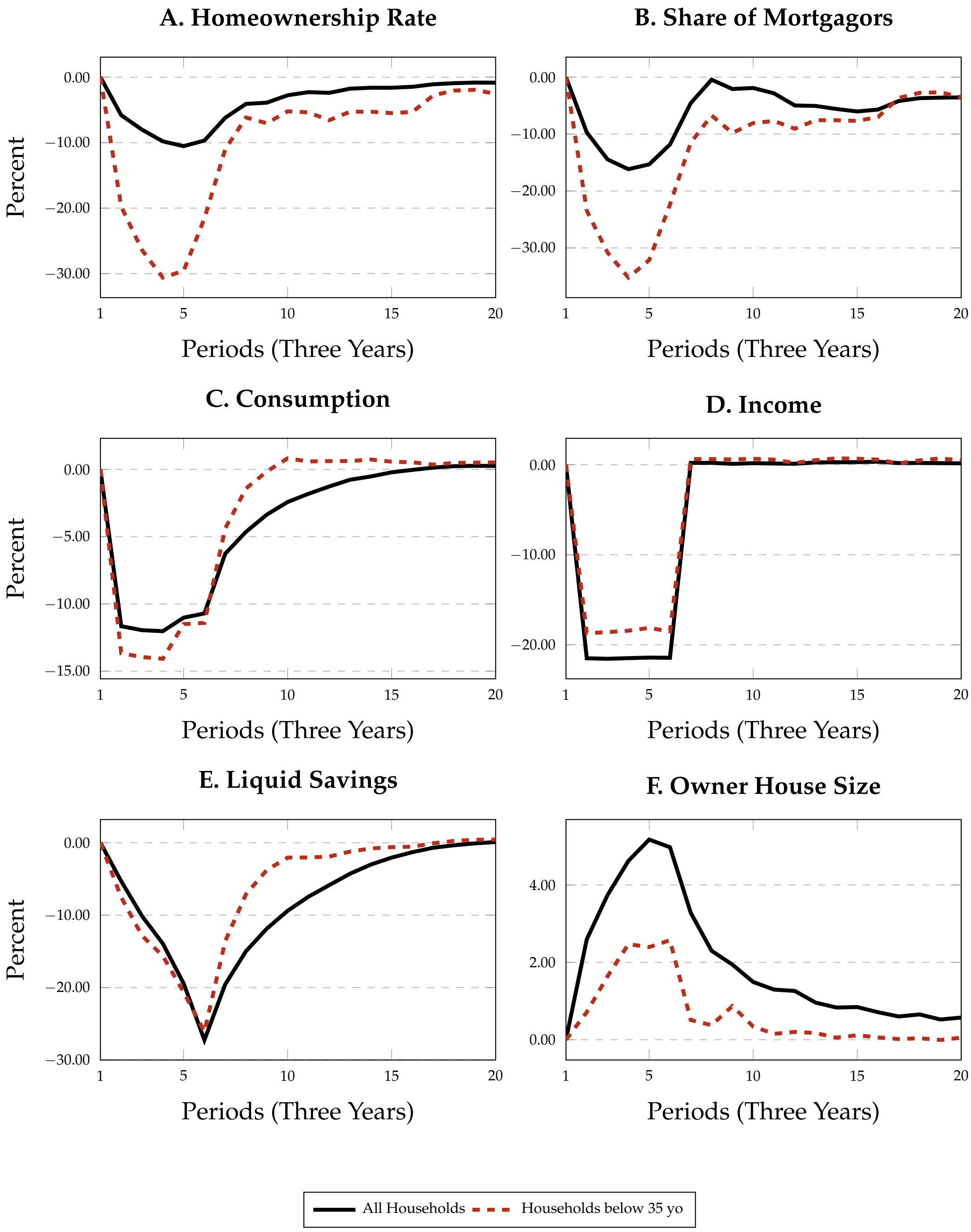
[17] In our experiment, we attribute the movements in house prices and rental rates to the three factors described above. There could be, of course, other potential factors that we omit from our analysis, for example, changes in the beliefs about house price growth as in Kaplan et al. (2020). Generating a potentially larger movement in house prices could, potentially, also affect the movements in other aggregates, such as consumption and mortgage. We are aware of this potential limitation and see this is a quantitative issue.

the benchmark scenario, the average income drops by around 20% (see panel D).[18] The aggregate consumption, however, does not drop as much, reaching a peak of around 10% (panel C). As the income conditions (and aggregate credit conditions) worsen in the benchmark scenario, households use their stock of liquid savings to partially maintain the pre-shock level of consumption: liquid savings do not fall immediately but reach a peak drop of around 28% (see Panel E). The level of aggregate liquid savings drops by more than the income. Since in the model, the households get utility both from consumption and the housing, as Panel F indicates, the households that do decide to buy the house in the benchmark scenario - buy the house of the bigger size on average. There are two opposing effects for the households that enter the housing market in the benchmark scenario. On the one hand, house prices are now lower, allowing households to access houses of the bigger size. On the other hand, the credit (and income) conditions worsen, preventing households from accessing the housing market. The evidence in Panels E and F indicates that households leverage an overall drop in house prices, utilizing their liquid savings to partially offset the drop in consumption and partially counterbalance more strict access to housing credit.

The housing bust in Spain had an unequal effect on different cohorts (see Section 2.2). As such, in Figure 15, (red dashed line) we also study the evolution of aggregate variables for households that are below 35 years. As indicated in Figure 15, households below 35 years experience more negative effects in terms of a drop in the share of homeowners, the share of households with a mortgage, and a more significant drop in consumption. As Panels A and B indicate, the shares of homeowners and mortgagors for this demographic group drop by 30% and 35%, respectively. This is compared to a 10% and 15% drop for all households - we see a similar differences by age in the data, see Section 2.2. While the income drop for this demographic group is quite similar to the overall drop in income for the whole population, the aggregate consumption drops by almost 15% for this demographic group (compared to 12% for the whole economy) - see Panels C and D - again, as we see in Section 2.2, the drop in consumption for younger individuals was only slightly lower than for the older ones. Finally, similarly to the discussion above, households below 35 years also use their liquid savings to both compensate the drop in consumption as well as leverage the drop in house prices. As such, the average house size of those deciding to become homeowners among this demographic group increases by around 2% (compared to 4% for all households) - see Panel F.

[18] Note that this comes directly from the estimated income process that we describe in Section 2.3.2.

Figure 15: Evolution of aggregate variables (all vs younger households)



Note: The figure depicts the evolution of homeownership rate (top left panel), the share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) in the benchmark scenario. The black solid line depicts the evolution of the variables for all households, while the red broken line depicts the evolution of the variables for households who are below 35 years of age.

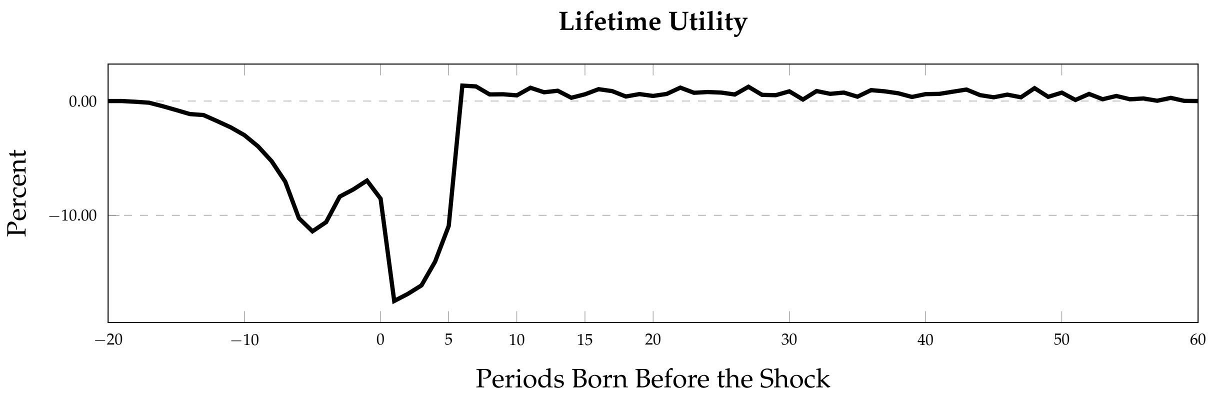
5.2 Cohort dynamics and welfare implications

The temporary nature of the shock we model implies that cohorts entering the model at different points in time will face different sets of prices and credit and income conditions. As such, at each point in time for each household, we construct the measure of welfare utility that considers both the prices/conditions when the household enters the model and all future realizations of those until the household is alive.

Figure 16 plots the change in lifetime utility for cohorts entering the economy at different points in time (relative to the "steady-state" cohort that exited the economy before any shock materialized). As the Figure indicates, households entering the period of the shock (period 1) have the largest drop in their lifetime utility (of almost 20%). This is largely explained by the drop in two variables from which households get the utility: non-durable consumption and housing.

As described in the section above, younger households (those below 35) experienced a larger drop in the homeownership rate and a large (while similar to other households) drop in aggregate consumption. While the shock had the most negative effect on younger households, as discussed in the previous section - all households experienced a drop in homeownership rate and non-durable consumption. Indeed, as Figure 16 indicates, while cohorts born at the or around the realization of the shock have the largest welfare loss (between 10% and 20%), the cohorts that were already born at the time also suffer a welfare loss up to 10%. What is noteworthy, the size of the welfare loss decreases the older the cohorts. Indeed, older households still experience a drop in non-durable consumption, but those households are more likely to be homeowners already (see Panel A in Figure 13), and hence do not experience a drop in the amount of housing services they consume. Finally, it is worth noting that the welfare loss largely disappears shortly after the simulated recovery of the aggregate income - around period 6 (see Panel D in Figure 15).

Figure 16: Evolution of lifetime utility



Note: The figure depicts the evolution of lifetime utility for cohorts born at a different point in time for the benchmark scenario. Model period corresponds to three years.

5.3 Disentangling the results

As we have discussed at the beginning of Section 5, we model the crisis (bust) period as a combination of contraction in credit supply, contraction in the labor market, and elimination of the fiscal incentives. We now analyze the role of each of these factors for the aggregate and cohort dynamics. As before, Figure 17 plots the evolution of house price and rent-to-price ratio, Figure 18 plots the evolution of other aggregate variables, and Figure 19 plots the evolution of the lifetime utility of the households.

Income Shocks Only We start with an experiment where we only model changes in income conditions. Those are denoted by a green dashed line in Figures 17, 18 and 19. As indicated in Panel A in Figure 17, shocks to the income conditions only would result in a peak drop of house price of 6-7%, implying that income shocks can explain between 60% and 70% of changes in house prices. Similarly, as Panel B indicates, income shocks explain a similar share in the evolution of the rent-to-price ratio.

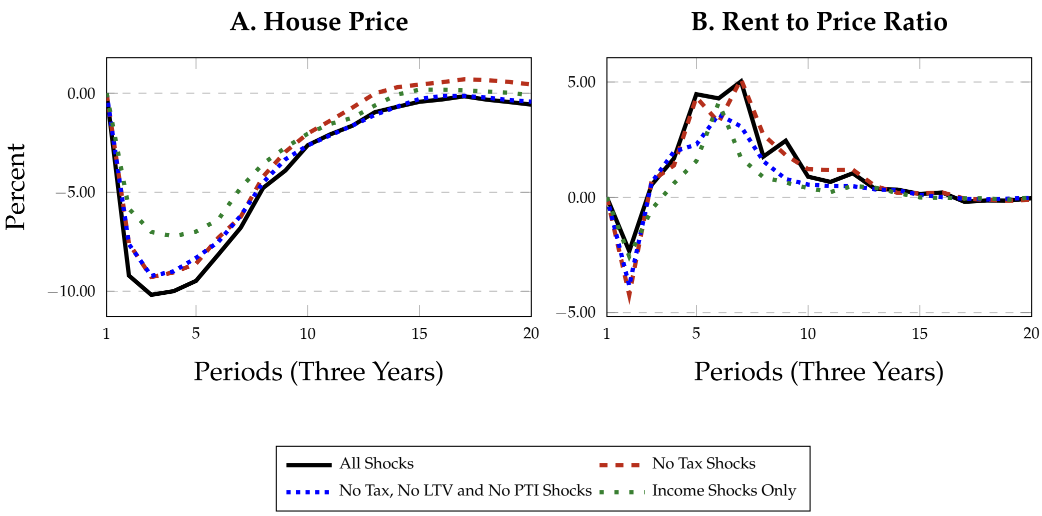
In terms of other aggregate variables, as Panels C-F of Figure 18 indicates, changes in income explain most of the movements in aggregate consumption, liquid savings, and the average size of the owner-occupied housing. As Panel A demonstrates, absent all other shocks, the changes in income conditions only would imply a peak drop in the homeownership rate of around 6% (compared to 10% in the benchmark scenario). The transitory nature of the income shock also implies a faster recovery compared to the benchmark scenario (see black solid line in Panel A). Similarly, as Panel B indicates, the drop in the average share of households with mortgages has a peak drop of around 7% (compared to 12% in the benchmark scenario). Again, the transitory nature of the income shock implies a faster recovery in the mortgagor rate. Moreover, since income returns to a pre-bust level, and house prices remain lower for a longer number of periods, the share of households with the mortgage first increases above the pre-bust level (this is also consistent with the fact that those households that do buy a house - buy a bigger one - see Panel F).

Finally, as Figure 19 indicates, changes in income conditions are largely responsible for changes in the overall level of lifetime utility (this is also consistent with Panel C in Figure 18).

Income Shocks and Changes in Credit Rate We now analyze the scenario where credit rates also increase on top of the income changes. This scenario is indicated as a blue dotted line in Figures 17, 18, and 19. As such, the difference between blue and green dotted lines can be understood as a marginal effect of changes in credit rates. As Panel A in Figure 17 indicates, the combination of income and credit rate shocks implies a peak drop in house prices of 8%. This, compared to a peak drop of 6% in the previous scenario and 10% in the benchmark scenario, implies that shock to credit rates is responsible for around 20% of changes in the house prices. Similar conclusions can be drawn regarding the rent-to-price ratio (see Panel B).

Regarding the other aggregate variables, as indicated above, changes to income conditions explain most (if not all) changes to consumption, liquid savings, and owned-occupied house size (see Panels C-F of Figure 18). In terms of changes in the aggregate homeownership rate, the change in credit rate implies an extra drop in this indicator of around 1pp, implying that credit shocks can explain about 10% of the drop in homeownership rate. As the shock to credit rate is persistent, the recovery of the homeownership rate is more prolonged. The changes to credit rate (on top of changes in income conditions) also generates a large drop in the share of households with a mortgage (a peak drop of around 20%). Since the shock to credit rate is more persistent, even though income recovers quite fast, we do not observe as fast of recovery of the share of mortgagors as in the previous scenario.

Figure 17: Evolution of house price and rent to price ratio



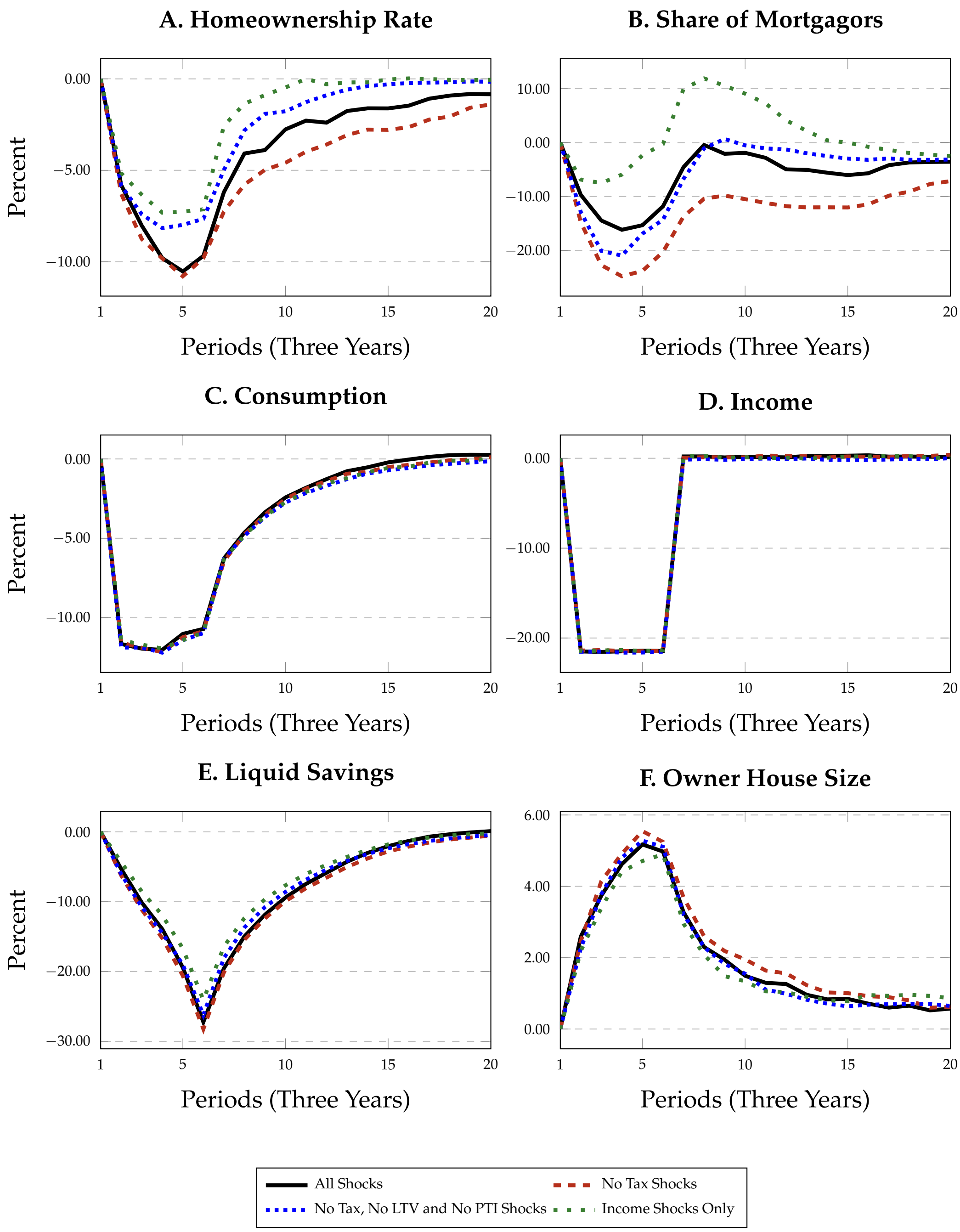
Note: The figure depicts the evolution of owner-occupied house price (left panel) and rent-to-price ratio (right panel) in the four scenarios described in the main text.

Income Shocks, Changes in Credit Rate and Changes in Credit Requirements In the final part of the breakdown analysis, we now add the shocks to the credit requirement (LTV and PTI constraints) on top of the previous scenario (changes to income conditions and credit rate). This scenario is indicated as a red broken line in Figures 17, 18, and 19. As such, the difference between the blue dotted and red broken lines could be understood as a marginal effect of changes in the credit requirements.

In terms of the effect of the aggregate prices, as Figure 17 indicates, the marginal effect of changes in credit requirements has no significant effect on house price (Panel A) and a very small effect on rent-to-price ratio (Panel B).

The extra effect of changes in credit requirements generates an extra 2pp drop in the homeownership rate and delays its recovery (relative to the previous and the benchmark scenario) - see Panel A in Figure 18. As the figure also indicates, the combina-

Figure 18: Evolution of aggregate variables (all households)

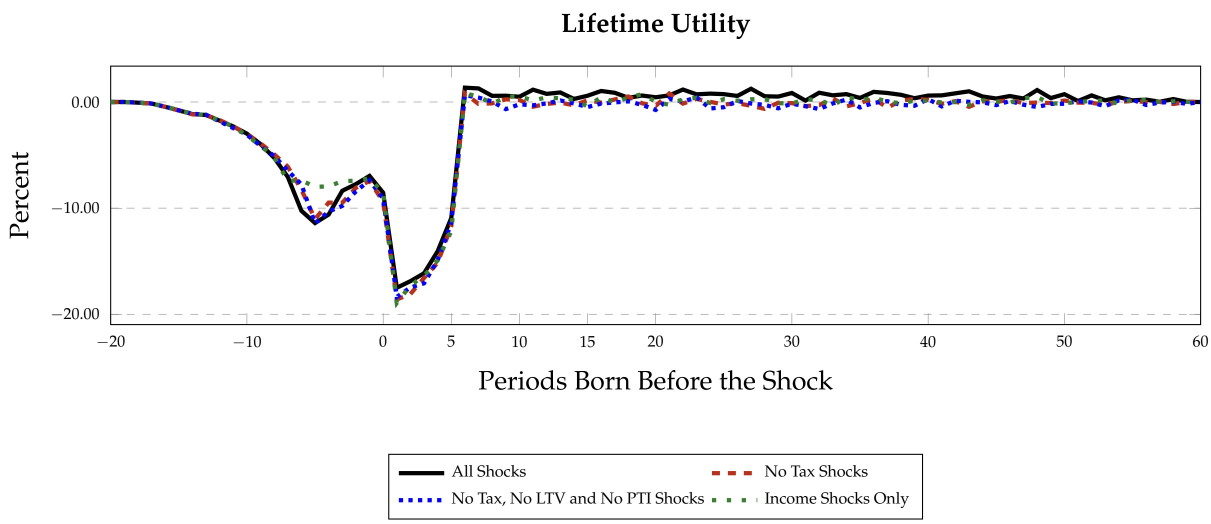


Note: The figure depicts the evolution of homeownership rate (top left panel), the share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) in the four scenarios described in the main text.

tion of the three shocks analyzed in this scenario explains all of the peak drop in the homeownership rate. When it comes to changes in the share of households with the mortgage, as Panel B indicates, the changes in credit requirements add marginally an extra 4pp decrease to this indicator, as well as postponing its recovery (both relative to the previous and the benchmark scenario).

Finally, it is worth documenting the marginal effect of changes in fiscal incentives (which could be understood as the difference between the red broken line and the black solid line in Figures 17, 18 and 19). Changes in fiscal incentives add an extra 1pp to the peak drop of house price and generate a slightly faster recovery for it (see Panel A in Figure 17). Changes in fiscal incentives do not have an extra effect on the peak drop in homeownership rate, but a faster increase in house prices delays the recovery of this variable. Interestingly, even though the removal of fiscal incentives has a negative effect on the households who take out the mortgage, the house price is lower in the benchmark scenario, making mortgages cheaper. Hence, the extra 2pp drop in house prices partially offsets the negative effect of all other shocks combined, generating a peak drop in the share of mortgagors of around 15% and faster recovery compared to the previous scenario.

Figure 19: Evolution of lifetime utility



Note: The figure depicts the evolution of lifetime utility for cohorts born at different points in time for the four scenarios described in the main text. Model period corresponds to three years.

6 Conclusion

The purpose of this paper is two-fold. First, using household-level data on assets, liabilities, income, and consumption covering the last housing boom-bust cycle in Spain

2002-2017, we document three cohort and life-cycle dynamics: (i) a significant and fast drop in home-ownership for young cohorts during the bust, combined with a mild and gradual decrease in overall home-ownership rate as well as significant movements in rent-price ratios; (ii) a change in income dynamics between expansion and recession, characterized by a drop in income levels as well as asymmetric shifts in conditional persistence and skewness of income shocks; and (iii) a significant consumption drop, which was relatively homogeneous across ages. Second, we estimate an equilibrium life-cycle model with non-linear income dynamics, mortgages, housing, and rental markets and use the model to carry out a set of counterfactual experiments to understand the dynamics of the housing bust cycle. We show that the lions-share observed drop in home ownership and consumption and the housing market dynamics can be explained by more cautious credit conditions and the estimated shift in income dynamics observed in Spain between the boom and bust phases. Moreover, these two factors account for about a third of the observed drop in house prices and rental rates. We also show the importance of other factors, such as the duration of credit contraction and worsening income conditions, as well as the structure of the housing market, in determining the dynamics of the bust cycle and the subsequent recovery.

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A Online Appendix

A.1 More Details on the Estimation of the Income Process

To estimate the deterministic and stochastic components of income, we utilize the 2002-2017 waves of the Spanish Survey of Household Finances, or the *Encuesta Financiera de las Familias* (hereafter EFF). The survey, which is administered by the Bank of Spain, is conducted to obtain direct information on income, assets and consumption of Spanish households. As opposed to other surveys, the EFF has two distinguishing characteristics that allow a comprehensive description of household wealth in Spain. The first is that the EFF oversamples wealthy households, which, in turn, provides for an accurate measurement of the aggregate distribution of wealth. The second is that the EFF has a panel component, which allows us to study earnings dynamics both in recessions and expansions.

We use a broad definition of labour income, which includes earnings, unemployment insurance, social security, and other transfers. As is noted in Cocco et al. (2005), this approach implicitly allows for other mechanisms that individuals can self-insure against income risk. Just including labour earnings could potentially overstate income risk, in the sense that workers can access unemployment insurance, or receive help from family and friends, and so on. However, we remove individuals for which the main source of income is pensions, and individuals that still reported zero for this

VARIABLES	(1) ALL	(2) Expansion	(3) Recession
Age	0.403	0.0755	0.970**
	(0.274)	(0.336)	(0.462)
Age squared	-0.0104	-0.000278	-0.0283*
	(0.00947)	(0.0118)	(0.0157)
Age cubed	0.000118	-1.15e-05	0.000362
	(0.000142)	(0.000180)	(0.000231)
Age fourth	-5.11e-07	8.19e-08	-1.72e-06
	(7.83e-07)	(1.01e-06)	(1.25e-06)
Constant	3.930	7.774**	-2.629
	(2.902)	(3.485)	(4.995)
Observations	21,180	9,923	11,257
R-squared	0.027	0.039	0.025

Robust standard errors in parentheses, $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A.1: Deterministic income profile

broad income category. This leaves us with 21,180 individual-year observations. Labor income is then deflated according to the Consumer Price Index, with 2002 as the base year.

To estimate the deterministic income profile, we regressed the logarithm of household labor income on a fourth-order polynomial on age, education dummies, family size dummies, the number of children in the household, a dummy for children living out of the household, and other household income earners. We estimate the labor income process for the whole sample, as well as separately for recession (waves 2002-2008) and expansion (waves 2011-2017). We report the results of the deterministic age profile in Table A.1, and the implied predicted age profile in Panel C of Figure 9.

A.2 Definition of Equilibrium

Let $\mathbf{x}^n = (a, y) \in \mathbb{X}^n$ denote the vector of individual states of a non-homeowner and let $\mathbf{x}^h = (a, m, h, y)\, \mathbb{X}^h$ denote the vector of individual states of a homeowner. Also, let ξ_j^n and ξ_j^h denote the measure of homeowners and non-homeowners, respectively, of age j with the restriction $\sum_{j=1}^{J} (\xi_j^n + \xi_j^h) = 1$. Finally, let Γ_ξ denote the law of motion of the measure ξ.

Stationary equilibrium A stationary recursive competitive equilibrium is (i) a set of households' value functions $\{V_j^r(\mathbf{x}^n), V_j^o(\mathbf{x}^n), V_j^p(\mathbf{x}^h), V_j^s(\mathbf{x}^h), V_j^m(\mathbf{x}^h)\}$, consumption decision rules
$\{c_j^r(\mathbf{x}^n), c_j^o(\mathbf{x}^n), c_j^p(\mathbf{x}^h), c_j^s(\mathbf{x}^h), c_j^m(\mathbf{x}^h)\}$, savings decision rules
$\{a_{j+1}^r(\mathbf{x}^n), a_{j+1}^o(\mathbf{x}^n), a_{j+1}^p(\mathbf{x}^h), a_{j+1}^s(\mathbf{x}^h), a_{j+1}^m(\mathbf{x}^h)\}$, mortgage decision rules
$\{m_{j+1}^o(\mathbf{x}^h), m_{j+1}^m(\mathbf{x}^h), \pi_j^p(\mathbf{x}^h)\}$, and housing choice rules
$\{\tilde{h}_j^r(\mathbf{x}^n), h_{j+1}^o(\mathbf{x}^n), h_{j+1}^p(\mathbf{x}^h), \tilde{h}_j^s(\mathbf{x}^h), h_{j+1}^m(\mathbf{x}^h)\}$; (ii) prices p_h and p_r; (iii) quantities of the total stock of owner-occupied housing $\bar{H}$ and rental housing $\bar{R}$; (iv) distributions ξ_j^n and ξ_j^h; such that the following conditions hold

1. Given prices p_h and p_r, value functions $\{V_j^r(\mathbf{x}^n), V_j^o(\mathbf{x}^n), V_j^p(\mathbf{x}^h), V_j^s(\mathbf{x}^h), V_j^m(\mathbf{x}^h)\}$ solve equations (24), (26), (28), (31) and (34) with the corresponding set of policy functions

2. Given price p_h, the rental rate p_r is given by equation (16).

3. The total owner-occupied housing stock is equal to total demand for owner-occupied housing

$$D_H = \sum_{j=1}^{J} \left[\int_{\mathbb{X}^h} \left(h_j^p \left(\mathbf{x}^h \right) \mathbb{1}^p \left(\mathbf{x}^h \right) + h_j^m \left(\mathbf{x}^h \right) \mathbb{1}^m \left(\mathbf{x}^h \right) \right) d\xi_j^h + \int_{\mathbb{X}^n} h_j^o \left(\mathbf{x}^n \right) \mathbb{1}^o \left(\mathbf{x}^n \right) d\xi_j^n \right] = \bar{H}$$

and total rental housing stock is equal to total demand for rental housing

$$D_R = \sum_{j=1}^{J} \left[\int_{\mathbb{X}^h} \tilde{h}_j^s \left(\mathbf{x}^h \right) \mathbb{1}^s \left(\mathbf{x}^h \right) d\xi_j^h + \int_{\mathbb{X}^n} \tilde{h}_j^r \left(\mathbf{x}^n \right) \mathbb{1}^r \left(\mathbf{x}^n \right) d\xi_j^n \right] = \bar{R}$$

4. The law of motion of the measure Γ_ξ is consistent with individual behaviour.

Let $\xi_{j,t}^n$ and $\xi_{j,t}^h$ denote the measure of homeowners and non-homeowners, respectively, of age j at time t with the restriction $\sum_{j=1}^{J} (\xi_{j,t}^n + \xi_{j,t}^h) = 1, \ \forall t$.

Transitional equilibrium Given a sequence of aggregate conditions $\{\Theta_t\}_{t=1}^{\infty}$ and initial distributions $\xi_{j,1}^n$ and $\xi_{j,1}^h$ a transitional equilibrium is (i) a set of households' value functions $\{V_{j,t}^r(\mathbf{x}^n), V_{j,t}^o(\mathbf{x}^n), V_{j,t}^p(\mathbf{x}^h), V_{j,t}^s(\mathbf{x}^h), V_{j,t}^m(\mathbf{x}^h)\}_{t=1}^{\infty}$, consumption decision rules $\{c_{j,t}^r(\mathbf{x}^n), c_{j,t}^o(\mathbf{x}^n), c_{j,t}^p(\mathbf{x}^h), c_{j,t}^s(\mathbf{x}^h), c_{j,t}^m(\mathbf{x}^h)\}_{t=1}^{\infty}$, savings decision rules $\{a_{j+1,t}^r(\mathbf{x}^n), a_{j+1,t}^o(\mathbf{x}^n), a_{j+1,t}^p(\mathbf{x}^h), a_{j+1,t}^s(\mathbf{x}^h), a_{j+1,t}^m(\mathbf{x}^h)\}_{t=1}^{\infty}$, mortgage decision rules $\{m_{j+1,t}^o(\mathbf{x}^h), m_{j+1,t}^m(\mathbf{x}^h), \pi_{j,t}^p(\mathbf{x}^h)\}_{t=1}^{\infty}$, and housing choice rules $\{\tilde{h}_{j,t}^r(\mathbf{x}^n), h_{j+1,t}^o(\mathbf{x}^n), h_{j+1,t}^p(\mathbf{x}^h), \tilde{h}_{j,t}^s(\mathbf{x}^h), h_{j+1,t}^m(\mathbf{x}^h)\}_{t=1}^{\infty}$; (ii) a sequence of prices $\{p_{h,t}\}_{t=1}^{\infty}$ and $\{p_{r,t}\}_{t=1}^{\infty}$; (iii) a sequence of the total demand of owner-occupied housing H_t and rental housing R_t; (iv) distributions $\xi_{j,t}^n$ and $\xi_{j,t}^h$; such that the following conditions hold

1. Given prices $p_{h,t}$ and $p_{r,t}$, value functions $\{V_{j,t}^r(\mathbf{x}^n), V_{j,t}^o(\mathbf{x}^n), V_{j,t}^p(\mathbf{x}^h), V_{j,t}^s(\mathbf{x}^h), V_{j,t}^m(\mathbf{x}^h)\}$ solve equations (24), (26), (28), (31) and (34) with the corresponding set of policy functions for all j and t

2. The total owner-occupied housing and rental housing markets clear in each period t

3. The law of motion of the measure Γ_ξ is consistent with individual behaviour for each period t.

A.3 OECD Equivalence Scale

We use the 2002 - 2008 waves of the Spanish Survey of Household Finances (EFF) to construct the OECD equivalence scale for each household in the following way: we assign value of 1 to the household head, a value of 0.7 to each additional adult and value of 0.5 to each child in the household. We then fit a fourth-order polynomial based on the age of the head of the household and adjust the coefficients to our 3-year model. The coefficients of the polynomial are in table A.2 below.

Variable	**Coefficient**
Constant	2.194993963
Age	-0.006298410565
Age^2	0.02635423082
Age^3	-0.002886589294
Age^4	0.00007484885598

Table A.2: The coefficients of the OECD equivalence scale polynomial

A.4 Survival Probabilities

We construct the probability of survival in the following way. First, we extract the average number of survivors for both males and females between 2002 and 2008 from the Population mortality tables for Spain from the National Statistics Institute. [19] We then define the probability of survival to age j as the share of the number of people that survive to age j over the number of people that survived to age $j-1$. We assume that households die with certainty in the last periods (that corresponds to age 82). The values of the survival probabilities are in table A.3 below.

Age	**Survival Probabilities**
25	0.99953
28	0.99950
31	0.99938
34	0.99924
37	0.99901
40	0.99872
43	0.99834
46	0.99783
49	0.99722
52	0.99640
55	0.99555
58	0.99431
61	0.99285
64	0.99080
67	0.98786
70	0.98388
73	0.97813
76	0.96913
79	0.95600
82	0

Table A.3: Survival probabilities

[19] Available at https://www.ine.es/jaxiT3/Tabla.htm?t=27153&L=1

A.5 Other Scenarios

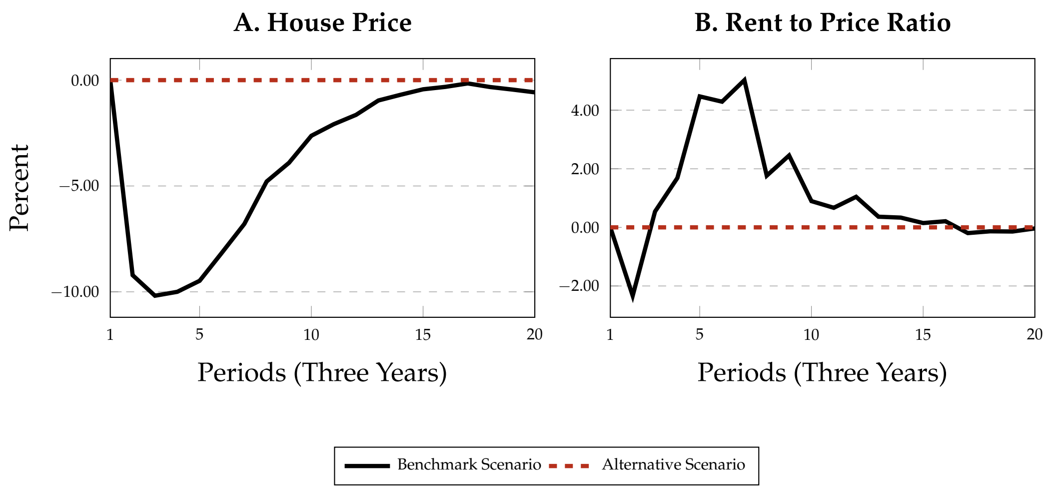
In this section, we analyze a set of alternative experiments. In particular, we analyze the role of equilibrium prices, the role of the persistence of credit and fiscal shocks, the role of monetary policy, and the role of segmentation of the housing and rental markets.

A.5.1 Partial Equilibrium

We start with an scenario in which we do not allow the prices (house price and rent price) to clear the corresponding markets, and instead keep them and the initial steady-state level.

Transitional dynamics Under this scenario, the aggregate prices remain fixed at the steady-state level (see Figure A.1).

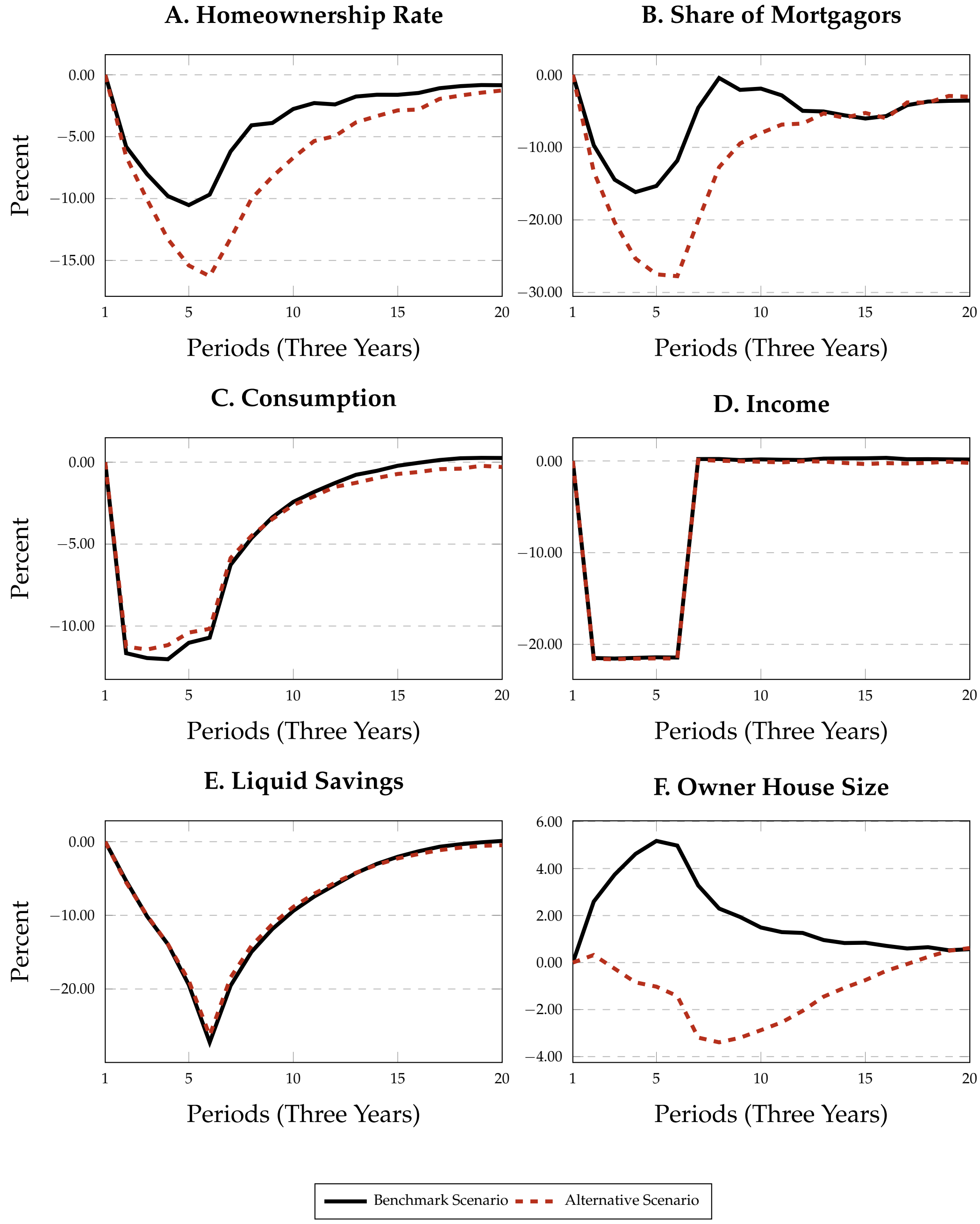
Figure A.1: Evolution of house price and rent to price ratio (benchmark vs alternative scenario)



Note: The figure depicts the evolution of owner-occupied house price (left panel) and rent to price ratio (right panel) in the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of partial equilibrium scenario.

As we described in the benchmark scenario in main text, the change in income conditions (and not the change in fiscal or credit conditions, or the changes in the aggregate prices) explains the evolution of consumption and aggregate savings (see Panels C and E in Figure A.2). Under this scenario, however, the prices remain at the higher, steady-state level and have the stronger effect on the housing market variables, such as homeownership rates, mortgagors rates and average of the owner-occupied housing (see Panels A, B and F in Figure A.2). In fact, under the alternative scenario

Figure A.2: Evolution of aggregate variables (all households, benchmark vs alternative scenario)

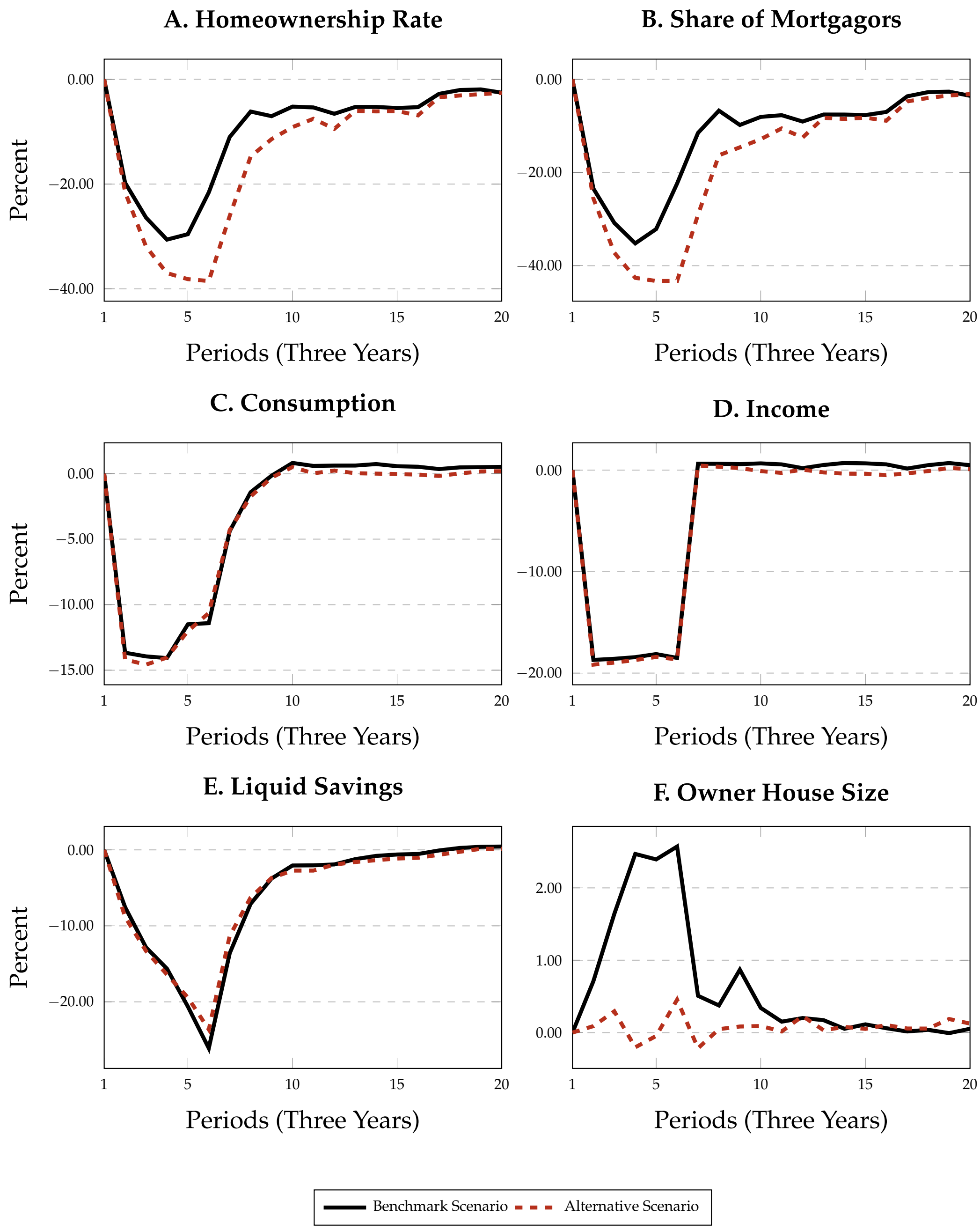


Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for all households under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of partial equilibrium scenario.

of fixed prices, the average size of owner-occupied housing drops when the aggregate prices remain fixed at the steady-state level (see Panel F in Figure A.2).

We observe the similar outcomes when looking at households who are below 35 years (see Figure A.3).

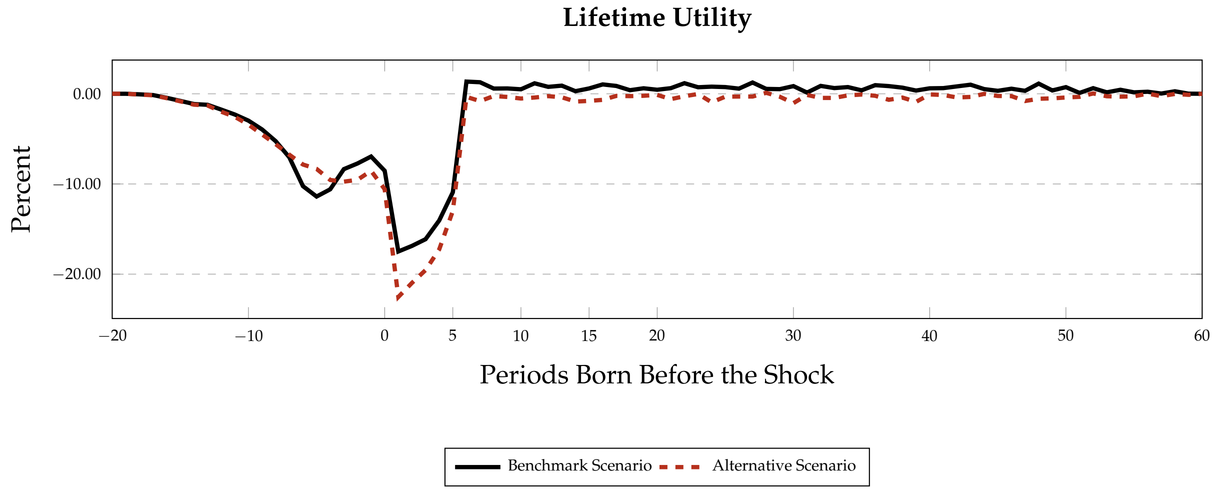
Figure A.3: Evolution of aggregate variables (younger households, benchmark vs alternative scenario)



Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for households below 35 years under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of partial equilibrium scenario.

Welfare Implications As before, we can also analyze the welfare consequences of this alternative scenario. As Figure A.4 depicts, under the scenario with fixed prices, those households born at the period (or a bit after) of the shock endure a bigger drop in their lifetime utility. This is mostly due to the larger drop in the aggregate homeownership rate and the drop in the size of the owner-occupied housing.

Figure A.4: Evolution of lifetime utility (benchmark vs alternative scenario)



Note: The figure depicts the evolution of lifetime utility for cohorts born at a different point in time under the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of partial equilibrium scenario. Model period corresponds to three years.

A.5.2 More Persistence

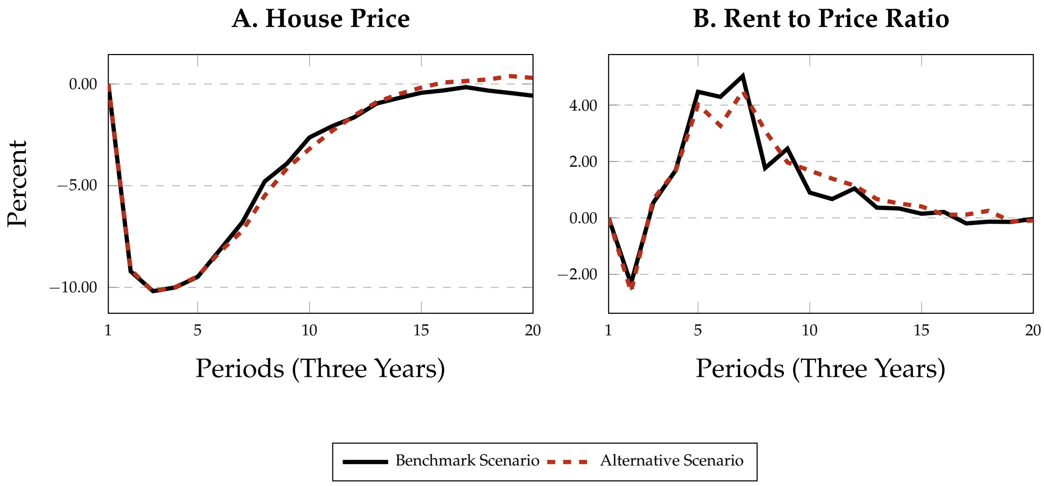
We then proceed to the scenario in which the changes to credit requirements, credit rate and fiscal incentives are more persistent. Under this alternative scenario, the change in income conditions is still of the transitory nature of the same duration as in the benchmark scenario, and the prices are allowed to adjust to clear the housing and rental markets.

Transitional dynamics As the lion-share of changes in the house and rental prices in the benchmark scenario is due to changes in income conditions, under the alternative scenario studied in this section we do not see a large difference in the movement of the aggregate prices (see Figure A.5).

Figures A.6 and A.7 depict the evolution of the other aggregate variables for all households and those below 35 years, respectively. Again, we observe the difference between the benchmark and the alternative scenario for those variables that are not mostly driven by changes in the income conditions, such as homeownership rate (Panel A) and share of households with the mortgage (Panel B). For those indicators, the speed of recovery is driven by the persistence of all the shocks other than the income one.

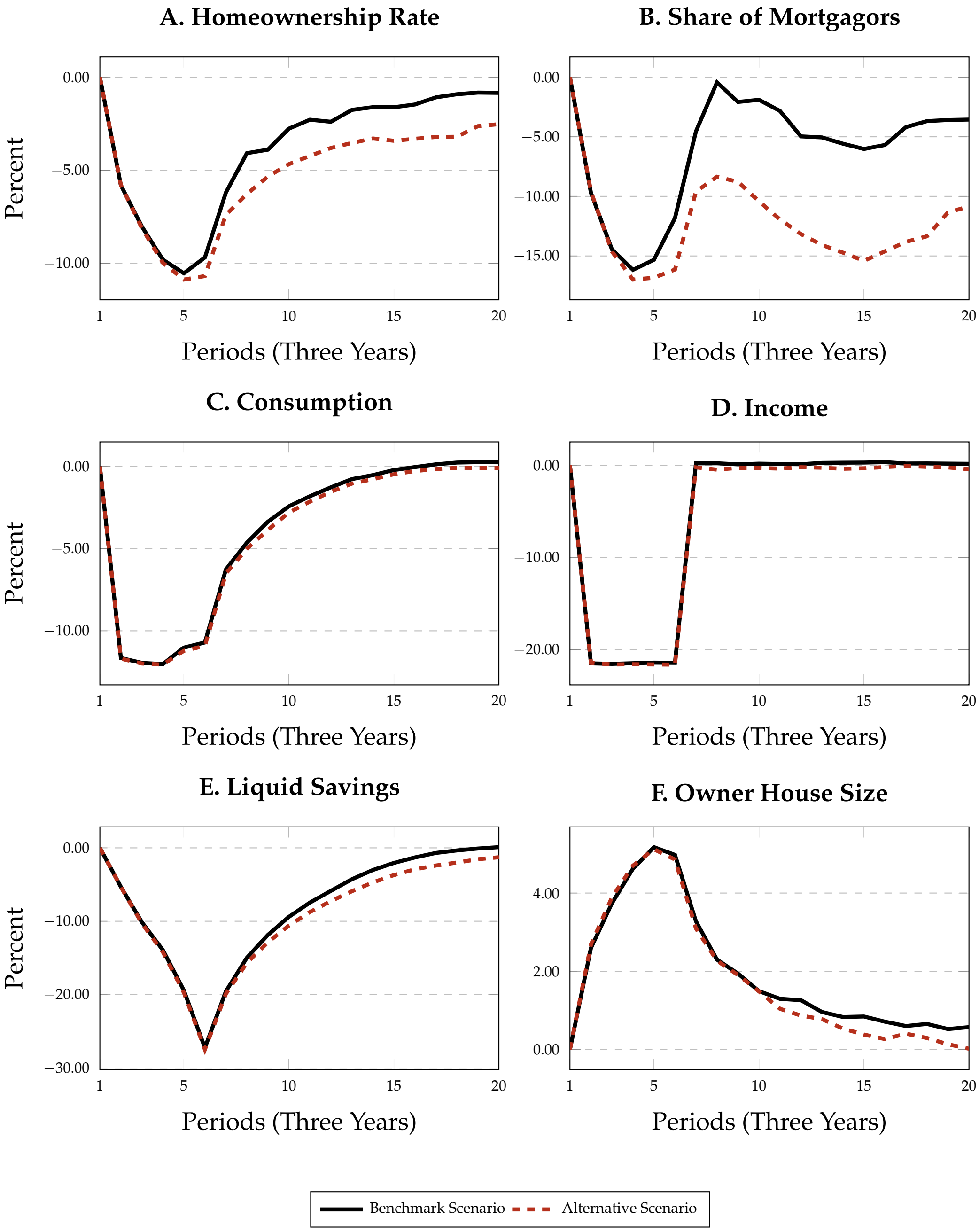
Welfare Implications As Figure A.8 depicts, there are no major differences in the evolution of the lifetime utility between benchmark and the alternative scenario in which the shocks are of a more persistent nature.

Figure A.5: Evolution of house price and rent to price ratio (benchmark vs alternative scenario)



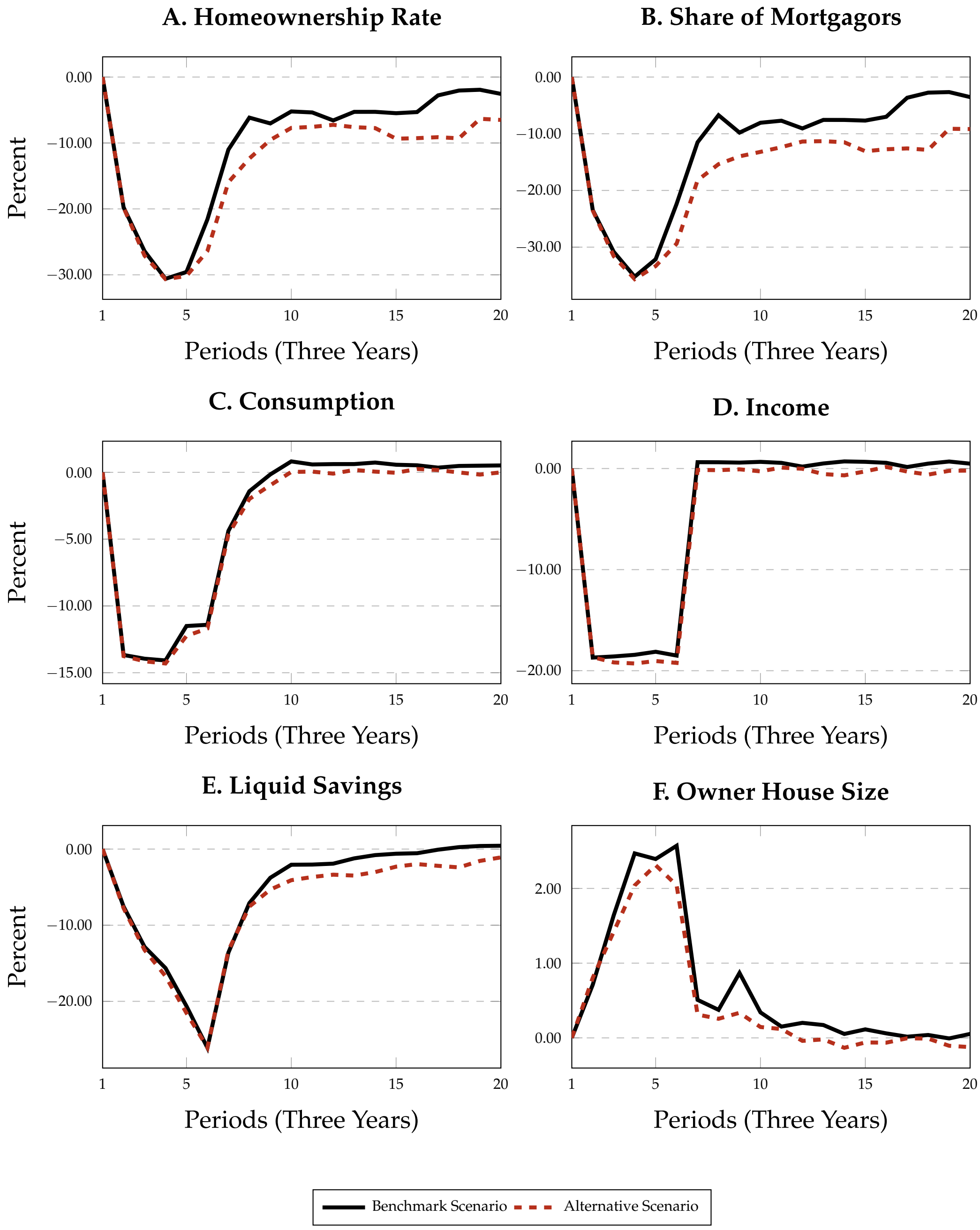
Note: The figure depicts the evolution of owner-occupied house price (left panel) and rent to price ratio (right panel) in the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of higher shock persistence.

Figure A.6: Evolution of aggregate variables (all households, benchmark vs alternative scenario)



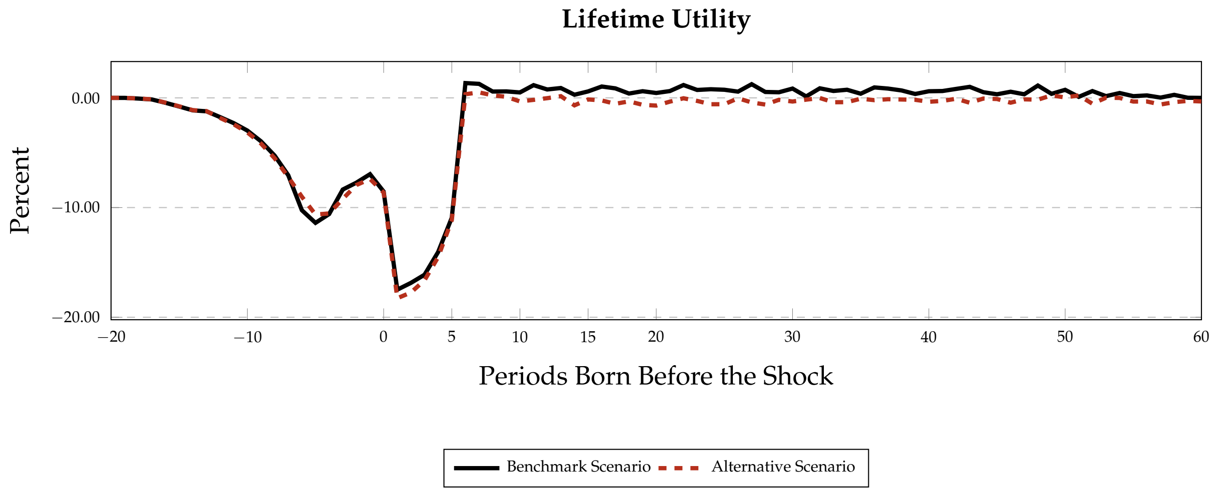
Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for all households under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of higher shock persistence.

Figure A.7: Evolution of aggregate variables (younger households, benchmark vs alternative scenario)



Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for households below 35 years under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of higher shock persistence.

Figure A.8: Evolution of lifetime utility (benchmark vs alternative scenario)



Note: The figure depicts the evolution of lifetime utility for cohorts born at a different point in time under the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of higher shock persistence. Model period corresponds to three years.

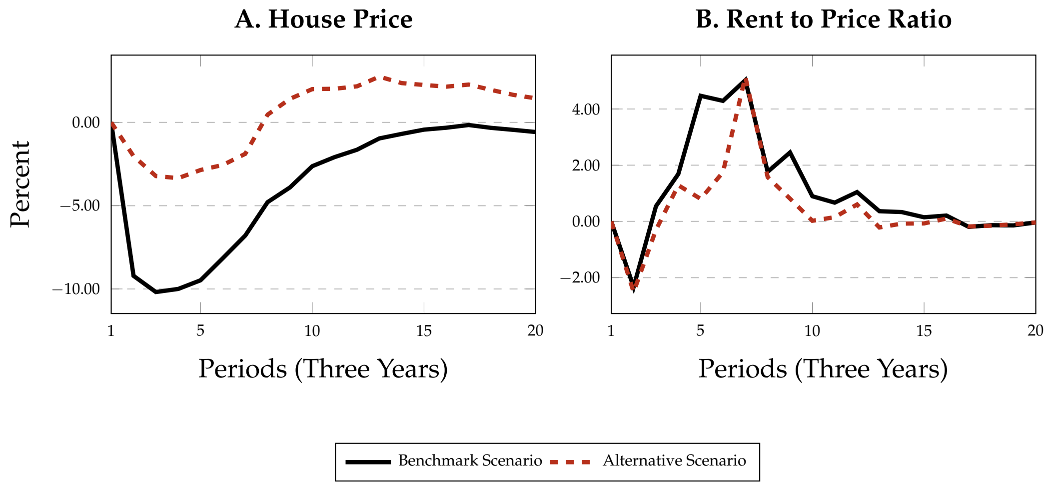
A.5.3 Accommodative Monetary Policy

In the benchmark scenario, when modelling the changes in the credit rate, we assumed that this change is driven purely by an increase in the spread between the interest and the mortgage rates. The bust period in Spain (post 2008), however, has been accompanied by the period of low interest rates. As such, in this alternative scenario we analyze the case of "accommodative" monetary policy, in which we not only model the increase in the spread between the two rates, but a simultaneous decrease in the interest rate. Under this scenario, the effective mortgage rate becomes lower that in the initial steady state, while the spread between the two rates is higher. We keep all other shock as in the benchmark scenario, and we allow the house and rental prices to adjust to clear the corresponding markets.

Transitional dynamics As mentioned above, under this alternative scenario, the effective mortgage rate becomes lower that in the initial steady state (and hence the simulated path of credit rate is below one in the benchmark scenario). As such, this decrease in the credit rate partially offsets the negative effect of all other shocks on the aggregate prices, implying a peak drop of around 4% (compared to 10% in the benchmark scenario) - see Figure A.9.

We can observe a similar effect for other aggregate variables. Indeed, as indicated in Panel A in Figures A.10 and A.11, the drop in aggregate homeownership, both for all households and those below 35 years, is now not as large. Moreover, once there is

Figure A.9: Evolution of house price and rent to price ratio (benchmark vs alternative scenario)

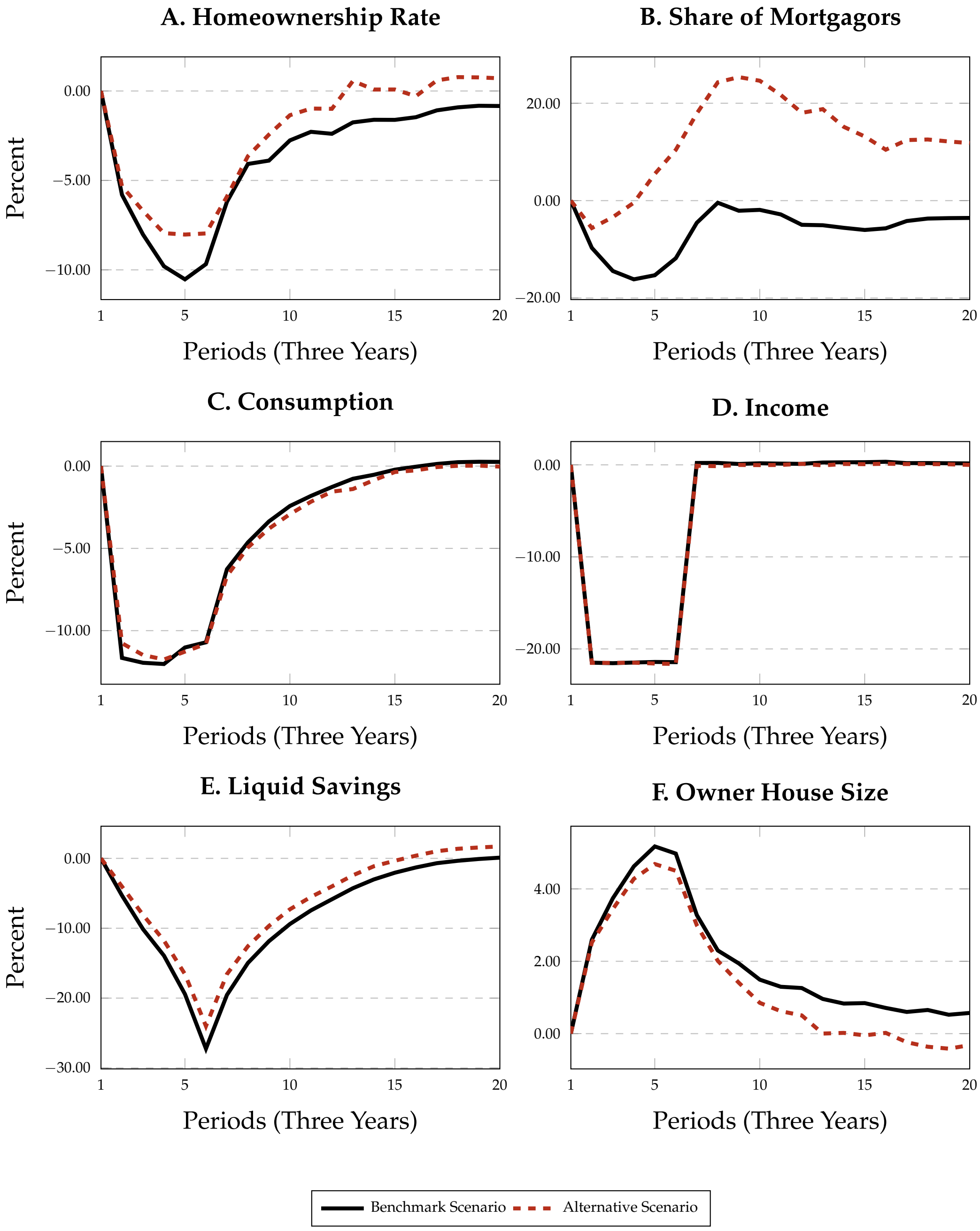


Note: The figure depicts the evolution of owner-occupied house price (left panel) and rent to price ratio (right panel) in the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the scenario where the monetary policy is of accommodative nature.

no effect on the income conditions, and that house prices and credit rate remain lower for several periods, we can observe a temporary increase in the share of households with the mortgage above the initial steady-state value, more so for older households (see Panel B in Figures A.10 and A.11).

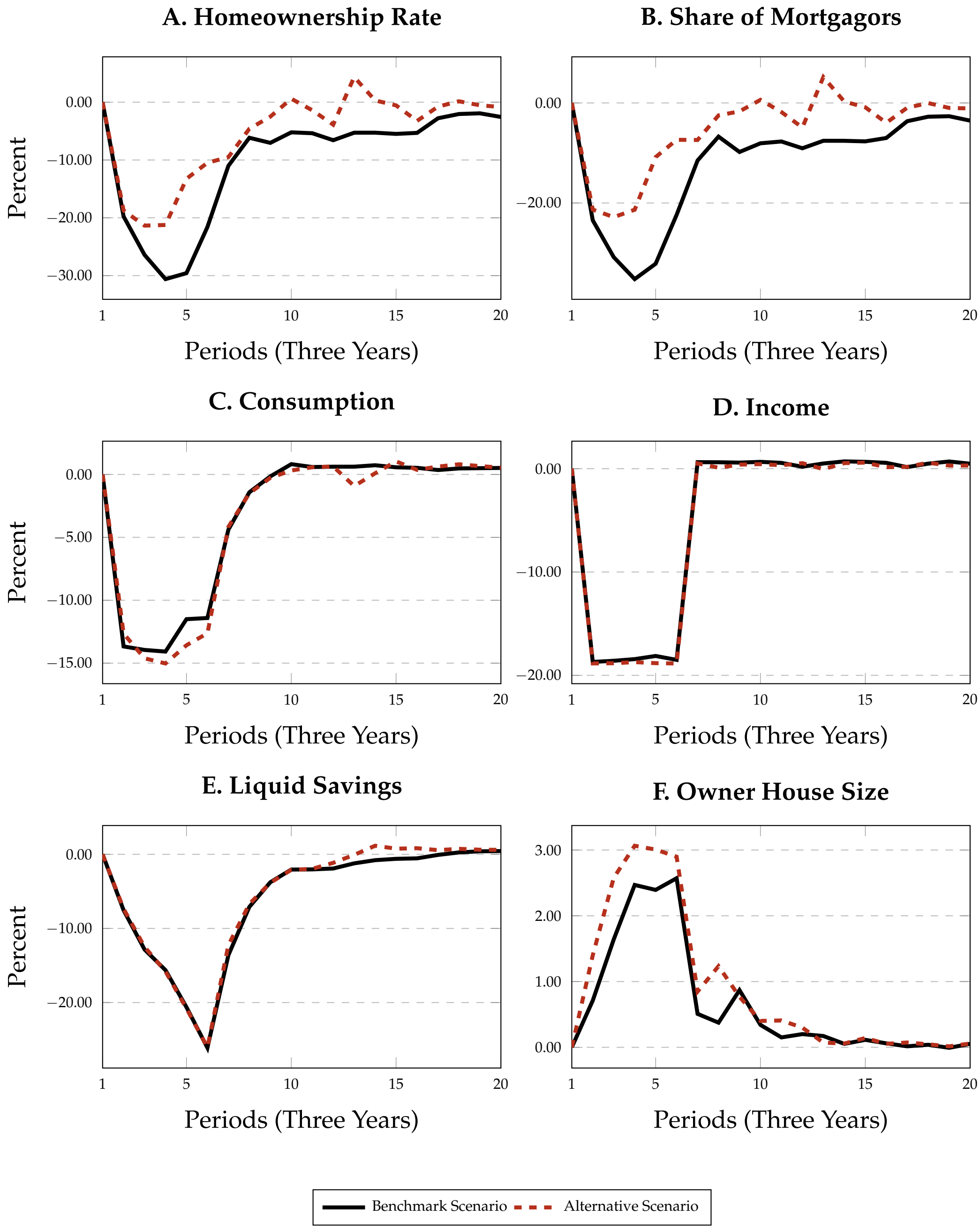
Welfare Implications Finally, as seen in Figure A.8, there are no major differences in the evolution of the lifetime utility between benchmark and the alternative scenario in which interest rate is allowed to drop.

Figure A.10: Evolution of aggregate variables (all households, benchmark vs alternative scenario)



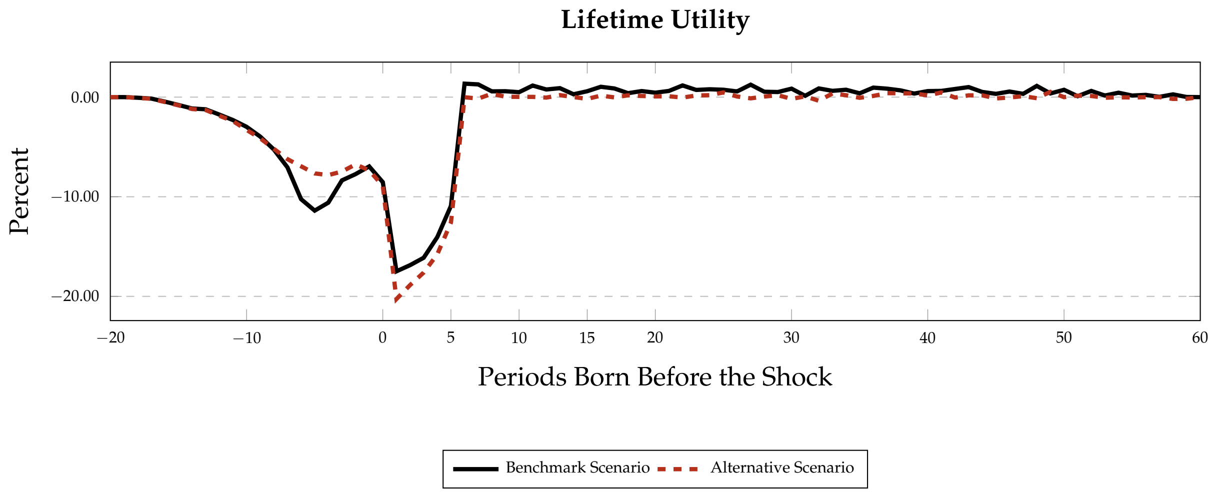
Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for all households under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the scenario where the monetary policy is of accommodative nature.

Figure A.11: Evolution of aggregate variables (younger households, benchmark vs alternative scenario)



Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for households below 35 years under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the scenario where the monetary policy is of accommodative nature.

Figure A.12: Evolution of lifetime utility (benchmark vs alternative scenario)



Note: The figure depicts the evolution of lifetime utility for cohorts born at a different point in time under the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the scenario where the monetary policy is of accommodative nature.

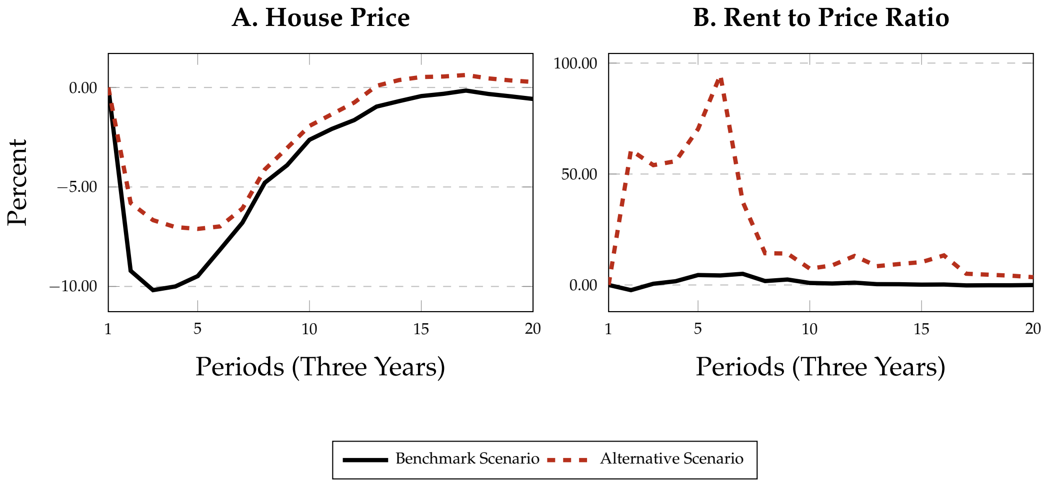
A.5.4 Housing Market Segmentation

As pointed out by Greenwald and Guren (2021), the structure and degree of segmentation between the ownership and rental markets have a direct impact on how shocks transmit into equilibrium prices and quantities. In our benchmark model, we allowed for partial segmentation in the housing markets, implying that both the aggregate prices and the quantities (homeownership rate) are allowed to move, but the house and rental prices move in the same direction. As such, in the final alternative scenario, we analyze the version of the model with full segmentation in the housing and rental markets.

Transitional dynamics As Figure A.13 indicates, following the same set of shocks that we model in the benchmark scenario, the house price decreases (with a peak drop of around 6%, compared to 10% in the benchmark scenario) - see Panel A. However, under the full segmentation scenario, the house price and the rental prices move in the opposite direction (resulting in a large increase in rent to price ratio), contrary to what we observe in the data.

As discussed above, and indicated by Greenwald and Guren (2021), under the full segmentation of the housing market, the prices (house and rent) will adjust but the aggregate quantities will not. Indeed, as we see in Panel A in Figure A.14, following the set of shocks, the aggregate homeownership rate remains at the steady state level. Same is true for the average size of the owner-occupied housing (Panel F). As the

Figure A.13: Evolution of house price and rent to price ratio (benchmark vs alternative scenario)



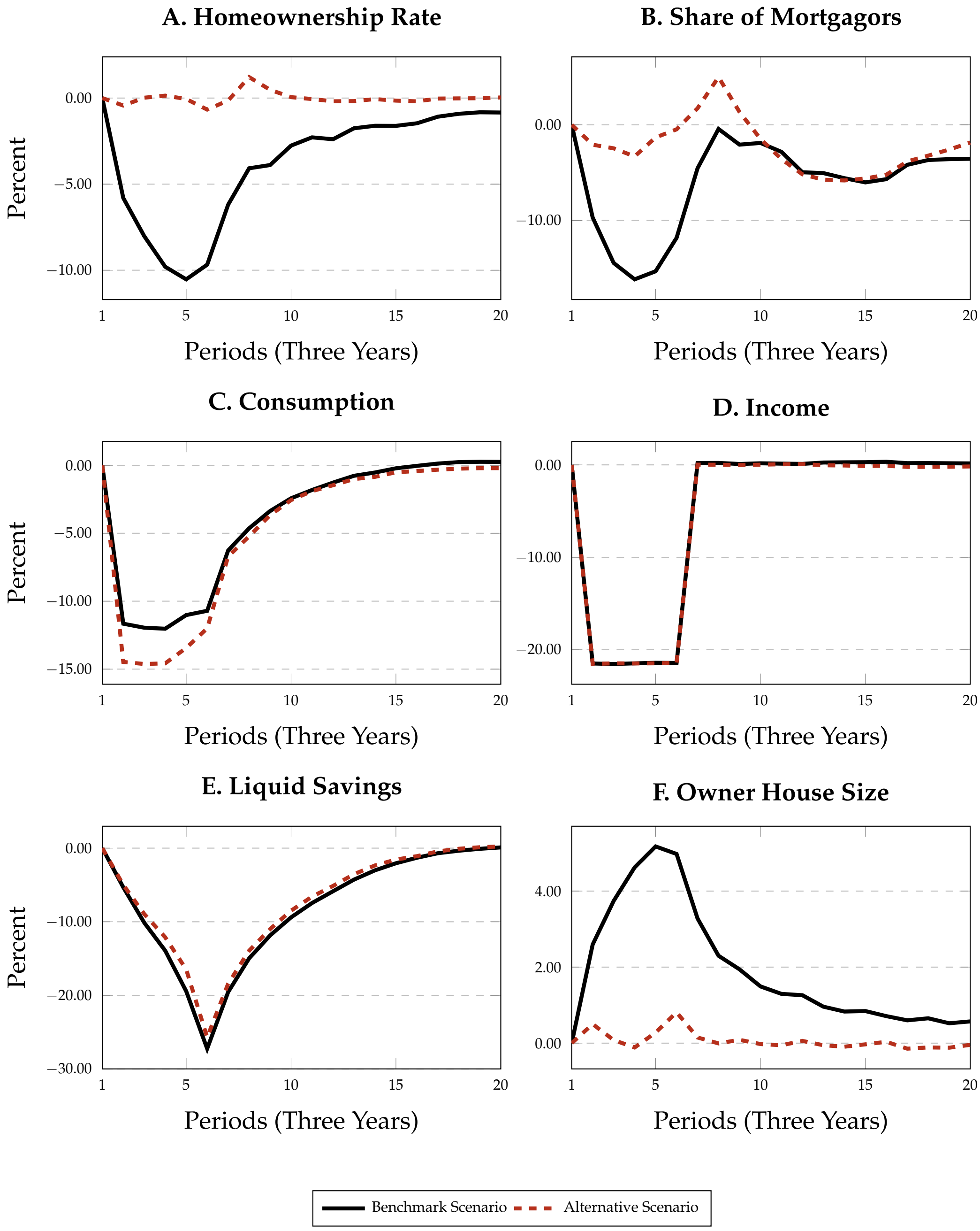
Note: The figure depicts the evolution of owner-occupied house price (left panel) and rent to price ratio (right panel) in the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of no segmentation in the housing markets.

credit, income and fiscal conditions deteriorate, we also observe a decrease in the share of households that take out the mortgage, see Panel B. This decrease, however, is not as pronounced as in the benchmark scenario for the following reason. In the benchmark scenario, the credit/income conditions prevented households from taking out the mortgage. On top of that, rental prices were falling as well, making the mortgage a less preferable option. In this alternative scenario, however, rental rates are increasing, partially offsetting the negative effect of the worse credit/income conditions.

We observe a very similar evolution of the aggregate variables for households that are below 35 years, as indicated in Figure A.15.

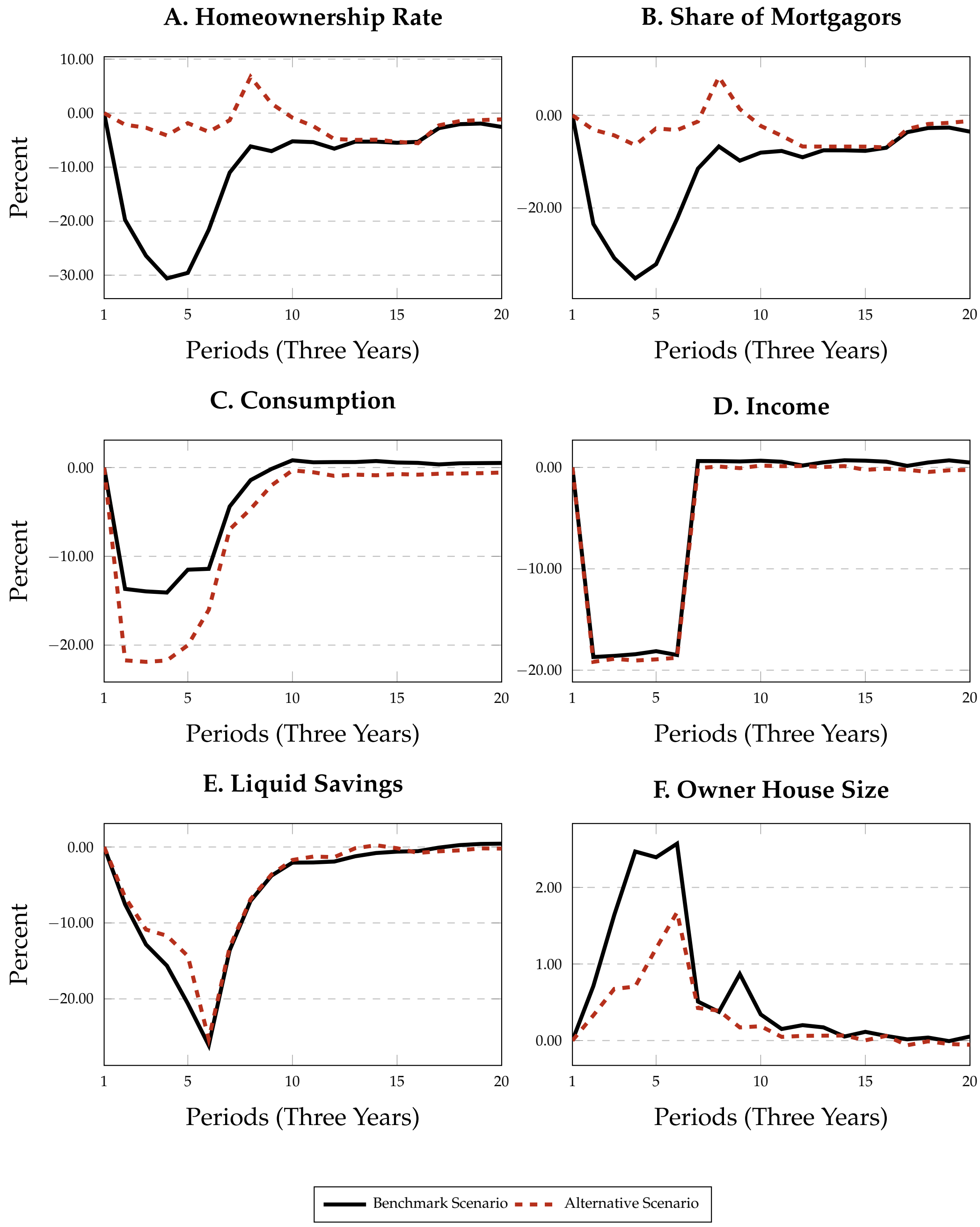
Welfare Implications Finally, we also compare the evolution of the lifetime utility between benchmark and the alternative scenario in which housing markets are fully segmented. Unlike other scenarios analyzed above, not only income changes have a negative effect on the aggregate non-durable consumption, but also higher rental payments that households have to make (see Panel C in Figures A.14 and A.15). Moreover, while there is no change in the aggregate homeownership rate, unlike in the benchmark or other alternative scenarios there is no increase in the average size of the owner-occupied houses, that would partially offset the consumption drop. As such, the overall welfare loss under this alternative scenario will be higher, as indicated in Figure A.16.

Figure A.14: Evolution of aggregate variables (all households, benchmark vs alternative scenario)



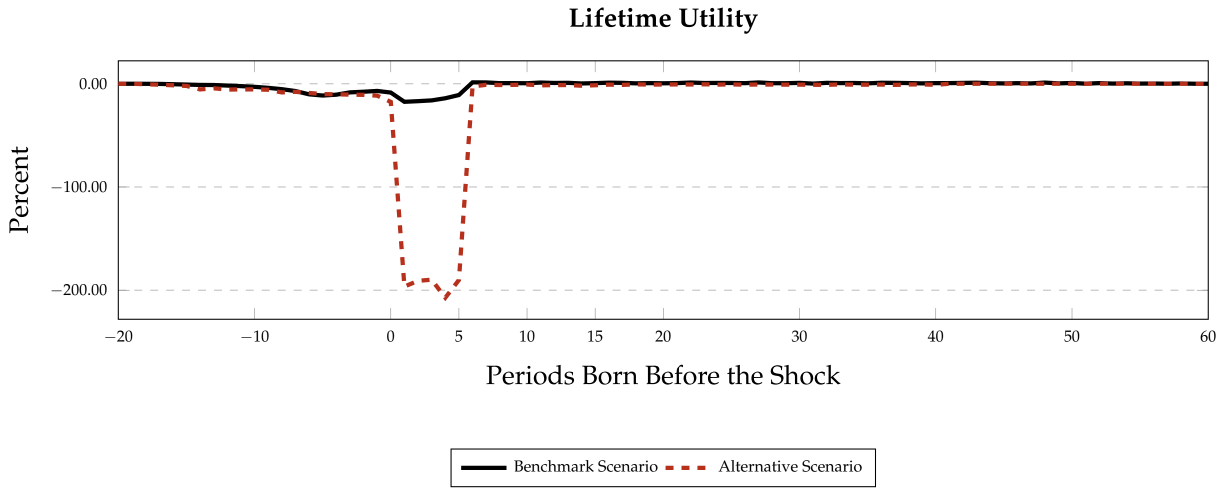
Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for all households under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of no segmentation in the housing markets.

Figure A.15: Evolution of aggregate variables (younger households, benchmark vs alternative scenario)



Note: The figure depicts the evolution of homeownership rate (top left panel), share of mortgagors (top right panel), non-durable consumption (middle left panel), income (middle right panel), liquid savings (bottom left panel) and owner-occupied house size (bottom right panel) for households below 35 years under two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of no segmentation in the housing markets.

Figure A.16: Evolution of lifetime utility (benchmark vs alternative scenario)



Note: The figure depicts the evolution of lifetime utility for cohorts born at a different point in time under the two alternative scenarios. The black solid line depicts the benchmark scenario described in the text, while the red broken line depicts the case of no segmentation in the housing markets.

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