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## Macroprudential policy and the role of institutional investors in housing markets

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Manuel A. Muñoz    Macroprudential policy and  
the role of institutional investors  
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## Abstract

Since the onset of the Global Financial Crisis, the presence of institutional investors in housing markets has steadily increased over time. Real estate funds (REIFs) and other housing investment firms leverage large-scale buy-to-rent investments in real estate assets that enable them to set prices in rental housing markets. A significant fraction of this funding is being provided in the form of non-bank lending (i.e., lending that is not subject to regulatory LTV limits). I develop a quantitative two-sector DSGE model that incorporates the main features of the real estate fund industry in the current context to study the effectiveness of dynamic LTV ratios as a macroprudential tool. Despite the comparatively low fraction of total property and debt held by REIFs, optimized LTV rules limiting the borrowing capacity of such funds are more effective in smoothing property prices, credit and business cycles than those affecting (indebted) households' borrowing limit. This finding is remarkably robust across alternative calibrations (of key parameters) and specifications of the model. The underlying reason behind such an important and unexpectedly robust finding relates to the strong interconnectedness of REIFs with various sectors of the economy.

*Keywords:* rental housing, real estate funds, loan-to-value ratios, leverage.

*JEL classification:* E44, G23, G28

## Non-technical Summary

Since 2012, institutional investment in euro area real estate assets has more than quadrupled in absolute terms and as a share of total housing investment. According to recent empirical studies, real estate funds (REIFs) and other housing investment firms have been leveraging large-scale buy-to-rent investments in real estate assets, a pattern that has arguably enabled them to set prices in rental housing markets. Importantly, a significant proportion of this funding is being provided in the form of non-bank lending (i.e., lending that is not subject to regulatory LTV limits). Moreover, real estate funds are generally not subject to leverage limits in the EU and there is significant uncertainty surrounding their actual leverage measures, among other reasons, due to the fact that investment funds often lever up synthetically through the use of derivatives.

Recent developments have underscored the need to strengthen the macroprudential policy framework for non-banks, in general, and for investment funds, in particular. Total assets of the euro area non-banking sector have doubled over the last decade, with the size of the investment fund industry expanding at a relatively higher pace and its interconnectedness with other segments of the financial sector and the real economy being well documented. Moreover, the short-term impact of the COVID-19 shock on the financial sector has highlighted the potential of the investment fund sector to trigger episodes of severe market volatility and price dislocations.

The paper develops a two-sector DSGE model that incorporates the main features of the real estate fund industry in the current context and calibrates it to quarterly euro area data in order to assess the potential effectiveness of countercyclical LTV ratios that limit their borrowing capacity (i.e., LTV limits on commercial mortgages) in smoothing housing price and credit cycles.

Despite the comparatively low fraction of property and debt held by REIFs, optimized countercyclical LTV rules directly affecting their borrowing limit are more effective in smoothing property prices, credit and business cycles than the well investigated optimized LTV limits restricting the borrowing capacity of (indebted) households. Moreover, if the sole objective of the macroprudential authority is to tame the housing price and credit cycle, the best option is to have an LTV rule affecting REIFs' borrowing limit in place (i.e., the LTV rule limiting households' borrowing capacity seems to be redundant in this case). Such findings are impressively robust across key alternative specifications and calibrations of the model.

These results shed light on some of the potential avenues for strengthening the macroprudential policy framework for non-banks. There are at least two policy instruments that

could be considered to tackle the issue of funds' leverage-induced procyclicality in practice and which are still not in place: (dynamic) limits on REIFs' leverage and countercyclical LTV limits on non-bank lending. Moreover, the quantitative analysis notes that such (quantity) regulation would allow for reference prices in rental housing markets to increase less abruptly during the boom, an issue that policymakers in several countries of the euro area have attempted to handle via price regulation (an alternative that could generate price distortions).

# 1 Introduction

The low-for-long interest rates environment has exerted a downward pressure on fixed income returns, thereby providing institutional investors with incentives to search for yield in alternative markets such as the real estate sector. Over the last decade, the increasing presence of institutional investors in housing markets - together with a tightening of lending standards - has revitalized rental housing markets, leading to higher rents and depressed homeownership rates (see Gete and Reher 2018 and Lambie-Hanson, Li and Slonkosky 2019). Real estate funds and other housing investment firms have been leveraging large-scale buy-to-rent investments in real estate assets; a pattern that seems to have conferred them with some capacity to set rents in the areas where they have concentrated.

The euro area is one of the economies in which the increasing presence of institutional investors in housing markets has been more evident. Since 2012, institutional investment in euro area real estate assets has more than quadrupled in absolute terms and as a share of total housing investment (see figure 1). Importantly, a non-negligible proportion of these investments seems to have been leveraged via non-bank lending (i.e., lending that is not subject to regulatory LTV limits). In addition, real estate funds are generally not subject to leverage limits in the EU and there is significant uncertainty surrounding their actual leverage measures, among other reasons, due to the fact that investment funds often lever up synthetically through the use of derivatives.<sup>1</sup>

The aim of this paper is to contribute to the ongoing debate on strengthening the macroprudential policy framework for non-banks by assessing the effectiveness of countercyclical LTV ratios that limit the REIFs' borrowing capacity in smoothing credit and housing price cycles. In order to do so, I adopt a DSGE perspective and develop a quantitative two-sector business cycle model in which households, real estate funds and final goods-producing firms interact in a real, closed, decentralized and time-discrete economy. The model is calibrated to quarterly data of the euro area and matches a number of first and second moments of macroeconomic aggregates. The proposed quantitative analysis concludes that optimized (countercyclical) LTV rules limiting the borrowing capacity of institutional investors (i.e., LTV limits on commercial mortgages) are more effective in smoothing housing price and credit cycles than those affecting the borrowing limit of impatient households (i.e., LTV limits on residential mortgages). Importantly, such result is notably robust across alternative calibrations (of key parameters) and specifications of the model.

One of the main novelties of the paper is the modelling of real estate funds (and other

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<sup>1</sup>Real estate funds operating in the European Union fall within the category of funds that are subject to the AIFMD (Alternative Investment Fund Managers Directive), for which no leverage limits apply.

housing investment firms) within a DSGE set up that is intended to capture several key features of this industry (as documented in the recent empirical literature). That is, the paper presents a model that has the potential to serve as a useful tool for assessing the macroeconomic effects of such sector. The supply side of the model has its similarities to Davis and Heathcote (2005) and Iacoviello and Neri (2010) in that it differentiates between housing producing firms and non-housing producing firms.<sup>2</sup> The demand side accounts for three different types of representative households which crucially differ from one another in the role they play in the real estate sector. Patient households save and purchase property housing to do both, live in and supply homogeneous rental services under perfectly competitive conditions; impatient households get indebted to acquire property for their own use, and renter households demand rental housing (services) to live in. In addition, real estate investment funds (also referred to as REIFs or funds) demand loans to buy homes and transform them into slightly differentiated rental housing services that are supplied under monopolistic competition.<sup>3</sup> That is, the real estate sector of this economy consists of a property housing market and a rental housing market. A key feature of the model is that, as in reality, patient households (i.e., savers) and institutional investors simultaneously supply services in the rental housing market to (renter) households and (non-housing) producing firms.

The model features two frictions which closely interconnect credit and housing markets in the economy and amplify the effects of exogenous shocks to the real economy. First, in the tradition of Kiyotaki and Moore (1997) and Iacoviello (2005), the borrowing capacity of indebted agents (i.e., impatient households and fund managers) is tied to the expected value of their housing stock. Second, institutional investors operate in the rental housing market under monopolistic competition. In this regard, the modelling of the real estate fund industry has some similarities to that of the banking sector in Gerali et al. (2010) and the motivation for that is twofold. Housing markets are, in practice, segmented according to some of their main features (location, type of construction, style, etc) and; the existence of a positive demand for different types of houses suggests there is a preference for variety at the aggregate level. From the supply side, purchasing a large amount of housing with a common characteristic (e.g., the neighborhood) grants the REIF market power in that particular segment of the market.

The macroprudential authority is assumed to have two policy instruments at hand; dy-

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<sup>2</sup>Such firms produce housing (or durable goods) and final non-durable goods, respectively.

<sup>3</sup>Although I indistinctively refer - throughout the paper - to real estate investment firms as institutional investors or real estate funds, the type of economic agent that I am attempting to model englobes all types of institutional investors whose main business is to carry out large-scale purchases of real estate assets to offer rental housing services (e.g., real estate funds, real estate investment trusts and other companies with a similar business model).

dynamic LTV policy rules that limit the borrowing capacity of both, impatient households and REIFs. Such policy rules are dynamic in the sense that they react to steady state deviations of a macroeconomic indicator of the choice of the regulator. In this regard, a key contribution of the paper is its assessment on the workings of the LTV rule that affects the borrowing capacity of REIFs (something that, to the best of my knowledge, has not been explored in the literature before). Such policy rule operates through the following transmission mechanism; a tightening of the REIFs' LTV limit in the face of a positive exogenous shock restricts funds' borrowing capacity and, thus, their activity. Fund managers eventually find optimal to demand less property housing and to supply less rental housing services. Consequently, property prices soar less abruptly and the share of savers' supply in rental housing markets increases, thereby exerting a downward pressure on the competitive rental price. That is, countercyclical LTV ratios affecting the borrowing capacity of REIFs have the potential to smooth lending, property prices and reference (i.e., competitive) rental housing prices over the cycle.

The main findings of the paper can be summarized as follows. First, the market power real estate funds have in rental markets induce significant (negative) level effects on real and financial aggregates, when compared to the benchmark, perfect competition scenario. Second, optimized (countercyclical) LTV rules limiting the borrowing capacity of institutional investors (i.e., LTV limits on commercial mortgages) are more effective in smoothing the housing and credit cycle than those affecting the borrowing limit of impatient households (i.e., LTV limits on residential mortgages). Moreover, if the aim of the prudential authority is to tame the financial cycle (characterized by lending and property prices), the best option is to solely have a dynamic LTV rule on commercial mortgages in place (i.e., countercyclical LTV limits on residential mortgages are basically redundant). The underlying reason behind these results relates to the strong interconnectedness of REIFs' activity with the dynamics of key economic sectors, including the rental housing market as well as the housing and non-housing production sectors. Third, such results are remarkably robust across alternative calibrations (of key parameters) and specifications of the model.<sup>4</sup> Fourth, the robustness checks suggest that the effectiveness of dynamic LTV ratios restricting institutional investors' borrowing capacity is increasing in the market power, leverage and productivity

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<sup>4</sup>However, the effectiveness of the two types of LTV policy rules materially declines if the assumption that allows for a certain degree of complementarity between the consumption of non-durable goods and that of durable goods (i.e., housing) is relaxed. It is worth noting, however, that such assumption is relevant not only to account for a variety of empirical facts at the macroeconomic level (see, e.g., Ogaki and Reinhart 1998 and Monacelli 2008) but also to provide the model with a greater deal of *realism* from a microeconomic perspective. Much of the (non-durable) consumption activities undertaken by household members in practice occur when they are inside their houses. That is, there are complementarities between the two types of consumption.

levels of such funds as well as in the fraction of total housing held by them.

These findings suggest that REIFs' behavior has the potential to amplify financial and business cycles and brings some clarity on how this type of leverage-induced procyclicality could be mitigated through the use of macroprudential tools. There are at least two policy instruments that could be considered to tackle this issue in practice and which are still not in place: (dynamic) limits on REIFs' leverage and countercyclical LTV limits on non-bank lending. Moreover, the quantitative analysis notes that such (quantity) regulation would allow for reference prices in rental housing markets to increase less abruptly during the boom, an issue that policymakers in several countries of the euro area have attempted to handle via price regulation (an alternative that is prone to generate price distortions).

The paper is organized as follows. Section 2 discusses how the paper fits into the existing literature. Section 3 describes the model. Section 4 develops a quantitative exercise to assess the effectiveness of dynamic LTV ratios in smoothing housing price and credit cycles. Section 5 offers a robustness checks analysis. Section 6 concludes.

## 2 Related Literature

The paper is motivated by recent empirical studies documenting the increasing presence of institutional investors in housing markets, recent developments in rental housing markets, as well as the leverage-induced procyclicality generated by certain investment funds. Lambie-Hanson, Li and Slonkosky (2019) establish a causality relationship between the increasing presence of institutional investors in housing markets and both, the steady recovery in housing prices as well as the decline in homeownership rates that followed the Great Recession. Similarly, Mills et al. (2016) conclude that large-scale buy-to-rent investors have pushed prices and rents upwards in the neighborhoods where they have concentrated, while the empirical analysis proposed in Gay (2015) suggests that, when operating in housing markets, institutional investors have applied a mark up and decreased affordability. These trends seem to have been exacerbated by the tightening in lending standards that followed the Global Financial Crisis, which according to Gete and Reher (2018) has led to higher rents, depressed homeownership rates and increased rental supply.

Leverage seems to have played a key role in conducting such large-scale buy-to-rent institutional investments in real estate assets. Tzur-Ilan (2018) studies the effects of hard LTV limits implemented in Israel in 2012 and finds that investors have been the most affected and constrained type of borrowers in housing markets, signalling their heavy reliance on borrowing to purchase real estate assets. In addition, Hoesli et al. (2017) concludes that the Basel III framework has imposed a regulatory burden on real estate companies, thereby

providing them with incentives to opt for funding sources other than bank lending. In recent years, market analysts have recurrently reported that a significant proportion of these investments is being leveraged via direct lending, often provided by debt funds; something that has raised fears of a credit bubble building up in the debt fund industry.<sup>5</sup> Recent empirical studies have found that debt funds are among the most leveraged investment funds in Europe, with fund managers in leveraged funds reacting in a relatively more procyclical manner (than those in non-leveraged funds) and leverage reportedly amplifying financial fragility in the investment fund sector (see, e.g., van der Veer et al. 2017 and Molestina Vivar et al. 2020).

At the same time, the paper connects with three strands of the literature that are well differentiated. First, the paper contributes to the strand of literature that incorporates housing markets in otherwise standard DSGE models (see Piazzesi 2016 for a recent and extensive literature review on housing and macroeconomics). In particular, the model builds on a large literature that incorporates a multi-sector structure with housing and non-housing goods (see, e.g., Greenwood and Hercowitz 1991, Benhabib, Rogerson and Wright 1991, Chang 2000, Davis and Heathcote 2005, Fisher 2007, Iacoviello and Neri 2010, and Justiniano et al. 2015) and credit restrictions by which the borrowing capacity of certain agent types is tied to the expected value of their housing collateral, as in Kiyotaki and Moore (1997) and Iacoviello (2005 and 2015). In this regard, Iacoviello and Neri (2010) is perhaps my closest antecedent as it combines both features. However, I omit a number of ingredients their model incorporates (e.g., intermediate goods, nominal rigidities, monetary policy and a wide range of shocks) in order to include other key features (e.g., rental housing markets and real estate funds) while keeping the complexity of the model to a minimum. Yet, I allow for a variety of technology and housing demand shocks, the type of exogenous shocks that have been shown to explain the bulk of the variability in housing investment and housing prices (see Iacoviello and Neri 2010).

The paper also connects to the literature in macroeconomics that attempts to model rental housing markets. Among others, Chambers et al. (2009a and 2009b), Kiyotaki et al. (2011), Ortega et al. (2011), Sommer et al. (2013), Alpanda and Zubairy 2016), Kaplan et al. (2017), Sun and Tsang (2017), Garriga et al. (2019), and Greenwald and Guren (2019). With regards to the heterogeneity of households, the closest model to the one I propose in this paper is probably Alpanda and Zubairy (2016). There are three types of households (i.e., savers, borrowers and renters) which crucially differ from one another in their subjective

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<sup>5</sup>See, among others, Evans, J., (2019). "Real Estate: post-crisis boom draws to a close." Financial Times. June 18, <https://www.ft.com/content/64c381c8-8798-11e9-a028-86cea8523dc2>, and Wigglesworth, R., (2017). "Rise of private debt creates fears of a bubble." Financial Times. April 13, <https://www.ft.com/content/e405a256-1fbf-11e7-b7d3-163f5a7f229c>.

discount factor (and, consequently, in the role each of them plays in financial markets) as well as in the role they play in the real estate sector. This assumption allows to strike a balance between the caveats related to assuming a unique representative household (in a model that integrates property and rental housing markets) and the limitations - in terms of tractability (and quantitative analysis) - a full heterogeneous agents model is subject to. As in Ortega et al. (2011) and Sun and Tsang (2017), suppliers in rental markets transform property housing into rental services by means of a simple linear technology.

A novel and distinctive feature of this paper is the modelling of real estate funds. As in reality, they offer rental housing services, although they do it under different conditions than patient households; Their capacity to carry out large-scale purchases of houses with a similar feature permits them to set prices in such segment of rental housing markets. Even though, there is no DSGE model that incorporates such a specific type of agent (to the best of my knowledge) its modelling, nevertheless, has some similarities to other contributions in the literature. As in Basak and Pavlova (2013), institutional investors coexist with retail investors (in this case, patient households) and both trade the same asset class (in this model, rental housing). Similar to the modelling of banks in Gerali et al. (2010), real estate funds can be decomposed into two branches (i.e., fund managers and retailers) and supply their services under monopolistic competition.

Third, the paper also relates to recent work that adopts a DSGE perspective to study and quantify the effects of macroprudential policies aimed at mitigating and preventing macro-financial imbalances stemming from housing market dynamics. Among others, Kannan et al. (2012), Gelain et al. (2013), Lambertini et al. (2013), Quint and Rabanal (2014), Mendicino and Punzi (2014) and Alpanda and Zubairy (2017). While none of these models incorporate rental markets or institutional investors, they all have nominal rigidities to study the interactions between monetary and macroprudential policies. In order to focus the modelling on features of housing markets, clearly identify the transmission mechanism through which dynamic LTV ratios affecting fund managers operate, and keep the complexity of the rest of the model to a minimum, I omit the monetary block.

### **3 The Model**

Consider an economy populated by households, real estate funds and producing firms who interact in a real, closed, decentralized and time-discrete economy. As in Alpanda and Zubairy (2016), there are three types of households. Patient households (savers) work, consume, rent the physical capital they own, accumulate housing for owner-occupied and rental purposes and supply funds to impatient households and real estate funds. Impatient households (bor-

rowers) work, consume, accumulate housing for owner-occupied reasons and borrow funds from savers.<sup>6</sup> Renter households (renters) work, consume and demand rental housing services. In the supply side, housing producing firms generate new (property) housing by using capital and labor whereas non-housing producing firms produce final consumption and business investment goods by using capital, commercial real estate and labor.<sup>7</sup> The real estate fund industry is populated by two types of agents. For each fund, there is a manager who acquires new housing and issues debt in order to produce rental housing services and a retailer who obtains such services and differentiates them at no cost in order to rent them applying a mark-up. For each type of agent, there is a continuum of individuals in the  $[0, 1]$  interval.

Some other assumptions have been made for empirical purposes and to improve the fit of the model to the data. Among others, household GHH preferences; the presence of complementarities between the consumption of durable and non-durable goods; an endogenous capital utilization rate; and a Dixit-Stiglitz aggregator to allow for intratemporal imperfect substitutability between the two types of individual labor supply (i.e., labor supply to the consumption sector and to the housing sector), on the one hand, and between homogeneous rental housing services (provided by savers) and slightly differentiated rental housing services (provided by REIFs), on the other hand.

### 3.1 Households: Savers and Borrowers

The representative patient (and impatient) household seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta_{\varkappa}^t \left[ \frac{1}{1 - \sigma_h} \left( Z_{\varkappa,t} - \frac{\tilde{N}_{\varkappa,t}^{1+\phi}}{(1 + \phi)} \right)^{1 - \sigma_h} \right], \quad (1)$$

where  $x = s, b$  denotes the type of household the problem refers to (i.e., saver or borrower),  $\beta_{\varkappa} \in (0, 1)$  is the household's discount factor ( $\beta_s < \beta_b$ ),  $\sigma_h$  stands for the risk parameter of the household and  $\phi > 0$  refers to the inverse of the Frisch elasticity. The representative saver (or borrower) consumes a basket of durable and non-durable final goods:

$$Z_{\varkappa,t} = C_{\varkappa,t}^{(1-\gamma_t)} H_{\varkappa,t}^{\gamma_t}, \quad (2)$$

where  $C_{\varkappa,t}$  denotes consumption of the final non-durable good,  $H_{\varkappa,t}^p$  refers to the services

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<sup>6</sup>The relationship between the discount factors of savers and borrowers is such that there are financial flows in equilibrium and the borrowing limits are binding in a neighborhood of the steady state (see Iacoviello 2005).

<sup>7</sup>The specification of a production function in which real estate enters as an input has become common practice in the macro-finance literature. See, e.g., Iacoviello (2005 and 2015), Andrés and Arce (2012) and Andrés et al. (2013).

from the stock of owner-occupied housing (durable good) and  $\gamma_t = \gamma \varepsilon_t^\gamma$  is the possibly time-varying share of  $H_{\mathcal{X},t}$  in consumption, where  $\gamma \in [0, 1]$  and  $\varepsilon_t^\gamma$  captures housing preference shocks.<sup>8</sup>  $\tilde{N}_{\mathcal{X},t}$  is a composite index of labor supply to the consumption sector,  $N_{\mathcal{X},t}^c$ , and the housing sector,  $N_{\mathcal{X},t}^h$ .

$$\tilde{N}_{\mathcal{X},t} = \left[ \omega_n^{1/\varepsilon} (N_{\mathcal{X},t}^c)^{(1+\varepsilon)/\varepsilon} + (1 - \omega_n)^{1/\varepsilon} (N_{\mathcal{X},t}^h)^{(1+\varepsilon)/\varepsilon} \right]^{\varepsilon/(\varepsilon+1)}, \quad (3)$$

where  $\omega_n \in (0, 1)$  is a weight parameter and  $\varepsilon$  is the elasticity of substitution between types of labor supply.<sup>9</sup>

### 3.1.1 Patient households (savers)

In the case of savers, the maximization of (1) is subject to the sequence of budget constraints:

$$\begin{aligned} C_{s,t} + B_t + \sum_{i=c,h} [I_t^i + \Phi_i(K_{s,t}^i)] + q_t \sum_{j=p,r} [H_{s,t}^j - (1 - \delta_h)H_{s,t-1}^j] \\ = P_{s,t}X_{s,t} + R_{b,t-1}B_{t-1} + \sum_{i=c,h} [W_t^i N_{s,t}^i + r_t^i u_t^i K_{s,t-1}^i] + \Pi_t, \end{aligned}$$

where  $i = c, h$  refers to the corresponding production sector (final consumption or housing) and  $j = p, r$  denotes the final use of housing (owner-occupied or rental).  $B_t$  is lending at time  $t$  and  $R_{b,t}$  is the gross interest rate on lending.  $I_t^i$  and  $K_t^i$  stand for net investment in physical capital and the stock of capital, respectively. The standard law of motion for capital applies,

$$K_{s,t}^i = (1 - \delta_t^i)K_{s,t-1}^i + I_t^i, \quad (4)$$

<sup>8</sup>Note that  $Z_{\mathcal{X},t} = C_{\mathcal{X},t}^{(1-\gamma_t)} H_{\mathcal{X},t}^{\gamma_t}$  is just a particular case of a more general specification of the final consumption index,  $Z_{\mathcal{X},t} = \left[ (1 - \gamma_t)^{1/\nu} (C_{\mathcal{X},t})^{(\nu-1)/\nu} + \gamma_t^{1/\nu} (H_{\mathcal{X},t})^{(\nu-1)/\nu} \right]^{\nu/(\nu-1)}$ , for which the elasticity of substitution between non-durables and durables (i.e., housing),  $\nu = 1$ . Such specification allows for the presence of empirically relevant complementarities between the two types of consumption. For the various empirical facts this specification of the consumption basket permits to account for, see among others, Ogaki and Reinhart (1998) and Monacelli (2008), with the latter also assuming that impatient households' borrowing limit is tied to the expected future value of the durable stock.

<sup>9</sup>Households are assumed to have GHH preferences (see Greenwood et al. 1988). This type of preferences - under which wealth effects on labor supply are arbitrarily close to zero - has been extensively used in the business cycle literature as a useful device to match several empirical regularities. As in this paper, GHH preferences have been formulated by other authors, when evaluating macroprudential policies, in order to prevent a counterfactual increase in labor supply during crises (see, e.g., Bianchi and Mendoza 2018).

where  $\delta_t^i$  is the depreciation rate of physical capital rented by firms producing in sector  $i$  and  $\delta_t^i$  is an increasing and convex function of the rate of capital utilization,  $u_t^i$ :<sup>10</sup>

$$\delta_t^i(u_t) = \delta_0^i + \delta_1^i(u_t^i - 1)^2 + \frac{\delta_2^i}{2}(u_t^i - 1)^2. \quad (5)$$

Housing depreciates at rate  $\delta_h$ .  $H_{s,t}^r$  is the part of housing accumulated by the representative saver to produce rental housing services,  $X_{s,t}$ , according to the following technology:

$$X_{s,t} = A_{s,t}H_{s,t-1}^r, \quad (6)$$

where  $A_{s,t}$  captures productivity shocks in the competitive segment of the rental housing market.  $P_{s,t}$  is the unitary price (or rent) of homogeneous rental housing services offered to renters (under competitive conditions),  $W_t^i$  is the wage rate prevailing in production sector  $i$ ,  $r_t^i$  is the corresponding rental rate on physical capital and  $\Pi_t$  denotes net profits from institutional investors.

### 3.1.2 Impatient households (borrowers)

In the case of borrowers, the maximization of (1) is restricted by a sequence of budget constraints and a borrowing limit,

$$C_{b,t} + R_{b,t-1}B_{b,t-1} + q_t [H_{b,t}^p - (1 - \delta_h)H_{b,t-1}^p] = B_{b,t} + W_t^c N_{bt}^c + W_t^h N_{bt}^h, \quad (7)$$

$$B_{b,t} \leq m_b E_t \left[ \frac{q_{t+1}}{R_{bt}} H_{b,t}^p \right]. \quad (8)$$

According to (7), each period, the representative impatient household devotes her resources in terms of wage earnings and borrowings to consume durable and non-durable goods as well as to repay her debt. Expression (8) stipulates that constrained households cannot borrow more than a fraction  $m_b \in [0, 1]$  of the expected value of their owner-occupied housing stock.

## 3.2 Renter Households

Renters seek to maximize:

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<sup>10</sup>This specification of the depreciation rate of physical capital has become standard in the business cycle literature. For the empirical relevance of the assumption see, among others, Taubman and Wilkinson (1970) and Baxter and Farr (2005). Other DSGE models in which such specification of the capital depreciation rate is assumed include, among others, Gerali et al. (2010) and Schmitt-Grohé and Uribe (2012).

$$U(Z_{r,t}, \tilde{N}_{r,t}) = \log Z_{r,t} - \frac{\tilde{N}_{r,t}^{1+\phi}}{(1+\phi)}, \quad (9)$$

where  $\tilde{N}_{r,t}$  is a composite index of labor supply analogous to the one in expression (3) and  $Z_{r,t}$  is a Dixit-Stiglitz aggregator of final (non-durable) consumption goods  $C_{r,t}$  and rental housing services  $\tilde{X}_{r,t}$ . Formally,

$$\tilde{N}_{r,t} = \left[ \omega_n^{1/\varepsilon} (N_{r,t}^c)^{(1+\varepsilon)/\varepsilon} + (1 - \omega_n)^{1/\varepsilon} (N_{r,t}^h)^{(1+\varepsilon)/\varepsilon} \right]^{\varepsilon/(1+\varepsilon)}, \quad (10)$$

$$Z_{r,t} = C_{r,t}^{(1-\gamma_t)} \tilde{X}_{r,t}^{\gamma_t}, \quad (11)$$

where  $\tilde{X}_{r,t}$  is a composite of homogeneous rental housing services provided by savers under perfect competition,  $X_{sr,t}$ , and slightly differentiated rental housing services provided by institutional investors under monopolistic competition,  $x_{fr,t}$ .

$$\tilde{X}_{r,t} = \left[ \omega_x^{1/\eta_r} (x_{fr,t})^{(\eta_r-1)/\eta_r} + (1 - \omega_x)^{1/\eta_r} (X_{sr,t})^{(\eta_r-1)/\eta_r} \right]^{\eta_r/(\eta_r-1)}, \quad (12)$$

where  $\omega_x \in (0, 1)$  is a weight parameter,  $\eta_r \geq 0$  is the elasticity of substitution between types of rental housing services and  $x_{fr,t}$  is a composite index that aggregates a continuum of rental housing varieties represented by the interval  $[0, 1]$ ,

$$x_{fr,t} = \int_0^1 \left[ x_{fr,t}(i)^{(\eta_r-1)/\eta_r} di \right]^{\eta_r/(\eta_r-1)}, \quad (13)$$

with  $x_{fr,t}(i)$  representing the quantity of variety  $i$  consumed by the representative renter in period  $t$ .<sup>11</sup> Although the assumption of preference for rental housing varieties at the micro level may seem unrealistic, this is just a modeling device to capture the fact that, at the aggregate level, there is a preference for variety in the rental housing market.<sup>12</sup>

Maximization of (9) is subject to a budget constraint given by

$$C_{r,t} + P_{s,t} X_{sr,t} + \int_0^1 p_{fr,t}(i) x_{fr,t}(i) di = W_t^c N_{r,t}^c + W_t^h N_{r,t}^h, \quad (14)$$

where  $p_{fr,t}(i)$  stands for the unitary price of variety  $i$ . Total resources in terms of wage earnings obtained by renters in period  $t$  are devoted to consume non-durable goods and

<sup>11</sup>Note that, for the sake of simplicity, I have assumed that the elasticity of substitution between rental housing services provided by savers and those provided by institutional investors,  $\eta_r$ , is constant and identical to the elasticity of substitution across varieties.

<sup>12</sup>Product differentiation in rental housing markets can be interpreted from very different perspectives (e.g., neighbourhood and location, number of rooms, services included in the rent, type of housing and building, furniture, etc).

rental housing services within the same period. That is, the optimization problem of the representative renter household is static.<sup>13</sup>

The inverse demand functions for the homogeneous rental housing services and for variety  $i$  can be derived from the first order conditions of the problem

$$P_{s,t} = \frac{\gamma_t}{\tilde{X}_{r,t} \lambda_{r,t}} \left[ (1 - \omega_x) \frac{\tilde{X}_{r,t}}{X_{sr,t}} \right]^{1/\eta_r}, \quad (15)$$

$$p_{fr,t}(i) = \frac{\gamma_t}{\tilde{X}_{r,t} \lambda_{r,t}} \left[ \omega_x \frac{\tilde{X}_{r,t}}{x_{fr,t}(i)} \right]^{1/\eta_r}. \quad (16)$$

### 3.3 Firms

#### 3.3.1 Non-housing producing firms

The representative non-housing producing firm chooses the demand schedules for labor  $N_{c,t}$ , physical capital  $K_{c,t}$  rental housing variety supplied by real estate fund  $j$ ,  $x_{fc,t}(j)$ , and homogeneous rental housing services provided by savers  $X_{sc,t}$  that maximize

$$Y_{c,t} - W_t^c N_{c,t}^c - r_{k,t}^c K_{c,t}^c - \int_0^1 p_{fc,t}(j) x_{fc,t}(j) dj - P_{s,t} X_{sc,t}. \quad (17)$$

The homogeneous final good is produced by using a Cobb-Douglas technology that combines labor, physical capital and rental housing services as follows

$$Y_{c,t} = A_{c,t} (u_t^c K_{c,t}^c)^\alpha \tilde{X}_{c,t}^\nu N_t^{c(1-\alpha-\nu)}, \quad (18)$$

where  $A_{c,t}$  captures technology shocks in the non-housing production sector,  $\alpha$  and  $\nu$  are the weights of physical capital and commercial real estate in non-housing production, respectively, and  $\tilde{X}_{c,t}$  is a composite of homogeneous rental housing services provided by savers under perfect competition,  $X_{sc,t}$ , and slightly differentiated rental housing services provided by institutional investors under monopolistic competition,  $x_{fc,t}$ .

$$\tilde{X}_{c,t} = \left[ \omega_x^{1/\eta_c} (x_{fc,t})^{(\eta_c-1)/\eta_c} + (1 - \omega_x)^{1/\eta_c} (X_{sc,t})^{(\eta_c-1)/\eta_c} \right]^{\eta_c/(\eta_c-1)}, \quad (19)$$

where  $\omega_x \in (0, 1)$  is a weight parameter,  $\eta_c \geq 0$  is the elasticity of substitution between types of rental housing services and  $x_{fc,t}$  is a composite index that aggregates a continuum of rental housing varieties represented by the interval  $[0, 1]$

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<sup>13</sup>In this model, renter households play the role of "hand-to-mouth" as they fully consume their disposable income every period.

$$x_{f,c,t} = \int_0^1 \left[ x_{f,c,t}(j)^{(\eta_c-1)/\eta_c} dj \right]^{(\eta_c-1)/\eta_c}, \quad (20)$$

with  $x_{f,c,t}(j)$  representing the quantity of variety  $j$  consumed by the representative non-housing producing firm in period  $t$

### 3.3.2 Housig producing firms

Similarly, the representative housing producing firm chooses the demand schedules for labor  $N_t^h$  and physical capital  $K_t^h$  that maximize:

$$IH_t - W_t^h N_t^h(j) - r_{k,t}^h K_{t-1}^h, \quad (21)$$

where  $IH_t$  stands for net investment in real estate (or total construction) in period  $t$  and is produced by using a Cobb-Douglas technology that combines labor and physical capital as follows

$$IH_t = A_{h,t} (u_t^h K_{t-1}^h)^\theta N_t^{h(1-\theta)} \quad (22)$$

where  $A_{h,t}$  captures technology shocks in the housing production sector and  $\theta$  is the share of physical capital in housing production. The standard law of motion for capital accumulation applies to the stock of real estate,  $H_t$ . Formally,

$$H_t = (1 - \delta_h)H_{t-1} + IH_t. \quad (23)$$

with  $\delta_h$  being the depreciation rate of housing.

## 3.4 Real Estate Funds

In a context in which renter households and non-housing producing firms have a preference for variety in the rental housing market, real estate funds play the key role of providing such agent types with slightly differentiated rental housing services under monopolistic competition. Fund managers accumulate housing and issue debt in order to produce rental housing services. Fund retailers obtain such services and differentiate them at no cost in order to rent them (to renter households and no housing producing firms) applying a mark-up. The aim of assuming that real estate fund managers operate in the rental housing market under monopolistic competition is twofold. First, from the demand side, renters exhibit a preference for variety at the aggregate level. Second, from the supply side, a real estate fund typically purchases a large amount of housing with a common characteristic (e.g., same neighborhood,

similar type of housing, etc) that confers her the capacity to set prices in that specific segment of the market (i.e., the representative real estate fund has market power in the market of her own variety).

### 3.4.1 Fund managers

Let  $\Pi_{f,t}$  be net profits,  $\sigma$  the elasticity of intertemporal substitution and  $\Lambda_{0,t}^f = \beta_s \frac{\lambda_{s,t+1}}{\lambda_{s,t}}$  the stochastic discount factor of fund managers with  $\lambda_{s,t}$  being the Lagrange multiplier on the budget constraint of the representative patient household. Then, the representative fund manager maximizes

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^f \frac{1}{(1 - \frac{1}{\sigma})} \Pi_{f,t}^{(1 - \frac{1}{\sigma})} \quad (24)$$

Subject to

$$\Pi_{f,t} + R_{b,t} B_{f,t-1} + q_t [H_{f_r,t}^r + H_{f_c,t}^r - (1 - \delta_h) (H_{f_r,t-1}^r + H_{f_c,t-1}^r)] = B_{f,t} + P_{f_r,t} X_{f_r,t} + P_{f_c,t} X_{f_c,t}, \quad (25)$$

$$B_{f,t} \leq m_f E_t \left[ \frac{q_{t+1}}{R_{b,t}} (H_{f_r,t}^r + H_{f_c,t}^r) \right], \quad (26)$$

$$X_{f_r,t} = \bar{A}_{f_r,t} H_{f_r,t-1}^r, \quad (27)$$

$$X_{f_c,t} = \bar{A}_{f_c,t} H_{f_c,t-1}^r, \quad (28)$$

where equations (25), (26), (27) and (28) refer to the sequence of cash flow restrictions, the borrowing limit and the corresponding technologies by which fund managers transform their stock of housing into rental housing services for renter households and final goods producing firms, respectively.

$H_{f_r,t}^r$  and  $H_{f_c,t}^r$  stand for the quantities of housing accumulated by the representative fund manager to produce rental housing services for renter households,  $X_{f_r,t}$ , and non-housing producing firms,  $X_{f_c,t}$ , whereas  $P_{f_r,t}$  and  $P_{f_c,t}$  denote the corresponding market prices for rental housing services.  $B_{f,t}$  is debt issued by the fund manager in period  $t$  and  $m_b \in [0, 1]$  the fraction of the expected value of her housing stock that limits her borrowing capacity.  $\bar{A}_{f_r,t} = A_{f_r} A_{f,t}$  and  $\bar{A}_{f_c,t} = A_{f_c} A_{f,t}$  are dynamic productivity parameters;  $A_{f_r} > 0$  and  $A_{f_c} > 0$  measure the efficiency with which fund managers transform property housing into

rental services whereas  $A_{f,t}$  captures productivity shocks in the segment of the rental housing market operated by REIFs.

The following optimality conditions can be derived from the first order conditions of the problem:

$$\Pi_{f,t}^{-\frac{1}{\sigma}} \left[ q_t - m_f E_t \left( \frac{q_{t+1}}{R_{b,t}} \right) \right] = \Lambda_{0,t}^e E_t \left\{ \Pi_{f,t+1}^{-\frac{1}{\sigma}} \left[ P_{fr,t+1} \bar{A}_{fr,t+1} q_{t+1} (1 - \delta_h - m_f) \right] \right\}, \quad (29)$$

$$\Pi_{f,t}^{-\frac{1}{\sigma}} \left[ q_t - m_f E_t \left( \frac{q_{t+1}}{R_{b,t}} \right) \right] = \Lambda_{0,t}^e E_t \left\{ \Pi_{f,t+1}^{-\frac{1}{\sigma}} \left[ P_{fc,t+1} \bar{A}_{fc,t+1} q_{t+1} (1 - \delta_h - m_f) \right] \right\}. \quad (30)$$

### 3.4.2 Fund retailers

Each retailer obtains wholesale rental housing services,  $X_{fr,t}(i)$  and  $X_{fc,t}(j)$ , from the wholesale unit at prices  $P_{fr,t}$  and  $P_{fc,t}$ , differentiate them at no cost and rent them to renter households and non-housing producing firms applying two different mark-ups. The problem of the representative fund retailer is to choose  $\{p_{fr,t}(i), p_{fc,t}(j)\}$  that maximize

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^f \left[ p_{fr,t}(i) x_{fr,t}(i) + p_{fc,t}(j) x_{fc,t}(j) - P_{fr,t} X_{fr,t}(i) - P_{fc,t} X_{fc,t}(j) \right] \quad (31)$$

subject to the aggregate demand functions for rental housing varieties  $i$  and  $j$

$$x_{fr,t}(i) = \left( \frac{p_{fr,t}(i)}{p_{fr,t}} \right)^{-\eta_r} x_{fr,t}, \quad (32)$$

$$x_{fc,t}(j) = \left( \frac{p_{fc,t}(j)}{p_{fc,t}} \right)^{-\eta_c} x_{fc,t}, \quad (33)$$

where  $p_{fr,t}$  and  $p_{fc,t}$  can be interpreted as rental housing price indices for renter households and non-housing producing firms, respectively.

$$p_{fr,t} = \left[ \int_0^1 p_{fr,t}(i)^{(1-\eta_r)} di \right]^{1/(1-\eta_r)}, \quad (34)$$

$$p_{fc,t} = \left[ \int_0^1 p_{fc,t}(j)^{(1-\eta_c)} dj \right]^{1/(1-\eta_c)}. \quad (35)$$

The first order conditions yield, after imposing a symmetric equilibrium

$$p_{fr,t} = \frac{\eta_r}{(\eta_r - 1)} P_{fr,t}, \quad (36)$$

$$p_{fc,t} = \frac{\eta_c}{(\eta_c - 1)} P_{fc,t}. \quad (37)$$

### 3.5 Aggregation and Market Clearing

By the Walras' law, all markets clear. The aggregate resource constraint of the economy represents the equilibrium condition for the final goods market.

$$Y_t = Y_{c,t} + q_t I H_t, \quad (38)$$

$$Y_t = C_{t,t} + I_{c,t} + I_{h,t} + q_t I H_t + \Phi(K_{c,t}) + \Phi(K_{h,t}). \quad (39)$$

where expressions (38) and (39) refer to the GDP of the economy from the output and the expenditure approach perspectives, respectively, and  $C_t = C_{s,t} + C_{b,t} + C_{r,t}$  denotes aggregate consumption. Similarly, the labor market, the physical capital markets, the credit market, the property housing market and the different segments of the rental housing services market all clear in equilibrium (see Appendix B for the full set of equilibrium conditions).

### 3.6 Macroprudential Policy

Consider three macroprudential policy scenarios alternative to the baseline case presented above. In each of them, the macroprudential authority has at hand - as an instrument - one or two of the following dynamic LTV ratios

$$m_{b,t} = \rho_b m_{b,t-1} + (1 - \rho_b) m_b + (1 - \rho_b) m_{bx} \left( \frac{x_t}{x} - 1 \right), \quad (40)$$

$$m_{f,t} = \rho_f m_{f,t-1} + (1 - \rho_f) m_f + (1 - \rho_f) m_{fx} \left( \frac{x_t}{x} - 1 \right), \quad (41)$$

where  $\rho_b$  and  $\rho_f$  are the corresponding autorregressive parameters,  $m_b$  and  $m_f$  are the static LTV limits (recall expressions 8 and 26),  $m_{bx}$  and  $m_{fx}$  are the macroprudential response parameters and  $x_t$  is a macroeconomic indicator of the choice of the regulator, while  $x$  corresponds to its steady state level.

### 3.6.1 The transmission mechanism

As the macroprudential rule that has not yet been explored in the literature refers to equation 41), I investigate its workings and the main transmission channel through which it operates. In doing so, I assume that the economy initially is in the steady state, where optimality conditions (29) and (30) read:

$$P_{fr} = \frac{q \left[ 1 - \Lambda^e(1 - \delta_h) - m_f \left( \frac{1}{R_b} - \Lambda^e \right) \right]}{\Lambda^e A_{fr}}, \quad (42)$$

$$P_{fc} = \frac{q \left[ 1 - \Lambda^e(1 - \delta_h) - m_f \left( \frac{1}{R_b} - \Lambda^e \right) \right]}{\Lambda^e A_{fc}}. \quad (43)$$

Expressions (42) and (43) stipulate that the sign of  $\frac{\partial P_{fr}}{\partial m_f}$  and  $\frac{\partial P_{fc}}{\partial m_f}$  (and, ultimately, the impact a tightening in  $m_{f,t}$  has on imperfectly competitive prices  $p_{fr,t}$  and  $p_{fc,t}$ ), after a particular shock has hit the economy, depends on the sign of the term  $\left( \frac{1}{R_b} - \Lambda^e \right)$ . In many cases, a positive shock pushes lending rates downwards (i.e.,  $R_{b,t} < R_b$ ), implying  $\left( \frac{1}{R_b} - \Lambda^e \right) > 0$  and, consequently,  $\frac{\partial P_{fr}}{\partial m_f} < 0$  and  $\frac{\partial P_{fc}}{\partial m_f} < 0$ . That is, tightening LTV ratios in the face of certain positive exogenous shocks restricts the borrowing capacity of fund managers and, thus, their activity. Fund managers then find optimal to demand less housing, which favours property prices to evolve in a smoother fashion. The corresponding decline in supplied differentiated rental housing services pushes  $p_{fr,t}$  and  $p_{fc,t}$  upwards. As a result of this, the share of savers in the rental housing market increases, thereby exerting a downward pressure on the competitive rental housing price,  $P_{s,t}$ . The bottom line is that, under plausible conditions, countercyclical LTV ratios affecting the borrowing capacity of REIFs smooth lending, property prices and reference (i.e., competitive) rental housing prices over the cycle.

## 4 Quantitative Analysis

The main goal of this section is to assess the potential of dynamic LTV limits to smooth lending and housing prices over the cycle. In order to do so, I assume that the prudential authority seeks to minimize an ad-hoc loss function specified as the weighted asymptotic variance (or linear combination of variances) of a macroeconomic indicator (or set of indicators)

of the choice of the regulator.<sup>14</sup>

## 4.1 Calibration

I calibrate the model to quarterly euro area data for the period 2002:I-2018:II in three steps. First, several parameters are set following convention (table 1A). Some of them are standard in the literature. Some others are based on papers in the field of macro-finance. The inverse of the Frisch elasticity of labor is set to a value of 1, whereas the risk aversion parameter of household preferences, the elasticity of substitution between labor types and the elasticity of substitution between rental housing varieties are fixed to standard values of 2, 1 and 2, respectively. Loan-to-value ratios on residential and commercial real estate are set equal to 0.7 and 0.6, respectively. The former is based on data of the big four euro area economies and coincides with the value presented in Gerali et al. (2010), and Quint and Rabanal (2014), among many others. The latter coincides with the maximum LTV limit the EU regulation on prudential requirements for credit institutions and investment firms imposes for the case of commercial mortgages.<sup>15</sup> The parameter values of the dynamic depreciation rates of physical capital and that of the real estate's share in non-housing production,  $v$ , are taken from Iacoviello and Neri (2010), Gerali et al. (2010) and Iacoviello (2015).

Second, another group of parameters is calibrated by using steady state targets (see tables 1B and 2A). The patient households' discount factor,  $\beta_s = 0.995$ , is chosen such that the annual interest rate equals 2%. The impatient households' discount factor is set to 0.975, so as to match a household loans-to-GDP ratio of 2.14. The housing weight parameter of the households' consumption aggregator,  $\gamma$ , is fixed to a value of 0.168 to match an aggregate consumption-to-GDP ratio of 0.76. The physical capital's share in non-housing and housing production,  $\alpha$  and  $\theta$ , are set to 0.144 and 0.025 to match an aggregate investment-to-GDP

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<sup>14</sup>Importantly, this exercise should not be interpreted as an attempt to adopt a normative approach and replace a hypothetical welfare analysis. Instead, the goal is to evaluate the effectiveness of countercyclical LTV limits in smoothing aggregates whose developments are closely monitored by macroprudential authorities due to the fact that they incorporate information on the potential build up of macro-financial imbalances (e.g., the credit-to-GDP gap and property prices). A welfare analysis is beyond the scope of this paper and the proposed set up may not be the most adequate one for carrying out such exercise as it would require to make very strong value judgements that could be easily rejected (e.g., to select a criterion for aggregating individual preferences in a context in which the objective function specified for the case of savers and borrowers differs from that of renters due to the fact that the optimization problem faced by the former is dynamic and the one faced by the latter is static).

<sup>15</sup>Note that uncertainty surrounding the empirical value of parameter  $m_f$  is high, among other reasons because a significant fraction of total credit flowing to REIFs is not being provided by the banking sector. Moreover, in this set up  $m_f$  crucially determines the debt-to-assets ratio of REIFs, whose empirical value is also uncertain, among other reasons, because investment funds often lever up synthetically through the use of derivatives (for which data is not readily available). Consequently,  $m_f$  is one of the parameters for which the sensitivity of the main results of the paper is checked in section 5.

ratio of 0.212 and a housing investment-to-GDP ratio of 0.118, respectively. The weight parameter of hours worked in the non-housing production sector that enters the households' labor supply aggregator is set to 0.51 to match a housing wealth-to-GDP ratio of 2.802. The weight parameter of real estate funds' rental housing in rental aggregators is fixed to a value of 0.445 to match an institutional investors' real estate-to-total housing ratio of approximately 0.05.<sup>16</sup> The depreciation rate of real estate is set to 0.010 to match a rental housing-to-total housing ratio of 0.327.

Third, the size of shocks and the physical capital adjustment cost parameter are calibrated to improve the fit of the model to the data in terms of relative volatilities (see tables 1C and 2B). The capital adjustment cost parameter  $\phi_k$  is set to target a relative standard deviation of total lending of 6.47%. I have matched the second moments of key macroeconomic aggregates, including housing investment and property prices, by calibrating the size of the various productivity and housing preference shocks. As in other references of the macro-finance literature (see, e.g., Clerc et al. 2015 and Mendicino et al. 2018), the autoregressive coefficients in the AR(1) processes followed by all shocks are set equal to 0.9. With regards to the policy block, I follow Lambertini et al. (2013) and fix  $\rho_b$  and  $\rho_f$  to a value of 0.5.<sup>17</sup>

## 4.2 Optimized LTV Policy Rules

With the aim of evaluating the effectiveness of dynamic LTV limits in smoothing the credit and the housing cycle in this environment, I assume the macroprudential authority solves the following problem under full commitment

$$\arg \min_{\Theta} L^{mp} = \omega_z \sigma_z^2 \quad \omega_z > 0, \quad (44)$$

where  $\Theta$  refers to the vector of policy parameters with respect to which the policymaker solves the optimization problem and  $\sigma_z^2$  is the asymptotic variance of a macroeconomic indicator of

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<sup>16</sup>The estimate of the numerator of this ratio is based on the balance sheet's information of real estate funds whose main geographical focus is the euro area as well as on estimates of the share of REIFs in rental markets provided by various property consulting firms. However, this estimate should be taken cautiously as there is still a lack of full transparency regarding all transactions and balance sheets of REIFs. The ESRB has already recommended to close real estate data gaps related to housing investors: [https://www.esrb.europa.eu/pub/pdf/recommendations/esrb.recommendation190819\\_ESRB\\_2019-3~6690e1fbd3.en.pdf](https://www.esrb.europa.eu/pub/pdf/recommendations/esrb.recommendation190819_ESRB_2019-3~6690e1fbd3.en.pdf). For this reason, one of the robustness checks presented in section 5 consists in evaluating how results of the quantitative analysis change as the share of REIFs in rental markets vary, by exploiting the fact that changes in  $\omega_x$  lead to variations in the institutional investors' housing-to-total housing ratio without significantly affecting the rest of the calibration targets.

<sup>17</sup>All time series expressed in Euros are seasonally adjusted and deflated. With regards to the matching of second moments, the log value of deflated time series has been linearly detrended before computing standard deviation targets. All details on data description and construction are available in Appendix A.

the choice of the regulator (i.e.,  $z_t$ ).<sup>18</sup> Based on the literature and without loss of generality, the exercise assumes that  $\omega_z = 1$  and  $x_t = Y_t$  (see, e.g., Angelini et al. 2014 and Muñoz 2020).

I consider three macroprudential policy scenarios alternative to the baseline case presented in section 3, each of them associated to one of the three eligible macroprudential parameter vectors  $\Theta \equiv \{m_{bx}; m_{fx}; (m_{bx}, m_{fx})\}$ . In order to identify the optimized LTV rules within the classes (40) and (41) that solve (44) for the three considered policy scenarios, it has been searched over the following grids of parameter values:  $m_{bx} \{(-9) - 0\}$  and  $m_{fx} \{(-100) - 0\}$ . Based on the recent literature on optimized LTV ratios, I have restricted the grids of values to those related to non-procyclical LTV policy rules (i.e.,  $m_{bx} \leq 0$  and  $m_{fx} \leq 0$ ). While I follow Lambertini et al. (2013) to set the grid of values for  $m_{bx}$ , I select a wider range of values for  $m_{fx}$  as this policy parameter has not been explored in the recent literature.

Table 3 reports the optimized policy parameters related to the solution to problem (44) and the corresponding percentage change in macroprudential losses with respect to the baseline scenario. The exercise is carried out for four different arguments of the loss function,  $z \equiv \{B/Y; B; P_s; q\}$  (i.e., the credit-to-output ratio, aggregate lending, rental housing prices in the perfectly competitive segment, and property housing prices), and for the three alternative policy scenarios (see the main results for the solution to problem (44) with respect to  $m_{bx}$ ,  $m_{fx}$  and  $\{m_{bx}, m_{fx}\}$  in parts (i), (ii) and (iii) of table 3, respectively).<sup>19</sup>

The main findings can be summarized as follows. The optimized rule within the class of policy rules (41) is more effective in smoothing property prices and the credit cycle (and the credit-to-output gap) than the optimized rule within the class (40), even though the stocks of housing and borrowing held by impatient households are notably larger than those held by fund managers. Moreover, if the aim of the prudential authority is to minimize the asymptotic variance of a credit gap or that of property prices, the best option is to solely have a dynamic LTV rule of the type (41) in place (i.e., policy rule (40) is basically redundant). The key reason underlying these results relates to the strong interconnectedness of REIFs' activity with the dynamics of key economic sectors, including the rental housing market as well as the housing and non-housing production sectors. Lastly, while both rules complement each other when it comes to smoothing perfectly competitive rental prices, the optimized rule within the class (41) is substantially more responsive than that of the type (40).

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<sup>18</sup>In a more general set up  $\sigma_z^2$  could represent a linear combination of variances of indicators of the choice of the public authority.

<sup>19</sup>Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare* (see Adjemian et al. 2011).

Figures 2 to 6 report the impulse responses of selected key aggregates to the exogenous shocks that are assumed to hit the economy. Without loss of generality, this exercise assumes that  $z_t = P_{s,t}$  (i.e., perfectly competitive rental prices), the only case in which the optimized LTV policy rule on residential mortgages,  $m_{bx,t}^*$ , is more effective than the optimized LTV policy rule on commercial mortgages,  $m_{fx,t}^*$ .<sup>20</sup> Interestingly, even in this case, the optimized policy rule within the class (41) seems to be more effective in smoothing aggregates of the real economy - such as output, final consumption or housing investment (i.e., total construction) - than that of the type (40).

### 4.3 Competition Policy vs Dynamic LTV Limits

Table 4 informs about the mean effects and volatility effects of introducing: (i) perfect competition in the real estate funds' industry, and (ii) optimized (countercyclical) LTV limits. Column (A) reports the percentage changes in the stochastic means and standard deviations of selected aggregates under an alternative scenario of perfect competition (in the segment of the rental housing market operated by real estate funds) with respect to the baseline scenario. While most of the level effects are positive and significant, stabilization effects are negligible if not negative. The levels of housing and non-housing economic activity increase but that comes at the cost of having to tolerate higher and more volatile levels of debt, property housing prices and competitive rental housing prices.<sup>21</sup>

Columns (B) and (C) report the same information, with the difference that the alternative scenarios differ from the baseline case in that the optimized LTV ratio that limits the borrowing capacity of real estate funds,  $m_{fx,t}^*$ , has been introduced. Not surprisingly, while level effects are comparatively modest in these cases, this type of macroprudential policies are effective in smoothing lending, housing prices and, ultimately, aggregates of the real economy. That is, in this case competition and macroprudential policies seem to complement one another.

Interestingly, columns (B) and (C) provide quantitative information on the transmission of dynamic LTV limit (on commercial mortgages) effects through rental housing markets. The countercyclical limit to their borrowing capacity obliges REIFs to restrict their rental housing supply,  $X_f = X_{fr} + X_{fc}$ . Consequently, their share in the rental housing industry,  $X_f/X$ , declines and rental prices charged by REIFs,  $P_{fr}$  and  $P_{fc}$  increase. A larger proportion of the market being operated under perfect competition means that overall rental

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<sup>20</sup>Note that the term "effective" in this case refers to the capacity of the policy rule to minimize the asymptotic variance of the indicator under consideration (i.e.,  $z_t = P_{s,t}$ ), under full commitment.

<sup>21</sup>Andrés and Arce (2012) find that policies aimed at fostering competition in a banking sector that operates under monopolistic competition induce similar mean and volatility effects.

housing supply,  $X$ , increases. The policy smooths competitive rental housing prices, which now apply to a larger proportion of the transactions held in rental markets.

## 5 Robustness Checks

This section investigates the robustness of the main results of the quantitative analysis (reported in table 3) to changes in key parameter values and in certain assumptions considered for empirical purposes. The exercise suggests that such results are remarkably robust across alternative specifications and calibrations (of key parameters) of the model.

### 5.1 Alternative Parameter Values

In the first part of this subsection, I further assume that  $z_t = p_{s,t}$  to investigate how changes in key parameters (related to institutional investors and rental housing markets) affect the results presented in table 3. Table 5 reports the corresponding results after having solved problem (44) for different values of the elasticity of substitution between rental housing varieties (it has been assumed that  $\eta_r = \eta_c = \eta$ ). Interestingly, the higher the degree of fund retailers' market power is (i.e., the closer the value of  $\eta$  is to unity), the more responsive optimized rules are and the more effective dynamic LTV ratios are in minimizing macroprudential losses.

Table 6 presents the same type of results after having solved problem (44) for different values of the fund manager's productivity parameter  $A_f$  (assuming that  $A_f = A_{fr} = A_{fc}$ ). The more productive fund managers are in transforming property housing into rental housing services, the more effective countercyclical LTV ratios are and the less responsive the policy rule within the class (41) needs to be in order to minimize macroprudential losses.

Table 7 informs about the sensitivity of the same results to changes in the static LTV limit on commercial mortgages,  $m_f$ , and, hence, to changes in REIFs' leverage. While changes in  $m_f$  only modestly affect the effectiveness of countercyclical LTV policies; the larger the LTV limit on commercial mortgages is, the more responsive optimized countercyclical LTV rules on residential mortgages are and the less responsive optimized LTV rules within the class (41) are.

Table 8 checks the robustness of the main results to changes in the weight parameter of funds' rental services in the rental services aggregator of renters and non-housing producing firms,  $\omega_x$  (i.e., expressions 12 and 19). The larger the proportion of total housing held by fund managers is (i.e., the higher the value of  $\omega_x$  is), the more effective rules within the class (41) are and the less responsive they need to be in order to minimize macroprudential

losses.<sup>22</sup>

Figures 7 to 10 report, for the alternative calibrations of the four parameters under consideration, the impulse-responses of key selected aggregates to all shocks under a hypothetical macroprudential scenario in which  $m_{fx} = -10$ . Not surprisingly, those calibrations under which countercyclical LTV rules on commercial mortgages are comparatively more effective in smoothing the financial cycle, are those under which the same type of policy rules are relatively more effective in taming the business cycle.

In the second part of this subsection, I consider  $z \equiv \{B/Y; B; q\}$  to assess whether the main results presented in table 3 still hold under the above considered parameterizations for which optimized LTV policy rules on commercial mortgages are comparatively less effective (i.e.,  $\eta = 6$ ,  $A_f = 0.5$ ,  $m_f = 0.4$ , and  $\omega_x = 0.10$ ). Indeed, tables 9, 10, 11 and 12 make clear that, even in these cases the main findings of the quantitative analysis still apply. The optimized policy rule within the class (41) is more effective in stabilizing the credit gap, the credit-to-output gap, and property prices than the optimized rule within the class (40). Furthermore, if the objective of the prudential authority is to minimize property price and credit cycles, the best alternative is to fully rely on a countercyclical LTV policy rule of the type (41) (i.e., policy rule (40) is redundant).

## 5.2 Alternative Assumptions

In this subsection I assume that  $z \equiv \{B/Y; B; P_s; q\}$  to check the robustness of the results reported in table 3 to changes in selected key assumptions that were incorporated to the model due to empirical purposes and in order to improve the fit of the model to the data. Table 13 presents the corresponding results after having solved problem (44) for the case in which physical capital depreciation rates are exogenous and constant, rather than variable and dependant on the capital utilization rate (recall equation 5). Overall conclusions remain unchanged. However, under constant capital depreciation rates, optimized LTV policy rules on commercial mortgages are even more responsive and relatively more effective in taming the credit cycle and property prices whereas optimized LTV policy rules on residential mortgages are comparatively less effective.

Lastly, table 14 reports the main results of the quantitative analysis for the particular case in which preferences on consumption of durable goods and non-durable goods are separable. In particular, the objective function of patient and impatient households is specified as

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<sup>22</sup>Recall that changing the value of parameter  $\omega_x$  affects the proportion of housing held by fund managers while leaving the rest of the steady state calibration targets roughly unchanged. A value of 0.10; 0.445, and 0.80 for parameter  $\omega_x$  corresponds to a REIFs' housing-to-total housing ratio of roughly 1%, 5%, and 10%, respectively.

follows:

$$E_0 \sum_{t=0}^{\infty} \beta_{\varkappa}^t \left[ \frac{1}{1 - \sigma_h} \left( C_{\varkappa,t} - \frac{\tilde{N}_{\varkappa,t}^{1+\phi}}{(1 + \phi)} \right)^{1 - \sigma_h} + \gamma_t \log H_{\varkappa,t}^p \right]. \quad (45)$$

Similarly, the objective function of renter households now reads

$$U(C_{r,t}, \tilde{X}_{r,t}, \tilde{N}_{r,t}) = \log C_{r,t} + \gamma_t \log \tilde{X}_{r,t} - \frac{\tilde{N}_{r,t}^{1+\phi}}{(1 + \phi)}, \quad (46)$$

The most important conclusion of this exercise is that, absent any degree of complementarity between the consumption of durables and non-durables, the main findings still apply but the overall effectiveness of countercyclical LTV policies in this set up becomes marginal. This result highlights the importance of allowing for the presence of complementarities between the two types of consumption in order for the transmission mechanism underscored in expressions (42) and (43) to operate and countercyclical LTV policies to be effective. If the consumption of durables and non-durables is complementary, a tightening of LTV ratios (in the face of positive shocks) that moderates the increase of lending and housing investment is going to call for a more moderate increase of final (non-durables) consumption and will, ultimately, be effective in smoothing the business cycle.

Beyond the importance of assuming that households consume a basket of durables and non-durables of the type (2) and (11) in order to account for a variety of empirical facts at the macroeconomic level (see, e.g., Ogaki and Reinhart 1998 and Monacelli 2008), allowing for a certain degree of complementarity between the consumption of durables and non-durables seems to be empirically relevant from a microeconomic perspective; Much of the (non-durable) consumption activities undertaken by household members in practice occur when they are inside their houses. That is, there are complementarities between the two types of consumption.

## 6 Conclusion

Based on recent empirical studies, the paper incorporates real estate institutional investors and rental housing markets in a two-sector DSGE model populated by three types of households (savers, borrowers and renters). These investors leverage buy-to-rent housing investments and supply slightly differentiated rental housing services that permits them to apply a mark up. The quantitative analysis reveals several important conclusions. First, the activity of housing investment firms seems to have non-negligible macroeconomic effects and amplifies procyclicality. Second, dynamic LTV ratios that directly impact the borrowing's capacity of

these investors are more effective in smoothing the property and the credit cycle than the already well investigated LTV limits affecting indebted households' decisions. Moreover, if the sole objective of the macroprudential authority is to tame the housing price and credit cycle, the best she can do is to have an LTV rule affecting REIFs' borrowing limits at hand (i.e., the LTV rule limiting households' borrowing capacity seems to be redundant). Such findings are impressively robust across key alternative specifications and calibrations of the model.

These findings may shed light on some of the potential avenues for strengthening the macroprudential policy framework for non-banks. There are at least two policy instruments that could be considered to tackle the issue of funds' leverage-induced procyclicality in practice and which are still not in place: (dynamic) limits on REIFs' leverage and countercyclical LTV limits on non-bank lending. Moreover, the quantitative analysis notes that such (quantity) regulation would allow for reference prices in rental housing markets to increase less abruptly during the boom, an issue that policymakers in several countries of the euro area have attempted to handle via price regulation (an alternative that could generate price distortions).

There are various dimensions along which the current analysis could be extended in order to have a better understanding of the workings, trade-offs and policy interactions of LTV limits affecting real estate funds' decisions. Among others, by assuming full heterogeneity of households or by including the monetary block in the model to assess the interactions between monetary and macroprudential policies in this environment.

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Table 1: Baseline parameter values

Parameter	Description	Value	Source/Target ratio
A) Pre-set params			
$\varphi$	Inverse of the Frisch elasticity	1	Standard
$\sigma_h$	HH risk aversion param.	2	Standard
$\varepsilon$	Elast. of subst. labor types	1	Standard
$\eta_r; \eta_c$	Elast. of subst. rental RE varieties	2	Standard
$m_b$	LTV ratio on residential mortgages	0.7	Standard
$m_f$	LTV ratio on commercial mortgages	0.6	Standard
$\delta_0^c; \delta_0^h$	Depreciation rates of physical capital	0.025; 0.03	Iacoviello & Neri (2010)
$\delta_1^i; \delta_2^i$	Endogenous depr. rate params.	$r_{ke}; 0.1^*r_{ke}$	Gerali et al. (2010)
$v$	RE share in non-RE production	0.04	Iacoviello (2015)
B) First moments			
$\beta_s$	Savers' discount factor	0.995	$R_h = (1.02)^{1/4}$
$\beta_b$	Borrowers' discount factor	0.975	$B_b/(Y) = 2.1403$
$\gamma$	Housing share in Cons. aggregator	0.168	$C/Y = 0.7607$
$\alpha$	Capital share in non-RE production	0.144	$I/Y = 0.2119$
$\theta$	Capital share in RE production	0.025	$qIH/Y = 0.1176$
$\omega_n$	Weight in labor supply aggregator	0.510	$(qH)/(4Y) = 2.802$
$\omega_x$	REIFs' weight in rental RE aggregator	0.445	$H_f^r/H \approx 0.050$
$\delta_h$	Depreciation rate of RE	0.010	$X/H = 0.3269$
C) Second moments			
$\phi_k$	Capital adj. cost param.	29.70	$\sigma_I / \sigma_Y = 2.642$
$\sigma_\gamma$	Std. preference shock	0.026	$\sigma_q / \sigma_Y = 2.429$
$\sigma_{Ax_s}$	Std. $X_s$ productivity shock	0.051	$\sigma_C / \sigma_Y = 0.748$
$\sigma_{Ax_f}$	Std. $X_f$ productivity shock	0.049	$\sigma_{B_f} / \sigma_Y = 6.099$
$\sigma_{Ah}$	Std. $IH$ productivity shock	0.018	$\sigma_{IH} / \sigma_Y = 2.797$
$\sigma_{Ac}$	Std. $Y_c$ productivity shock	0.001	$\sigma_Y = 2.138$

Note: Parameters in A) are set to standard values in the literature. Parameters in B) are calibrated to match key steady state ratios. Parameters in C) are calibrated to match second moments of selected macroeconomic aggregates. Abbreviations HH, LTV, RE and REIFs refer to households, loan-to-value ratio, real estate and real estate investment funds, respectively.

Table 2: Calibration targets

Variable	Description	Model	Data
A)First moments			
$C/Y$	Total consumption-to-GDP ratio	0.7791	0.7607
$I/Y$	Gross fixed capital formation-to-GDP ratio	0.2210	0.2119
$B_b/(Y)$	HH loans-to-GDP ratio	2.0149	2.1291
$(qH)/(4Y)$	Housing wealth-to-GDP ratio	2.8023	2.8018
$qIH/Y$	Total construction-to-GDP ratio	0.1121	0.1176
$H_f^r/H$	RE funds' rental housing-to-total housing	0.0500	0.0500
$X/H$	total rental housing-to-total housing	0.3020	0.3269
B)Second moments			
$\sigma_{B_f} / \sigma_Y$	Std. REIFs loans	6.383	6.099
$\sigma_q / \sigma_Y$	Std. property housing prices	1.691	2.429
$\sigma_{qIH} / \sigma_Y$	Std. housing investment	4.401	2.797
$\sigma_I / \sigma_Y$	Std. investment	2.632	2.642
$\sigma_C / \sigma_Y$	Std consumption	0.609	0.748
$\sigma_Y$	Std(GDP)*100	2.477	2.138

Note: All series in Euros are seasonally adjusted and deflated. With regards to the computation of the standard deviation targets, I have linearly detrended the corresponding series after having taken their log value. The standard deviation (Std.) of GDP is in quarterly percentage points. Data targets have been constructed from euro area quarterly data for the period 2002:I-2018:II. Data sources are Eurostat and ECB

Table 3: Optimized LTV limits and macroprudential losses

		$\sigma_{B/Y}^2$ <sup>(1)</sup>	$\sigma_B^2$	$\sigma_{P_s}^2$	$\sigma_q^2$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-63.91)	(-71.91)	(-15.00)	(-31.07)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-3.179	-0.000
	$m_{fx}$	-11.965	-14.786	-8.798	-30.762
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-61.20)	(-68.95)	(-14.63)	(-0.07)
	$m_{bx}$	-1.564	-1.911	-3.112	-0.459
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-63.91)	(-71.91)	(-6.12)	(-31.07)
	$m_{fx}$	-11.965	-14.786	-21.060	-30.762

Note:(1) Asymptotic variance that enters the objective function of the prudential authority. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 4: Aggregate effects of competition and macroprudential policies affecting REIFs

	(A) $\eta \rightarrow \infty$		(B) $\sigma_B^2$ <sup>(1)</sup>		(C) $\sigma_{P_s}^2$	
Variable	$\Delta\%$ Mean <sup>(2)</sup>	$\Delta\%$ Std	$\Delta\%$ Mean	$\Delta\%$ Std	$\Delta\%$ Mean	$\Delta\%$ Std
<i>Y</i>	1.98	-1.02	-0.12	-16.14	-0.14	-20.83
<i>C</i>	1.35	-4.82	-0.13	-18.94	-0.04	-23.58
<i>IH</i>	2.96	0.93	0.07	-3.86	-0.38	-7.55
<i>N</i>	0.95	-3.02	-0.02	-6.13	-0.16	-18.61
<i>B</i>	32.12	22.64	0.08	-26.02	-4.38	-1.70
<i>H</i>	2.96	1.13	0.07	-3.45	-0.38	-14.63
<i>X</i>	15.21	-10.46	0.69	4.74	0.39	0.86
$\frac{X}{H}$	11.88	-14.33	0.63	4.95	0.75	-0.16
$\frac{X_f}{X}$	158.37	96.91	-6.64	152.68	-1.58	59.22
<i>q</i>	3.56	3.28	0.06	-10.70	-0.23	-5.80
<i>P<sub>s</sub></i>	3.59	10.27	0.04	-2.26	-0.24	-8.32
<i>P<sub>fr</sub></i>	-48.06	-48.12	14.53	241.18	4.16	98.05

Note: (1) Asymptotic variance that enters the objective function of the prudential authority for the macroprudential policy scenarios considered in columns B and C. Macroprudential losses are minimized with respect to the macroprudential policy parameter of the LTV limit on commercial mortgages (see table 3(iii) for the optimized policy parameter values). (2) Percentage changes in the stochastic mean and standard deviation of key selected simulated series under alternative policy scenarios with respect to the baseline scenario. Second-order approximation. In order to compute the moments for each of the considered scenarios, the model has been simulated 1.000 times.

Table 5: Optimized LTV limits, macroprudential losses and REIFs' market power

		$\sigma_{P_s}^2/\eta = 1$ <sup>(1)</sup>	$\sigma_{P_s}^2/\eta = 2$	$\sigma_{P_s}^2/\eta = 6$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-24.86)	(-15.00)	(-12.33)
	$m_{bx}$ <sup>(3)</sup>	-5.861	-3.179	-2.798
	$m_{fx}$	-14.816	-8.798	-5.305
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-23.39)	(-14.63)	(-12.04)
	$m_{bx}$	-3.656	-3.112	-2.861
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-10.89)	(-6.12)	(-1.65)
	$m_{fx}$	-31.752	-21.060	-10.992

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 6: Optimized LTV limits, macroprudential losses and REIFs' productivity

		$\sigma_{P_s}^2/A_f = 0.5$ <sup>(1)</sup>	$\sigma_{P_s}^2/A_f = 1$	$\sigma_{P_s}^2/A_f = 2$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-11.12)	(-15.00)	(-21.44)
	$m_{bx}$ <sup>(3)</sup>	-2.765	-3.179	-3.637
	$m_{fx}$	-11.726	-8.798	-7.412
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-10.81)	(-14.63)	(-20.50)
	$m_{bx}$	-2.690	-3.112	-3.639
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-3.61)	(-6.12)	(-10.92)
	$m_{fx}$	-30.825	-21.060	-15.790

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 7: Optimized LTV limits, macroprudential losses and REIFs' structural LTV ratio

		$\sigma_{P_s}^2/m_f = 0.4$ <sup>(1)</sup>	$\sigma_{P_s}^2/m_f = 0.6$	$\sigma_{P_s}^2/m_f = 0.8$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-14.48)	(-15.00)	(-16.84)
	$m_{bx}$ <sup>(3)</sup>	-3.092	-3.179	-3.380
	$m_{fx}$	-11.278	-8.798	-6.289
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-14.09)	(-14.63)	(-15.78)
	$m_{bx}$	-3.0665	-3.112	-3.167
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-5.98)	(-6.12)	(-6.31)
	$m_{fx}$	-30.450	-21.060	-11.497

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. 2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 8: Optimized LTV limits, macroprudential losses and the weight of REIFs' rental services

		$\sigma_{P_s}^2/\omega_x = 0.10$ <sup>(1)</sup>	$\sigma_{P_s}^2/\omega_x = 0.445$	$\sigma_{P_s}^2/\omega_x = 0.80$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-7.65)	(-15.00)	(-32.25)
	$m_{bx}$ <sup>(3)</sup>	-2.305	-3.179	-4.011
	$m_{fx}$	-27.352	-8.798	-6.693
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-7.49)	(-14.63)	(-30.52)
	$m_{bx}$	-2.243	-3.112	-4.337
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-1.90)	(-6.12)	(-21.34)
	$m_{fx}$	-79.724	-21.060	-12.162

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. 2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 9: Optimized LTV limits, macroprudential losses and a low REIFs' market power

		$\sigma_{B/Y}^2/\eta = 6$ <sup>(1)</sup>	$\sigma_B^2/\eta = 6$	$\sigma_q^2/\eta = 6$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-54.29)	(-62.85)	(-17.34)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-0.000
	$m_{fx}$	-6.953	-8.518	-30.112
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-51.71)	(-60.53)	(-0.001)
	$m_{bx}$	-1.617	-1.982	-0.458
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-54.29)	(-62.85)	(-17.34)
	$m_{fx}$	-6.953	-8.518	-30.112

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 10: Optimized LTV limits, macroprudential losses and a low REIFs' productivity level

		$\sigma_{B/Y}^2/A_f = 0.5$ <sup>(1)</sup>	$\sigma_B^2/A_f = 0.5$	$\sigma_q^2/A_f = 0.5$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-49.78)	(-61.56)	(-25.66)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-0.000
	$m_{fx}$	-12.977	-16.984	-47.700
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-48.74)	(-60.33)	(-0.00)
	$m_{bx}$	-1.07583	-1.395	-0.000
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-49.78)	(-61.56)	(-25.66)
	$m_{fx}$	-12.977	-16.984	-47.700

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 11: Optimized LTV limits, macroprudential losses and a low REIFs' LTV ratio

		$\sigma_{B/Y}^2/m_f = 0.4$ <sup>(1)</sup>	$\sigma_B^2/m_f = 0.4$	$\sigma_q^2/m_f = 0.4$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-67.27)	(-75.15)	(-30.71)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-0.000
	$m_{fx}$	-15.809	-19.432	-45.302
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-61.64)	(-69.48)	(-0.14)
	$m_{bx}$	-1.460	-1.787	-0.683
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-67.27)	(-75.15)	(-30.71)
	$m_{fx}$	-15.809	-19.432	-45.302

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 12: Optimized LTV limits, macroprudential losses and a low weight of REIFs' rental services

		$\sigma_{B/Y}^2/\omega_x = 0.10$ <sup>(1)</sup>	$\sigma_B^2/\omega_x = 0.10$	$\sigma_q^2/\omega_x = 0.10$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-61.66)	(-69.91)	(-29.69)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-0.000
	$m_{fx}$	-54.963	-67.691	-161.854
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-59.29)	(-67.35)	(-0.06)
	$m_{bx}$	-1.360	-1.659	-0.444
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-61.66)	(-69.91)	(-29.69)
	$m_{fx}$	-54.963	-67.691	-161.854

Note:(1) Asymptotic variance that enters the objective function of the prudential authority and value taken by the parameter against which the robustness of the main results is checked. Problem (44) has been solved numerically by means of the *osr* (i.e., optimal simple rule) command in *dynare*. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 13: Optimized LTV limits, macroprudential losses and constant capital depreciation rates

		$\sigma_{B/Y}^2$ <sup>(1)</sup>	$\sigma_B^2$	$\sigma_{P_s}^2$	$\sigma_q^2$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-65.86)	(-72.75)	(-15.89)	(-33.70)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-3.650	-0.000
	$m_{fx}$	-13.700	-16.499	-9.891	-36.584
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-62.79)	(-69.54)	(-15.35)	(-0.36)
	$m_{bx}$	-1.807	-2.156	-3.570	-1.223
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-65.86)	(-72.75)	(-6.11)	(-33.70)
	$m_{fx}$	-13.700	-16.499	-24.086	-36.584

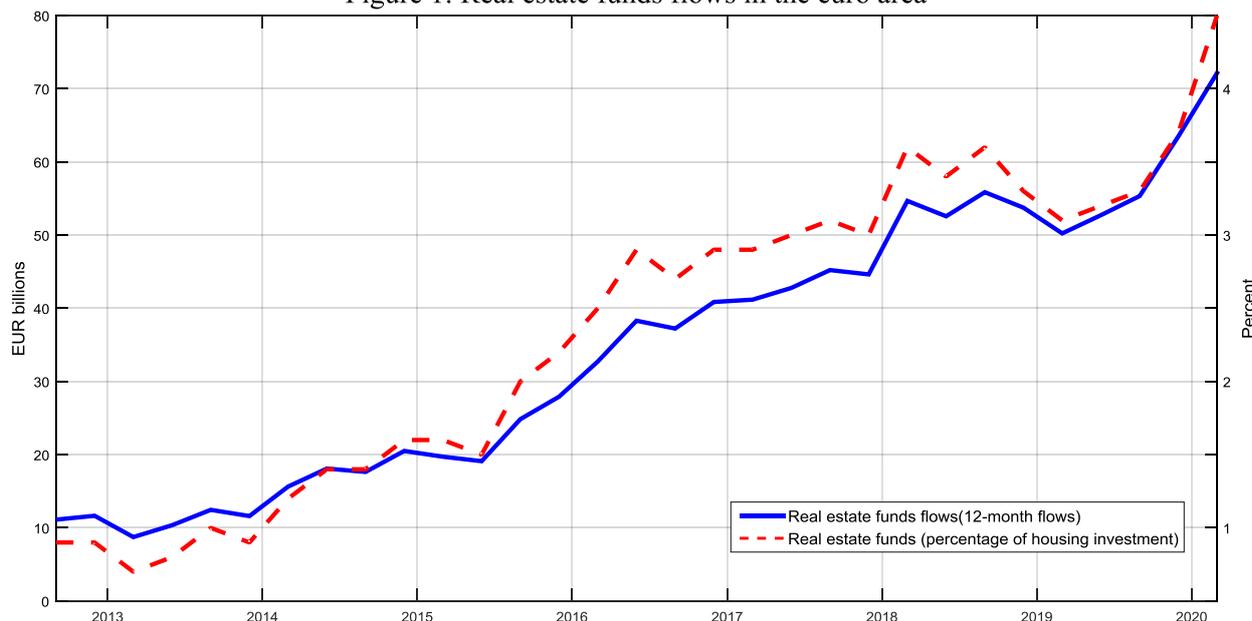
Note:(1) Asymptotic variance that enters the objective function of the prudential authority. Problem (44) has been solved numerically by means of the osr (i.e., optimal simple rule) command in dynare. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority.

Table 14: Optimized LTV limits, macroprudential losses and separable preferences

		$\sigma_{B/Y}^2$ <sup>(1)</sup>	$\sigma_B^2$	$\sigma_{P_s}^2$	$\sigma_q^2$
(i) $\{m_{bx}, m_{fx}\}$	<i>Loss Variation</i> <sup>(2)</sup>	(-0.0002)	(-3.96)	(-0.00)	(-0.001)
	$m_{bx}$ <sup>(3)</sup>	-0.000	-0.000	-0.000	-0.000
	$m_{fx}$	-0.074	-1.080	-0.000	-2.054
(ii) $\{m_{bx}\}$	<i>Loss Variation</i>	(-0.000)	(-3.28)	(-0.00)	(-0.000)
	$m_{bx}$	-0.000	-0.416	-0.000	-0.000
(iii) $\{m_{fx}\}$	<i>Loss Variation</i>	(-0.0002)	(-3.96)	(-0.00)	(-0.001)
	$m_{fx}$	-0.074	-1.080	-0.000	-2.054

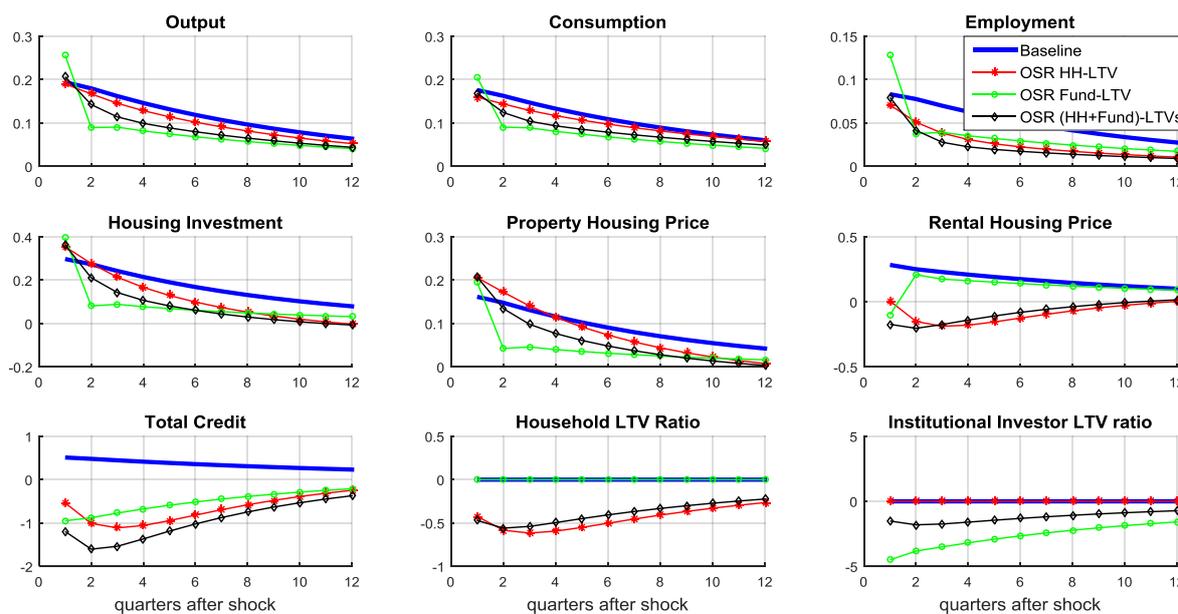
Note:(1) Asymptotic variance that enters the objective function of the prudential authority. Problem (44) has been solved numerically by means of the osr (i.e., optimal simple rule) command in dynare. (2) Percentage changes in the value of the loss function under the policy scenario associated to the optimized LTV rule, with respect to the baseline scenario. (3) Value of the policy parameter/s that solve the optimization problem of the prudential authority. Results reported in this table correspond to the case in which preferences on the consumption of non-durables and durables (i.e., housing) are assumed to be separable.

Figure 1: Real estate funds flows in the euro area



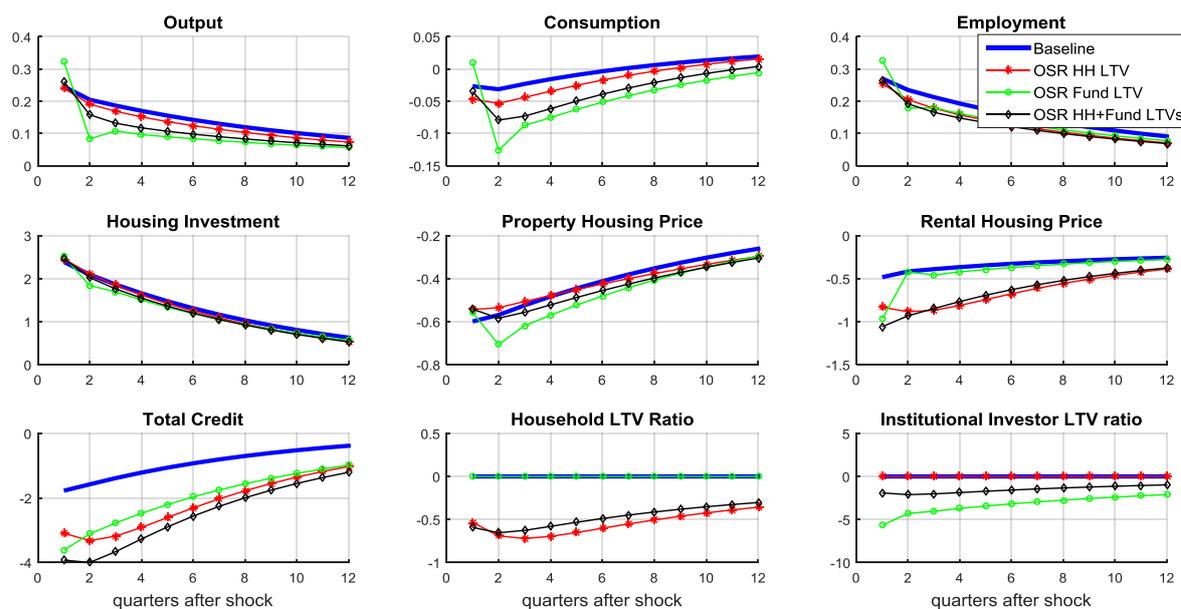
Note: This figure reports real estate funds flows (12-month flows) in the euro area both, in absolute terms and as a percentage of aggregate housing investment in the euro area. Time series are at quarterly frequency and have been plotted for the period 2012:III-2020:I. The figure is based on Battistini et al. (2018). Sources: ECB, Eurostat and own calculations.

Figure 2: Impulse-responses to a positive non-housing productivity shock



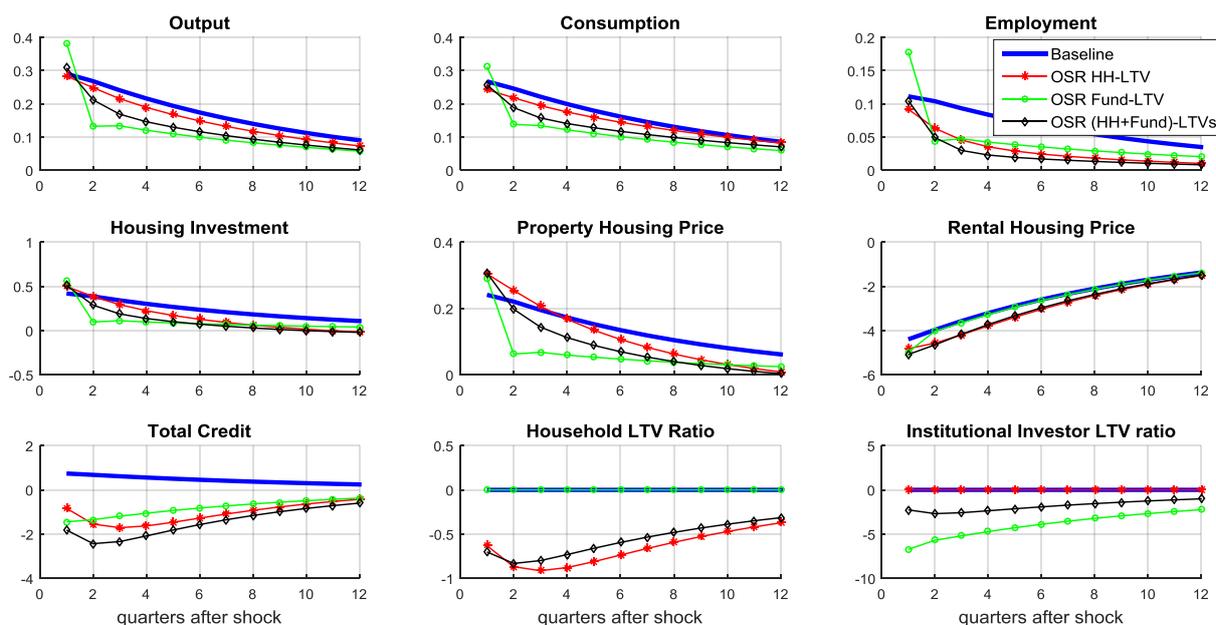
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to the baseline scenario. The starred line corresponds to the optimized LTV ratio on residential mortgages (borrowers) scenario. The dotted line relates to the optimized LTV ratio on commercial mortgages (investors) scenario. The diamond line makes reference to the jointly-optimized LTV limits on residential and commercial mortgages scenario.

Figure 3: Impulse-responses to a positive housing productivity shock



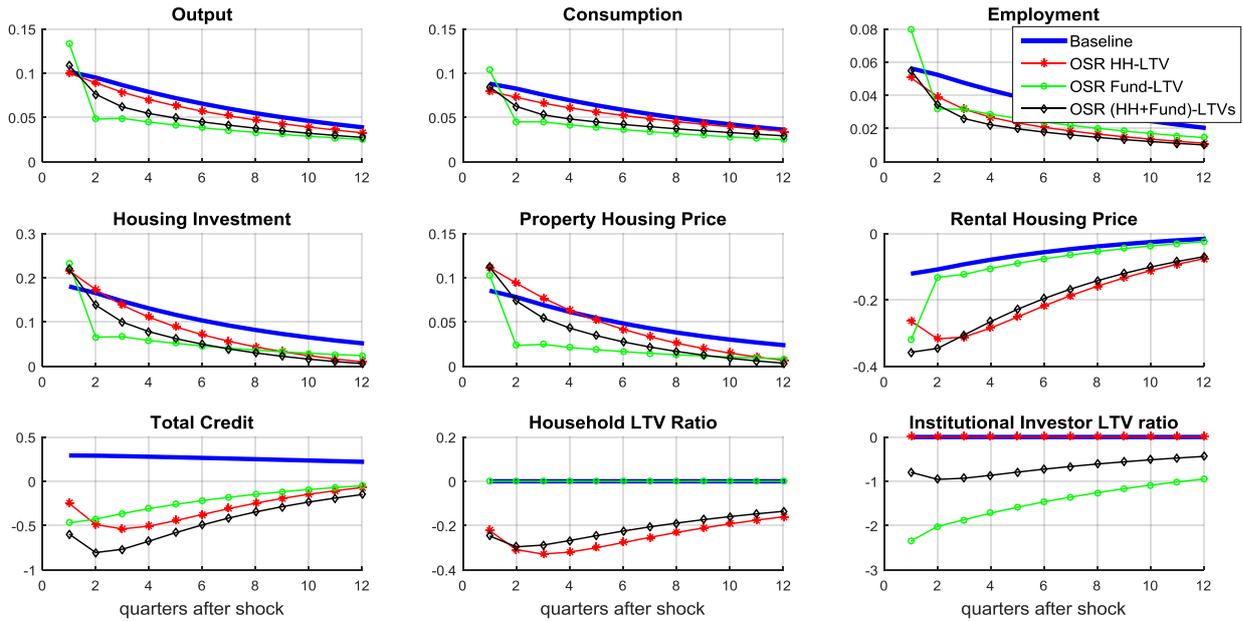
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to the baseline scenario. The starred line corresponds to the optimized LTV ratio on residential mortgages (borrowers) scenario. The dotted line relates to the optimized LTV ratio on commercial mortgages (investors) scenario. The diamond line makes reference to the jointly-optimized LTV limits on residential and commercial mortgages scenario.

Figure 4: Impulse-responses to a positive household rental housing productivity shock



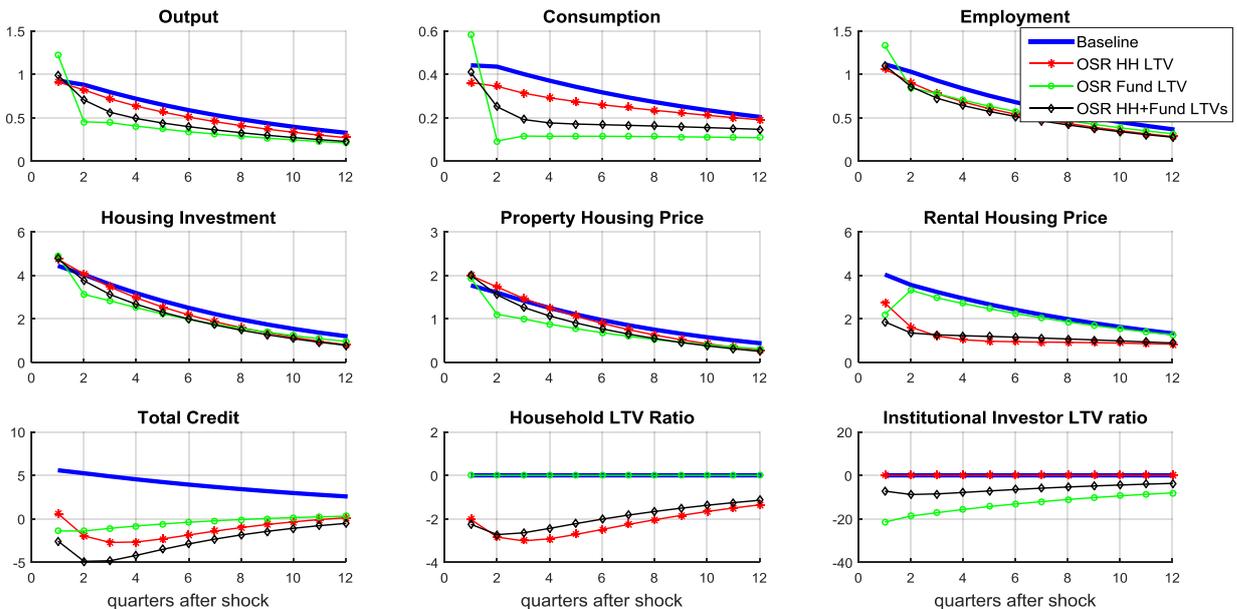
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to the baseline scenario. The starred line corresponds to the optimized LTV ratio on residential mortgages (borrowers) scenario. The dotted line relates to the optimized LTV ratio on commercial mortgages (investors) scenario. The diamond line makes reference to the jointly-optimized LTV limits on residential and commercial mortgages scenario.

Figure 5: Impulse-responses to a positive fund rental housing productivity shock



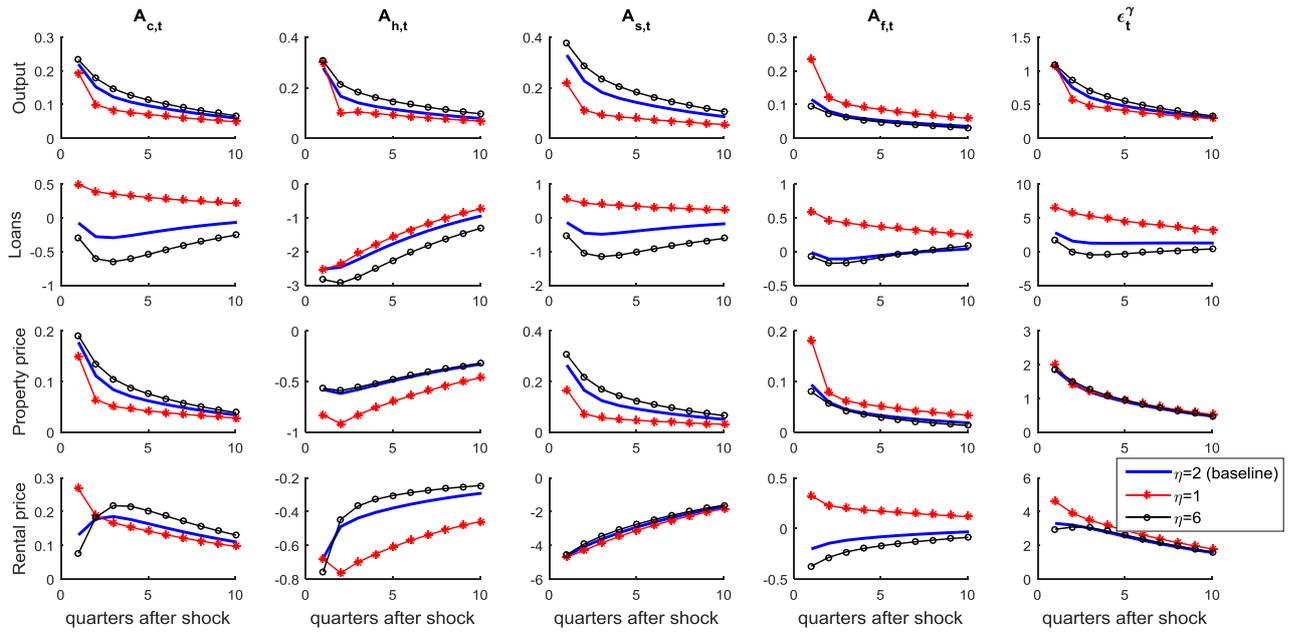
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to the baseline scenario. The starred line corresponds to the optimized LTV ratio on residential mortgages (borrowers) scenario. The dotted line relates to the optimized LTV ratio on commercial mortgages (investors) scenario. The diamond line makes reference to the jointly-optimized LTV limits on residential and commercial mortgages scenario.

Figure 6: Impulse-responses to a positive preference shock



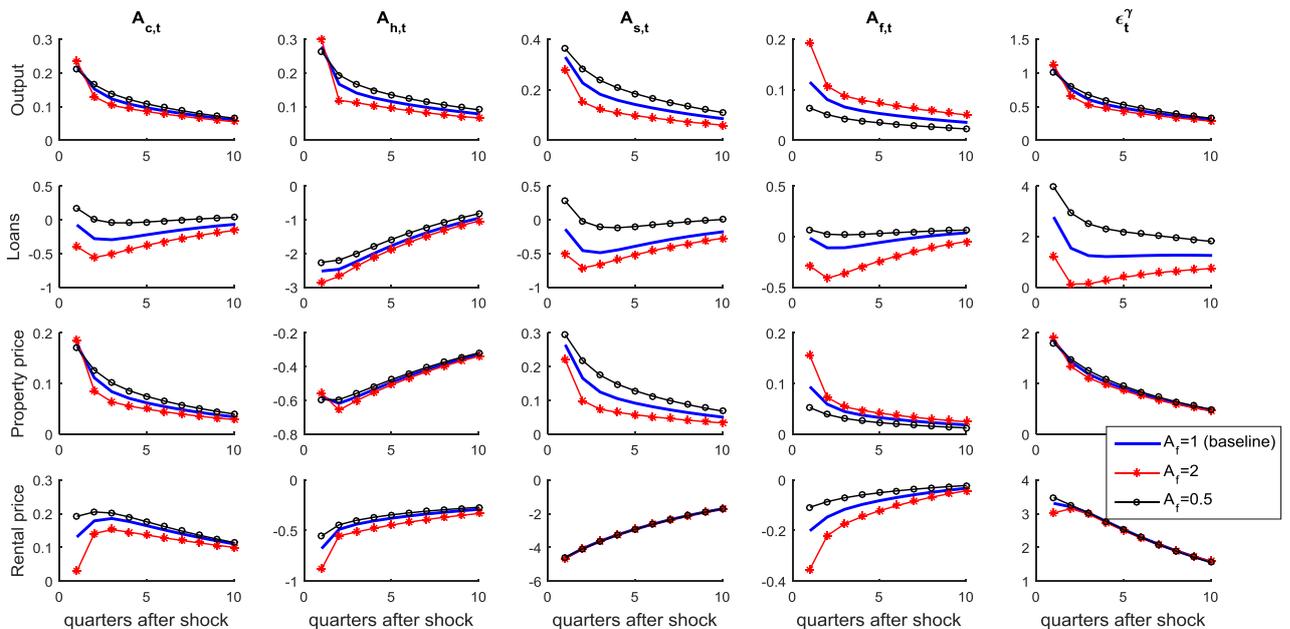
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to the baseline scenario. The starred line corresponds to the optimized LTV ratio on residential mortgages (borrowers) scenario. The dotted line relates to the optimized LTV ratio on commercial mortgages (investors) scenario. The diamond line makes reference to the jointly-optimized LTV limits on residential and commercial mortgages scenario.

Figure 7: Robustness checks ( $\eta$ ); Impulse-responses to all shocks



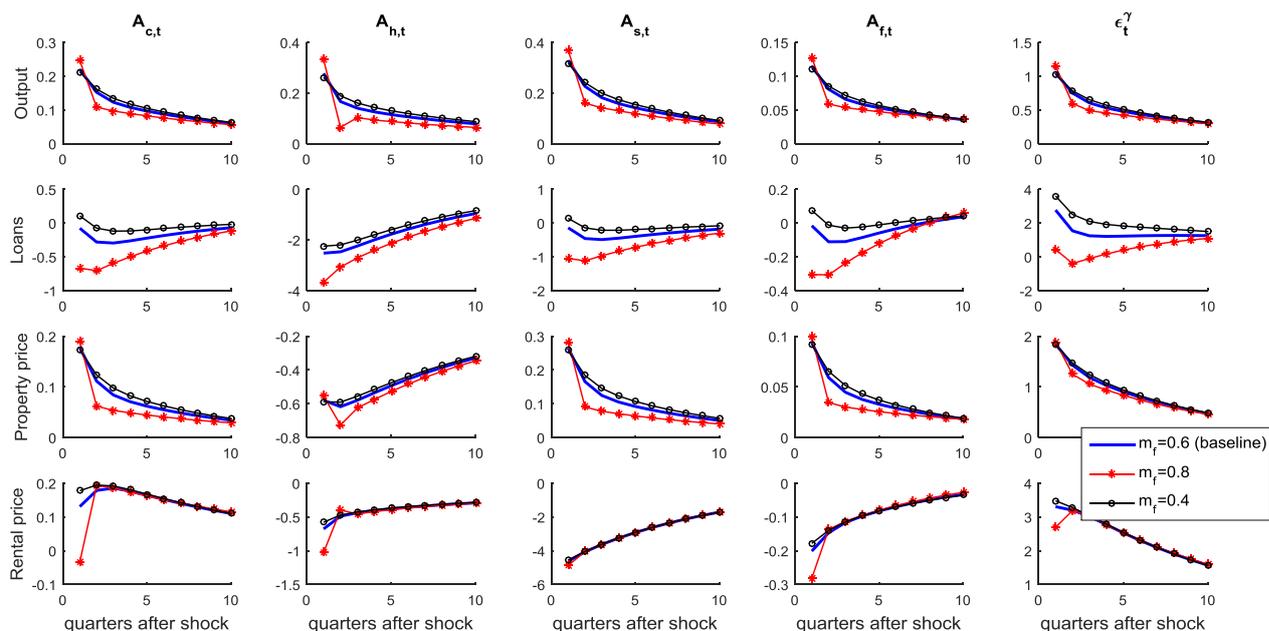
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to a scenario in which  $\eta=2$  (i.e., as in the baseline scenario). The starred line corresponds to an alternative scenario in which  $\eta=1$ . The dotted line relates to an alternative scenario in which  $\eta=6$ . The macroprudential parameter of the LTV limit on commercial mortgages has been set to -10 in the three scenarios.

Figure 8: Robustness checks ( $A_f$ ); Impulse-responses to all shocks



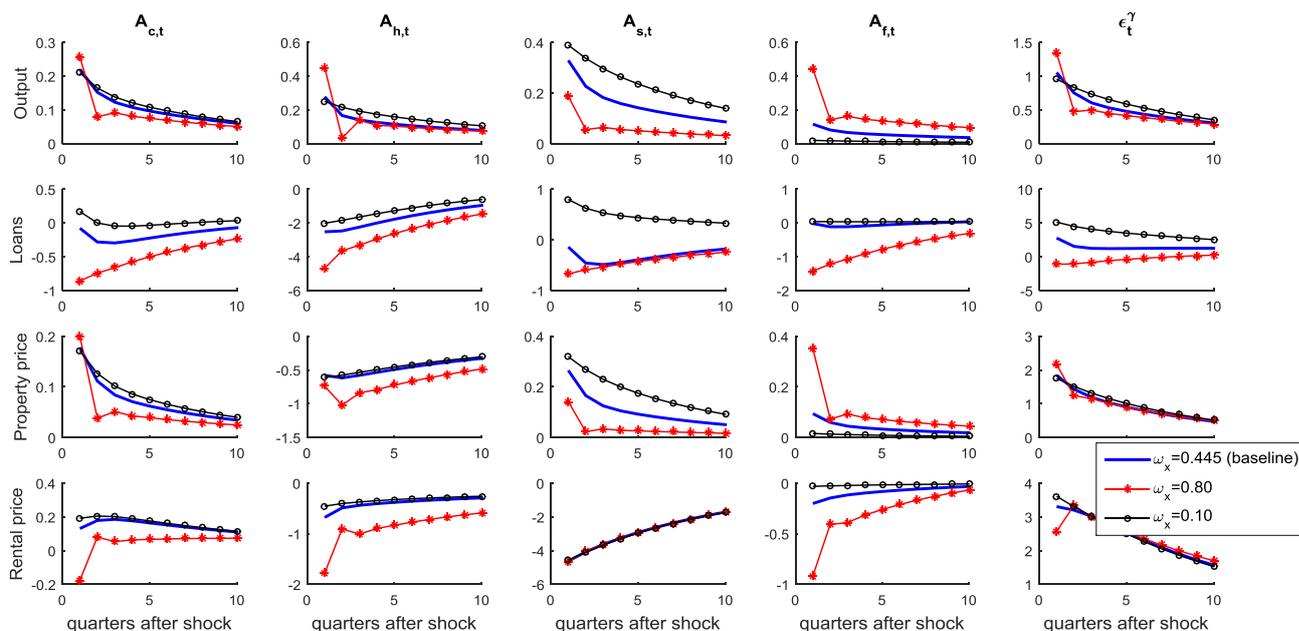
Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to a scenario in which  $A_f=1$  (i.e., as in the baseline scenario). The starred line corresponds to an alternative scenario in which  $A_f=2$ . The dotted line relates to an alternative scenario in which  $A_f=0.5$ . The macroprudential parameter of the LTV limit on commercial mortgages has been set to -10 in the three scenarios.

Figure 9: Robustness checks ( $m_f$ ); Impulse-responses to all shocks



Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to a scenario in which  $m_f=0.6$  (i.e., as in the baseline scenario). The starred line corresponds to an alternative scenario in which  $m_f=0.8$ . The dotted line relates to an alternative scenario in which  $m_f=0.4$ . The macroprudential parameter of the LTV limit on commercial mortgages has been set to -10 in the three scenarios.

Figure 10: Robustness checks ( $\omega_x$ ); Impulse-responses to all shocks



Note: Variables are expressed in percentage deviations from the steady state. The solid line refers to a scenario in which  $\omega_x=0.445$  (i.e., as in the baseline scenario). The starred line corresponds to an alternative scenario in which  $\omega_x=0.80$ . The dotted line relates to an alternative scenario in which  $\omega_x=0.10$ . The macroprudential parameter of the LTV limit on commercial mortgages has been set to -10 in the three scenarios.

## A Data and Sources

This section presents the full data set employed to construct figure 1 and to calibrate the model.

**Gross Domestic Product:** Gross domestic product at market prices, Chain-linked volumes (rebased), Domestic currency (may include amounts converted to the current currency at a fixed rate), Seasonally and working day-adjusted. Source: Eurostat.

**GDP Deflator:** Gross domestic product at market prices, Deflator, Domestic currency, Index (2010 = 100), Seasonally and calendar adjusted data - ESA 2010 National accounts. Source: Eurostat.

**Final Consumption:** Final consumption expenditure at market prices, Chain linked volumes (2010), Seasonally and calendar adjusted data. Source: Eurostat.

**Gross Fixed Capital Formation:** Gross fixed capital formation at market prices, Chain linked volumes (2010), Seasonally and calendar adjusted data. Source: Eurostat.

**Total Construction:** (Gross) total construction (within Gross fixed capital formation), Euro, Chain linked volume (rebased), Calendar and seasonally adjusted data. Source: Eurostat.

**Housing Wealth:** Housing wealth (net) of Households and non profit institutions serving households sector (NPISH), Current prices, Euros, Neither seasonally adjusted nor calendar adjusted - ESA 2010. Source: European Central Bank.

**Percentage of owner-occupied housing:** Type of tenure - Owner-occupied accommodation, total, Percentage, Euro area 19 (fixed composition). Source: Structural Housing Indicators Statistics, European Central Bank.

**Percentage of rented housing:** Type of tenure - Rented accommodation, total, Percentage, Euro area 19 (fixed composition). Source: Structural Housing Indicators Statistics, European Central Bank.

**Property Housing Prices:** Residential property prices; New and existing dwellings, Residential property in good and poor condition. Neither seasonally nor working day adjusted. Source: European Central Bank.

**Households Loans:** Outstanding amounts at the end of the period (stocks) of loans from MFIs excluding ESCB reporting sector to Households and non-profit institutions serving households (S.14 & S.15) sector, denominated in Euros. Source: MFI Balance Sheet Items Statistics (BSI Statistics), Monetary and Financial Statistics (S/MFS), European Central

Bank.

**Real Estate Funds Loans and Deposits:** Outstanding amounts at the end of the period (stocks) of loans and deposits received by real estate funds in the euro area, Total maturity, denominated in Euro. Neither seasonally nor working day adjusted. Source: Investment Funds Balance Sheet Statistics, European Central Bank.

**Real Estate Funds Total Assets and Non-financial Assets (stocks):** Outstanding amounts at the end of the period (stocks) of total assets and non-financial assets held by real estate funds in the euro area, denominated in Euros. Neither seasonally nor working day adjusted. Source: Investment Funds Balance Sheet Statistics, European Central Bank.

**Real Estate Funds Total Assets (flows):** Transactions (flows) of total assets held by real estate funds in the euro area, denominated in Euros. Neither seasonally nor working day adjusted. Source: Investment Funds Balance Sheet Statistics, European Central Bank.

## B Equations of the Model

This section presents the full set of equilibrium equations of the model.

### B.1 Patient Households

Patient households seek to maximize (1) subject to the following constraints:

$$\begin{aligned} C_{s,t} + B_t + \sum_{i=c,h} [I_t^i + \Phi_i(K_{s,t}^i)] + q_t \sum_{j=p,r} [H_{s,t}^j - (1 - \delta_h)H_{s,t-1}^j] \\ = P_{s,t}X_{s,t} + R_{b,t-1}B_{t-1} + \sum_{i=c,h} [W_t^i N_{s,t}^i + r_t^i u_t^i K_{s,t-1}^i] + \Pi_t, \end{aligned} \quad (\text{B.1})$$

$$Z_{s,t} = C_{s,t}^{(1-\gamma_t)} H_{s,t}^{\gamma_t}, \quad (\text{B.2})$$

$$\tilde{N}_{s,t} = \left[ \omega_n^{1/\varepsilon} (N_{s,t}^c)^{(1+\varepsilon)/\varepsilon} + (1 - \omega_n)^{1/\varepsilon} (N_{s,t}^h)^{(1+\varepsilon)/\varepsilon} \right]^{\varepsilon/(\varepsilon+1)}, \quad (\text{B.3})$$

$$K_{s,t}^c = (1 - \delta_t^c)K_{s,t-1}^c + I_t^c, \quad (\text{B.4})$$

$$K_{s,t}^h = (1 - \delta_t^h)K_{s,t-1}^h + I_t^h, \quad (\text{B.5})$$

$$\delta_t^c(u_t) = \delta_0^c + \delta_1^c(u_t^c - 1)^2 + \frac{\delta_2^c}{2}(u_t^c - 1)^2, \quad (\text{B.6})$$

$$\delta_t^h(u_t) = \delta_0^h + \delta_1^h(u_t^h - 1)^2 + \frac{\delta_2^h}{2}(u_t^h - 1)^2, \quad (\text{B.7})$$

$$X_{s,t} = A_{s,t}H_{s,t-1}^r. \quad (\text{B.8})$$

Their choice variables are  $C_{s,t}$ ,  $B_t$ ,  $H_{s,t}^p$ ,  $H_{s,t}^r$ ,  $N_{s,t}^c$ ,  $N_{s,t}^h$ ,  $K_{s,t}^c$ ,  $K_{s,t}^h$ ,  $u_t^c$  and  $u_t^h$ . The optimality conditions of the problem read

$$\lambda_{s,t} = (1 - \gamma_t) \frac{Z_{s,t}}{C_{s,t}} \left( Z_{s,t} - \frac{\tilde{N}_{s,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h}, \quad (\text{B.9})$$

$$\lambda_{s,t} = \beta_s R_{b,t} E_t \lambda_{s,t+1}, \quad (\text{B.10})$$

$$q_t \lambda_{s,t} = \gamma_t \frac{Z_{s,t}}{H_{s,t}^p} \left( Z_{s,t} - \frac{\tilde{N}_{s,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h} + \beta_s (1 - \delta_h) E_t (q_{t+1} \lambda_{s,t+1}), \quad (\text{B.11})$$

$$q_t \lambda_{s,t} = \lambda_{s,t} P_{s,t} A_{s,t} + \beta_s (1 - \delta_h) E_t (q_{t+1} \lambda_{s,t+1}), \quad (\text{B.12})$$

$$W_t^c \lambda_{s,t} = \tilde{N}_{s,t}^\phi \left[ \omega_n \frac{N_{s,t}^c}{\tilde{N}_{s,t}} \right]^{1/\varepsilon} \left( Z_{s,t} - \frac{\tilde{N}_{s,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h}, \quad (\text{B.13})$$

$$W_t^h \lambda_{s,t} = \tilde{N}_{s,t}^\phi \left[ (1 - \omega_n) \frac{N_{s,t}^h}{\tilde{N}_{s,t}} \right]^{1/\varepsilon} \left( Z_{s,t} - \frac{\tilde{N}_{s,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h}, \quad (\text{B.14})$$

$$\left( 1 + \frac{\partial \Phi_c(K_{s,t}^c)}{\partial K_{s,t}^c} \right) \lambda_{s,t} = \beta_s E_t [\lambda_{s,t+1} (1 + u_{t+1}^c r_{t+1}^c - \delta_{t+1}^c)], \quad (\text{B.15})$$

$$\left( 1 + \frac{\partial \Phi_c(K_{s,t}^h)}{\partial K_{s,t}^h} \right) \lambda_{s,t} = \beta_s E_t [\lambda_{s,t+1} (1 + u_{t+1}^h r_{t+1}^h - \delta_{t+1}^h)], \quad (\text{B.16})$$

$$\delta_1^c + \delta_2^c (u_t^c - 1) = r_t^c, \quad (\text{B.17})$$

$$\delta_1^h + \delta_2^h (u_t^h - 1) = r_t^h, \quad (\text{B.18})$$

where  $\lambda_{s,t}$  is the Lagrange multiplier on the budget constraint of the representative patient household.

## B.2 Impatient Households

The representative impatient household chooses the trajectories of consumption  $C_{b,t}$ , property housing  $H_{b,t}^p$ , labor supply in each of the two production sectors,  $N_{b,t}^c$  and  $N_{b,t}^h$ , and demand for loans  $B_{b,t}$  that maximize (1) subject to the following restrictions:

$$C_{b,t} + R_{b,t-1}B_{b,t-1} + q_t [H_{b,t}^p - (1 - \delta_h)H_{b,t-1}^p] = B_{b,t} + W_t^c N_{b,t}^c + W_t^h N_{b,t}^h, \quad (\text{B.19})$$

$$Z_{b,t} = C_{b,t}^{(1-\gamma_t)} H_{b,t}^{p \gamma_t}, \quad (\text{B.20})$$

$$\tilde{N}_{b,t} = \left[ \omega_n^{1/\varepsilon} (N_{b,t}^c)^{(1+\varepsilon)/\varepsilon} + (1 - \omega_n)^{1/\varepsilon} (N_{b,t}^h)^{(1+\varepsilon)/\varepsilon} \right]^{\varepsilon/(\varepsilon+1)}, \quad (\text{B.21})$$

$$B_{b,t} \leq m_{b,t} E_t \left[ \frac{q_{t+1}}{R_{bt}} H_{b,t}^p \right]. \quad (\text{B.22})$$

The resulting optimality conditions are,

$$\lambda_{b,t} = (1 - \gamma_t) \frac{Z_{b,t}}{C_{b,t}} \left( Z_{b,t} - \frac{\tilde{N}_{b,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h}, \quad (\text{B.23})$$

$$\lambda_{b,t} \left[ q_t - E_t \left( m_{b,t} \frac{q_{t+1}}{R_{b,t}} \right) \right] = \gamma_t \frac{Z_{b,t}}{H_{b,t}^p} \left( Z_{b,t} - \frac{\tilde{N}_{b,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h} + \beta_b E_t [q_{t+1} \lambda_{b,t+1} (1 - \delta_h - m_{b,t})], \quad (\text{B.24})$$

$$W_t^c \lambda_{b,t} = \tilde{N}_{b,t}^\phi \left[ \omega_n \frac{N_{b,t}^c}{\tilde{N}_{b,t}} \right]^{1/\varepsilon} \left( Z_{b,t} - \frac{\tilde{N}_{b,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h}, \quad (\text{B.25})$$

$$W_t^h \lambda_{b,t} = \tilde{N}_{b,t}^\phi \left[ (1 - \omega_n) \frac{N_{b,t}^h}{\tilde{N}_{b,t}} \right]^{1/\varepsilon} \left( Z_{b,t} - \frac{\tilde{N}_{b,t}^{1+\phi}}{(1 + \phi)} \right)^{-\sigma_h}, \quad (\text{B.26})$$

where  $\lambda_{b,t}$  is the Lagrange multiplier on the budget constraint of the representative impatient household.

### B.3 Renter Households

The representative renter household seeks to maximize (9) subject to:

$$C_{r,t} + P_{s,t}X_{sr,t} + p_{fr,t}x_{fr,t} = W_t^c N_{r,t}^c + W_t^h N_{r,t}^h, \quad (\text{B.27})$$

$$Z_{r,t} = C_{r,t}^{(1-\gamma_t)} \tilde{X}_{r,t}^{\gamma_t}, \quad (\text{B.28})$$

$$\tilde{N}_{r,t} = \left[ \omega_n^{1/\varepsilon} (N_{r,t}^c)^{(1+\varepsilon)/\varepsilon} + (1 - \omega_n)^{1/\varepsilon} (N_{r,t}^h)^{(1+\varepsilon)/\varepsilon} \right]^{\varepsilon/(1+\varepsilon)}, \quad (\text{B.29})$$

$$\tilde{X}_{r,t} = \left[ \omega_x^{1/\eta_r} (x_{fr,t})^{(\eta_r-1)/\eta_r} + (1 - \omega_x)^{1/\eta_r} (X_{sr,t})^{(\eta_r-1)/\eta_r} \right]^{\eta_r/(\eta_r-1)}. \quad (\text{B.30})$$

Its choice variables are  $C_{r,t}$ ,  $x_{fr,t}$ ,  $X_{sr,t}$ ,  $N_{s,t}^c$  and  $N_{s,t}^h$ . The optimality conditions of the problem read,

$$\lambda_{r,t} = \frac{(1 - \gamma_t)}{C_{r,t}}, \quad (\text{B.31})$$

$$P_{s,t} \lambda_{r,t} = \frac{\gamma_t}{\tilde{X}_{r,t}} \left[ (1 - \omega_x) \frac{\tilde{X}_{r,t}}{X_{sr,t}} \right]^{1/\eta_r}, \quad (\text{B.32})$$

$$p_{fr,t} \lambda_{r,t} = \frac{\gamma_t}{\tilde{X}_{r,t}} \left[ \omega_x \frac{\tilde{X}_{r,t}}{x_{fr,t}} \right]^{1/\eta_r}, \quad (\text{B.33})$$

$$W_t^c \lambda_{r,t} = \tilde{N}_{r,t}^\phi \left[ \omega_n \frac{N_{r,t}^c}{\tilde{N}_{s,t}} \right]^{1/\varepsilon}, \quad (\text{B.34})$$

$$W_t^h \lambda_{r,t} = \tilde{N}_{r,t}^\phi \left[ (1 - \omega_n) \frac{N_{r,t}^h}{\tilde{N}_{r,t}} \right]^{1/\varepsilon}, \quad (\text{B.35})$$

where  $\lambda_{r,t}$  is the Lagrange multiplier on the budget constraint of the representative renter household.

### B.4 Non-housing Producing Firms

Non-housing producing firms seek to maximize (17) subject to the following constraints

$$Y_{c,t} = A_{c,t} (u_t^c K_{t-1}^c)^\alpha \tilde{X}_{c,t}^\nu N_t^{c(1-\alpha-\nu)}, \quad (\text{B.36})$$

$$\tilde{X}_{c,t} = \left[ \omega_x^{1/\eta_c} (x_{fc,t})^{(\eta_c-1)/\eta_c} + (1 - \omega_x)^{1/\eta_c} (X_{sc,t})^{(\eta_c-1)/\eta_c} \right]^{\eta_c/(\eta_c-1)}. \quad (\text{B.37})$$

Their choice variables are  $N_{c,t}$ ,  $K_{c,t}$ ,  $x_{fc,t}$  and  $X_{sc,t}$ . The following optimality conditions can be derived from the first order conditions of the problem:

$$W_t^c = (1 - \alpha - \nu) \frac{Y_{c,t}}{N_t^c}, \quad (\text{B.38})$$

$$r_t^c = \alpha \left( \frac{Y_{c,t}}{u_t^c K_{t-1}^c} \right), \quad (\text{B.39})$$

$$P_{s,t} = \nu \frac{Y_{c,t}}{\tilde{X}_{c,t}} \left[ (1 - \omega_x) \frac{\tilde{X}_{c,t}}{X_{sc,t}} \right]^{1/\eta_c}, \quad (\text{B.40})$$

$$p_{fc,t} = \nu \frac{Y_{c,t}}{\tilde{X}_{c,t}} \left[ \omega_x \frac{\tilde{X}_{c,t}}{x_{fc,t}} \right]^{1/\eta_c}. \quad (\text{B.41})$$

## B.5 Housing Producing Firms

Housing producing firms choose the demand schedules for labor  $N_t^h$  and physical capital  $K_t^h$  that maximize (21) subject to the available technology:

$$IH_t = A_{h,t} (u_t^h K_{t-1}^h)^\theta N_t^{h(1-\theta)}. \quad (\text{B.42})$$

Their choice variables are  $N_t^h$  and  $K_t^h$ . The optimality conditions are as follows,

$$W_t^c = (1 - \alpha - \nu) \frac{Y_{c,t}}{N_t^c}, \quad (\text{B.43})$$

$$r_t^c = \alpha \left( \frac{Y_{c,t}}{u_t^c K_{t-1}^c} \right). \quad (\text{B.44})$$

## B.6 Real Estate Fund Managers

The representative fund manager seeks to maximize (24) subject to a sequence of cash flow restrictions, a borrowing limit and the corresponding technologies to transform housing into rental services:

$$\Pi_{f,t} + R_{b,t} B_{f,t-1} + q_t [H_{fr,t}^r + H_{fc,t}^r - (1 - \delta_h) (H_{fr,t-1}^r + H_{fc,t-1}^r)] = B_{f,t} + P_{fr,t} X_{fr,t} + P_{fc,t} X_{fc,t}, \quad (\text{B.45})$$

$$B_{f,t} \leq m_{f,t} E_t \left[ \frac{q_{t+1}}{R_{b,t}} (H_{fr,t}^r + H_{fc,t}^r) \right], \quad (\text{B.46})$$

$$X_{fr,t} = \bar{A}_{fr,t} H_{fr,t-1}^r, \quad (\text{B.47})$$

$$X_{fc,t} = \bar{A}_{fc,t} H_{fc,t-1}^r. \quad (\text{B.48})$$

The resulting optimality conditions read:

$$\Pi_{f,t}^{-\frac{1}{\sigma}} \left[ q_t - m_{f,t} E_t \left( \frac{q_{t+1}}{R_{b,t}} \right) \right] = \Lambda_{0,t}^e E_t \left\{ \Pi_{f,t+1}^{-\frac{1}{\sigma}} [P_{fr,t+1} \bar{A}_{fr,t+1} q_{t+1} (1 - \delta_h - m_{f,t})] \right\}, \quad (\text{B.49})$$

$$\Pi_{f,t}^{-\frac{1}{\sigma}} \left[ q_t - m_{f,t} E_t \left( \frac{q_{t+1}}{R_{b,t}} \right) \right] = \Lambda_{0,t}^e E_t \left\{ \Pi_{f,t+1}^{-\frac{1}{\sigma}} [P_{fc,t+1} \bar{A}_{fc,t+1} q_{t+1} (1 - \delta_h - m_{f,t})] \right\}. \quad (\text{B.50})$$

## B.7 Real Estate Fund Retailers

The representative fund retailer maximizes (31). After having imposed a symmetric equilibrium, the first order conditions yield:

$$p_{fr,t} = \frac{\eta_r}{(\eta_r - 1)} P_{fr,t}, \quad (\text{B.51})$$

$$p_{fc,t} = \frac{\eta_c}{(\eta_c - 1)} P_{fc,t}. \quad (\text{B.52})$$

## B.8 Macroprudential Authority

The policy instruments (dynamic LTV limits) of the macroprudential authority have the following specification:

$$m_{b,t} = \rho_b m_{b,t-1} + (1 - \rho_b) m_b + (1 - \rho_b) m_{bx} \left( \frac{x_t}{x} - 1 \right), \quad (\text{B.53})$$

$$m_{f,t} = \rho_f m_{f,t-1} + (1 - \rho_f) m_f + (1 - \rho_f) m_{fx} \left( \frac{x_t}{x} - 1 \right). \quad (\text{B.54})$$

## B.9 Aggregation and market clearing

Market clearing is implied by the Walras' law, by aggregating all the budget constraints. The aggregate resource constraint of the economy represents the equilibrium condition for the final goods market:

$$Y_t = C_{,t} + I_{c,t} + I_{h,t} + q_t I H_t + \Phi_c(K_{c,t}) + \Phi_h(K_{h,t}). \quad (\text{B.55})$$

Similarly, in equilibrium labor demand equals total labor supply in each of the two production sectors,

$$N_t^c = N_{s,t}^c + N_{b,t}^c + N_{r,t}^c, \quad (\text{B.56})$$

$$N_t^h = N_{s,t}^h + N_{b,t}^h + N_{r,t}^h. \quad (\text{B.57})$$

The stock of physical capital accumulated by savers must equal the one rented by firms in each of the two production sectors,

$$K_{s,t}^c = K_t^c, \quad (\text{B.58})$$

$$K_{s,t}^h = K_t^h. \quad (\text{B.59})$$

Similarly, in equilibrium demand for loans of impatient households and fund managers equals aggregate credit supply,

$$B_t = B_{b,t} + B_{f,t}. \quad (\text{B.60})$$

In equilibrium, the different segments of the rental housing services market clear:

$$X_{s,t} = X_{sr,t} + X_{sc,t}, \quad (\text{B.61})$$

$$X_{fr,t} = x_{fr,t}, \quad (\text{B.62})$$

$$X_{fc,t} = x_{fc,t}. \quad (\text{B.63})$$

The aggregate stock of produced real estate must be equal to the stock of housing held by savers, borrowers and fund managers:

$$H_t = H_{s,t}^p + H_{s,t}^r + H_{b,t}^p + H_{fr,t}^r + H_{fc,t}^r, \quad (\text{B.64})$$

where  $H_t$  evolves according to the standard law for capital accumulation,

$$H_t = (1 - \delta_h)H_{t-1} + IH_t. \quad (\text{B.65})$$

## B.10 Shocks

The following zero-mean, AR(1) shocks are present in the model:  $A_{c,t}$ ,  $A_{h,t}$ ,  $A_{s,t}$ ,  $A_{f,t}$ , and  $\varepsilon_t^\gamma$ . These shocks follow the processes given by:

$$\log A_{c,t} = \rho_{Ac} \log A_{c,t-1} + e_{Ac,t}, \quad e_{Ac,t} \sim N(0, \sigma_{Ac}), \quad (\text{B.66})$$

$$\log A_{h,t} = \rho_{Ah} \log A_{h,t-1} + e_{Ah,t}, \quad e_{Ah,t} \sim N(0, \sigma_{Ah}), \quad (\text{B.67})$$

$$\log A_{s,t} = \rho_{As} \log A_{s,t-1} + e_{As,t}, \quad e_{As,t} \sim N(0, \sigma_{As}), \quad (\text{B.68})$$

$$\log A_{f,t} = \rho_{Af} \log A_{f,t-1} + e_{Af,t}, \quad e_{Af,t} \sim N(0, \sigma_{Af}), \quad (\text{B.69})$$

$$\log \varepsilon_t^\gamma = \rho_\gamma \log \varepsilon_{t-1}^\gamma + e_{\gamma,t}, \quad e_{\gamma,t} \sim N(0, \sigma_\gamma). \quad (\text{B.70})$$

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