The aggregate and distributional implications of credit shocks on housing and rental markets

Juan Castellanos Andrew Hannon Gonzalo Paz-Pardo

July 2024

Abstract: We build a model of the aggregate housing and rental markets in which house prices and rents are determined endogenously. Households can choose their housing tenure status (renters, homeowners, or landlords) and the size of their homes depending on their age, income and wealth. We use our model to study the impact of changes in credit conditions on house prices, rents and household welfare. We analyse the introduction of policies that limited loan-to-value (LTV) and loan-to-income (LTI) ratios of newly originated mortgages in Ireland in 2015 and find that, consistent with empirical evidence, they mitigate house price growth but increase rents. Homeownership rates drop, and young and middle-income households are negatively affected by the reform. An unexpected permanent rise in real interest rates has similar effects – by making mortgages more expensive and alternative investments more attractive for landlords, it increases rents relative to house prices.

Keywords: House Prices, Rental Prices, Homeownership, Life-cycle, Credit Conditions, Macro-prudential Policy

JEL classification: D15, E21, E30, E51, G51

Juan Castellanos, European University Institute, juan.castellanos@eui.eu
Andrew Hannon, European Central Bank, andrew.hannon@ecb.europa.eu
Gonzalo Paz-Pardo, European Central Bank, gonzalo.paz_pardo@ecb.europa.eu

We would like to thank Jesus Bueren, Russell Cooper, Andrea Gazzani, Jonathan Heathcote, Tim Landvoigt, Dario Laudati, Ralph Luetticke, Ramon Marimon, Kurt Mitman, Ben Moll, Lukas Nord, Monika Piazzesi, Morten Ravn, Jirka Slacalek, Oreste Tristani and Gianluca Violante, as well as conference and seminar participants at the Bank of England, Bank of Ireland, Bank of Spain, BI Norwegian Business School, European Central Bank, European University Institute, Norges Bank, Paris School of Economics, Sveriges Riksbank, University of St. Gallen, University of Vienna, 6th QMUL Economics and Finance Workshop, 2023 ECHOPPE, 2023 Lisbon Macro Workshop, 2023 Spanish Economic Association Meeting, 2023 TADC, and 2024 Theories and Methods in Macro for useful comments and discussion. We are also grateful to Matteo Crosignani for providing us with the distance measure for our empirical analysis.

1. Introduction

Housing is the largest asset in most household portfolios and housing-related expenses, such as rental payments, represent a substantial share of households' consumption baskets (Piazzesi and Schneider 2016). Over the last decade, large increases in rental prices and concerns about housing affordability, particularly for the young, have brought housing and rental markets to the forefront of the political debate in many advanced economies. At the same time, many countries have introduced macro-prudential measures to prevent the buildup of excessive household leverage, potentially constraining the access of many first-time buyers to mortgage credit.

Because housing and rental markets are closely connected, understanding how credit shocks, housing policies or developments in housing supply affect households requires studying how they impact both markets. For example, supply constraints that restrict the building of new housing might generate increases in both housing prices and rents. On the other hand, a credit tightening might push prospective buyers into renting, thus decreasing house prices and increasing rents (Gete and Reher 2018).

In this paper we study how households are affected by a shock that reduces the availability of mortgage credit, both through its direct impact and its equilibrium effects on rents and house prices. To do so, we develop a model of the rental and housing markets with two key features. First, households are heterogenous as they differ in their age, income, and wealth, and make endogenous housing tenure choices which lead them to be renters, homeowners, or landlords of homes of different sizes. To get on and climb the property ladder, households can borrow through long-term mortgages for which downpayment and other constraints only bind at origination. And second, both rental and housing markets must be in equilibrium, which implies that house prices and rental prices must adjust to clear both markets as a result of potential shocks, but they may do so in different directions.

This flexibility contrasts with standard assumptions in macroeconomic models with housing, in which the rental sector is either non-existent or is owned by a deep-pocketed risk-neutral investor, implying that rents are fixed to a constant fraction of house prices. By allowing households to choose to become landlords in the context of a standard savings and portfolio choice model, we endogenously generate a distribution of landlords who are heterogeneous in their income, wealth and real estate holdings, with many of them being small owners.[1] As a result, the model displays an upward sloping rental sup-

[1] This feature corresponds to the structure of rental markets in many advanced economies. In Ireland, which is the object of our study, more than 50% of all tenancies are held by households who only own one

ply curve at a given house price without assuming that the rental and owner-occupied markets are segmented (Greenwald and Guren 2024). Our framework with endogenous landlords is close to that in studies of the tax treatment of housing (Sommer and Sullivan 2018), but accounts for the lumpiness of housing and thus generates empirically reasonable rental supply elasticities (Rotberg and Steinberg 2024).

We use the model to show that restricting credit access to potential mortgagors increases rental prices, reduces house prices and decreases the homeownership rate. The intuition is that, in the presence of binding constraints to mortgage credit, prospective homeowners need to either: *(i)* postpone or cancel their home buying decisions and stay renters for longer or *(ii)* downsize and purchase a smaller house with a smaller mortgage. Option *(i)* implies that more landlords need to enter the market, buy housing and provide it for rent. Because the marginal prospective landlord must be compensated above the previous one in order to step in and provide additional rental housing, rents go up to clear the market at a given house price. Option *(ii)*, downsizing, pushes house prices down as the share of low quality/small houses increases. However, given that housing is lumpy and that no houses are available below a certain minimum size, some households do not have access to the downsizing adjustment channel and must switch to renting. The relative strength of these two channels determines the relative changes of house prices and rents. The more households choose to buy smaller houses rather than become renters, the smaller the effect on rental prices and the larger the house price drop.

In our main experiment, we analyze a borrower-based macro-prudential policy intervention that imposes maximum loan-to-value (LTV) and loan-to-income (LTI) ratios to newly originated mortgages, focusing on the introduction in Ireland in 2015 of a minimum 20% downpayment on a house and a maximum 3.5 ratio of mortgage debt to household income. This intervention, which was largely unanticipated and binding for many prospective buyers, is an excellent case study for the credit shocks we model. Acharya, Bergant, Crosignani, Eisert, and McCann (2022) showed empirically that this policy led to a reduction in house price growth in the areas in which the limits were particularly binding. We extend their analysis to rental prices and find that, consistent with our model mechanism, the reform led to a larger acceleration in rental price growth in those areas in which it had stronger effects.

---

or two rental properties (see Appendix A.1). French administrative data shows that most rental properties are held in lumpy quantities by undiversified, small and home-biased landlords (Levy 2022). Even in the United States, where institutional investors are quite developed, private individual investors own 71.6% of all rental properties, with 14 million of them owning between 1 and 4 properties (Pew Research 2021).

We use our model, calibrated to the Irish economy, to quantify the short and long-run effects of the reform while keeping all other features of the housing and rental markets fixed. We find that the rent-to-price ratio increases by 2.79% upon impact, reaches its maximum (a 3.66% increase) during the fifth year after the introduction of the reform and attains a level similar to that of the new equilibrium in 10 years. Most of these dynamics are explained by the evolution of the rental price, as the average house price drops, but very little - highlighting the importance of realistic rental supply elasticities. Moreover, the reform reduces the homeownership rate by 1.8 percentage points in the long run and generates an increase in wealth concentration as landlords hold a larger fraction of the aggregate housing stock.

Our model reveals that constraining housing credit is particularly harmful for renters, young households and those in the bottom and middle of the income distribution not only because they find it harder to obtain a mortgage and need to postpone their buying decision, but also because they face higher rental prices in equilibrium. Prospective landlords, older households and those in the top of the income distribution benefit because they obtain higher returns from their housing investments. Overall, the 25 year old agents that are impacted by the reform suffer a loss equivalent to 1% of their lifetime consumption. Our results provide a first measure of the unintended, but large heterogeneous costs imposed on households by macro-prudential policies through both the rental and housing sectors and point to a redistribution of resources from poor renters to richer landlords. Nonetheless, we cannot measure the benefits of those policies given that we do not model the cyclical buildup of risk in the financial sector and, as a result, we are silent on optimal LTV or LTI ratios.

In our second exercise, we study a permanent, exogenous rise in the real interest rate of 1 percentage point. Compared to the macro-prudential intervention, this shock not only affects new buyers, but also existing mortgagors with a floating-rate mortgage who see their payments go up, and savers in financial assets who see their returns increase. This shock also reduces the homeownership rate, increases rents and reduces the average house price. Differently to the macro-prudential experiment, many households react to the more expensive mortgage rate by buying comparatively smaller houses and thus acquiring smaller mortgages. Additionally, because the rise in the real interest rate on savings makes financial assets comparatively more attractive than housing for prospective landlords, the rental rate raises further to keep the rental market in equilibrium. The welfare impact is also highly heterogeneous, with households at the bottom of the income distribution losing and those at the top benefitting. Although we model a permanent increase in the real interest rate, the implications we find are consistent with the empirical evidence for monetary policy shocks, such as for example that in Dias and Duarte (2019). Thus, our real interest rate experiment suggests that tightening cycles of monetary policy that raise real interest rates may benefit some households via the reduction in asset prices (including housing), but may also make it harder for low-income households to afford increasing rents.

Related Literature. A broad literature studies the role of credit in driving the boom and bust cycle in house prices that was associated with the Great Recession (Favilukis, Ludvigson, and Van Nieuwerburgh (2017), Greenwald (2018) or Justiniano, Primiceri, and Tambalotti (2019)), while other papers studying this period focus on the role of liquidity in housing markets (Garriga and Hedlund 2020) or house price expectations (Kaplan, Mitman, and Violante 2020). Recently, Greenwald and Guren (2024) show that the implications of these models depend on their assumptions about rental markets. In particular, in a model in which rental and owner-occupied properties are identical, an increase in the homeownership rate does not impact house prices as households buy these additional houses from deep-pocketed landlords that do not use credit. Instead, when markets for rental and owner-occupied housing are segmented, an increase in housing demand raises house prices.

Our paper builds precisely on the intuition that modeling the rental market is key to understand house price dynamics. Differently from Greenwald and Guren's (2024) economy, we do not assume that the market between rental and owner-occupied properties is segmented. In our model, instead, the rent-to-price ratio of housing moves in response to a credit shock because of two reasons. First, even with a single house type, the supply curve for rental accommodation at a given house price is upward sloping due to the heterogeneity in landlords' stochastic discount factors. Although house prices are still the expected discounted future value of rents as in the standard user cost formula (Poterba 1984), the marginal landlord who is pricing rental housing can change endogenously, and thus credit shocks that reduce the homeownership rate can push rents upwards. Second, with heterogeneity in housing qualities, households react to the shock by moving to smaller properties, either owned or rented, which pushes house prices down in equilibrium. Both forces act together moving rent-to-price ratios up. The ability to separately study movements in house prices and rents, rather than just looking at their ratio, is an additional contribution of our framework.

Our endogenous landlords are closest to those in studies of the tax treatment of housing (Floetotto, Kirker, and Stroebel (2016) or Sommer and Sullivan (2018)). Because of our focus on credit shocks, we introduce long-term mortgages, which allow us to study the effects of LTV and LTI ratios which only bind at morgage origination. Additionally, in these frameworks homeowners decide every period which share of their home they rent out, while in ours households become landlords by buying additional discrete housing units. This more realistic feature introduces an additional friction to rental supply through the lumpiness of housing, and implies reduced rental supply elasticities which are much closer to those that we observe in the data. As Rotberg and Steinberg (2024) show in recent work, replicating these elasticites is key to understand the responses of rents to shocks or policies such as the mortgage interest deduction. Compared to their model, we do not explicitly target the elasticity by modeling the supply curve of a rental company, but let prospective landlords determine it endogenously.

This endogenous determination of rents and house prices, although novel to macro applications with heterogeneous households that study credit shocks, is also present in state-of-the-art equilibrium models of local housing markets, such as Favilukis, Mabille, and Van Nieuwerburgh (2022). On the household side, our model builds on the partial equilibrium framework in Paz-Pardo (2024), but it is augmented to allow households to own multiple properties and lease them out in the rental market.

We use our model to study the effects of borrower-based macroprudential interventions. Recent empirical literature has shown that the introduction of LTV and LTI limits reduces mortgage leverage (Van Bekkum, Irani, Gabarro, and Peydró 2023) and cools down tensioned housing markets (Acharya et al. 2022). We contribute to this work by showing that it increased rental prices, which is consistent with Gete and Reher (2018), who find that rents increased as a result of the contraction of mortgage supply in the United States after the Great Recession.

Our results in terms of the costs imposed by mortgage regulation on heterogeneous households complement a broad theoretical literature that shows that macroprudential frameworks are useful to guarantee financial and macroeconomic stability, like Lambertini, Mendicino, and Punzi (2013) or Farhi and Werning (2016). In recent work, Ferrero, Harrison, and Nelson (2023) and Muñoz and Smets (2022) focus on countercyclical borrower-based macroprudential rules and show how these interact with either monetary policy or credit to the large institutional investors in the rental market, respectively. Oliveira and Queiró (2023) study the effects of the LTV and Payment-to-Income (PTI) constraints implemented in Portugal in 2018 in a framework based on Kaplan, Mitman, and Violante (2020) and find that the reform is welfare reducing due to changes in homeownership and the quality of housing.

The study of the link between monetary policy and house prices has a longer history. Iacoviello (2005) introduces housing in a business cycle model and finds that, although house prices react to monetary policy, there are little gains for the monetary authority to react to asset prices. Aastveit and Anundsen (2022) show that an expansionary 1 percentage point monetary policy shock raises house prices between 3 and 7 percent, depending on local housing supply elasticities. Dias and Duarte (2022) highlight, like we do, that monetary policy shocks increase the demand for renting with respect to home-owning, and as a result, rents tend to rise. However, in their model the changes in rent-to-price ratios are driven by the different relative stickiness of prices and rents, rather than through the endogenous formation of new landlords. Amaral, Dohmen, Kohl, and Schularick (2024) study the effect of a persistent decline in the real interest rate across geographical areas and highlight that it can have different impacts on rents and house prices depending on the initial rent to price ratio in a given location.

Overview. The rest of the paper is structured as follows. In Section 2, we present the model. In Section 3, we analyze the Irish macroprudential reform of 2015. First, by presenting some empirical evidence in section 3.1; and then by using a calibrated version of the model to analyze the effects on quantities and prices as well as on welfare. We discuss the parametrization in Section 3.2, and present model results in Section 3.3. In Section 4 we study the effects of a permanent real rate increase. Finally, Section 5 concludes.

2. The Model Economy

Our model economy is populated by households that differ in their age, income and wealth. They supply labor inelastically to a competitive production sector during their working age and make decisions about non-durable consumption, savings and housing tenure. Thus, they choose endogenously whether they are renters, homeowners or landlords. Although owning a house provides higher utility than renting, some households are forced or choose to rent because of binding credit constraints and up-keeping costs. At the other end of the spectrum, there are some households that own more than one house to lease them out and earn extra income. These heterogenous renters and landlords meet in a competitive market and determine the equilibrium rental rate. The housing stock is built by a construction sector that uses land permits and structures. The latter are produced, together with the final consumption good, by a competitive firm that uses labor as its only factor of production. The final good's price acts as the *numeraire*, while the house price is determined by the intersection between the supply from the construction sector and the demand from households.

2.1. Production

Final-good sector. The competitive final-good sector operates a linear technology

$$Y_c = A_c N \tag{1}$$

where A_c is the constant aggregate labor productivity and N are the units of labor services. These firms hire labour in a competitive labour market, which implies that their profit maximization yields an equilibrium wage $w = A_c$. Final goods, whose price is normalized to 1, can be used both for household consumption C or as an intermediate input for the production of the housing good, in which case we label them structures S.

$$Y_c = C + S \tag{2}$$

Construction sector. The competitive construction sector operates a Cobb-Douglas technology

$$Y_h = A_h L^{\alpha_L} S^{1-\alpha_L} \tag{3}$$

where S is the quantity of structures, L is the amount of buildable land or housing permits in a given period, $\alpha \in (0, 1)$ is the constant share of land in production, and Y_h is the quantity of the housing good produced. We assume that the total amount of housing permits every period is fixed and they are priced competitively. Hence, the housing developer solves the following static problem

$$\max_{S,L} \; p_h A_h L^{\alpha_L} S^{1-\alpha_L} - p_L L - S \tag{4}$$

where p_L is the equilibrium price of buildable land. The first order conditions of the competitive housing developers' problem imply the following relation between housing production Y_h and the house price:

$$Y_h = A_h^{1/\alpha_L} \left((1 - \alpha_L)\, p_h\right)^{(1-\alpha_L)/\alpha_L} \bar{L} \tag{5}$$

where $\bar{L}$ is the aggregate amount of housing permits every period. Consequently, the elasticity of aggregate housing supply to house prices ϵ_{Y_h, p_h} equals $(1 - \alpha_L)/\alpha_L$.

Housing comes in different qualities that represent different bundles or aggregations of the housing good. We denote them as $\tilde{h} = \{\tilde{h}_1, \ldots, \tilde{h}_N\}$, and make the assumption that the final transaction price for each of these types is a multiple of the per-unit housing price. That is, $p(\tilde{h}) = \tilde{h}\, p_h$.

The construction sector's output is used for three purposes: the production of new houses, the upkeep of existing houses and the costly conversion between housing types. Upkeep costs are both for regular maintenance, amounting to δ_h per unit of housing in every period, and for the refurbishment of houses occupied by a terminal-age household after the occupant dies. The latter force implies that in every period $1/J$ of the housing stock needs to be rebuilt, where J is the population share of terminal-age households. With respect to conversion costs, we assume that each unit of housing which is converted from one housing quality into another incurs a proportional cost ξ.

The aggregate housing stock, i.e. the aggregate amount of the housing good, can be measured as the quality-weighted sum of all housing units in the economy. If we let H_n^{sh} denote the share of houses of quality n,

$$H = \sum_{n=1}^{N} H_{n,t}^{sh} \tilde{h}_n \tag{6}$$

As a result, the law of motion for the housing stock is akin to a standard capital accumulation equation with the presence of adjustment costs:

$$H_{t+1} = \left(1 - \delta_h - \frac{1}{J}\right) H_t + Y_{h,t} + \sum_{n=1}^{N} \mathbb{1}\left\{H_{n,t+1}^{sh} - H_{n,t}^{sh} < 0\right\} \xi \left(H_{n,t+1}^{sh} - H_{n,t}^{sh}\right) H_t \tag{7}$$

2.2. Households

Demographics. Household's age is indexed by $j = 1, \ldots, J$. In the first $J^{ret} - 1$ periods they work. Thereafter they are retired until they die with certainty at age $J + 1$.

Preferences. Households derive utility from non-durable consumption and housing services. They value these streams of consumption according to

$$\mathbb{E}_0 \left\{ \sum_{j=1}^{J} \beta^{j-1} \frac{\left(c_j f\left(h_j, \tilde{h}_j\right)\right)^{1-\gamma}}{1-\gamma} \right\} \tag{8}$$

where $\beta \in (0,1)$ is the discount factor, $\gamma > 0$ captures both risk aversion and intertemporal elasticity of substitution, $c > 0$ is consumption of non-durables, and f is a function of the number of houses owned h_j and the housing quality of the house in which the household lives $\tilde{h}_j$:

$$f(h, \tilde{h}_j) = \begin{cases} \left(\tilde{h}_j / \tilde{h}_1\right)^{\alpha_h} & \text{if} \quad h = 0 \\ \left(\left(\tilde{h}_j / \tilde{h}_1\right) \theta\right)^{\alpha_h} & \text{if} \quad h \geq 1 \end{cases} \tag{9}$$

and as standard in the literature reflects that the housing service flow for homeowners is larger than for renters as reflected by $\theta > 1$, as well as the larger utility flow from better quality housing, captured by the ratio of the housing quality j to the lowest quality available $\tilde{h}_1$.

Endowments. Working-age households receive an idiosyncratic labor income endowment. We assume that it has a deterministic component that depends on age and a stochastic, persistent component. That is

$$\log y = \log A_c + g(j) + \eta \tag{10}$$

where A_c is an index of aggregate productivity, $g(j)$ is a polynomial in age and η represents the stochastic persistent component of earnings. We estimate the earnings process non-linearly as in De Nardi, Fella, and Paz-Pardo (2020) – see Section 3.2.1 for details. Retired households receive a fixed fraction of their last working period income for the rest of their lifetime. Households are also born with an initial endowment of liquid wealth that is drawn from a log-normal distribution. We also assume that they start their life as renters and thus have no housing wealth.

Liquid assets. Households can save in a one-period risk-free bond, $a \geq 0$ that yields a constant interest rate $r_s = r$, which is determined in the world market and is therefore exogenous.

Housing choices. Households decide on the quantity h and the quality $\tilde{h}$ of the housing they acquire. Households that do not own a house ($h = 0$) must rent one in the market at a unit rental rate p_r. For simplicity, we assume that the quality of this rental unit is as good as the lowest available quality in the owner-occupied market. Owner-occupiers ($h = 1$) choose the quality of the house that they live in across all possible $\tilde{h}$. Therefore, when a homeowner buys additional houses as an investment ($h > 1$), she purchases houses of quality $\tilde{h}_1$, rents them out and receives p_r per period and per house.

For both homeowners and landlords, there are some costs associated with housing purchases beyond its transaction price. Housing is illiquid. Consequently, we assume that households pay a proportional transaction cost that depends on the value of the house being sold or bought, $\tau_h\, p(\tilde{h})$. This cost captures real estate agent fees, taxation and other administrative costs. Houses are also costly to maintain. Therefore, homeowners and landlords pay maintenance costs to keep up with their depreciation, $\delta_h\, p(\tilde{h})$, where δ_h is the housing depreciation rate. When there is a transaction in the housing market, these costs are covered by the seller.

Mortgages. The purchase of a house can be financed through a mortgage at a fixed rate $r_b = r(1+\kappa)$, where $(1+\kappa)$ is the is the intermediation wedge between the mortgage rate and the risk-free rate. To reduce the dimensionality of the household problem, we treat mortgages as negative asset holdings $a \leq 0$, which prevents mortgagors from simultaneously having liquid assets. In other words, a denotes the net asset position.

The borrower must satisfy two constraints. First, a maximum loan-to-value (LTV) limit, which imposes that the size of the mortgage has to be smaller than a fraction of the value of the house. And second, a loan-to-income (LTI) requirement that limits household's borrowing to a multiple of its current (annual) income. Formally,

$$a' \geq -\lambda_{LTV}\ p(\tilde{h}')\, h' \tag{11}$$

$$a' \geq -\lambda_{LTI}\ y \tag{12}$$

where λ_{LTV} and λ_{LTI} are parameters. These two constraints only hold at origination.[2] After the mortgage contract is signed and the house is purchased, the borrower chooses the repayment schedule freely. We make this modeling choice, instead of allowing

[2] These constraints are potentially different for first-time buyers and for buy-to-let investors. We detail how in Appendix B.2.

for mortgage default, because in Europe delinquency – contract being breached by underpaying – is more frequent than foreclosure – contract being terminated (Hannon 2023). Nonetheless, we impose that: *(i)* all debts must be paid before the terminal age J, i.e. $a_J = 0$ and *(ii)* interest payments and a minimum amortization payment must be made in each period. As in Kaplan, Mitman, and Violante (2020), the minimum payment is determined by the constant-amortization formula

$$m_j = \frac{r(1+\kappa)(1+r(1+\kappa))^{J-j}}{(1+r(1+\kappa))^{J-j}-1} \tag{13}$$

Optimization Problem. A household of age j, income y, with h houses of quality $\tilde{h}$ and a assets solves the following dynamic programming problem

$$\begin{aligned} V(a, \underbrace{\{h, \tilde{h}\}}_{=s}, y, j) = \max_{c, a', s'} & \left\{ \frac{(c\, f(s))^{1-\gamma}}{1-\gamma} + \sigma_\varepsilon \varepsilon(s) + \beta \mathbb{E} V\left(a', s', y', j+1\right) \right\} \\ \text{s.t.} & \\ & c + a' + p(\tilde{h}')h' + \mathbb{1}_{sell}\tau_h p(\tilde{h})h + \mathbb{1}_{buy}\tau_h p(\tilde{h}')h' + \delta_h p(\tilde{h})h \leq \\ & \quad y + \left(1 + r\left(1 + \mathbb{1}_{a'<0}\kappa\right)\right) a + p(\tilde{h})h + p_r(h-1) \\ & a' \geq \begin{cases} \max\left\{-\lambda_{LTV}\, p(\tilde{h}')\, h', -\lambda_{LTI}\, y\right\} & \text{if } h' > h \\ a(1 + r(1+\kappa) - m(j)) & \text{if } h > 0 \text{ and } a < 0 \\ 0 & \text{otherwise} \end{cases} \end{aligned} \tag{14}$$

where $\sigma_\varepsilon \varepsilon(s)$ are choice-specific random taste shocks that are *i.i.d.* Extreme Value Type I distributed with scale parameter σ_ε. These represent shocks to the utility of homeownership (i.e., they are alike to moving shocks), but are also computationally convenient as they help to smooth out expected value functions (Iskhakov, Jørgensen, Rust, and Schjerning 2017).

2.3. Equilibrium

For a given risk free rate r, a competitive equilibrium in this economy consists of: *(i)* a value function, a housing choice probability, and a consumption and asset policy function for the households: $\{V, \mathbb{P}(h, \tilde{h}), c, a'\}$, *(ii)* a stationary distribution over households' state: $\{\mathcal{D}\}$, *(iii)* policy functions for the firms: $\{N, L, S\}$, and *(iv)* prices: $\{w, p_L, p_h, p_r\}$

such that they jointly solve the household, final-good firm and construction firm problems, as well as satisfy the following market clearing conditions:

$$\sum_{h=0}^{X} (h-1) \left(\int \int \sum_{j=1}^{J} \mathcal{D}(a, s, y, j)\, da\, dy \right) = 0 \tag{15}$$

$$Y_h = \left(\delta_h + \frac{1}{J} \right) \underbrace{\sum_{n=1}^{N} \tilde{h}_n H_n^{sh}}_{=H} - \sum_{n=1}^{N} \mathbb{1} \left\{ H_{n,t+1}^{sh} - H_{n,t}^{sh} < 0 \right\} \xi \left(H_{n,t+1}^{sh} - H_{n,t}^{sh} \right) H_t \tag{16}$$

$$Y_c = C + S \tag{17}$$

$$\bar{L} = L \tag{18}$$

where equation (15) gurantees the equilibrium in the rental market, i.e. the demand for rental units by renters ($h = 0$) equals the supply of rental units by landlords ($h > 1$). Meanwhile, equations (16), (17) and (18) ensure that the housing, the goods and the land permits market clear. Note that the equilibrium per-unit house price p_h can be recovered analytically by substituting the housing investment function (5) into market clearing condition (16), which results in

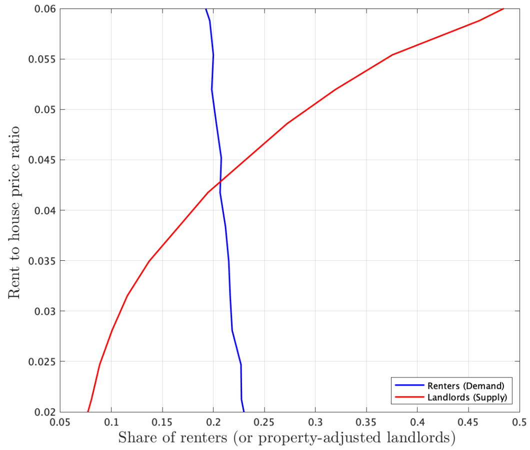
$$p_h = \frac{1}{1-\alpha} \left(\frac{1}{A_h} \right)^{\frac{1}{1-\alpha}} \left(\frac{\delta_h H}{\bar{L}} \right)^{\frac{\alpha}{1-\alpha}} \tag{19}$$

Finding the equilibrium rental rate p_r is more challenging as the market clearing condition involves a distribution, which is an infinite dimensional object. Nonetheless, it can be recovered computationally by exploiting the fact that rental demand is decreasing while rental supply is increasing in p_r, as shown below.

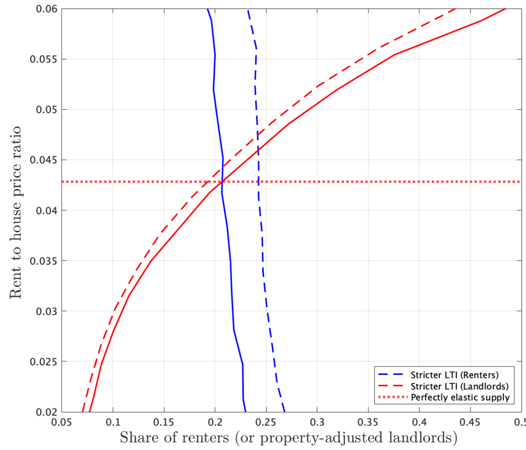
2.4. Model intuition: a supply & demand explanation

Before we turn to the two experiments performed with the help of our model economy, we present the intuition for how reducing the access to credit, either through tighter borrowing limits or via higher interest payments, affects the homeownership rate as well as house and rental prices. To that end, we use a supply and demand framework where we plot relative rather than absolute prices and quantities to capture the rent vs. owning margin, as in Greenwald and Guren (2024).

Figure 1 plots the share of renters (demand) or the share of landlords adjusted by the number of properties they own (supply) on the x-axis against the rent-to-price ratio on the y-axis. Rental demand, depicted by the blue line, is downward sloping because



A. Equilibrium



B. Credit shock

FIGURE 1. Supply and demand in the rental market

NOTE. This figure shows the main mechanisms of the model through a supply and demand illustration. The demand and supply curves are computed numerically using a suitable parameterization of the model economy.

increases in the rental to house price ratio incentivize homeownership and consequently less and less households are willing to rent. On the other hand, such increases in the rent to house price ratio make buying buy-to-let properties more attractive, and as result more and more households are willing to become landlords. This results in an upward sloping rental supply curve (red line). As standard, the intersection of these two curves forms an equilibrium which determines relative price and quantities.

Now, consider the impact of a negative credit shock associated, for example, to the introduction of macro-prudential mortgage limits. On impact, the reform primarily affects potential buyers that were close to the borrowing limit before and that do not qualify for a mortgage after. These households who are not able to buy a house anymore will be pushed into renting. This shifts the demand curve outwards as shown by the blue dash line in right panel of Figure 1.

In a model with perfectly elastic rental supply (red dotted line), the increase in rental demand only translates into a reduction of the homeownership rate since the share of renters goes up. Prices do not move because deep-pocketed landlords are willing to buy as many houses as needed at the present value of rents to meet rental demand. However, in our model rental supply is upward sloping because the equilibrium share of landlords is endogenous. Consequently, an increase in rental demand associated with a negative credit shock results not only in a reduction of the homeownership rate, but also in an increase in the rent-to-price ratio. Moreover, this increase in the price ratio is slightly amplified in our model because landlords also use credit to buy additional rental properties, which shifts rental supply inwards (red dashed line).

Overall, a reduction in credit results in an increase of the rent-to-price ratio and a reduction of the homeownership rate because potential house buyers are credit constrained (shift in rental demand), and importantly potential landlords are sensitive to both prices (upward sloping supply curve) and credit conditions (shift in rental supply).

3. The Irish macro-prudential reform

Macro-prudential regulations that limit household leverage in the residential mortgage market have been widely used by policymakers to smooth the house price and credit cycles. We study the case of Ireland, whose central bank introduced these mortgage measures for the first time in February 2015 after a first discussion in October 2014. At that time, the Central Bank of Ireland established a maximum Loan-To-Income (LTI) limit of 3.5, which only applied to first-time-buyers (FTBs), and several Loan-To-Value (LTV) limits depending on the borrower and property type. For primary dwellings the limit was set to 80% of the value of the house; for FTBs, the limit was more generous: 90% for the first €220,000 and 80% for the excess amount; and for buy-to-let (BTL) properties the threshold was more stringent and set to 70%. Banks and other lenders were allowed to lend certain amounts above those limits. Specifically, for LTVs, 15% of all lending could take place above the limits, while for LTIs there was a 20% allowance. These measures have been reviewed on an annual basis since then. Nonetheless, the alterations of these rules have been of modest nature, and the fundamental core remained unaltered until 2022. We focus on the 2015 regulation because of the prompt implementation of the reform, which, paired with data availability, makes this Irish reform a compelling case study to analyze the effects of these measures on house prices and rents in the data. We will then use this analysis as motivating evidence for the calibrated version of our model.

3.1. Empirical evidence

Using data for the universe of originated mortgages in Ireland, Acharya et al. (2022) study the 2015 reform and find that it generated a reduction in house price growth. In order to control for potentially confounding effects in macroeconomic aggregates, they develop a *"distance"* measure that correlates with the exposure to the macro-prudential reform. In counties where house prices were high with respect to incomes, many mortgages signed before the reform were at or above the limits: these are categorized as *low-distance* areas. One would expect that the reform would have stronger effects in these areas. In contrast, in counties where house prices were relatively low with respect to incomes, the reform was closer to non-binding and thus expected to have low to no effects. Consistently, Acharya et al. find that the *"distance"* measure positively correlates with house price growth around the reform. In other words, house prices grew more in areas where the constraints were less binding (high distance), while house price growth moderated in areas where the intervention was more binding (low distance). Non-parametric evidence of these positive correlations across Irish counties are shown in the first two panels of Figure A3.

We extend their empirical framework to analyze the effects of the reform on rental prices. We use the same *"distance"* measure and combine it with house price and rental data extracted from daft.ie (Lyons 2018). Following Acharya et al.'s empirical strategy, we regress changes in house prices and rents between the third quarter of 2014 and the last quarter of 2016 on the aforementioned *"distance"* measure. Formally, we estimate the following two regressions

$$\Delta \text{ House Prices}_i = \beta_0 + \beta_1 \text{Distance}_i + \epsilon_i \tag{20}$$

$$\Delta \text{ Rents}_i = \gamma_0 + \gamma_1 \text{Distance}_i + \nu_i \tag{21}$$

where i denotes the county, Δ is the growth rate over a 9 quarter window, and β_1 and γ_1 are the coefficients of interest. Table 1 shows the results of these two regressions. The first column replicates the positive coefficient that Acharya et al. obtain for house prices. The second column shows that the impact of the reform on rents was also significant, but had the opposite sign: rents increased by more in areas where the macro-prudential intervention was more binding (low distance). Quantitatively, a one standard deviation in the county-level distance measure is associated with 4.2% higher house prices and 2.5% lower rental rates. As for house prices, non-parametric evidence of these negative correlations between the distance measure and rental price growth across counties are shown in Figure A3.

To establish whether these opposite effects on rents and house prices might be the result of contrasting long-run trends in different local housing and rental markets, rather than the impact of the reform, we re-estimate equations (20) and (21) for different time windows. As in the main regression, we use the changes in house prices and rents

TABLE 1. Effect of lending limits on house and rental prices

	Δ House Prices	**Δ Rents**
Distance	0.289	-0.171
	(0.068)	(0.039)
Obs.	54	54
R^2	0.34	0.31

NOTE. This table shows the OLS coefficients from the regressions of house price and rental price changes on the distance measure that captures the exposure to the borrowing limits.

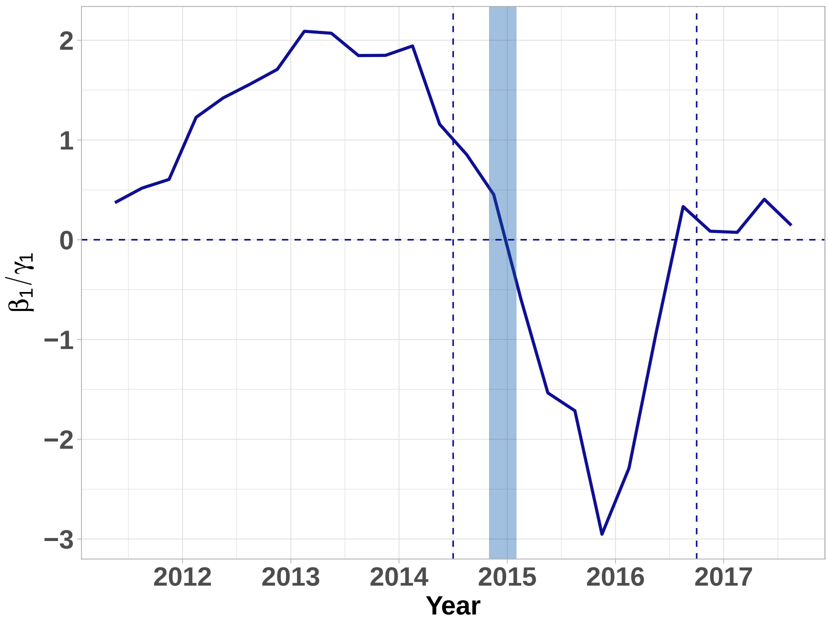


FIGURE 2. Placebo regression

NOTE. This figure shows the correlation between house prices and rents in response to the macro-prudential reform. Before its implementation, the ratio of OLS coefficients is positive $\beta_1/\gamma_1 > 0$, indicating co-movement between house and rental prices, while after the reform this relationship breaks and β_1/γ_1 becomes negative for a few years before it goes back to its normal positive co-movement.

between 9 consecutive quarters as our dependent variables while keeping the *"distance"* measure fixed to its value in 2014. We find that, consistently with our interpretation, the movement of rents and house prices in opposite directions is restricted to the time around the implementation of the policy and is not present for the rest of our sample. We report these results graphically in Figure 2, which shows the ratio of coefficients β_1 and γ_1 (y-axis) for the central part of each rolling window (x-axis). The unconditional average and the median value of the ratio of coefficients is positive, reflecting that, in general, house prices and rents tend to co-move. This positive co-movement is consistent with the theory as the value of a house should equal the expected discounted value of future rents. However, around the macro-prudential reform (a credit shock) this long-run relationship breaks and the ratio of coefficients becomes negative. In the short-run, potential home-buyers are constrained and pushed into the rental market which in turn generates effects going in opposite directions. The fact that the ratio of the coefficients returns to positive territory after a few years is reassuring as that the *"distance"* measure does not capture other relevant, time-invariant omitted variables, like urban vs. rural areas.

In short, this placebo test confirms that our findings are not driven by time-invariant omitted variables which are correlated with the *"distance"* measure and reinforces the idea that the credit shock induced a decoupling of the usually positive relationship between the evolution of house prices and rents.

3.2. Model calibration

We parametrize our model economy to be consistent with the cross sectional features of the Irish economy and use the calibrated version of the model to: *(i)* understand the opposite impact of the macro-prudential reform on house prices and rents and *(ii)* further analyze the distributional effects and the costs imposed on households by these reforms, while taking into account a broad life-cycle perspective.

As standard in the macroeconomic literature, we assign some of these parameters externally, while others are chosen internally with the objective of minimizing the distance between a collection of data and model moments.

3.2.1. Externally calibrated parameters

Demographics and Preferences. The model period is one year. Households enter the economy at age 25, they retire with certainty at age 65 and live until age 95. This means that $J^{ret} = 41$ and $J = 71$. There is no population growth. We set the CRRA risk aversion coefficient γ to 2, a common value in the literature. The scale parameter of the taste shock σ_{ε} is within the range suggested by Iskhakov et al. (2017) and equal to 0.05.

Earnings process. Our measure of income in the data is disposable household income after both taxes and transfers. We estimate our earnings process following De Nardi, Fella, and Paz-Pardo (2020). Namely, we extract out the persistent and the transitory component of earnings using the procedure described in Arellano, Blundell, and Bonhomme (2017), and then incorporate the dynamics for the persistent component in a nonparametric way. Applying this procedure allows us to estimate earnings dynamics under flexible assumptions, and in particular incorporating potential age-dependence, non-normalities and non-linearities in earnings dynamics. The first element is of particular relevance for our question. Most households become homeowners when they are relatively young, still changing jobs and potentially subject to large fluctuations to their labour market income. A standard earnings process in which earnings are a random walk is a poor representation of the earnings risk faced by households at this particular age. Middle-aged households with stable jobs, instead, have much higher persistence, but significant negative skewness risk (e.g., through job loss). For a detailed description of the method and the economic implications of flexible earnings dynamics, see De Nardi, Fella, and Paz-Pardo (2020).

We use data from the Household Finance and Consumption Survey (HFCS) to extract the average age-earnings profile in the Irish economy after taking into account year effects. The HFCS, which takes place every three years, collects rich data on the income and wealth of European households, including their homeownership status, rental income, etc., which we also use as targets for our model. However, the triennial nature of the survey does not allow us to estimate an annual earnings process. Hence, for the stochastic component of the earnings process we use household earnings data for the United Kingdom from De Nardi, Fella, and Paz-Pardo (2024), who extract them from the BHPS/Understanding Society survey, and assume that the stochastic properties of household earnings are similar across both countries.[3]

Housing. We set the maximum amount of houses that a household can own X to 3 both for simplicity and computational considerations. However, this choice implies that we can capture the vast majority of landlords in Ireland: over 80% of them have only 1 or 2 rental properties, and they represent over half of all tenancies. Indeed, around 37% of all rental properties are owned by households with just one buy-to-let property – see Figure A2 – and over 60% of non-occupier transactions in 2015 involve household buyers – see Figure A1. Large institutional investors (non-household buyers) have grown in relevance over the past decade, but they were still relatively small players when the reform took place. [4] Since then, institutional investors have been mostly concentrated in a set of particular rental submarkets (e.g. new builds in highly sought-after areas). Given that we do not model this spatial heterogeneity, we abstract from them in our framework.

We assume that there are two house qualities and normalize the lowest quality $\tilde{h}_1$ such that the aggregate amount of housing H is equal to 1 in equilibrium. The value

[3] We have also estimated an annual earnings process for Ireland based on EU-SILC data (European Union Statistics on Income and Living Conditions), which, despite being nationally representative, is targeted to produce statistics on poverty and living conditions and hence might capture the earnings dynamics of the upper part of the income distribution in a more limited way. Our main results with this alternative earnings process are very similar.

[4] Oosthuizen (2023) explains this upward trend in the US by the decreasing operating costs of larger institutional investors, while Muñoz and Smets (2022) argue that it is associated to the lack of regulatory lending limits to real estate funds.

for the better quality $\tilde{h}_2$ is chosen such that the ratio of prices is fixed and equal to the owner-occupied to buy-to-let price ratio in the data. These two different type of houses not only differ in their final transaction price, but also in the housing utility flow they report to those living in them. We assume that households get a premium from ownership which is increasing and concave in the quality of the house with $\alpha_h = 0.5$ controlling the curvature of this function.

The housing depreciation rate δ_h is set to be 1.2% per year and it is within the range of typical values used in the literature. The transaction cost for selling and buying a house τ_h equals 3% of its value. The maximum loan-to-value, λ_{LTV}, and loan-to-income, λ_{LTI}, ratios before the macroprudential reform are 1.0 and 6.0, respectively. This is

TABLE 2. Parameter values

Parameter	**Interpretation**	**Value**
Externally calibrated		
J^{ret}	Working life (years)	41
J	Length of life (years)	71
γ	Risk aversion coefficient	2.0
σ_ε	Taste shock scale parameter	0.05
X	Maximum amount of houses owned	3
$\{\tilde{h}_1, \tilde{h}_2\}$	Housing qualities	{0.905, 1.095}
α_h	Curvature in utility premium function $f(\cdot)$	0.5
δ_h	Housing depreciation rate	0.012
τ_h	Proportional transaction cost	0.03
λ_{LTV}	Maximum loan-to-value ratio	1.0
λ_{LTI}	Maximum loan-to-income ratio	6.0
r	Risk-free rate	0.02
κ	Intermediation wedge	1
A_c	Aggregate labor productivity	1.2055
$\bar{L}$	Amount of land	1.0
α_L	Share of land in production	0.33
ξ	Adjustment cost scale in housing production	0.16
Internally calibrated		
β	Discount factor	0.9656
θ	Utility premium from living in a low quality house	1.3378
A_h	Scaling factor in housing production	0.121

NOTE. This table shows the value of the parameters used for solving our model economy and to carry out the experiments. For the macro-prudential intervention, λ_{LTV} and λ_{LTI} will change; while for the increase in rates, r and κ will be adjusted.

consistent with the evidence in Kelly, McCann, and O'Toole (2018) that estimate the 98*th* percentile of observed LTI and LTVs ratios on quarterly mortgage data during the period 2003 to 2011. Note that prior to the 2015 reform, there were no institutional limits. Therefore, these limits correspond to those that were imposed by Irish banks based on their own risk assessment.

Financial instruments. The risk-free rate on liquid savings r_s is set to 2% per annum. The proportional wedge κ is set to 1, implying a mortgage rate r_b of 4% per annum. This is consistent with the gap between the average mortgage rate and the 10-year yield on government debt.

Production. The final good aggregate productivity shifter A_c is set to 1.2055, which is also the average wage in the economy. The amount of buildable land $\bar{L}$ is normalized to 1, and the share of land used in production in the housing sector α_L is fixed to 0.33, which implies an elasticity of housing supply of approximately 3.

3.2.2. Internally calibrated parameters, targets, and model fit

The remaining three parameters: the discount factor β, the homeownership utility premium for living in a small/low quality house θ, and the scaling factor in housing production A_h, are jointly chosen to match four moments of the data. We target the average wealth to income ratio, which is around 7 in the HFCS; the homeownership rate that was on average around 80% according to EU-SILC; a house price to income ratio of 5 that is consistent with the data in the Central Statistics Office (CSO); and the house price to rent ratio that is computed using data from the Residence Tenancies Board (RTB) and the CSO. The first block of Table 3 shows the exact value of these four moments in the data as well as their model counterparts, which were obtained using the parameters in the last block of Table 2.

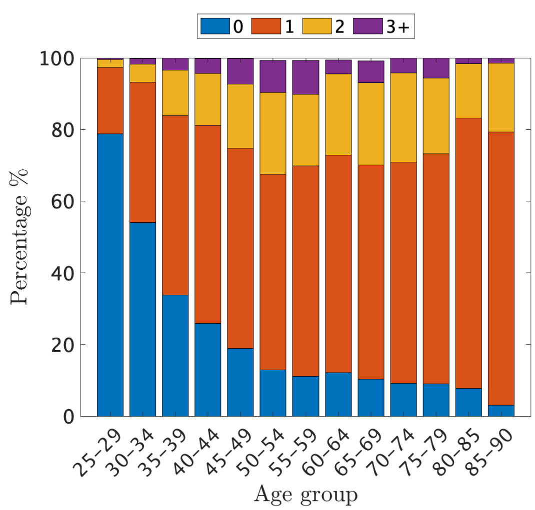
The model is able to match the average homeownership rate, the average house price to income ratio and the house price to rent ratio reasonably well. However, it slightly under-predicts the average wealth to income ratio. More importantly, the model is able to replicate the share of landlords in the economy, both at the aggregate level and along the age distribution. At the aggregate, the share of landlords with two rented out properties (the upper bound) is 4.30% in the model; while in the data, 5.11% of landlords own two or more rental properties. Along the life-cycle, it is only at mid age when a significant faction of households can afford to buy a second or third home, consistently

TABLE 3. Targets and model fit

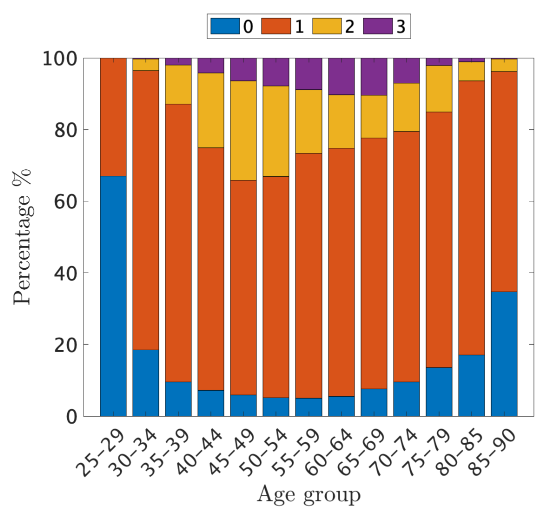
Moment	Model	Data	Source
Targeted			
Wealth to income ratio	5.89	6.78	HFCS
Homeownership rate	79.42%	80%	EU-SILC
Avg. house price to income ratio	4.93	5.0	CSO
House price to rents ratio	22.73	22.58	RTB/CSO
Untargeted			
Rents to avg. income ratio	0.196	0.2216	RTB/CSO
Share of households with 3+ properties	4.30%	5.11%	HFCS

NOTE. This table shows the model ability to capture certain features of the Irish economy. The top block corresponds to the targets used in a minimum distance estimation, while the bottom block show the performance of the model relative to untargeted moments.

with the data. Later in life, households in the model, unlike those in real life, sell these properties to finance retirement – see Figure 3. This mismatch is a standard feature of life-cycle models which do not include a set of relevant features of retiree saving behavior, such as precautionary savings related to medical costs or long-term care



A. Data



B. Model

FIGURE 3. Number of properties along the life-cycle

NOTE. This figure shows the number of properties owned by households in the data (panel A) and in the model (panel B) at different ages. Since the data is aggregated in 5 year groups, we also aggregate it in the model for ease of comparability.

and bequest motives (Nakajima and Telyukova 2020). As also shown in Figure 3, the share of renters decreases with age in both the model and in the data. However, this happens more quickly in the model than in real life. In any case, these life-cycle patterns are endogenously captured by the model without explicitly targeting them, which is reassuring about the validity of the model as a laboratory to study the distributional effects of the macro-prudential reform discussed above.

Rental supply elasticity. An additional moment that is informative about the ability of the model to generate realistic changes in house prices and rents as a response to policies and shocks is the elasticity of rental supply, i.e. by how much rental prices need to increase in order to encourage landlords to supply 1% more units of rental housing, which is closely related to the slope of the rental supply curve that we represent as a solid red line in Figure 1. In our model, this elasticity is an endogenous object that depends on the distribution of wealth and income of landlords in the economy and their policy functions.

Identifying rental supply elasticities in the data requires, ideally, a shock that affects rental demand alone without having any impact on house prices or rental supply. As a result, there are no readily available estimates for the Irish case that we can use as indicators of model fit for our experiment. Rotberg and Steinberg (2024) estimate this parameter for the United States using information on the incidence of property taxes, and find that it is 1.4 in the long run (a 1% increase in rental prices leads to a 1.4% increase in quantity supplied), with some other empirical studies suggesting that it might be even lower. In comparison, they show that this elasticity is infinite in models with rental sectors in which prices are determined by a user-cost formula (as price to rent ratios are independent of quantities), and that it is very large in models in which landlords are homeowners that choose every period how much of their housing stock to rent out (e.g. 38 in Floetotto, Kirker, and Stroebel (2016)).

The elasticity of rental supply in our model is 3.5 in our pre-reform steady state – larger than that in Rotberg and Steinberg (2024), but an order of magnitude smaller than in other models with endogenous landlords. The reason is that, in our model, housing is lumpy and illiquid also for landlords, who need to buy one complete house to be able to rent it out. Thus, there are frictions associated with becoming a landlord, which makes them less responsive to changes in rent-to-price ratios than those in Floetotto, Kirker, and Stroebel (2016) or Sommer and Sullivan (2018). Additionally, and compared to the rental company in Rotberg and Steinberg (2024), our model generates a nonlinear rental supply function with elasticities varying along the curve, derived from the fact that the wealth, income and age of the marginal landlord change as we move along the supply curve.

3.3. Aggregate and distributional effects of tighter borrowing limits

We study the effects of the macroprudential reform under the assumption that it is a permanent change. We begin by comparing two steady state equilibria that only differ in their mortgage borrowing limits.[5] Then, we consider the effects of the transition from the (initial) *pre-reform* steady state to the (final) *post-reform* steady state. That is, agents unexpectedly observe that borrowing limits become more stringent but after this first initial surprise they are aware of such permanent change in credit conditions. Finally, we use these results to evaluate the welfare effects of the reform on our heterogenous households.

3.3.1. Steady state comparison

In the *pre-reform* economy, households are able to borrow up to 100% of the value of their house and up to 6 times their annual income. Equilibrium quantities and prices under these credit conditions are reproduced in the first column of Table 4. The second column presents the equilibrium outcomes in an economy where these limits correspond to the institutional ones introduced by the 2015 reform. Hence, in the *post-reform* economy, households face: *(i)* a 80% loan-to-value limit if they buy an owner-occupied property, *(ii)* a 70% loan-to-value limit if they purchase a buy-to-let home, and *(iii)* a 3.5 loan-to-income limit if they are first time buyers. In the model we identify owner-occupied and first time buyers as those households that move from being renters into homeowners. Similarly, buy-to-let purchases correspond to those carried out by households that transition from homeowner to landlord as well as those from landlords expanding their real estate portfolio. All other borrowers face the borrowing constraints that were in place in the *pre-reform* economy and capture limits imposed by banks based on their own risk assessment.

As a result of these changes, and consistently with the intution in Section 2.4, the homeownership rate falls by 1.83 percentage points while the rent-to-price ratio increases by 2.82% in the long-run. Note that such increase in the rent-to-price ratio could

[5] Appendix C.2 shows the effects of tightening LTV and LTI limits in isolation. Given our parameterization, the LTI limit has a stronger effect than the LTV but there are interactions between the two.

TABLE 4. A credit crunch – tightening LTI & LTV limits

	Pre-Reform	**Post-Reform**	**Percentage Change**
Rent-to-Price	3.98 %	4.09 %	2.82 %
Average house price to income	4.930	4.925	-0.01 %
Rent to Income	0.196	0.201	2.73 %
Homeownership rate	79.42 %	77.59 %	-1.83 p.p.
Share of households living in high-quality homes	50.41 %	50.03 %	-0.38 p.p.
Share of households with 3 properties	4.29 %	4.51%	0.22 p.p.

NOTE. This table show the equilibrium prices and quantities for the two economies considered: *(i)* the pre-reform economy in which borrowing limits are loose ($\lambda_{LTV} = 1$ and $\lambda_{LTI} = 6$), and *(ii)* the post-reform economy in which tighter borrowing limits are imposed ($\lambda^{oo}_{LTV} = 0.8$, $\lambda^{btl}_{LTV} = 0.7$ and $\lambda_{LTI} = 3.5$).

be explained by either an increase in rents or a fall in house prices. Importantly, our model is able to disentangle these two effects. We find that most of this increase in the price ratio is driven by the rental price as it *increases* by 2.74%, while the average house price in the economy stays more or less *constant* and falls only by less than 0.01%.

These price dynamics arise because: *(i)* the marginal landlord needs to be compensated even more, via higher rental prices, to meet the increased rental demand coming from households that do not qualify for a mortgage at the new borrowing limits, and *(ii)* some households are forced to buy lower quality houses (downsize). As this second effect is rather limited – there is only a tiny increase in the share of low quality homes (0.38 p.p.) – the reduction in the average house price coming from a composition effect with a higher share of cheaper low quality homes is very small. Moreover, we find that the marginal landlord is typically a homeowner that becomes landlord for the first time rather than already existing landlord that expand their real estate business, as more than 75% of the new rental demand is covered by households that weren't landlords in the pre-reform economy ($0.22 \times 2/1.83 \approx 0.25$). Figure A4 summarizes these flows across different housing tenure statuses.

As a result of the reform, the concentration of housing wealth rises in two ways. First, the increase in the number of renters implies that their homes are now owned by landlords, who are already homeowners themselves. Second, the number of landlords that hold two rental properties, which in our framework proxies relatively larger owners, increases by 0.22 percentage points as a result of the reform.

3.3.2. Transition dynamics & welfare

The steady state comparison is extended to consider the transition from the *pre-reform* to the *post-reform* economy. This analysis will allow us to determine which household groups benefited and which ones lost from the introduction of tighter LTV and LTI limits.

Transition paths. Figure 4 illustrates the path of rental and house prices as well as the evolution of the homeownership rate during the transition to the steady state in which borrowing limits are set to those imposed by the Central Bank of Ireland in 2015. Following the macro-prudential reform, prospective homeowners cancel or postpone their buying decisions and stay renters, increasing the demand for rental accommodation. As a result, rental prices initially jump near the new steady state equilibrium price to incentivize the (endogenous) landlord formation that meets the excess demand. The homeownership rate declines, but does not immediately adjust to its new steady state level as new born generations face a more difficult environment to get on the property ladder and stay in the rental market for longer. Consequently, the rental price has to

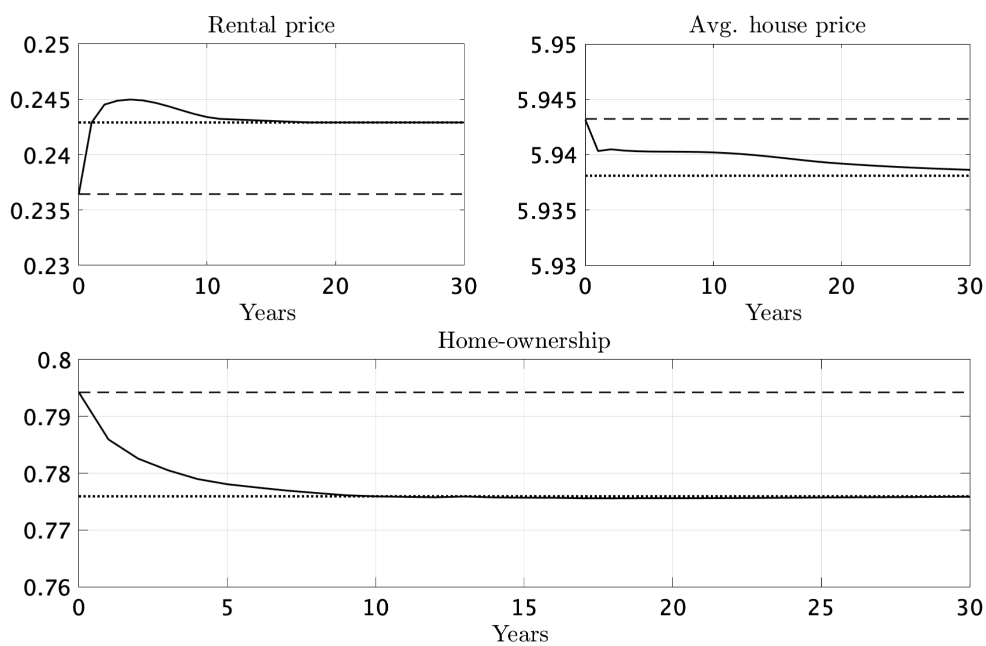


FIGURE 4. Transition paths: from loose to tight credit limits

NOTE. This figure shows the evolution of the rental price (top-left), the average house price (top-right) and the homeownership rate (bottom) along the transition from the old to the new steady state.

further increase and reaches its maximum level after 4 years – a 3.61 % increase relative to the pre-reform – before slowly going back to its new steady state level. Average house prices also fall initially as the composition of the housing stock changes and features a slightly higher fraction of cheaper low quality homes. Given that this compositional effect is stronger than the change in the pre-unit house price, which jumps below the post-reform level and reverts back to its new steady state level quickly, the average house price doesn't overshoot and slowly converges to the new steady state level. These price paths are consistent with the negative empirical correlation of tighter macro-prudential borrowing limits and house prices, as well as the positive empirical correlation of these limits and rental prices.

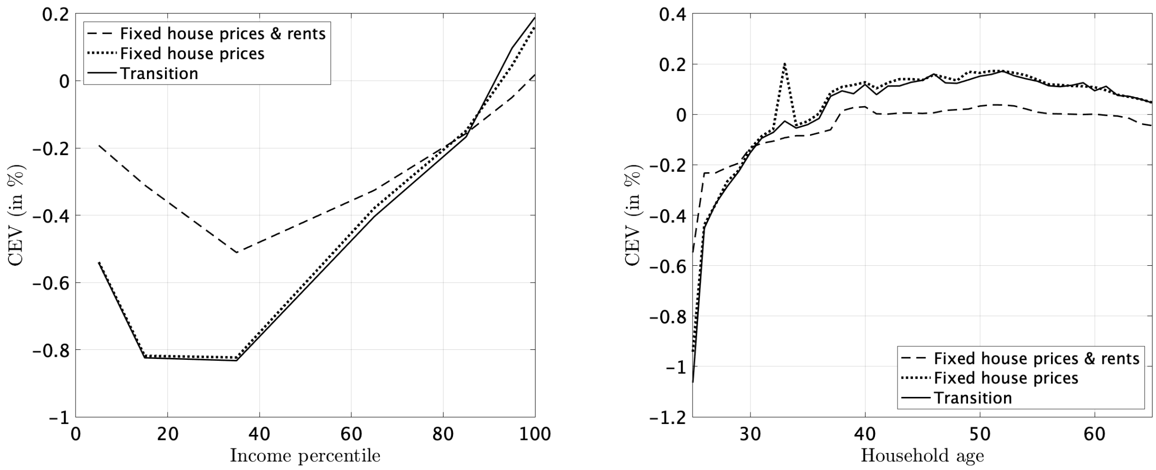
Welfare. We evaluate the distributional effects of the reform through the traditional lifetime consumption equivalent variation (CEV) measure. This metric informs us about how much consumption (in percentage) needs to change in the pre-reform economy such that the households are indifferent between living in the pre-reform steady state and living through the transition induced by the policy reform. Formally, for a given set of state variables $x = (a, y, h, j)$, we compute the consumption equivalent variation $g(x)$ as

$$V_0(x; g) \equiv (1+g)^{1-\gamma} V_0(x) = V_1(x) \quad \Rightarrow \quad g(x) = \left[\frac{V_0(x)}{V_1(x)}\right]^{\frac{1}{1-\gamma}} - 1 \tag{22}$$

where we are using the fact that the utility function is CRRA. From (22) it is easy to realize that a negative value of $g(x)$ is associated with agents being worse-off by the introduction of the reform. Figure 5 depicts the value of this metric along the income distribution (panel A) and household's age (panel B).

Because welfare is affected by the tighter limits as well as by the associated price movements, we decompose the CEV into partial and general equilibrium effects. The dashed line depicts the welfare effects of the macro-prudential reform in absence of price movements. As expected, the tightening of borrowing limits in itself is welfare reducing for all agents in this economy as we are constraining the feasible set. Young and middle-income households bear most of the costs given that they are prospective homeowners.

Turning now to the price effects, rental prices need to adjust upwards to incentivize more household to become landlords and cover the additional rental demand. As a result, there is a further welfare loss experienced by young, poor and middle income



A. Income distribution B. Life-cycle

FIGURE 5. Price adjustments & welfare

NOTE. This figure plots the value of the CEV along the income (panel A) and age distributions (panel B) and decomposes the overall welfare effect on the contribution of the reform itself (tighter borrowing limits) and the price adjustments (higher rents, lower house prices).

households. These household are forced to pay higher rental prices reducing their savings and cash available for consumption. Graphically, this effect is shown by the gap between the dashed and the dotted line, which is shrinking along the income distribution and it is even positive, and hence welfare improving, for the very rich. In fact, those at the top of the income distribution as well as middle age households benefit from the increase in rents because they are typically landlords and hence receive a larger cash flow from their real estate investment. Finally, the welfare effect of house prices is rather limited as they remain nearly constant during the transition. Graphically, this is shown by the overlap between the solid and the dotted lines.

Finally, we decompose the CEV based on households's housing tenure. As we have just seen, the macro-prudential reform has a direct impact on prospective homeowners and it also indirectly affects renters and landlords through price adjustments. In fact, housing tenure status is a great indicator to disentangle the winners and losers of constraining credit via more stringent LTV and LTI limits, as shown in Figure 6. In a nutshell, renters lose, homeowners are indifferent and landlord benefit. Consequently, a welfare neutral policy would require a redistribution of consumption from landlords to renters to compensate for the unintended effects of the macro-prudential reform.

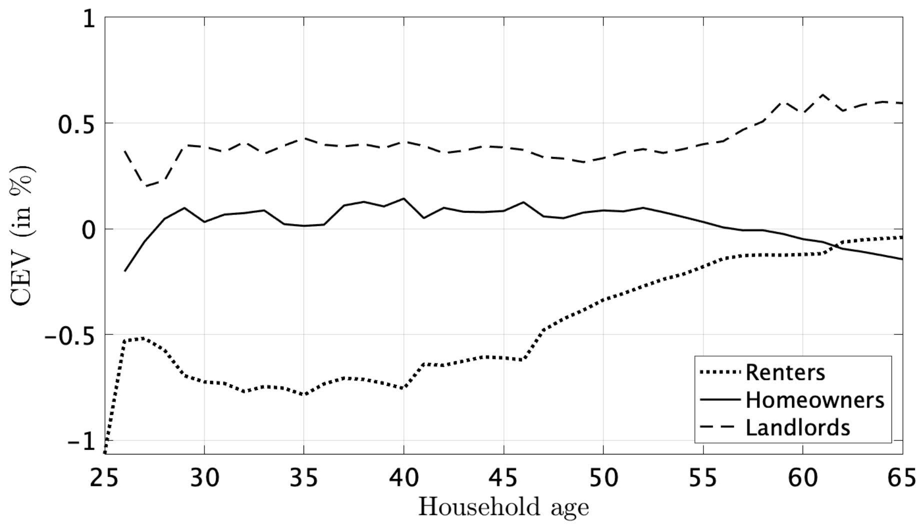


FIGURE 6. Housing tenure & welfare

NOTE. This figure plots the value of the CEV along the age distribution for three group of households: renters, homeowners and landlords.

4. Interest rates, credit standards, and price dynamics

In this section, we use the model presented in Section 2 to study the effects of a different type of credit shock: an exogenous, unexpected and permanent rise to the real interest rate of 1 percentage point. We do so under the assumption that the economy has the macro-prudential measures described in Section 3 in place, and then show how effects would differ under a looser credit conditions.

4.1. A permanent rise in the real interest rate

An increase in the interest rate has a direct impact on prospective homeowners as it makes mortgage credit more expensive. In this regard, this experiment is similar to the tightening of LTV and LTI limits studied in Section 3. Unlike the macro-prudential reform, the increase in interest rates also has a direct impact on savers because the return on bonds increases, and on current mortgagors because their mortgage interest payments also increase.

In Table 5, we show the joint impact of all of these channels on the rent and price to income ratios, the homeownership rate, and the share of high quality homes. By comparing the *low interest rate* and *high interest rate* economies shown in the leftmost and rightmost columns, we observe that the increase in the real interest rate reduces the homeownership rate (-0.92 p.p.) and increases the rental rates (12.7%). Unlike in our previous experiment, the drop in average house prices is significant (-1.62%) and many households choose to downsize and buy smaller houses. Similar to Figure A4, Figure A5 shows the flows across different housing tenure status for the interest rate experiment and in particular the larger movement from big to small owners relative to the macro-prudential credit tightening.

In order to understand and decompose the different channels that drive these results, we proceed in steps and study the effect of the increase in the savings rate and the morgage rate in isolation. To do so, we introduce a counterfactual economy in which the return on savings is $r_s = 3\%$ but the mortgage rate is still $r_b = 4\%$.

4.1.1. An increase in the return on savings versus a rise in the borrowing rate

A permanent rise in the return on savings. To analyze the effect of an increase in the rate of return of savings alone, we compare the *low interest rate* economy (1st column, Table 5) and the counterfactual economy (2nd column, Table 5). Under tight credit conditions, rising the saving rate leads to a 0.6 p.p. fall in the homeownership rate. Financial assets become relatively more profitable than housing, ceteris paribus, thus generating a substitution effect that decreases the incentives to own a house. This effect is stronger than the higher returns from savings that allow prospective homeowners to save for downpayment at a much faster rate (income effect). The substitution effect is particularly strong for landlords, who do not get utility from any additional properties and thus treat them as a pure financial investment. As a result, they require a very large rise in the rental rate, higher than 11%, to meet the increased rental demand. This channel explains the bulk of the overall increase in rental prices that we observe as a result of the permanent rise in r. Moreover, the negative substitution effect between housing and financial assets also results in many households buying a smaller house, which puts downward pressure on aggregate house prices (-0.5%).

A permanent rise of the mortgage rate. To study the effects of an increase in the mortgage rate alone, we compare the counterfactual economy (2nd column, Table 5) to the *high interest rate* economy (3rd column, Table 5). The rise in the borrowing rate has a negative income effect on housing demand, as it increases the interest payments of current mortgagors, but also a negative substitution effect, as it increases the cost of accessing credit. As a result of the rise in borrowing costs, the homeownership rate falls by 0.33 percentage points and there is a sizable mass of households that opt for the less

TABLE 5. Increasing the real interest rate

	Low Int. Rate	Decomposition	High Int. Rate
	$r^s = 0.02, r^b = 0.04$	$r^s = 0.03, r^b = 0.04$	$r^s = 0.03, r^b = 0.05$
		Tight credit conditions	
Rent-to-Price	4.09 %	4.58 %	4.69 %
Average house price to income	4.925	4.899	4.846
Rent to Income	0.201	0.224	0.227
Homeownership rate	77.59 %	76.99 %	76.67 %
Share of households living in big houses	50.03 %	47.74 %	43.02 %
		Loose credit conditions	
Rent-to-Price	3.98 %	4.48 %	4.57 %
Average house price to income	4.930	4.880	4.835
Rent to Income	0.196	0.219	0.221
Homeownership rate	79.42 %	78.93 %	78.35 %
Share of households living in big houses	50.41 %	46.01 %	42.02 %

NOTE. This table show the equilibrium quantities and prices for three economies: *(i)* low interest rate, *(ii)* high interest rate and *(iii)* a counterfactual economy that decomposes the effects of the return on savings and the borrowing rate. Each of these economies are analyze under different credit conditions: tight credit (top block) and loose credit (bottom block).

expensive house – the share of low quality homes increases by 4.72 percentage points. Consequently, the average house price in the economy falls by 1.1%, which is more than twice as large as the fall associated to the increase in the return on savings. On the other hand, the increase in the rental price associated with the increase rental demand is of an order of magnitude smaller and it only rises by 1.2%.

In our model, we assume that all mortgagors have a floating-rate mortgage and thus the adjustment to their mortgage payments happens immediately after the shock. This assumption is consistent with the Irish institutional structure, in which around 80% of mortgages were de facto adjustable rate in 2018 (Badarinza, Campbell, and Ramadorai 2018), with some of them being fully adjustable and some of them having fixed rates for a relatively short period, such as 1 or 2 years. In an economy where fixed-rate mortgages are more prevalent, such as the United States, the steady state impact would be similar, but over the transition existing mortgagors would be less negatively impacted.

4.2. Interaction with credit standards

In the results we have shown so far, we have analyzed the effects of the interest rate increase in an environment in which institutional limits on mortgage borrowing were in place. To gauge to which extent macroprudential policies can help cushion the aggregate effects of shocks such as an unexpected interest rate rise, we also study the effects of the same shock in a context in which borrowing limits are less stringent and equal to those prevailing in Ireland before 2015. The results from this last experiment are shown in the bottom panel of Table 5.

We find that the fall in the homeownership rate (-1.07 p.p.) as well as the fall in average house prices (-1.93%) are larger under looser credit conditions. On the other hand, the rise in the rental price is of similar magnitude as it rises by 12.84% under looser credit conditions. Prospective landlords are less affected by the borrowing limits than prospective homeowners, and consequently the adjustments in the housing market are more sensitive to the credit conditions than those in the rental market. These results suggest that macroprudential policies, despite the negative welfare effects we have discussed in Section 3, can be effective at mitigating the fluctuations in housing markets originated by other types of shocks.

4.3. Transition dynamics & welfare

We now turn to studying how the change in the real interest rate impacts rents and house prices over the transition, and then look into the welfare of the households who are impacted by the shock. For this section, we assume that tight LTI and LTV limits are in place already in the initial steady state.

Transition paths. Figure 7 depicts the equilibrium paths for the rental price, the average house price and the homeownership rate after an exogenous permanent change in the real interest rate. Similarly to our previous experiment, rental prices overshoot and reach its peak after 4 years with an increase of 20.8% relative to the low interest rate economy. Nonetheless, the convergence to its new steady state level is slower and takes about 20 years. On the other hand, the average house price adjustment is relatively faster, but still takes about 15 years to reach its new lower level. The homeownership rate jumps to its new level within the first couple of years and stays there for the remaining of the transition.

Consumption Equivalent Variation. Figure 8 plots the welfare impact for households who are initially young (25-30 years old) when the interest rate shock takes place, decomposing it into interest rate changes (borrowing rate vs. return on savings) as well as into house and rental price adjustments. The overall impact, depicted by the solid

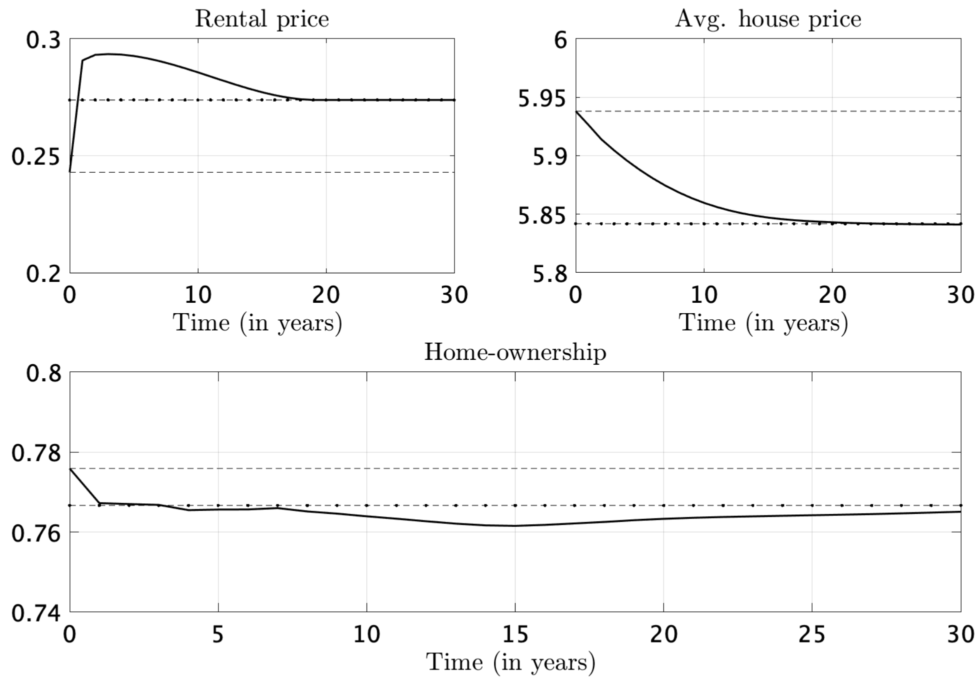


FIGURE 7. Transition paths: from low to high real interest rates

NOTE. This figure shows the evolution of the rental price (top-left), the average house price (top-right) and the homeownership rate (bottom) along the transition from the low to the high interest rate economy.

line, shows that there are winners and losers from the permanent increase in the real interest rate. In particular, those below the median of the income distribution are worse off, while those above are better off. Adding one channel at a time, we observe first that all households benefit from the rise of the return on savings (dash-dotted line), but high income households benefit comparatively more because they have more wealth. Adding the increase in the cost of mortgages (dashed line) reduces the welfare gains for some parts of the distribution, particularly those in middle income deciles who need to acquire larger mortgages to buy a house, but less for the relatively richer, who are more likely to buy homes outright or with smaller mortgages, and for the relatively poorer, who are mostly renters. Like in our previous experiment, the general equilibrium effect coming from price adjustments in the rental markets is relatively large and has a very negative welfare impact on low income households, who as a result lose after the shock (dotted line). Although the drop in house prices is larger in this experiment, its welfare effects are relatively small in comparison.

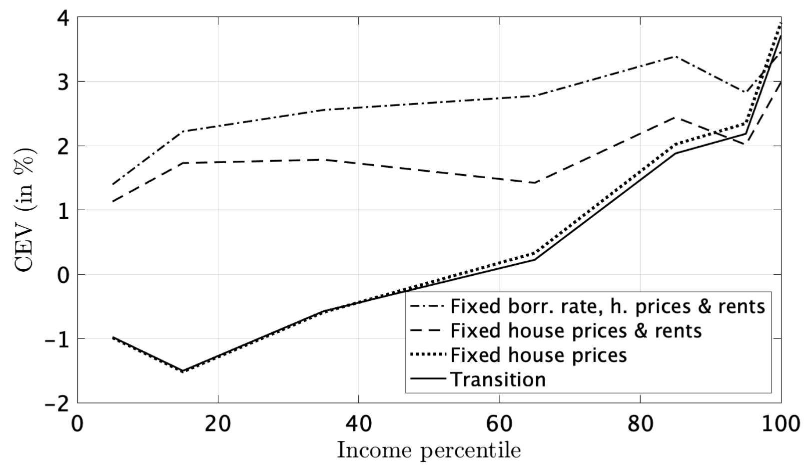


FIGURE 8. Rate changes, price adjustments & welfare along the income distribution

NOTE. This figure shows the consumption equivalent variation for a group of young households along the income distribution. The dashed-dotted line shows the effect of increasing the return on savings alone, the dashed line factors in the increase in the borrowing rate, while the dotted line takes into account the adjustment of the rental price. Finally, the solid line shows the overall effect of the increase in the real rate in terms of welfare.

5. Conclusion

In this paper, we build an equilibrium model of the housing and rental markets in which households differ in their age, income and wealth as well as in their housing tenure status (renters, homeowners, or landlords). Endogenous landlord formation allows us to have an upward slopping rental supply curve that is crucial to understand the effect of credit conditions on house and rental prices. We use this model to analyze two shocks to the availability of credit for households: *(i)* the introduction of LTI and LTV limits in Ireland in 2015, and *(ii)* a permanent rise in the real interest rate.

Regarding the 2015 Irish macro-prudential reform, we show empirically that it had opposite effects on house prices and rents. In the model, these effects are explained by a rise in rental demand that needs to be met by a landlord sector which is heterogeneous and constrained, and that as a result displays an upward sloping rental supply curve. Quantitatively, most of the adjustment occurs through the increase in rental prices (2.74% upon impact and 3.61% after 4 years) with house prices not reacting much to the tightening of LTI and LTV limits in the long run. Nonetheless, adjustments via quantities in the housing market were sizable as the homeownership rate fell by 1.8 p.p in the long run. These changes impacted households welfare differently. Renters, who are typically young, poor or middle-income households, suffered the most because they had to pay higher rents and were forced to postpone or cancel their buying decisions. On the other hand, landlords who are top income earners benefited as they are not constrained by the new limits, they can get slightly cheaper houses and receive higher cash flows from their real estate businesses.

Turning to our second experiment: the rise in the real interest rate, we find that it also leads to a reduction of the homeownership rate and the average house price as well as to an increase in rental prices. Moreover, these price adjustments in the housing and rental markets generate losers and winners, highlighting the potential redistributive effects of interest rate shocks or monetary policy more broadly via the housing and rental markets. In particular, middle-income and top earners benefit from the higher return on savings as well as the lower house prices, while poor households lose from the higher rental prices.

Our paper highlights that rental markets are key to understand the equilibrium impacts and welfare effects of credit shocks, and provides a theoretical and quantitative framework to analyze shocks in which both house prices and rents can react endogenously and in potentially different directions. These results open interesting avenues for future research. For instance, although in our second experiment we focus on an exogenous real interest rate shock, it is likely that similar channels operate as a reaction to monetary policy shocks in a model with nominal rigidities, which could help us to better understand its transmission channel through the housing market. Besides, our model assumes that there is one single housing and rental market at the national level, with different housing qualities but a common price. Consequently, an interesting extension would consider spatial heterogeneity across different urban and rural areas, and the interaction of a credit shock in a context of accelerated urbanization and increased house price and rent inequalities.

References

Aastveit, Knut Are, and André K Anundsen. 2022. "Asymmetric effects of monetary policy in regional housing markets." *American Economic Journal: Macroeconomics* 14 (4): 499–529.

Acharya, Viral V., Katharina Bergant, Matteo Crosignani, Tim Eisert, and Fergal McCann. 2022. "The Anatomy of the Transmission of Macroprudential Policies." *The Journal of Finance* 77 (5): 2533–2575.

Amaral, Francisco, Martin Dohmen, Sebastian Kohl, and Moritz Schularick. 2024. "Interest rates and the spatial polarization of housing markets." *American Economic Review: Insights* 6 (1): 89–104.

Arellano, Manuel, Richard Blundell, and Stéphane Bonhomme. 2017. "Earnings and Consumption Dynamics: A Nonlinear Panel Data Framework." *Econometrica* 85 (3): 693–734.

Badarinza, Cristian, John Y Campbell, and Tarun Ramadorai. 2018. "What calls to ARMs? International evidence on interest rates and the choice of adjustable-rate mortgages." *Management Science* 64 (5): 2275–2288.

De Nardi, Mariacristina, Giulio Fella, and Gonzalo Paz-Pardo. 2020. "Nonlinear Household Earnings Dynamics, Self-Insurance, and Welfare." *Journal of the European Economic Association* 18 (2): 890–926.

De Nardi, Mariacristina, Giulio Fella, and Gonzalo Paz-Pardo. 2024. "Wage risk and government and spousal insurance." *Review of Economic Studies*: forthcoming.

Dias, Daniel A, and João B Duarte. 2019. "Monetary policy, housing rents, and inflation dynamics." *Journal of Applied Econometrics* 34 (5): 673–687.

Dias, Daniel A, and Joao B Duarte. 2022. "Monetary Policy and Homeownership: Empirical Evidence, Theory, and Policy Implications."Technical report, Working Paper, Board of Governors of the Federal Reserve System (US).

Farhi, Emmanuel, and Iván Werning. 2016. "A Theory of Macroprudential Policies in the Presence of Nominal Rigidities." *Econometrica* 84 (5): 1645–1704.

Favilukis, Jack, Sydney C Ludvigson, and Stijn Van Nieuwerburgh. 2017. "The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk Sharing in General Equilibrium." *Journal of Political Economy* 125 (1): 140–223.

Favilukis, Jack, Pierre Mabille, and Stijn Van Nieuwerburgh. 2022. "Affordable Housing and City Welfare." *The Review of Economic Studies* 90 (1): 293–330.

Fella, Giulio. 2014. "A generalized endogenous grid method for non-smooth and non-concave problems." *Review of Economic Dynamics* 17 (2): 329–344.

Ferrero, Andrea, Richard Harrison, and Benjamin Nelson. 2023. "House Price Dynamics, Optimal LTV Limits and the Liquidity Trap." *The Review of Economic Studies*: 1–32.

Floetotto, Max, Michael Kirker, and Johannes Stroebel. 2016. "Government intervention in the housing market: Who wins, who loses?" *Journal of Monetary Economics* 80: 106–123.

Garriga, Carlos, and Aaron Hedlund. 2020. "Mortgage Debt, Consumption, and Illiquid Housing Markets in the Great Recession." *American Economic Review* 110 (6): 1603–1634.

Gete, Pedro, and Michael Reher. 2018. "Mortgage Supply and Housing Rents." *The Review of Financial Studies* 31 (12): 4884–4911.

Greenwald, Daniel L. 2018. "The Mortgage Credit Channel of Macroeconomic Transmission." SSRN Electronic Journal.

Greenwald, Daniel L, and Adam Guren. 2024. "Do Credit Conditions Move House Prices?". SSRN Electronic Journal.

Hannon, Andrew. 2023. "Falling Behind: Delinquency and Foreclosure in a Housing Crisis." Manuscript.

Iacoviello, Matteo. 2005. "House prices, borrowing constraints, and monetary policy in the business cycle." *American Economic Review* 95 (3): 739–764.

Ireland's Department of Finance. 2019. "Institutional Investment in the Housing Market."

Iskhakov, Fedor, Thomas H. Jørgensen, John Rust, and Bertel Schjerning. 2017. "The endogenous grid method for discrete-continuous dynamic choice models with (or without) taste shocks." *Quantitative Economics* 8 (2): 317–365.

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti. 2019. "Credit Supply and the Housing Boom." *Journal of Political Economy* 127 (3): 1317–1350.

Kaplan, Greg, Kurt Mitman, and Giovanni L Violante. 2020. "The Housing Boom and Bust: Model Meets Evidence." *Journal of Political Economy* 128 (9): 3285–3345.

Kelly, Robert, Fergal McCann, and Conor O'Toole. 2018. "Credit conditions, macroprudential policy and house prices." *Journal of Housing Economics* 41: 153–167.

Lambertini, Luisa, Caterina Mendicino, and Maria Teresa Punzi. 2013. "Leaning against boom–bust cycles in credit and housing prices." *Journal of Economic Dynamics and Control* 37 (8): 1500–1522.

Levy, Antoine. 2022. "Housing Policy with Home-Biased Landlords: Evidence from French Rental Markets." *Working paper*.

Lyons, Ronan C. 2018. "Credit conditions and the housing price ratio: Evidence from Ireland's boom and bust." *Journal of Housing Economics* 42: 84–96.

Muñoz, Manuel A, and Frank Smets. 2022. "Macroprudential policy and the role of institutional investors in housing markets." ECB Working Paper Series.

Nakajima, Makoto, and Irina A Telyukova. 2020. "Home equity in retirement." *International Economic Review* 61 (2): 573–616.

Oliveira, João G, and Leonor Queiró. 2023. "Mortgage borrowing caps: leverage, default and welfare." Bank of Portugal Working Papers.

Oosthuizen, Dick. 2023. "Institutional Housing Investors and the Great Recession." Manuscript.

Paz-Pardo, Gonzalo. 2024. "Homeownership and Portfolio Choice Over the Generations." *American Economic Journal: Macroeconomics* 16 (1): 207–237.

Pew Research. 2021. "Who rents and who owns in the U.S.."

Piazzesi, Monika, and Martin Schneider. 2016. "Housing and macroeconomics." *Handbook of Macroeconomics* 2: 1547–1640.

Poterba, James M. 1984. "Tax subsidies to owner-occupied housing: an asset-market approach." *The Quarterly Journal of Economics* 99 (4): 729–752.

Rotberg, Shahar, and Joseph B Steinberg. 2024. "Mortgage interest deductions? Not a bad idea after all." *Journal of Monetary Economics* 144.

Sommer, Kamila, and Paul Sullivan. 2018. "Implications of US tax policy for house prices, rents, and homeownership." *American Economic Review* 108 (2): 241–74.

Van Bekkum, Sjoerd, Rustom M Irani, Marc Gabarro, and José Luis Peydró. 2023. "Take It to the

Limit? The Effects of Household Leverage Caps." SSRN Electronic Journal.

Appendix A. Additional empirical evidence

A.1. Irish rental sector

In our model economy we assume that the rental sector is populated by households that own one or two rental properties. Although, this assumption may seem restrictive, it is consistent with the Irish private rental sector.

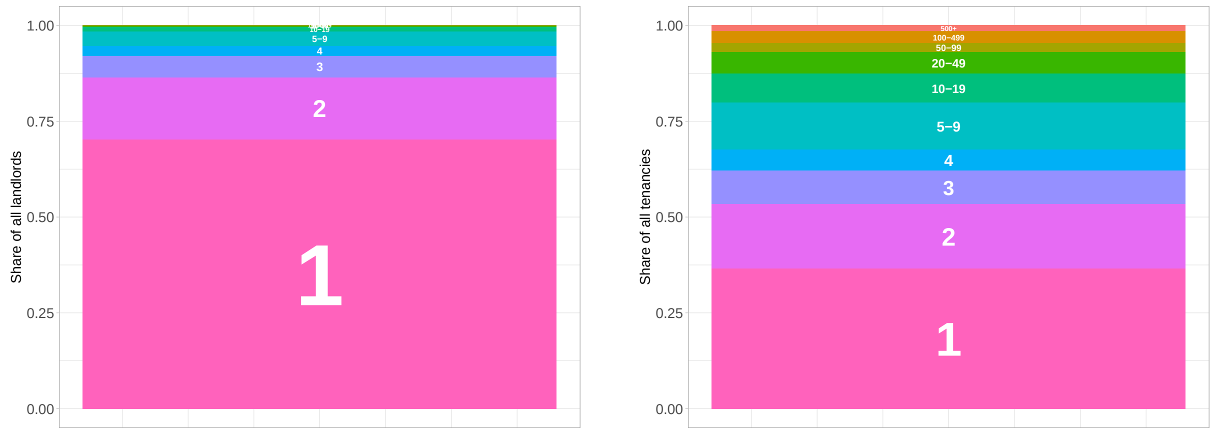
In Figure A1, we use data from the Central Statistical Office (CSO) on residential property transactions to show that the vast majority of non-occupier property purchases correspond to household buyers. In fact, in 2015, the year when the macro-prudential reform was introduced, around 70% of those transactions correspond to household buyers. Nonetheless, these data also confirms that the role of non-household buyers such as pension funds, private rental firms and Real Estate Investment Trusts (REITs) has increased over the last decade.

In Figure A2, we dig deeper into the ownership structure in the rental sector and use data from the Residential Tenancies Board (RTB) using RTB registrations as a proxy for ownership. Panel A shows the share of landlords by number of tenancies. Note that a tenancy is not fully analogous to a property as there may be some instances where there are multiple tenancies in one property (e.g. a flat with multiple rented rooms). Nonetheless, the vast majority of tenancies are individual properties. With that in mind,

A. All properties B. All properties bought by non-owner-occupiers

FIGURE A1. Share of property transactions, by type of buyer and year

NOTE: This figure shows the share of all house sales by type of buyer and year in panel A. Panel B focus the attention in non-occupier buyers which are split into two categories: household buyers and non-household buyers. Data is available at the CSO.



A. Share of landlords by number of tenancies

B. Share of all tenancies owned by landlords

FIGURE A2. Irish rental sector structure

NOTE: This figure shows the share of landlords by number of registered tenancies (panel A) as well as the share of tenancies owned by landlords with different number of registered tenancies (panel B). Data is from the RTB.

the evidence on the RTB data points to a lesser role of large scale professional landlords as only 4.6% of tenancies are held by landlords with more than 100 units. On the other hand, the vast majority of landlords register a single rental property (70%) or at most two (86%). One gets a similar picture, if looks at the share of tenancies by landlords – panel B. In fact, landlords with one or two properties registered more than 50% of all tenancies.

Figure A1 and A2 are consistent with each other as the rise of institutional investors in Ireland is mostly concentrated in newly constructed, high quality and well located units, but not so relevant at the aggregate level (Ireland's Department of Finance 2019).

A.2. Macro-prudential limits, house & rental prices

In this section, we describe the data used in our regression analysis, provide additional non-parametric evidence on the opposite response of house and rental prices to the introduction of macro-prudential limits, and run some robustness test that verify such relationships.

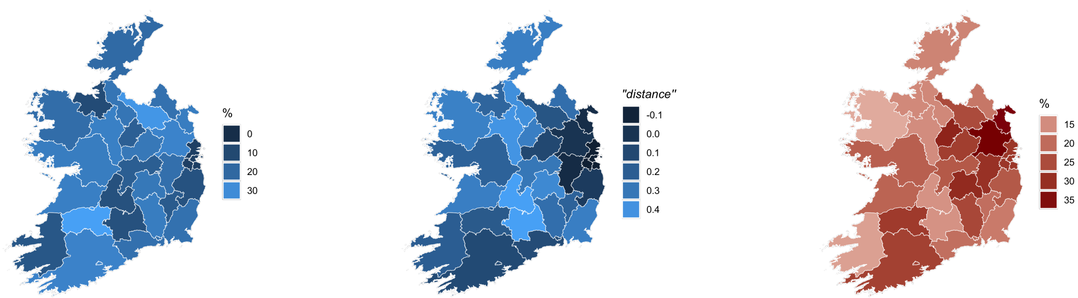
A.2.1. Data sources

The core of our final data set is the result of combining the *"distance"* measure with county-level selling and rental house prices. In our main specifications, we borrow the *"distance"* measure from Acharya et al. (2022). They construct this measure using loan-level information on residential mortgages. In particular, they "calculate what would have been the distance from the limits for each borrower in the year before the policy, assuming that the limits were in place during that period" (p. 12, Acharya et al., 2022). For confidential reasons, we got this information aggregated to the county level.

Data on house and rental prices comes from Daft.ie. We borrow these data from Lyons (2018) since in his website he has the aggregated time series for each Irish county of both selling and rental prices.

A.2.2. Non-parametric evidence

Figure A3 shows the variation in house price growth (panel A), the distance measure (panel B) and rental price growth (panel C) across all Irish counties. In low-distance counties, such as those areas around Dublin, house price growth was slower and close to zero, while rental prices were growing faster at a pace around 30-35%. This observation suggests that the distance measure is positively correlated with house price growth while it is negatively correlated with rental price growth. This statement was formally verified in our regression analysis in Section 3.1.



A. House price growth B. Distance measure C. Rental price growth

FIGURE A3. Counties, lending limits, house & rental price growth

NOTE. This figure shows the county-level distance from the limits (panel A), house price (panel B) and rental price (panel C) growth between the third quarter of 2014 and the fourth quarter of 2016. Data on prices comes from Daft.ie while the distance measure was provided by Mateo Crosignani and corresponds to the one in their paper: Acharya et al. (2022). Darker colors indicate less distant counties, lower house price growth and higher rental price growth.

Appendix B. Further model details

B.1. Solution method

The steady state solutions of the model consist of two main loops: an inner loop that solves the household problem given structural parameters and prices, and an outer loop that recovers the equilibrium distribution and prices. A description of the algorithms used for the approximation of the steady state equilibria can be found in Appendix B.1.1 and B.1.2. In addition to steady state equilibria, welfare comparisons also require to solve the transition from one steady state to another. The computational approach used to solve for such transition is described in Appendix B.1.3.

B.1.1. Household problem

As shown in Section 2.2, the household state variables are age, j, income, y, the housing state, $s = (h, \tilde{h})$, and net financial wealth, a. Consequently, the first step is to discretize the continuous state variables. Financial wealth lie on a non-linearly spaced grid with 150 points that includes 50 negative values and 100 positive ones, while the stochastic component of income is discretized using the approach in De Nardi, Fella, and Paz-Pardo (2020) that accounts for non-linearities and age-dependence. In particular, we allow for 7 points for the stochastic component of income whose values vary with the working age of the household. [6] The remaining state variables are already discrete. Recall that: *(a)* the model period is one year and household live up to 71 years, and *(b)* the housing state can take 5 different values: *(i)* $s = (0, \tilde{h}_1)$ if renter, *(ii)* $s = (1, \tilde{h}_1)$ if small owner, *(ii)* $s = (1, \tilde{h}_2)$ if big owner, *(iv)* $s = (2, \tilde{h}_2)$ if landlord with one rented house, or *(v)* $s = (3, \tilde{h}_2)$ if landlord with two rented houses.

Since households die with certainty at age J, we know their optimal policy in their terminal period, so we can proceed by backward induction and compute the remaining age-dependent policy functions. Note that households make the standard consumption-savings choice, a', as well as decide on the next period housing tenure, s', at each age. Given that the housing choice is discrete, the solution of the household problem requires using computational techniques employed to solve discrete-continuous dynamic choice models. We follow closely the recipe from Fella (2014) and Iskhakov et al. (2017) to use the endogenous grid method (EGM) together with taste shocks to solve for these discrete-

[6] The transition matrix that controls the evolution of household's income over time is also age-dependent and hence it is of dimension $7 \times 7 \times 41$ where 41 is the retirement age J^{ret}.

choice specific policy and value functions. In a nutshell, for each $j < J$ we first compute the expected marginal utility to then invert the Euler equation and get the endogenous consumption-asset policy in a normal EGM step. After that, we apply the general EGM procedure to verify the global optimality of these choices in the non-concave region and discard those that are not. Finally, we use the obtained s'-dependent value and policy functions to compute the probability of the discrete choice using the Logit probability formula and the expected value function using the log-sum formula. These are stored and used in the next step of the backward induction. Once the backward induction is finished, the final outcomes of the algorithm are s'-dependent consumption-savings policy functions, a discrete choice probability and a value function.

B.1.2. General equilibrium

To compute the equilibrium in the housing and rental markets we proceed as follows:

1. Make a guess for the rental price, p_r^g.
2. Make a guess for the share of low quality housing, $H_2^{sh,g}$. Note that this allows us to know the share of the high quality housing H_1^{sh} as both sum up to one. Recall that there are no empty houses and population size is normalized to 1.
3. Use these guessed shares to recover the transaction prices of the two qualities, $p^g(\tilde{h}_1)$ and $p^g(\tilde{h}_2)$, using the equilibrium condition (19). Note that the only endogenous object in that expression is the aggregate housing stock H, which only changes because of the equilibrium share of each quality type. Recall that $\tilde{h}_1$ and $\tilde{h}_2$ are fixed during calibration.
4. Given price guesses $\left\{p_r^g, p^g(\tilde{h}_1), p^g(\tilde{h}_2)\right\}$, use the algorithm loosely described in Appendix B.1.1 to get the value and policy functions that solve the household problem.
5. Using the household's consumption-saving policy and the discrete choice probability, recover the stationary distribution of households $\mathcal{D}(a, s, y, j)$ as it contains all the information needed for evaluating if the rental and housing market clear.
   a. Rental demand equals the share of households that choose to be renters

$$R^d = \sum_{i_a=1}^{n_a} \sum_{i_y=1}^{n_y} \sum_{j=1}^{J} \mathcal{D}(a_{i_a}, s_1, y_{i_y}, j)$$

b. Rental supply is given by the sum of landlords with one rented out property plus two times the share of landlords with two rented out properties.

$$R^s = \sum_{i_a=1}^{n_a} \sum_{i_y=1}^{n_y} \sum_{j=1}^{J} \mathcal{D}(a_{i_a}, s_3, y_{i_y}, j) + 2 \times \sum_{i_a=1}^{n_a} \sum_{i_y=1}^{n_y} \sum_{j=1}^{J} \mathcal{D}(a_{i_a}, s_5, y_{i_y}, j)$$

c. The share of households living in the low quality home is also given by the equilibrium distribution

$$H_2^{sh,d} = \sum_{i_a=1}^{n_a} \sum_{i_y=1}^{n_y} \sum_{j=1}^{J} \mathcal{D}(a_{i_a}, s_1, y_{i_y}, j) + \sum_{i_a=1}^{n_a} \sum_{i_y=1}^{n_y} \sum_{j=1}^{J} \mathcal{D}(a_{i_a}, s_2, y_{i_y}, j)$$

6. If $|R^d - R^s| < \varepsilon_r$ and $|H_2^{sh,g} - H_2^{sh,d}| < \varepsilon_h$, then we are done. Otherwise, we need to update the guesses and go back to step 3. For the share of low quality houses, we use the convex combination between the previous guess and the solution from the household problem, while for the rental price we increase the guess if $R^s < R^d$ and decrease it otherwise.

Hence, the final outcomes of this algorithm are: an equilibrium rental price, an equilibrium average house price, the stationary distribution of households over their state space and optimal policy and value functions.

B.1.3. Transition dynamics

To compute the transition paths shown in Figures 4 and 7, we resort to the traditional approach that assumes that at time $t = 0$ the economy is initially in a steady state. Then, at $t = 1$ the policy reform is introduced as a surprise for households and maintained forever. Recall that in the macroprudential experiment the policy reform consists in introducing tighter LTV and LTI limits, so that λ_{LTV} and λ_{LTI} change while everything else remains untouched; while for the interest rate experiment, it is only the return on financial assets r_s and the mortgage rate r_b that increase in the new steady state. In either case, the key idea is to assume that after T periods the transition from the old to the new steady state is completed. As a result, one can safely assume that policy and value functions at time $t = T$ are those from the new steady state. So that $c_T = c_{ss}^{new}$, $a_T = a_{ss}^{new}$ and $\mathbb{P}_T(s) = \mathbb{P}_{ss}^{new}(s)$.

For a given sequence of prices $\left\{ p_t^r,\ p_t(\tilde{h}) \right\}_{t=1}^{T}$, the previous insight allow us to solve the household problem backwards and obtain their policy functions at each point in time $\left\{c_t, a_t, \mathbb{P}_t(s)\right\}_{t=1}^{T}$. Knowing that $\mathcal{D}_0 = \mathcal{D}_1$, these are useful to iterate the distribution forward: $\mathcal{D}_{t+1} = \Gamma_t(\mathcal{D}_t)$ where Γ_t is the mapping obtained from the policy functions. Finally, using the sequence of household distributions over their state space $\{\mathcal{D}_t\}_{t=0}^{T}$ one can check if rental and housing markets clear at each point in time. If they do not, then the given sequence of prices needs to be updated until they do.

Thus, the most difficult aspect of the transition is to find suitable paths for rental and house prices. We approach this problem by first guessing different rental and housing price paths and evaluating ex-post which ones are closer to form an equilibrium sequence in housing and rental markets. These guesses are constructed parametrically by imposing an initial jump and a degree of curvature in its reversal to the new steady state level. Once we have a sense on how these equilibrium paths should look like, we follow a similar approach to that described in point 6 of the general equilibrium algorithm with the caveat that we now update the guesses based on the gaps between supply and demand along the entire path and not just based on one point in time.

B.2. LTI and LTV implementation in Ireland

As stated in Section 2.2, the borrower must satisfy two constraints. First, a loan-to-income (LTI) requirement that limits household's borrowing to a multiple, λ_{LTI}, of its current (annual) income. And second, a maximum loan-to-value (LTV) limit, which imposes that the size of the mortgage has to be smaller than a fraction of the value of the house.

When Central Banks establish these limits, they often include some exemptions based on the type of borrower or the type of property households purchase. For example, the Irish reform of 2015 imposed a LTI limit of 3.5 that only applied to First Time Buyers (FTBs). In the model, we identify FTBs with households that transition from renting into owning as there are very few (or even zero) households that after selling their primary residence become homeowners for a second time during their life-cycle. For all other borrowers, we let the pre-reform limit to apply as this was the LTI implicitly imposed by banks in absence of the Bank of Ireland macro-prudential framework. Hence, formally, the LTI in the *post-reform* economy is

$$a' \geq -\lambda_{LTI}^{post}\, y \qquad \text{if} \quad h' = 1 > h \tag{A1}$$

$$a' \geq -\lambda_{LTI}^{pre}\, y \qquad \text{otherwise} \tag{A2}$$

Moreover, the reform also included some exceptions for the LTV limit based on the type of purchase. For example, buy-to-let buyers faced a more stringent 70% loan-to-value limit. We include this feature in the model by distinguishing between owner-occupied and buy to let purchases for which we let $\lambda_{LTV}^{oo} = 0.8$ and $\lambda_{LTV}^{btl} = 0.7$ to apply. In the model, it is easy to identify this purchases as households that one more than one property always lease it out. Hence, in the *post-reform* economy the LTV limit is given by

$$a' \geq -\lambda_{LTV}^{oo}\ p(\tilde{h}') \quad \text{if} \quad h' = 1, h = 0 \tag{A3}$$

$$a' \geq -\left(\lambda_{LTV}^{oo}\ p(\tilde{h}') + \lambda_{LTV}^{btl}\ p(\tilde{h}_1')h'\right) \quad \text{if} \quad h' > 1 \geq h. \tag{A4}$$

Appendix C. Additional model results and experiments

C.1. Understanding house and rental price responses

We have seen that rental prices rise and house prices fall in response to a tightening in credit conditions. Figure A4 is useful for explaining these price dynamics as it plots the cross sectional distribution of the housing state in the *pre-* and *post-reform* economies, as well as the flows in and out of these states.

At the new tighter limits, many pre-reform homeowners cannot afford to purchase a house and therefore are pushed into renting. In order to meet that additional rental demand, rental prices need to rise to incentivize some households to purchase buy-to-let properties. Motivated by the higher rental prices, many homeowners of the better quality homes transition into the landlord state. This flow, from OWNER (big) to LANDLORD 1P, compensates about 75% of the increase in the rental demand. To a lesser extent, some existing landlords also buy additional buy-to-let properties. Overall, rental prices need to increase by 2.84% to push homeowners into the landlord state and meet the extra rental demand.

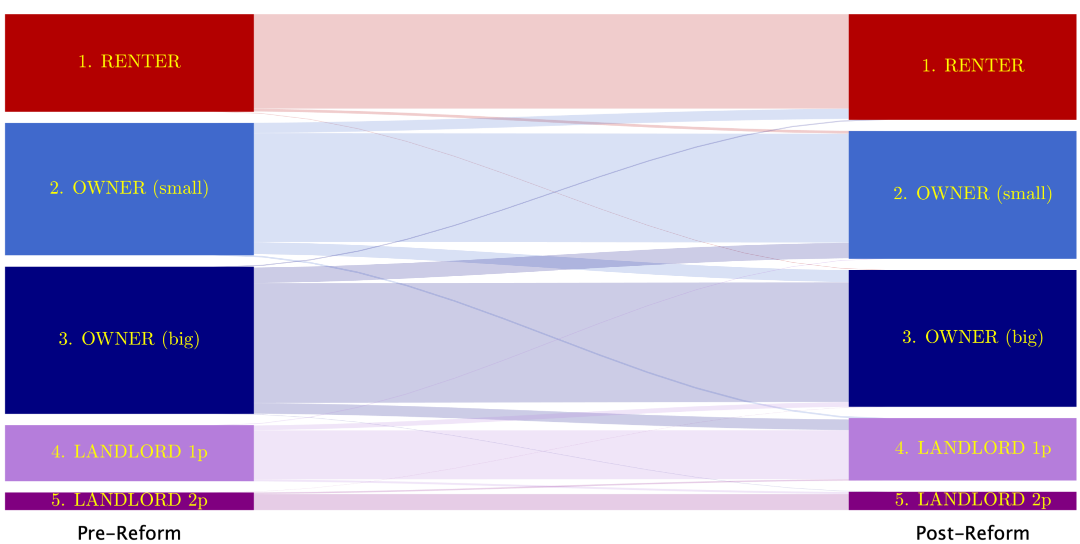


FIGURE A4. Housing flows – Pre vs. Post Reform

NOTE. This figure shows the equilibrium share of households in each housing state for the pre- and post-reform economies. Flows from a house state to another as credit conditions change helps explaining the response of rental and house prices.

Average house prices in this economy fall due to a change in the composition of the aggregate housing stock. First, the increase in rental demand results in a higher share of buy-to-let properties in the post-reform equilibrium. Since these are of lower quality and cheaper, the average house price falls. Moreover, tighter credit also pushes some households into buying the low quality house instead of the better quality one since it requires a smaller mortgage. This is shown by the flow from OWNER (big) to OWNER (small). Nonetheless, downsizing is quantitatively small in this experiment and thus there is only a small increase in the share of low quality homes in the post-reform equilibrium, leading to an also small fall in the average house price.

To highlight the big role that downsizing may have in the evolution of the average house price, we repeat the simulation used to generate the flow chart above but now for the interest rate experiment. The flows across the *low* and *high interest rate* economies are shown in Figure A5. It is easy to see that now there are more households that are OWNER (big) in the old steady state (low interest rate economy) that become OWNER (small) in the new steady state (high interest rate economy). As a result, and as we have seen in section 4.1.1 the average house prices fall significantly more (-1.62%) despite the smaller fall in the homeownership rate (-0.92 p.p.).

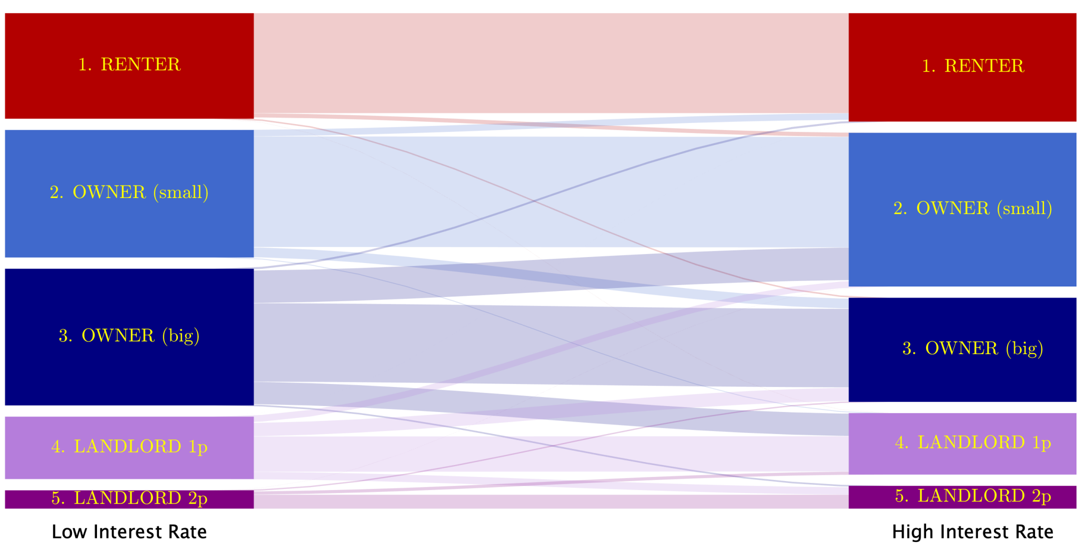


FIGURE A5. Housing flows – High vs. Low Real Interest Rate Economies

NOTE. This figure shows the equilibrium share of households in each housing state for the high and low interest rate economies. Flows from a house state to another as interest rate change helps explaining the response of rental and house prices.

C.2. The macro-prudential reform: interaction between limits

Loan to Value (LTV) and Loan to Income (LTI) limits are often introduced jointly, as it was the case for Ireland. To understand the contribution to each of them to the overall quantity and price effects of the reform, we compute two counterfactual economies: *(i)* the *Only LTI* economy which imposes the institutional 3.5 LTI limit but leaves the LTV unchanged, and *(ii)* the *Only LTV* economy which imposes the institutional 80% LTV limit but leaves the LTI unaltered.

Table A1 shows the change relative to the *pre-reform* economy in the rent-to-price ratio as well as the homeownership rate after imposing both (full-reform) or one of these two limits. Results show that the LTI alone has a larger effect than the LTV, but these effects are smaller than those obtained after imposing the two limits jointly. Hence, there is an iteration between the two as it has been highlighted in Greenwald (2018).

TABLE A1. Non-linear interactions between credit limits

	Full-Reform	**Only LTI**	**Only LTV**
Δ% Rent-to-Price	+2.82 %	+1.71 %	+0.73 %
Δ Homeownership rate	-1.83 p.p	-1.13 p.p.	-0.53 p.p.

NOTE. This table shows the effects of the reform on the rent to house price rate and home-ownership rate (first column) and decomposes the role of each limit by imposing one at a time. A tighter LTI (second column) has a larger effect than the tighter LTV (third column) if they are introduced on their own.