Rethinking Basel III and beyond: a theory model to understand credit allocation and real state bubbles

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We develop a theoretical framework that explains the decision-making process of banks concerning the allocation of credit to two sectors: (i) households seeking real estate assets, and (ii) companies requiring capital for consumer goods production. By analyzing the interaction between the credit and the real estate markets, the model shows how in the context of high lending capacity, banks have a natural incentive to bias the credit allocation towards real estate acquisition. This, in turn, leads to a trade-off where productive capital funding takes a backseat, fostering the emergence of real estate bubbles. We conclude that the "one-size-fits-all" banks' macroprudential capital requirements policy might fail in the prevention of credit financial bubbles. Instead, a more effective approach will need to account for real estate market, production technology as well as credit market and banks' characteristics. On the one hand, these conclusions highlight the importance of the flexible macroprudential capital buffers introduced in Basel III, suggesting a tailored approach based on specific factors. On the other hand, they also suggest to consider important changes in the capital regulation, such as reducing the mortgages capital requirements benefits or incorporating differentiation by loan purpose, credit market concentration or bank's local market share as potential capital buffer requirement add-ons.

1. Introduction

Albeit bubble driven financial crisis had already been an economic phenomenon for most of the XXth century, the impact of the 2008 crisis, both in terms of its direct banks' support costs and, most importantly, its crucial role on the consequential severe economic downturns, have placed banking regulation and macroprudential supervision at the core of the economic policy agenda. In Spain, a paradigmatic case of the credit and real estate bubble financial crisis, the direct cost of banks' support implied (depending on sources and perimeter defined) between 60 and 100 billion euros. Most importantly, the subsequential economic crisis signified one lost decade of growth, unemployment reaching levels above 27% and sovereign debt more than doubling, something that has not even happened under the pandemic crisis.

In this context, economic research developments around the financial crisis can be structured around three main axes.

First, the development of the theoretical background to explain some of the key financial market failures. This includes most developments before the last crisis, including the rationale for credit deposit insurance (Diamond-Dybvig, 1983), the role of asymmetric information in the credit market as a financial accelerator under negative economic shocks (Diamond, 1984) or the explanation of the systematic mispricing and excess volatility of certain assets, just caused by a subset of investors being irrational (DeLong, Shleifer, Summers, and Waldman, 1990), giving room to later broader developments on that front.

Second, parallel to those and somewhat disconnected, the development of credit risk measurement frameworks either following a structural approach (Merton, 1974) or discriminant analysis (Altman, 1968), setting the grounds for future credit risk modelling. This was subject to intense progress by the end of the 90s and the first half of 2000s, mostly around Basel II. The main objectives of those developments were both to forecast credit risk losses and to set the capital requirements to protect banks' solvency. These were done mostly building over the frameworks developed by Altman (which source the internal model developments that would serve as input to the capital requirements formula) and Merton (as an approach to set the regulatory capital requirements formula). The new BIS regulatory proposals (BCBS, 2004 and 2006), together with multiple research papers on credit modelling (e.g. Gordy, 2000, 2003), are good examples of these developments.

Third, albeit previously anticipated by some less extreme real estate bubble crashes (e.g. Japan, Sweden, Hong Kong), the economic impact of the US 2008 crisis and the later most dramatic cases of countries such as Spain or Ireland, raised the need to better address the credit and real estate bubble driven crisis and, in particular, in understanding better the connections between the financial markets and the overall economy. These developments cover a wide range of topics around the financial crisis, credit modelling and capital requirements, ranging from more global themes, such as the links between mortgage credit expansion and business cycles (Jordà, Schularick and Taylor, 2016; Ian, Sufi, 2016) or the endogenous origination of boom and bust cycles (Martínez-Miera and Repullo, 2017), to more specific topics, such as the consequences of business cycles for capital requirements (Repullo and Suárez, 2013; Mendicino, Nikolov, Suarez and Supera, 2018), or even the implication of competition on risk of banks' failures (Martínez-Miera and Repullo, 2010). In parallel, Basel III and the informally called Basel IV (BCBS, 2010, 2017) and its later amendments, effective 1st January 2023, were set defining significant additional capital requirements, introducing capital buffers (the Conservative Capital Buffer, CCB, and the Countercyclical Capital buffer, CCyB) as a means to better prevent financial crisis and protect bank's solvency, particularly at those moments where the credit market and the overall economy might well be overheated.

However, little attention has been placed to credit allocation decisions and, most importantly, to the connections between those decisions and the markets that drive credit demand, whilst those might well be instrumental in better understanding the origin of the financial crisis and, therefore, on most effectively identifying the policies to address them. Müller and Verner (2021) empirically show the relationship between credit expansions, macroeconomic fluctuations and financial crises considering a sectoral distribution of private credit. Most recently, San Millán (2022) shows how the asymmetric exposure to systemic risk might bias credit in favor of the former, arguing to reconsider lower capital requirements for mortgages or a more specific capital buffer add-on for real estate credit.

In this paper we develop a theoretical framework to analyze the generation of real estate bubbles at its origin, by structurally modelling the interaction between the credit market and the markets that source credit demand (particularly, the real estate market) and the impact of the latter on banks' credit granting decisions. Specifically, we describe how the different characteristics of the real estate market (supply inelasticity, household's use of this good as a form of savings and adaptative price expectations) compared to those of the consumer good market (perishable good, capital subject to diminishing returns unless counterbalanced by technology developments, internationally open markets) imply that when banks have high lending capacity (e.g. in bigger liquidity and capital surplus or capital generation contexts) they have incentives to skew credit to real estate acquisition, hence favoring, under certain conditions, the generation of real estate and credit bubbles. As the real estate supply growth is limited, bigger credit allocation to real estate implies bigger real estate prices today and therefore, on the one hand, bigger future price expectations and, on the other hand, a reduction of real estate credit risk, given the implied Loan to Value reduction; both effects being at the core of the banks' credit granting bias. By analyzing equilibria under different hypothesis on banks' credit lending capacity, credit and real estate market characteristics, capital regulation, households' preferences and production technology, we identify the circumstances that favor the origination of real estate and credit bubbles. Conditions such as bigger households' preferences for the real estate good, lower supply elasticity of that good, bigger local credit market concentration or lower productivity growth play a fundamental role in favoring real estate bubbles, being the scenarios of banks' high lending capacity particularly sensitive to this favoring conditions.

These insights are essential to anticipate and prevent the risk of real estate and credit bubbles and should be considered in the overall macroprudential supervision mechanisms at its origin (i.e. before ex-post indicators show that the bubble dynamics have been originated and therefore the cost of addressing them has increased). Furthermore, the paper shows how the regulatory capital buffer requirements transversally applied to all credit types, such as the ones defined in Basel III, might even be counterproductive in preventing those bubbles under certain conditions. On the contrary, a more effective approach should focus on directing the additional capital buffer requirements to real estate related credit. Finally, by not considering the interaction between the credit and the real estate markets described in this paper, the traditionally capital requirement benefits applied to mortgages might well be overstated and a revisitation should be considered. More specifically, even under less extreme scenarios than the real estate bubbles, we show that the dynamics of the real estate market and their interaction with the credit market might well more broadly bias the credit to the former, sacrificing bigger investment in productive capital and a more sustainable economic growth.

The remainder of this document is structured as follows. Section 2 explains the theoretical model by first providing an overview of its grounds, linking some of them to the Spanish case, an archetype of the real estate bubble driven financial crisis modelled in this paper. Then it details each of the model components: the banks' credit allocation decision framework, the real estate good and credit demands (which are derived from household's utility maximizing behavior), the real estate good supply and market equilibria and, finally, the firm's credit demand. Section 3 sets the conditions for the global model equilibrium, which is defined by simultaneously reaching equilibria in the credit and in the real estate markets. This is set under different banks' behavior assumptions –in particular, on whether banks consider or not the second order benefits of real estate acquisition credit granting–. Then, equilibria under both assumptions are first analyzed excluding credit risk losses (Section 4) to then fully embed them into the model (Section 5).

Finally, Section 6 summarizes this paper's conclusions and potential implications for banking regulation and provides some recommendations for future research.

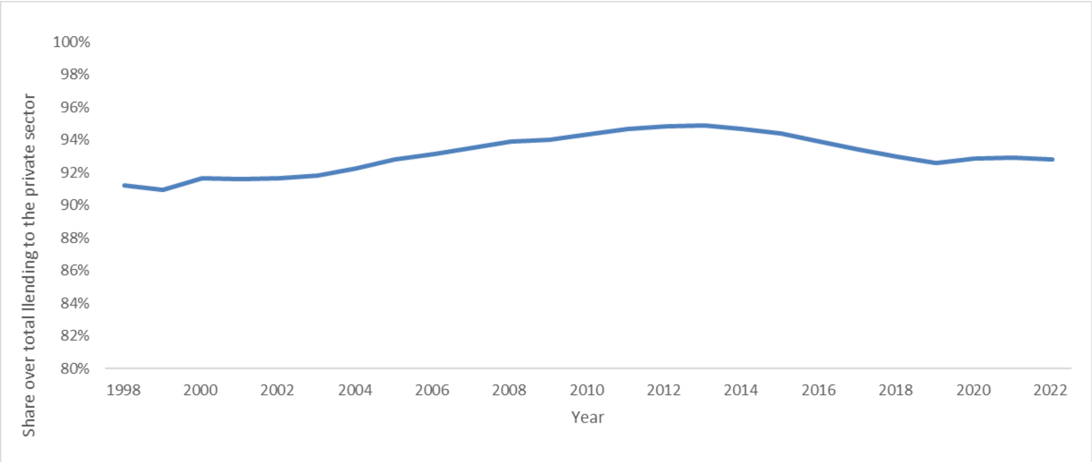
2. The model

The framework developed in this paper is structured around four main components.

First, we consider a financial system composed of *N* banks that need to decide over one period of time on either, granting credit to (i) households that would like to fund the acquisition of real estate goods or to (ii) companies that produce consumer goods.

If we consider the above first source of credit demand as a consolidation of real estate development and mortgage funding, the above two categories of credit constitute the vast majority of the financial institutions private lending in any advanced financial system. For example, this composition of credit holds substantial significance in Spain, a notable case study in this paper concerning the conceptual modeling of real estate financial bubbles. Specifically, the combined share of these two components in relation to total private sector lending remained consistently stable, ranging between 92% and 95% from 1998 to 2022. This timeframe spans a decade preceding the beginning of the financial crisis and a decade after the financial sector was restructured. The chart below illustrates this idea.

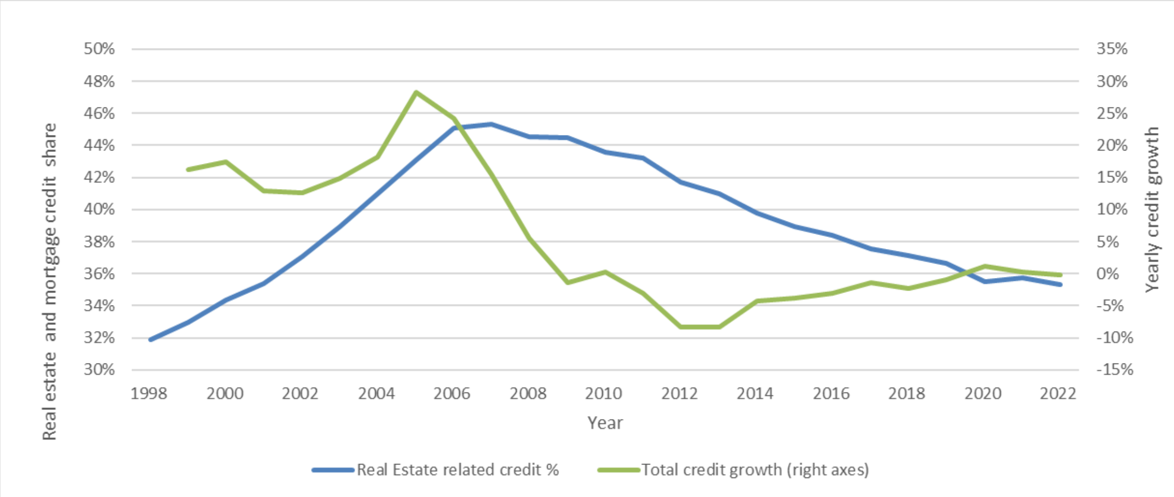
Figure 1. Share of retail mortgages and real estate, construction and other credit to companies over total lending to the private sector.



Source: Bank of Spain and authors' analysis.

On the contrary, the relative weight of these two credit components has significantly changed over time, from 32% or 35% in 1998 and 2022, respectively, to 45% in 2007, the peak of the real estate boom. This reallocation process is closely linked to total credit growth or, in other words, in contexts of high banks' lending capacity, as exemplified during the period spanning from 1998 to 2007. This pattern serves as the foundation and resemblance of the conceptual model devised within this study. The chart below illustrates this phenomenon within the context of the Spanish credit market.

Figure 2. Share of real estate related lending (i.e. mortgages + real estate development funding) over real estate related lending plus credit to companies non-related to real estate.



Source: Bank of Spain and authors' analysis.

Hence, our model analyses the credit allocation decisions over the vast majority of the credit granted to the private sector in any advanced financial system.

The other three model components relate to the characterization of (2) demand for real estate acquisition and the credit to fund it, (3) the specific dynamics of the real estate market, and (4) the demand for credit to invest in productive capital by companies.

Therefore, the second key model component is the demand for real estate acquisition credit, which naturally depends or, more broadly, is fully interdependent with the real estate demand. This is derived from modelling the household decisions between the consumption of two types of goods, the real estate and a consumption good, in two periods (i.e., households either acquire and consume them in the present or push forward its acquisition and consumption to the future). In this regard, households can acquire units of the real estate good, which is durable, so that any unit of it acquired in the first period will last (and provide utility to households) for the future. Alternatively, they can acquire the consumption goods, which are perishable and will last (and provide utility) only for one period. In this context, two key real estate demand drivers - the current price of the real estate good and the expectation of its future evolution, which, in turn, depends on the former (and more specifically, on its growth) - exert an indirect yet substantial influence on the demand for credit, which, in conjunction with the dynamics introduced by the real estate market, will be crucial to understand the credit allocation choices described earlier, ultimately setting the seeds for the real estate and credit boom dynamics in certain contexts.

In addition to the real estate demand, the real estate market is characterized by the inelasticity of the real estate good supply. Specifically, we consider a natural growth rate of the real estate good, so that the supply of the real estate good is highly (almost perfectly) inelastic for growth levels below this natural growth rate (as once the real estate good is produced, it cannot be destroyed) and inelastic (albeit clearly less rigid) for increases of the real estate good beyond this natural growth rate. In particular, the latter upper supply naturally depends on the price of the real estate good, similarly to q-Tobin dynamics.

Finally, we also model the other source of credit demand, which is capital funding to companies that produce the consumer good. In this regard, both the production of the good and the demand for credit to fund the capital to produce it depend on the technology used for that purpose. Consequently, a change in the technology driven by an increase in the productivity will increase the consumer goods demand for credit. As previously indicated, in this paper we do not consider a global general equilibria model. Thus, we adopt an open economy perspective, where the consumer good production is cleared in the market.

As we will see later, the interaction between these four model components is key both, in explaining banks' credit allocation decisions and, most interestingly, in characterizing the scenarios that drive the real estate and credit boom processes. The next sections detail each of these four model components.

2.1. Banks' behavior: credit allocation

The credit system consists of *N* homogeneous banks, each of them (i) with the following two credit business alternatives: granting credit to families to purchase a real estate good $(\mathrm{CRV_{it}})$, or granting it to enterprises to fund the capital required for consumer goods production $(\mathrm{CRK_{it}})$. To this end, they are subject to a restriction on the total volume of credit they can grant ($\overline{CRT_{it}}$). This limit can be considered either as a consequence of the market context, Central Banks' policy or banks' available capital surplus (i.e., excess over minimum required by regulators or the market) or capital generation easiness.

Each bank maximizes its economic profit or value added (Π_{it}), being this defined as income minus operational costs minus cost of capital. Concretely, income is determined by the interest charged to customers, which is the result of multiplying the interest rate (i.e., the credit price, $\mathrm{r_v}$ for the real estate acquisition credit and $\mathrm{r_k}$ for the consumer goods capital production credit) by the volume of credit finally granted for each of the two sources of credit demand.

The cost consists of the credit risk loss (m_{v} and m_{k} per unit of credit, as a consequence of the fact that some of the credits granted for real estate acquisition and consumer goods capital production will default), the operating cost (c), and the cost of funding (i.e. the costs associated to fund the credit volume that will be granted, which in unitary terms will be denotes as r). The unitary operational cost and the cost of funding are assumed to be the same for the two types of credit that can be granted, and therefore irrelevant for the credit allocation decisions. The differences among them for each credit type will have a similar effect to the differences in the regulatory capital for each bank, which are analyzed in Section 4.3 and 5.3.

Finally, the cost of capital results from multiplying the unitary cost of capital (i.e. the "hurdle rate" or minimum return required by the shareholders, R) by the volume of capital required. In line with the Risk Weighted Assets method, the minimum capital requirement results from multiplying a percentage parameter, which is set differently depending on the type of credit ($\%\mathrm{K_v}$ for Real Estate acquisition vs. $\%\mathrm{K_k}$ for productive capital funding), and the volume granted for each of the two categories $(\mathrm{CRV_{it}}$ and $\mathrm{CRK_{it}})$.

Hence, the economic profit function maximized by each bank *i* in period *t* is specified as:

$$\max_{CRV_{it},CRK_{it}} \Pi_{it} = (r_v - m_v - c - r - \%K_v R)CRV_{it} + (r_k - m_k - c - r - \%K_k R)CRK_{it} \qquad [1]$$

Subject to $CRV_{it} + CRK_{it} \leq \overline{CRT}_{it}$.

Given that the purpose of this paper is to analyze credit booms dynamics, we assume that banks exhaust their lending capacity and therefore that the above restriction is binding. Hence, applying the Lagrange method, we obtain the economic profit optimal condition. Intuitively, this implies that the marginal profitability of an additional unit of lending to households should be equivalent to the marginal profitability of an additional unit lent to companies.

$$\frac{\partial \Pi_{it}}{\partial CRV_{it}} = \frac{\partial \Pi_{it}}{\partial CRK_{it}} \; . \qquad [2]$$

If we consider that the market is composed of *N* banks of the same characteristics, the credits they offer are homogeneous products inside each of the two credit types and banks' behavior follow Cournot's conjure (i.e., they assume $\frac{\partial CRV_t}{\partial CRV_{it}} = 1$)[1] then the market equilibria is defined by the following expression:

$$\left(r_v + \frac{\partial r_v}{\partial CRV_{it}} CRV_{it}\right) - \left(m_v + \frac{\partial m_v}{\partial CRV_{it}} CRV_{it}\right) - \%K_v R = \left(r_k + \frac{\partial r_k}{\partial CRK_{it}} CRK_{it}\right) - \left(m_k + \frac{\partial m_k}{\partial CRK_{it}} CRK_{it}\right) - \%K_k R. \qquad [3]$$

As stated above, notice that *c*, the unitary operational cost for each unit of credit granted, and *r*, the unitary funding cost, are irrelevant for the equilibria conditions as they have been assumed to be the same for both types of credit, therefore not impacting their relative profitability.

Therefore, as it can be seen Equation [3], the marginal return of an additional unit of credit granted to each of the two options for lending can be set around the three main components: income, credit loss and cost of capital.

$$\left(r_v + \frac{\partial r_v}{\partial CRV_t}\frac{CRV_t}{N}\right) - \left(m_v + \frac{\partial m_v}{\partial CRV_t}\frac{CRV_t}{N}\right) - \%K_v R = \left(r_k + \frac{\partial r_k}{\partial CRK_t}\frac{CRK_t}{N}\right) - \left(m_k + \frac{\partial m_k}{\partial CRK_t}\frac{CRK_t}{N}\right) - \%K_k R$$

1a 1b 1c 2a 2b 2c

In the case of credit for the acquisition of real estate assets, the first component (1a in Equation [3]) is the marginal income, which is made up by the interest rate adjusted by the impact that an additional unit of credit per bank has in decreasing that rate. This will depend on the household demand for credit, a factor influenced by the household utility function and its real estate demand. As we will show later, the real estate demand depends on real estate prices and its future expectation, which, subsequently, depend on the credit volumes allocated to real estate acquisition. These circular dependencies are at the origin of real estate bubbles. The demand for real estate asset acquisition and the credit demand will be discussed in Section 2.2.

The second component of the credit marginal profitability (1b) is the cost of risk, as well as the impact of an additional unit of credit in that cost. As we will discuss in Section 5, we consider

[1] This expression means that each bank will consider that the increase of one unit of credit offered will have an impact of one unit of additional credit in the market.

Loan-to-Value as the key driver of such cost of risk, in line with banks' risk management practices, capital regulation and empirical evidence. Interestingly, given the specifics of the real estate market, and, in particular, its supply inelasticity, the impact of an additional credit unit over the real estate price mitigates the increase (and, in some scenarios, even decreases) the credit risk cost, which provides a structural explanation for the observed pattern of extremely low credit losses associated to strong credit growth and subsequent real estate bubbles.

Finally, the cost of capital is the third component (1c) of the marginal return of the credit allocated to households, resulting from multiplying the return required by shareholders (the "hurdle rate", R) and the capital requirements for the real estate acquisition ($\%K_v$). In Sections 4 and 5 we will explain that, under the current capital regulation, this requirement is lower for the credit allocated to the acquisition of real estate assets than for credit allocated to companies (i.e. $\%K_v < \%K_k$). Interestingly, the conclusions of this paper suggest to consider revisiting this regulation.

Likewise, in the case of credit for capital investment for the consumer good production, the marginal profitability of one additional unit of credit granted consists of income, credit loss and cost of capital.

First, the marginal income of the credit allocated to companies (2a) is composed of its market price (the interest rate), adjusted by the impact that one additional unit of credit has in decreasing it. This is driven by the companies' demand for credit, which depends on marginal capital returns. In turn, marginal capital returns result from the production technology. In particular, following the framework applied in traditional growth models, the assumption of constant returns of scale in the production function implies having decreasing marginal capital returns, which therefore will reduce the marginal interest rate as the credit allocated to companies increases. On the contrary, this could be counterbalanced by capital productivity improvements through technology progress.

The cost of risk and the impact of an additional unit of credit over such cost make up the second component of credit marginal return (component 2b). As discussed later in Section 5, we will consider leverage as the key driver of such cost of risk, in line with the widely accepted Merton framework, banks' risk management practices, capital regulation and empirical evidence. Interestingly, an additional unit of credit will increase leverage, therefore increasing expected credit risk losses.

The third component, the cost of capital (2c), results from multiplying the return required by shareholders (the "hurdle rate", R) and the capital requirements for credit granted to companies. As stated above, this requirement will be bigger than for real state household acquisition (i.e. $\%K_v < \%K_k$).

Finally, as it will be shown in Sections 4 and 5, *N*, the number of banks in the industry significantly influences the way credit is allocated. In particular, the degree of concentration in the credit market, or conversely, the average size of banks, plays a crucial role in the allocation of credit as one of the key factors affecting the emergence of a credit-driven financial bubble. The parameter *N* could also be easily anchored to the Herfindahl concentration index, where:

$$Herfindahl\ Index_{base\ 1000} = 1000\,\frac{1}{N} \qquad [4]$$

helping therefore linking the results to the concentration levels of different credit markets measured through this indicator.

2.2. Household's behavior: real estate and credit demand

As stated above, the real estate demand and the credit demand for real estate good acquisition are closely interconnected, being both of them derived from household utility maximizing behavior. In Sections 2.2.1 and 2.2.2 we derive both demands and show the interconnexions between them.

2.2.1. Real estate good demand

We consider households that make decisions over a two period time horizon (present, *t*, and future, *t*+1) and get utility from the consumption of a perishable ($\mathrm{C_t}$ and $\mathrm{C_{t+1}}$) and a real estate good ($\mathrm{V_t}$ and $\mathrm{V_{t+1}}$).

On the one hand, the perishable good provides utility to the consumer on each period of time only by the amount purchased during that period, as it is perishable and therefore cannot be stored. For simplicity, we consider it as the numerary, i.e. with price equal to 1. On the other hand, the real estate good provides utility by the stock owned by the consumer in each period. In contrast to the consumer good, the real estate good endures, so that the additional expense in the real estate good within period t implies also greater utility in period t+1, by increasing its future stock. We do not consider transaction costs and depreciation of the consumer good explicitly in the model, but rather embed it into the price and price evolution of the real estate good. Implications of both of them will be discussed below.

If we denote by P_t the price of the real estate good in period *t* and by P_{t+1} its expected price in period t+1, we have that:

$$P_{t+1} = (1 + p^e)P_t \qquad [5]$$

where p^e is the expected net revalorization of the real state good in real terms, net of depreciation, inflation as well as any other transaction costs. As it will be seen later, the way the expectations on the future prices are set and, in particular, how P_t impacts on those expectations (e.g. to what extent expectations are adaptative) are key in the risk of generating real estate price and credit bubbles.

Consumers are endowed with several components: known wages in both periods *t* and *t*+1 (w_t and w_{t+1}), an initial quantity of the real estate asset (V_0), and an initial net financial wealth, designated as I_0.

Households have two alternative ways to transfer income from one period to another. They can borrow or invest at a rate r_d or, alternatively, they can borrow to buy a real estate good at a rate r_v. In contrast to the perishable good, the real estate good has a double role: it brings utility to households by the stock available within each period, and it is also a mechanism to transfer wealth (the transfer rate will depend on r_v and on the expected revalorization of the real estate good, p^e).

We denote the utility function of each period following a Cobb-Douglas logarithmic specification:

$$\mathrm{U}_t = \alpha ln(V_t) + (1-\alpha)ln(C_t) \qquad [6]$$

where V_t denotes the real estate good at period t, C_t denotes the perishable consumer good at period t and α denotes the relative consumer preference for the real estate good. As we will discuss below, this will also be a relevant parameter to consider in setting the prudential policies to prevent real estate bubbles. In particular, countries with different preferences for real estate goods might imply different patterns of real estate demand that will impact credit dynamics.

Therefore, considering two periods, we have:

$$U = \alpha ln(V_t) + (1-\alpha)ln(C_t) + \beta[\alpha ln(V_{t+1}) + (1-\alpha)ln(C_{t+1})] \qquad [7]$$

being β is the future utility discount factor.

The optimization problem of a representative household in period *t* can be expressed as:

$$\max_{\mathrm{V_t, V_{t+1}, C_t, C_{t+1}}} \alpha ln(V_t) + (1-\alpha)ln(C_t) + \beta[\alpha ln(V_{t+1}) + (1-\alpha)ln(C_{t+1})]$$

subject to the constraint:

$$C_{t+1} + P^e_{t+1}V_{t+1} \leq P^e_{t+1}V_t - (1+r_v)\,P_t(V_t - V_0) - (1+r_d)(C_t - I_0 - w_t) + w_{t+1} \qquad [8]$$

as $P_{t+1} = (1+p^e)P_t$ being p^e the expected net revalorization of real estate from *t* to *t*+1. Later on, we will assume that expectations on real estate good revalorization are adaptative. In particular, for positive increases in prices ($P_t > P_0$), we will assume $p^e = s\left(\frac{P_t}{P_0} - 1\right)$, being *s* the sensitivity of future expectations with respect to the observed revalorization; i.e., typically, 0 < s < 1.

Then we can specify the budget restriction as:

$$C_{t+1} + (1+p^e)P_tV_{t+1} \leq (1+p^e)P_tV_t - (1-r_v)\,P_t(V_t - V_0) - (1-r_d)\,P_t(C_t - I_0 - w_t) + w_{t+1}.$$

Given that the utility function is monotonic on the consumption of both the perishable and the real estate good at t and t+1, we can consider the above restriction as binding under the optimal household decision. Hence, following the Lagrange method, the optimization problem of a representative household is set as:

$$\max_{V_t, V_{t+1}, C_t, C_{t+1}, \lambda} \alpha ln(V_t) + (1-\alpha)ln(C_t) + \beta[\alpha ln(V_{t+1}) + (1-\alpha)ln(C_{t+1})] + \lambda[B - A]$$

$$\overbrace{C_{t+1} + (1+p^e)P_tV_{t+1}}^{\mathbf{A}} = \overbrace{(1+p^e)P_tV_t - (1+r_v)\,P_t(V_t - V_0) - (1+r_d)\,(C_t - I_0 - w_t) + w_{t+1}}^{\mathbf{B}}.$$

It should be noted that in cases where $p^e > r_v$, i.e. in cases where the net revalorization of the real estate good (adjusted by depreciation, inflation and transaction costs) is above the interest rate to fund its acquisition, households acquire all possible amount of the real estate good, only limited by all credit offered in the market to purchase it.[2]

[2] This results from the fact that households' utility (U) grows in C_{t+1}, V_{t+1} and V_t and that the second component of the budget constraint is increasing in $V_t\left[\frac{\partial \mathrm{B}}{\partial \mathrm{V_t}} = \mathrm{P_t}(\mathrm{p^e} - \mathrm{r_v}) > 0\right]$, so that consuming more V_t expands the budget contrain, in addition to provide more utility itself.

Going back to the most general case $r_v > p^e$, we can obtain the following relationships between consumption of both goods in the two periods:

$$C_t = V_t P_t (r_v - p^e) \frac{(1-\alpha)}{\alpha} \frac{1}{(1+r_d)} \quad [9]$$

$$C_{t+1} = \beta C_t (1 + r_d) \quad [10]$$

$$V_{t+1} = \beta V_t \frac{(r_v - p^e)}{(1+p^e)} \quad [11]$$

$$C_{t+1} = V_{t+1} P_t (1 + p^e) \frac{(1-\alpha)}{\alpha} \quad . \quad [12]$$

Replacing the above expressions in the budget constraint results in the demand for the real estate good:

$$V_t^D = \frac{\alpha((1+r_v)\, P_t V_0 + WNV_0)}{P_t (r_v - p^e)(1+\beta)} \quad [13]$$

where:

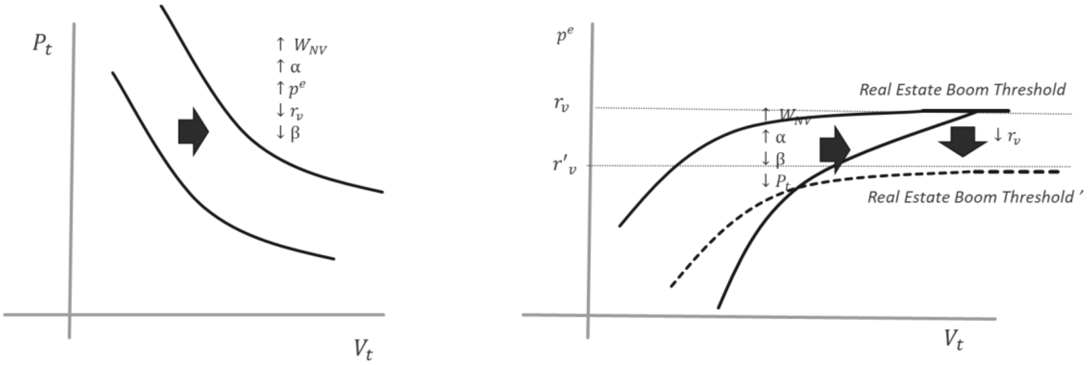
$$WNV_0 = (1 + r_d)\,(I_0 + w_t) + w_{t+1} \quad [14]$$

denotes the financial wealth (other than real estate) valued in period *t*+1.

Households' demand for real estate assets is intuitive. It raises with households' wealth —both real state wealth (V_0) and non-real estate wealth (WNV_0) —, families' preference for housing against consumption (α) and expectations for future house prices (p^e). Conversely, it falls with increases on the current price of the real estate good (P_t) (even though this is mitigated by the positive wealth effect that has over the real estate wealth through $P_t V_0$), on the interest rate or cost of the credit for real estate acquisition (r_v) and on β, the discount factor (i.e. the value that the households give to the future).

Figure 3 shows the real estate demand, both with respect to its price and its expected future net revalorization, as well as the shifts on it when the rest of variables change. In the right-hand side of the same figure, we show the severe real estate boom scenario discussed above (i.e. the case where $r_v < p^e$).

Figure 3. The real estate good demand, its drivers and the impact on future real estate price expectations on it.



2.2.2. Credit demand

The demand for real estate acquisition credit can be expressed as:

$$CRV_t = P_t V_t^D - P_t V_0 \tag{15}$$

Then, replacing V_t^D by the expression in Equation [13], yields:

$$CRV_t = \frac{\alpha[P_t(1+r_v)V_0 + WNV_0]}{(r_v - p^e)(1+\beta)} - P_t V_0. \tag{16}$$

Again, the demand for credit is intuitive. It decreases when the cost of credit (r_v) or the value of the future (the discount factor, β) grow, and increases when the preference for real assets (α), financial net wealth (WNV_0) and, most importantly, its expected future revalorization (p^e) grow. As discussed below, the latter plays an important role in setting the credit dynamics towards real estate and credit booms. The impact of P_t and V_o —which appear always multiplied as $P_t V_0$, meaning the value of real estate endowment valued at t—, is a priori less clear. However, if we obtain the derivative with respect to P_t, we have that:

$$\frac{\partial CRV_t}{\partial P_t} = \frac{\alpha(1+r_v)V_0}{(r_v - p^e)(1+\beta)} - V_0. \tag{17}$$

Thus, the sign of the relationship of CRV_t with respect to the price of real estate assets will be positive when:

$$\frac{\alpha(1+r_v)}{(r_v - p^e)(1+\beta)} > 1.$$

This will happen in cases of (i) high preference for real estate assets (high α), (ii) short term driven preferences (low β), and, more specifically, (iii) when expected real estate asset revalorization (p^e) is relatively high and closer to r_v. In those cases, an increment in the price of real estate goods increases the demand for credit. Furthermore, in the case of a severe real estate boom ($p^e = r_v$), households will take all credit offered to them.

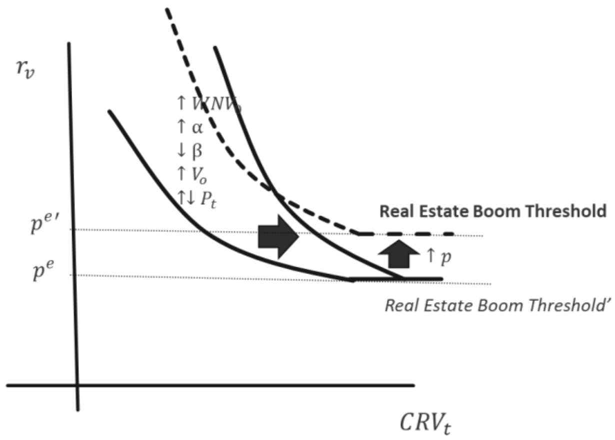
The inverse credit demand is expressed as:

$$r_v = \frac{p^e(CRV_t + P_t V_0)(1+\beta) + \alpha P_t V_0 + \alpha WNV_0}{(CRV_t + P_t V_0)(1+\beta) - \alpha P_t V_0}. \tag{18}$$

Note that the interest rate that households are willing to pay is strongly dependent on the expected future real estate revalorization, even outside real estate boom conditions.

Figure 4 represents the demand for credit with respect to the interest rate, and how it shifts with the rest of factors.

Figure 4. Real Estate credit demand.



2.3. The real estate market

As stated, the real estate market and its interaction with the credit market play a fundamental role in explaining the dynamics that originate credit and real estate bubbles. After deriving the real estate market demand in the previous section, we will derive the real estate supply function (Section 2.3.1) and explain how equilibria is reached in the real estate (Section 2.3.2).

2.3.1. Real estate good supply

The supply of the real estate good is characterized as follows. First, by its own nature, the real estate supply cannot be below the initial endowment (V_0). Second, we consider a natural supply growth rate (g_v), which is linked to each market real estate good characteristics. The supply of the real estate good can be increased above this natural rate when its price rises in real terms (Tobin's q logic), although this growth is limited by the supply elasticity (γ_u). In general, we assume that the supply of the real estate good is inelastic (γ_u<1), meaning that additional real estate good supply increases will only occur with a more than proportional growth on its price[3]. Below the level that determines the natural rate of the real estate growth, the supply is severely inelastic (parameter γ_d close to zero).

Therefore, the supply of the real estate good is specified as:

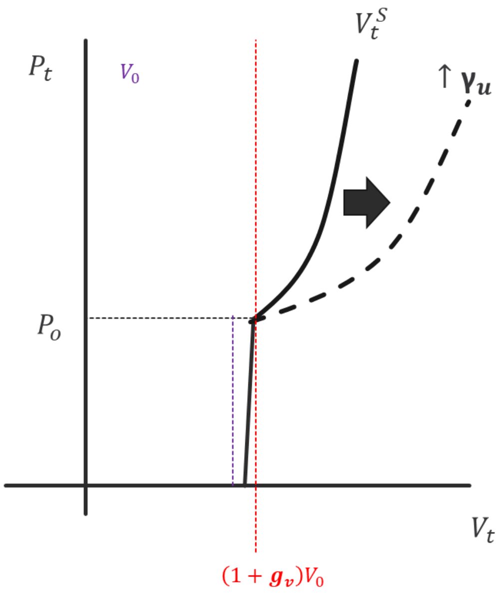
$$V_t^S = \begin{cases} V_0(1+g_v)\left(\frac{P_t}{P_0}\right)^{\gamma_u} & if\ P_t > P_0 \\ V_0(1+g_v)\left(\frac{P_t}{P_0}\right)^{\gamma_d} & if\ P_t \leq P_0 \end{cases} \quad [19]$$

with $V_t \nless V_0$, $\gamma_d \gtrsim 0, 0 < \gamma_u < 1$.

Figure 5 illustrates the real estate good supply.

[3] The model could also be applied with γ_u> 1. Obviously, a bigger demand elasticity will moderate the generation of real estate bubbles, as it could be observed in results shown in Sections 4 and 5.

Figure 5. Real Estate good supply.



2.3.2. Real estate market equilibrium

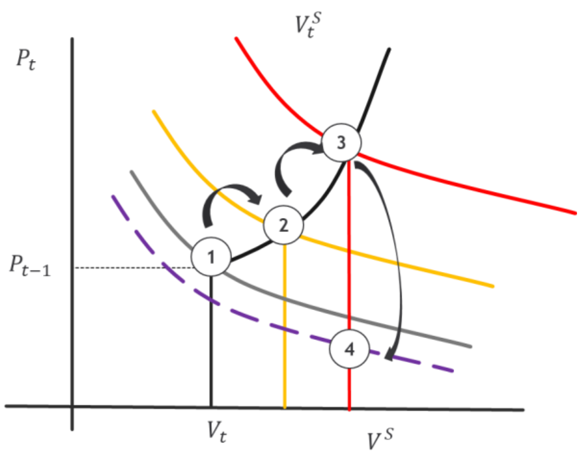
Real estate market equilibrium is reached when the supply and the demand of the real estate good meet each other, i.e. when

$$V_t^D = V_t^S \tag{20}$$

being demand and supply set at Equations [13] and [19]

Despite this model is set for two periods, it should be noted that our supply set up allows to resemble well a real estate boom and its posterior crisis, which typically follows the steps illustrated in Figure 6 below.

Figure 6. Real Estate demand and supply and Real Estate boom dynamics.



We assume to start from a stable initial point with moderate or no growth in real estate good prices (point 1 in Figure 6). Then, a shock occurs (for example, credit increases because there is more liquidity), which increases the demand and price of real estate assets, increasing its stock, which, given the severe inelasticity of real estate supply reduction, will remain for the future (point 2). The initial increase in prices raises future price growth expectations and reduces the credit losses of the existing credits, increasing the demand for credit and, thus, the demand for housing; therefore, the price (and the stock of housing that will remain for the future) accelerate their growth (point 3). Finally, at some point, the high capacity of lending becomes unsustainable (perhaps triggered by a negative shock). When the volume of credit breaks, so does the demand for housing, which causes the price of assets to go down (as well as its future expectation), increasing risk and reducing the supplied credit (point 4). Thus, real estate demand falls even below the initial equilibrium levels, but with a much higher housing stock than in 1 (given supply downwards inelasticity), sinking its price.

The different scenarios analyzed in Sections 4 and 5 will help us to understand what drives market equilibrium in points 1,2,3 or 4.

2.4. Firm's behavior: credit demand for productive capital

Firms demand credit to fund its investment in capital used to produce the perishable consumer good. In line with the framework applied in the classical growth models, we use a Cobb-Douglas production function (e.g. Solow (1956), Diamond (1965)). In particular, we consider that there are infinite firms with identical constant returns to scale production functions. Hence the production function will be:

$$Y_t = A_t K_t^{\alpha} = A_0(1+g)K_t^{\alpha_K} = A_0(1+g)(CRK_t + K_0)^{\alpha_K} \qquad [21]$$

where:

Y_t, is the amount produced of the consumer good;

K_t is the total amount of capital allocated to produce the consumer good. This can be decomposed into K_0, the initial capital endowment net of depreciation available at the beginning of the period, and CRK_t the capital acquired within the period through credit.

A_t is the technology productivity factor at t, that can be specified as a technology productivity factor at the beginning of the period (A_0,) subject to the technical progress during the analyzed period (g).

α_K is the relative importance of capital in the production technology, assumed to be 0 > α_K > 1.

We consider a workforce (denoted by *L* in the growth models) normalized to one, i.e., L=1.

In a competitive market such as the one described above, the demand for capital can be set by its marginal return of as:

$$\partial Y_t / \partial K_t = \alpha \, K_t^{\alpha-1} A_0(1+g). \qquad [22]$$

This capital marginal return is what firms would pay for an additional unit of capital and therefore, in a competitive environment, the interest rate that firms will pay for one unit of credit to fund their capital. Therefore, considering the initial capital endowment K_0 , the inverse demand for credit and the demand for credit are:

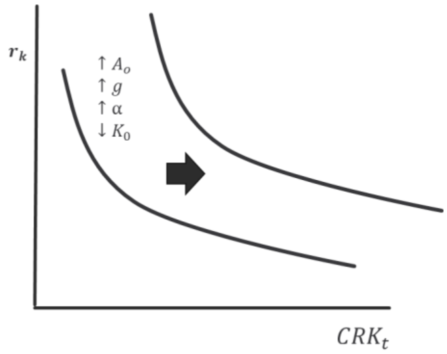
$$r_k = {\partial Y_t}/{\partial K_t} = \alpha_K\,(K_0 + CRK_t)^{\alpha_K - 1}\,A_0(1+g). \qquad [23]$$

So that,

$$CRK_t = \left(\frac{\alpha_K A_0(1+g)}{r_k}\right)^{\frac{1}{1-\alpha_K}} - K_0\,. \qquad [24]$$

As a result of the diminishing marginal capital returns, the demand for credit will decrease as interest rates (r_k) raise. Additionally, for a given interest rate (r_k), the demand increases with better technology endowment (A_0), technology progress (g) and with more capital driven technologies (α_K). Accordingly, it decreases with a bigger initial capital endowment (K_0) given the diminishing marginal capital returns. As a consequence, economies with a larger capital endowment and poor technology progress will be subject to higher credit allocation biases towards real estate acquisition and, as a consequence, to higher real estate bubble generation risk. Figure 7 illustrates the companies' credit demand and its drivers.

Figure 7. Consumer good production companies' credit demand.



3. Equilibria

The model is solved by simultaneously reaching equilibrium in the credit and real estate markets.

On the one hand, credit market equilibrium is reached when Equation [3] holds:

$$\left(r_v + \frac{\partial r_v}{\partial CRV_t}\frac{CRV_t}{N}\right) - \left(m_v + \frac{\partial m_v}{\partial CRV_t}\frac{CRV_t}{N}\right) - \%K_v R = \left(r_k + \frac{\partial r_k}{\partial CRK_t}\frac{CRK_t}{N}\right) - \left(m_k + \frac{\partial m_k}{\partial CRK_t}\frac{CRK_t}{N}\right) - \%K_k R.$$

On the other hand, the real estate market equilibrium is reached when Equation [20] holds (i.e. $V_t^D = V_t^S$).

$$V_t^D = \frac{\alpha((1+r_v)\,P_t V_0 + WNV_0)}{P_t(r_v - p^e)(1+\beta)} = \left\{ \begin{array}{ll} V_0(1+g_v)\left(\frac{P_t}{P_0}\right)^{\gamma_u} & if\ P_t > P_0 \\ V_0(1+g_v)\left(\frac{P_t}{P_0}\right)^{\gamma_d} & if\ P_t \le P_0 \end{array} \right\} = V_t^S.$$

Interestingly, both markets are interconnected as the credit provided to real estate acquisition will impact the real estate market. Most concretely, reorganizing Equation [15] we have:

$$CRV_t = P_t V_t - P_t V_0 \iff P_t V_t = CRV_t + P_t V_0 \qquad [25]$$

and, as stated inequation [19],

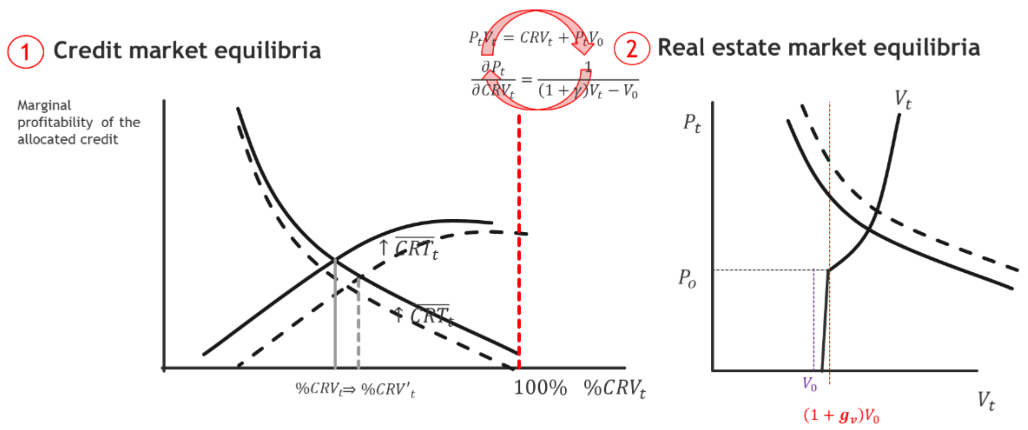
$$V_t^S = V_0(1 + g_v)\left(\frac{P_t}{P_0}\right)^{\gamma}$$

so that, credit impacts the price of the real estate asset as:

$$\frac{\partial CRV_t}{\partial P_t} = \frac{\partial V_t}{\partial P_t} P_t + V_t - V_0 = (1+\gamma)V_t - V_0 \Rightarrow \frac{\partial P_t}{\partial CRV_t} = \frac{1}{(1+\gamma)V_t - V_0}. \qquad [26]$$

Hence, any changes in the credit allocated to real estate acquisition impacts the price of the real estate asset. This price impacts the expected future revalorization of the real estate asset and both of them – the price and the future expected revalorization – affect the credit demand. As it will be seen later, these dynamics imply that the higher is the capacity to lend (i.e. for large levels of $\overline{CRT}_t$), the larger will be the proportion of credit allocated to real estate. It should be noted the key role that the (in)elasticity of the real estate good supply plays in this process. In particular, as Equation [26] shows, the lower the elasticity of the real estate supply good, the bigger the impact of a further unit of credit in the real estate price (as this unit cannot be fully translated into real estate growth). As this inelasticity is intrinsic to the real estate good, this reinforces the dynamics that favors credit bias towards real estate credit (vs. capital for consumer good production) in high lending capacity scenarios. This phenomenon explains why, as a general pattern, real estate assets that inherently lack the potential for self-expansion (e.g., properties situated in city centers or coastal areas) often experience more substantial price surges during real estate booms. Additionally, it highlights that, in broader terms, countries with limited capacity for real estate development (e.g., greater concentration of real estate assets in urban areas and limited availability of urban land) tend to witness more pronounced price increments when credit expansion occurs. Figure 8 illustrates the interaction between both markets.

Figure 8. Interaction between credit and real estate markets.



In other words, $\overline{CRT}_t$ impacts the relative credit allocation, since the additional volume of available credit has a larger marginal return in funding real estate acquisition than in funding capital for consumer goods production. This is a consequence of the interaction between the two markets (credit and real estate) since the volume of real estate credit affects the demand for housing, through both its price and its future price expectation, which in turn increases the demand for credit itself, smoothing the interest rate decrease required for households to take the additional credit. On the contrary, the credit assigned to productive capital has diminishing returns (i.e. the additional credit needs to be allocated to the funding of the worse investment projects that are on the margin) unless this is counterbalanced by technology progress.

From a different perspective, we see that for any additional unit of credit lent for real estate acquisition, the value of the real estate properties assets grows more than proportionally. In particular, we have that:

$$P_t V_t = CRV_t + P_t V_0 \Rightarrow \frac{\partial P_t V_t}{\partial CRV_t} = 1 + \frac{\partial P_t}{\partial CRV_t} V_0 \Rightarrow \frac{\partial P_t V_t}{\partial CRV_t} = 1 + \frac{1}{(1+\gamma)\, V_t - V_0} V_0. \quad [27]$$

Therefore, an additional unit of credit implies an increase in the demand for the real estate asset whose price rise depends on its elasticity. However, this rise in price also impacts the value of the real estate good which was already in the hands of households (V_0), generating a wealth effect that contributes to accelerate the real estate bubbles when further credit can be allocated to real estate acquisition. As we will see in Section 5, this will also play an important role in explaining the positive real estate risk evolution that typically accompanies credit growth in boom periods.

To gain a deeper comprehension of the determinants of credit dynamics, we will analyze the equilibrium in two steps. First, Section 4 discusses credit dynamics without considering credit risk, to obtain an understanding of the source of market dynamics on its origination. Second, Section 5 analyzes credit risk and embeds it into the credit market dynamics. As we will see, the specifics of the real estate market (and in particular the inelasticity of the real estate supply) play an important role in the credit risk dynamics that can even reinforce further the conditions that favor credit and real estate bubbles. For each step we will consider two hypothesis regarding banks' behavior.

First, we will assume that banks do not consider the secondary effects in the real estate market in their optimal credit allocation decisions. In particular, we will assume that, when banks decide on credit allocation, they just follow the direct signs of the credit market and do not consider the full chain of circular effects (in which growing credit to households might increase the current real estate price and its future expectation and therefore, again, the demand for credit). In other words, we consider that each bank management committee is not explicitly considering the impact of their credit allocation on the real estate market. Furthermore, as it will be seen later, the secondary effects of the real estate market on the demand for credit will be a key factor to determine equilibrium.

Second, we will explore the idea that banks take into account the consequences of their lending choices on the real estate market. In this scenario, banks make their decisions considering, not just the immediate signals from the credit market, but also the bonus benefits or the side effects that more lending can generate through the dynamics of the real estate market, i.e. they consider that growing credit to households might increase the current real estate price and its future expectation and therefore, again, the demand for credit.

For each hypothesis, we consider the optimal credit allocation along with its consequences in the real estate market. We do this under various assumptions about the initial model conditions and different levels of banks' lending capacity ($\overline{CRT_t}$). Then, we will undertake sensitivity analysis for changes in parameters, reflecting different key characteristics of the household preferences, production technology, real estate market and credit market. This will give us an insight on the credit allocation and real estate results drivers, hence providing a better understanding of the conditions that favor credit and real estate bubbles.

4. Equilibrium without risk

In this section, we describe the equilibrium conditions without credit risk, first under the hypothesis of banks' not considering the secondary effects in the real estate market in their credit allocation decisions (Section 4.1.) and second under the hypothesis of banks taking into account the full chain of consequences of their lending choices on the real estate market (Section 4.2.). Finally, we show the results and sensitivity analysis under both hypothesis in Section 4.3.

4.1. Equilibrium when banks do not consider second order effects in their lending decisions

Following Equation [3], the equilibrium in the credit market without considering risk could be specified as:

$$\left(r_v + \frac{\partial r_v}{\partial CRV_t}\frac{CRV_t}{N}\right) - \%K_v R = \left(r_k + \frac{\partial r_k}{\partial CRK_t}\frac{CRK_t}{N}\right) - \%K_k R \qquad [28]$$

reflecting that banks optimize their economic profit by equaling marginal profitability of credit for real estate acquisition and productive investment. To fulfill the above condition in their decision process to maximize economic profit, banks consider the demand for credit for real estate acquisition as stated in Equation [18]:

$$\mathrm{r_v} = \frac{\mathrm{p^e(CRV_t+P_tV_0)(1+\beta)+\alpha P_tV_0+\alpha WNV_0}}{\mathrm{(CRV_t+P_tV_0)(1+\beta)-\alpha P_tV_0}}.$$

As observed, the price of the real estate asset, $\mathrm{P_t}$, and its future expectation, $\mathrm{p^e}$ (which in turns depends on $\mathrm{P_t}$), play an important role in determining the interest rate that consumers are willing to pay to fund their real estate investments. However, as stated above, the key question is whether banks consider the impact of their credit policies in $\mathrm{P_t}$ (and therefore the implied second order effects in the demand for credit) or just follow the direct the signals of the credit demand. Now we will assume that they just follow the direct signals of the credit demand, so banks consider ${\partial P_t}/{\partial CRV_t} = 0$. Under this assumption we have:

$$\left.\frac{\partial r_v}{\partial CRV_t}\right|_{\partial P_t/\partial CRV_t=0} = -\frac{\alpha(1+\beta)[(1+p^e)P_tV_0+WNV_0]}{[(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0]^2}. \qquad [29]$$

Likewise, in the case of the inverse demand of credit allocated to companies, as per Equation [23], we have:

$$r_k = \alpha_K\,(K_0 + CRK_t)^{\alpha_K - 1}$$

where,

$$\frac{\partial r_k}{\partial CRK_t} = \alpha(\alpha-1)A_0(1+g)(K_0+CRK_t)^{\alpha-2}. \qquad [30]$$

Therefore, the credit market equilibrium condition becomes:

$$\frac{p^e(1+\beta)(CRV_t+P_tV_0)+\alpha P_tV_0+WNV_0}{(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0}-\frac{\alpha(1+\beta)[(1+p^e)P_tV_0+WNV_0]}{[(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0]^2}\frac{CRV}{N}-\%K_vR=$$

$$=\alpha A_0(1+g)(K_0+CRK_t)^{\alpha-1}+\alpha(\alpha-1)A_0(1+g)(K_0+CRK_t)^{\alpha-2}\frac{CRK_t}{N}-\%K_kR. \quad [31]$$

Likewise, the condition for the real estate market equilibrium is the one set in Equation [20].

4.2. Equilibrium when banks consider second order effects in their lending decisions

If banks consider their impact on the real estate market in their credit allocation decisions (i.e. they consider $\partial P_t/\partial CRV_t \neq 0$), this yields:

$$\frac{\partial r_v}{\partial CRV_t}=\left.\frac{\partial r_v}{\partial CRV_t}\right|_{\partial P_t/\partial CRV_t=0}+\frac{\partial P_t}{\partial CRV_t}\left[V_0\frac{\alpha(1+p^e)(1+\beta)CRV_t-(1+\beta-\alpha)\alpha WNV_0}{[(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0]^2}+\frac{\partial p^e}{\partial P_t}\frac{(1+\beta)P_tV_t}{(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0}\right]. \quad [32]$$

The sensitivity of the real estate price to credit volume impacts the negative slope of the credit demand curve. In other words, the decrease in the interest rate that occurs for bigger levels of CRV_t, which is embedded in the inverse demand curve (represented through $\left.\frac{\partial r_v}{\partial CRV_t}\right|_{\partial P_t/\partial CRV_t=0} < 0$) is moderated by the impact the credit has in the price of real estate assets. This is done in two ways. First, directly through the impact the credit has on the price of the real estate good $\frac{\partial P_t}{\partial CRV_t}$, and then through the impact on its future expectation $\left(\frac{\partial p^e}{\partial P_t}\right)$.

Hence, as seen above in Equation [26] we have:

$$\frac{\partial P_t}{\partial CRV_t}=\frac{1}{(1+\gamma)V_t-V_0}$$

where, in line with real estate supply characteristics, this implies that the lower is the elasticity of real estate supply, the larger will be the impact on the real estate price of an additional unit of credit lent for real estate acquisition.

Then, as previously stated, if $P_t > P_0$ then $\rho = s\frac{P_t}{P_0}$. Therefore, we obtain:

$$\frac{\partial \rho}{\partial P_t}=\frac{s}{P_0} \quad [33]$$

so that:

$$\frac{\partial r_v}{\partial CRV_t}=\left.\frac{\partial r_v}{\partial CRV_t}\right|_{\partial P_t/\partial CRV_t=0}+\frac{1}{(1+\gamma)V_t-V_0}\left[V_0\frac{\alpha(1+p^e)(1+\beta)CRV_t-(1+\beta-\alpha)\alpha WNV_0}{[(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0]^2}+\frac{s}{P_0}\frac{(1+\beta)P_tV_t}{(1+\beta)(CRV_t+P_tV_0)-\alpha P_tV_0}\right]$$

$$\text{With } \gamma=\begin{cases}\gamma_u \text{ if } V_t \geq V_0(1+g_v)\\ \gamma_d \text{ if } V_t < V_0(1+g_v)\end{cases} \quad [34]$$

with s=0 when $P_t < P_0$.

4.3. Results and sensitivity analysis

To understand the decision-making process behind banks' credit allocation and its repercussions in the real estate market, we have conducted an examination of equilibria across multiple scenarios under the two abovementioned banks' behavior hypothesis. Initially, we explore various scenarios related to banking lending capacity, while considering the initial parameter hypothesis. Notably, this involves changes in CRT, a parameter that reflects fluctuations in banks' lending capacity which results from market liquidity, i.e. either derived from dynamic market conditions, such as in the years previous to the 2008' financial crisis, or central bank's expansive monetary policies, and banks' capital surpluses beyond the minimum (market or regulatory) capital requirements or easiness of capital generation. Then, we analyze the sensitivity of results to changes in the key parameters that shape the real estate and the credit markets, as well as the consumer goods technology function. This sheds a light on the driving forces behind the equilibrium, thus laying the foundation for the discussion on macroprudential policy recommendations in Section 6.

Table 1 summarizes the initial hypothesis on the parameters that characterize credit and real estate markets, as well as the applied changes over them in order to undertake results' sensitivity analysis.

Table 1. Input parameters for equilibria and sensitivity analysis

I. Parameters		Base	*Lower*	*Upper*
Households	β- discount factor	95%	90%	97%
	α- Household preference for real estate good	20%	18%	22%
	s- sensitivity of Pt on future price expectations	50%	25%	75%
Companies	α_K- capital weight in technology	*25%*	-	-
	g- productivity growth in t	*2,5%*	*1%*	*5%*
	Ao- starting point at productivity	*10*	-	-
Real Estate	γ_u- real estate supply elasticity (over g)	70%	40%	100%
	γ_d- real estate supply elasticity (under g)	10%	-	-
	P_0- Starting point price of the real estate good	1	0,95	1,05
	g_v- natural growth rate of the real estate good	5,0%	4,0%	6,0%
Banks industry	*Herfindahl Index*	*1000*	*500*	*2000*
II. Starting point				
Consumer	WNV_0- Household's non-real estate wealth	100	90	110
Real estate	V_0- Starting point real estate good	100	90	110
Company	K_0- Starting point production capital	10	8	12
III. Regulation and capital return				
	$\%K_v$- % capital req. over real estate credit	5,0%	2,5%	10%
	$\%K_k$- % capital req. over real estate credit	8,0%	4,0%	16,0%
	R - % Hurdle rate - target return over capital	15,0%	7,5%	30,0%

The economic interpretation of each parameter is summarized below.

β is the classical household discount factor. Given the role of the real state good, both as utility provider to households over time and as an intertemporal wealth transfer mechanism, ceteris paribus, a lower discount factor implies an anticipation of the acquisition of the real estate asset. Consequently, this anticipation leads to an upsurge in its demand, subsequently driving up the demand for credit to facilitate real estate acquisition. This, in turn, contributes to a scenario where a larger portion of credit is allocated to real estate acquisition and where real estate prices experience more substantial increases. As a result, these dynamics favors the emergence of real estate bubbles.

α represents the preference of households for the real estate good. Obviously, a stronger preference for the real estate asset (as the one observed in the Spanish economy, where the proportion of households owning homes significantly surpasses other markets) results in larger proportions of credit allocation towards real estate, which would lead to bigger increases on real estate prices. This particularly holds in contexts of high lending capacity, hence favoring the generation of real estate bubbles.

s measures the effect of current changes in real estate prices on the expectation on its future revalorization (i.e. as stated, $p^e = s\left(\frac{P_t}{P_{t-1}} - 1\right))$. We expect that the bigger this sensitivity is, the faster credit and real estate boom will accelerate as banks' lending capacity increases. As explained previously, this results from the impact that current real estate price increases has on future expectations, being this a key accelerator of real estate boom dynamics in our model.

g is the productivity growth in the production of the consumer good. Hence, as it increases, the profitability of the capital used in its manufacture and therefore the demand for credit to invest in capital of the consumer good will raise. It will tend to reduce the credit allocation share to the real estate good, therefore mitigating the real estate credit boom dynamics.

γ_u is the elasticity of the real estate good supply (for the real estate good growing above its natural growth rate). A larger elasticity of the housing supply will allow to absorb increases in real estate demand through bigger increases in the volume of the real estate good (rather than through larger price increases). Hence it mitigates one of the real estate credit boom dynamics generators described in Section 2.

g_v represents the natural growth rate of the real estate good. For lower natural growth rates (and hence for more limitations of the real estate good to grow naturally), the larger is the credit allocated to real estate, the bigger will its impact be on its price and hence on its future revalorization expectation. Therefore, a lower value for this parameter benefits the real estate and credit boom dynamics.

P_0 is the initial price of the real estate good. Ceteris paribus, a smaller initial price leads to an increased demand for housing and consequently, to a higher propensity to allocate credit to acquire real estate assets. Note that this situation does not inherently mean the presence of a real estate bubble dynamic. Instead, the growth in real estate prices could be attributed to an initial undervaluation of the real estate asset.

The *Herfindahl index* represents the banking concentration. More concentration (or broadly speaking, banks with bigger market share) increases the marginal impact of the credit allocated by each individual bank into the real estate market, both in terms of the current price increase of the real estate good and its future expectation. Therefore, concentrated markets (or, conversely, bigger banks) tend to benefit real estate market and credit booms[4].

WNV_0, denotes the household's non-real estate wealth. It impacts positively the real estate demand as this raises with wealth. Hence, more wealth favors the credit allocation bias towards real estate and, therefore, real estate bubble processes. Interestingly, this implies that increases in wealth originated from sources other than real estate, such as a surge in the stock market, can also contribute to the formation of real estate bubbles.

The intrinsic value of the real estate good, V_0, has an undetermined effect. On the one hand, its growth implies bigger demand for the real estate good through a wealth effect. On the other hand, greater V_0 implies less scarcity of the real estate good, hence disabling the price spiral which favors real estate and credit booms. Consequently, its effect will depend on other parameters. In particular, on household preferences for the real estate good and household supply elasticity relative levels.

Finally, we have the credit regulatory and return capital parameters, which include capital requirements – both for real estate acquisition funding ($\%K_v$) and companies' productive capital funding ($\%K_k$) – and the minimum required return for capital (R). In line with current capital requirements, a lower parameter has been allocated to real estate acquisition credit (a credit type in our model that could be mapped to a combination of mortgages plus real estate development in the current regulation) than to companies' credit. In particular, we have set 5% capital requirements over each unit of credit granted for household real state acquisition and 8% for companies' productive investment funding. The initial capital target return parameter has been set to 15%. In this regard, the following sensitivity analysis have been set: (i) a change (increase by 100% or decrease by 50%) in the capital requirement only for mortgages and (ii) in line with Basel III countercyclical and conservation capital buffers, a simultaneous change (again, an increase by 100% or decrease by 50%) in both capital requirements. The latter is in turn mathematically equivalent to changes in the same percentage of the capital profitability requirements (R), hence the results for the former apply to both to sensitivity analysis.

A priori, it is expected that larger capital requirements will freeze the credit and real estate boom dynamics, being this one of the key reasons why the flexible Counter-Cyclical Capital buffer has been set in Basel III.

To undertake the analysis, we set as base scenario for CRT an equilibrium where banks fund real estate growing at its natural rate, and hence not changing its relative price over the consumer good. Then, first, we increase (decrease) CRT to understand impact on the credit allocation and real estate equilibria under banks' different lending capacities. Second, we analyze the sensitivity of the results around the assumption of 50% increase over the CRT's base scenario. We have undertaken this analysis under both banks' behavior assumptions described in Sections 4.1 and 4.2. Figures 9, 10 and 11 summarize the results.

Figure 9. Credit and real estate equilibria characterization for different banks' lending capacity scenarios under the assumptions of banks not considering and considering their impact on the real estate market. a) Share of real estate credit under the assumption of banks considering their impact on the real estate market. b) Volume of credit allocated to real estate and consumer good's production capital under the assumption of banks considering (dotted lines) and

[4] As a reference, ECB 2017's Report on financial structures shows an average *Herfindahl* concentration index of 697 for Europe and 937 *for Spain.*

non-considering (solid lines) their impact on the real estate market. c) Real Estate volumes, prices and credit volumes under different assumptions on credit lending.

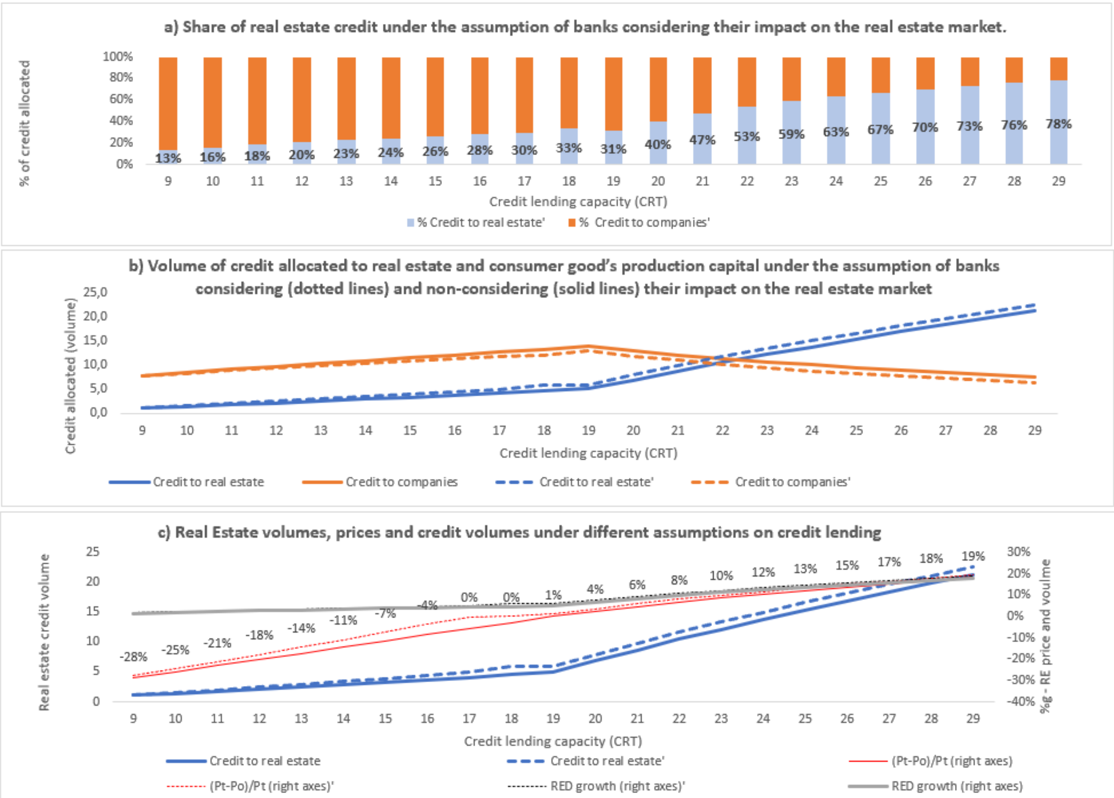


Figure 10. Increase in percentage allocated to credit and real estate prices by assuming banks consider their impact on the real estate markets (vs. non-considering that impact).

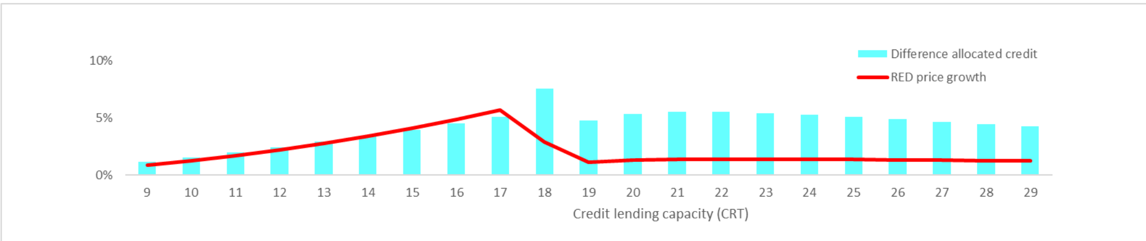
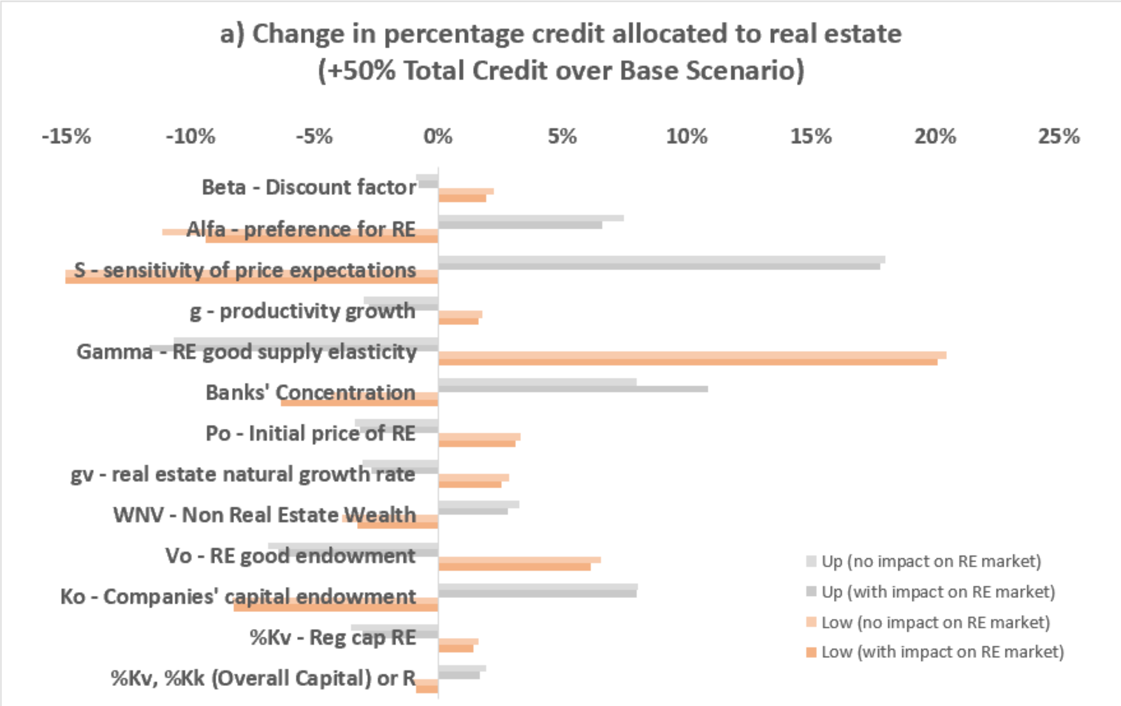
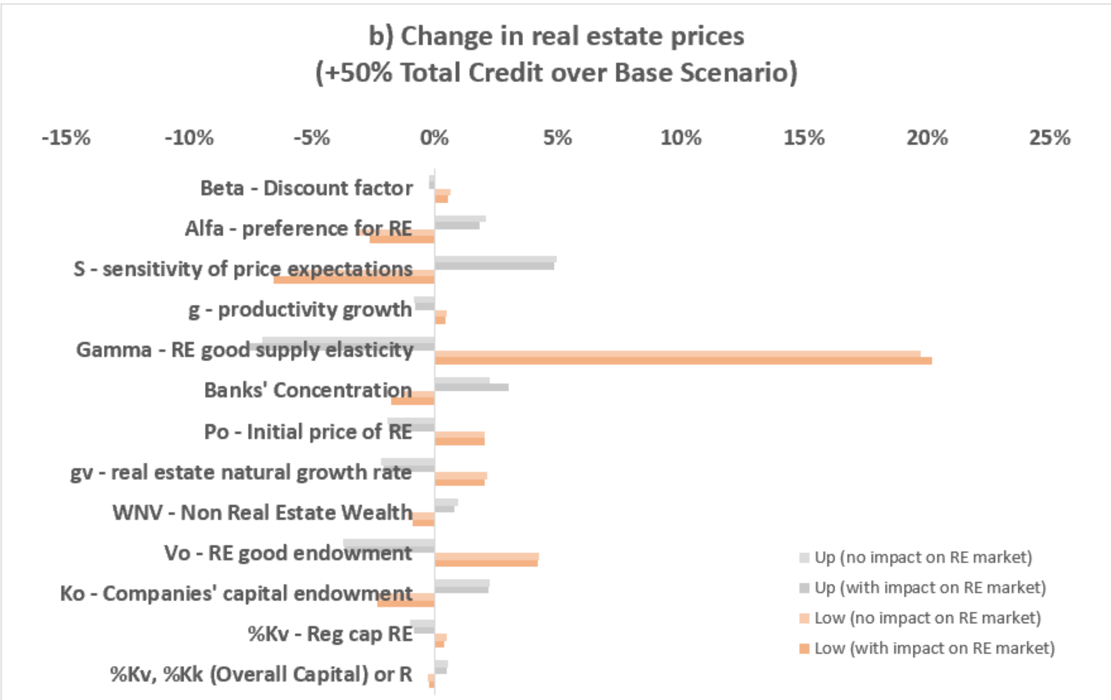


Figure 11. Real estate credit share (a) and real estate price (b) sensitivity analysis under changes in household preferences, consumer good production technology, real estate and credit markets and regulatory parameters for high lending capacity scenarios (+50% over base scenarios).





In the realm of the credit market, the level of banking concentration has a considerable influence on the emergence of credit and real estate bubbles. This influence stems from the fact that the lending decisions of larger banks carry significantly greater weight in the real estate market. Consequently, these decisions can accelerate the dynamics in both, credit allocation and the real estate sector, thereby favoring the origination of bubbles.

Regarding households' wealth, the positive effect that non-real estate wealth (WNV_0) has over real estate demand is translated into bigger credit allocation and price increases in the real estate good. Conversely, the previous real estate wealth (V_0) has, under the initial parameter hypotheses, a weaker mitigating impact over the real estate boom dynamics. This is attributed to the increased supply of real estate assets, which alleviates market pressures and, consequently, moderates the escalation in prices.

Finally, the sensitivity analysis on regulatory and capital return parameters suggests that changes in capital requirements focused just on real estate acquisition funding ($\%K_v$) mitigate credit and real estate boom dynamics. However, proportional changes in both capital requirements, such as the one implemented in Basel III through the Conservative and Countercyclical capital buffers, are counterproductive as, in context of high liquidity, banks even bias more their credit allocation to real estate. The macroprudential policy implications of this will be addressed in Section 6.

5. Equilibrium with risk

In this section, we describe the structural approach to model lending implications on credit risk, first by introducing a simplified generalized Merton framework (Section 5.1.), and then by applying it to model real estate credit risk (Section 5.2.) and the companies' credit risk (Section 5.3.). Finally, in Section 5.4. we show some equilibria results by embedding credit risk into income and capital costs driven equilibria shown in Section 4.3.

5.1. The risk model

To introduce the risk associated to credit losses, we follow a simplified Merton model, a structural framework which is also used to derive capital formulas under the advanced regulatory framework. In particular, we consider that a default event occurs when the value of a specific underlying asset (denoted by S), falls below the value of the credit value (L). The value of the underlying asset, S, results from a given initial value (S_0) impacted by a stochastic return, as:

$$S = S_0(1 + x) \qquad [35]$$

being *x* the return of the asset, which is assumed to follow a normal distribution with an expected value μ and volatility σ.

Therefore, the probability of default can be estimated as:

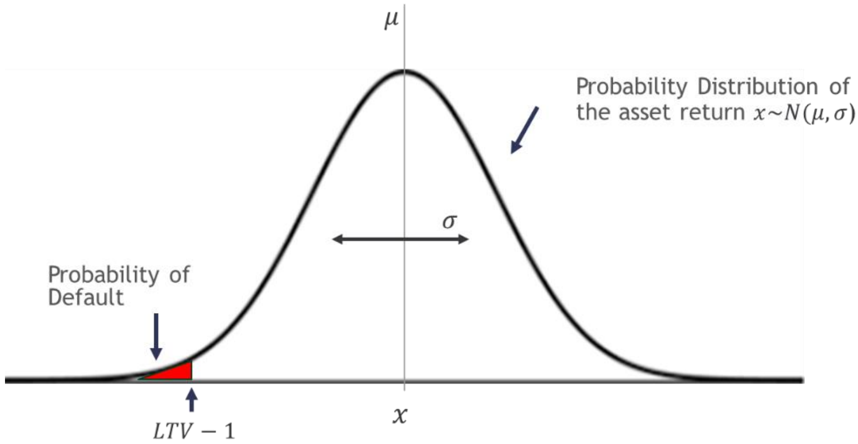
$$PD_t = P(S < L) = P(S_o(1 + x) < L) = P\left(x < \frac{L}{S} - 1\right) = P(x < LTV - 1) \qquad [36]$$

with $x \sim N(\mu, \sigma)$

being LTV (Loan-to-Value) defined as the ratio between the loan amount and the value of the underlying asset.

The diagram below illustrates this idea.

Figure 12. Default event under the Merton framework.



The next two sections explain how this simplified Merton framework is applied to both, real estate and companies' lending. Interestingly, it should be noted that, to determine the credit losses and the default probabilities, and, most importantly, the lending decisions made by the banks, we consider the overall creditor aggregated debt, not just the debt generated in the last period. This is consistently reflected at Merton's framework, where *L* reflects the overall creditor debt. Conversely to the past decisions over income and prices (i.e. interest rates) that cannot be now modified by banks, the lending decisions at *t* will impact credit losses not only over the credit granted at *t*, but also over the previously existing credit (i.e., the credit already held at t). This is a consequence of the fact that: (i) the default probability depends on the overall creditors leverage, and (ii) once it occurs, the default will impact the overall creditors debt. Hence, risk modeling requires some assumptions on the initial level of debt both by households and companies.

Finally, we will not consider the credit interest rates in modeling the default event and the subsequent risk losses, as this has a marginal impact on them, but adds unnecessary complexity to the model.

5.2. The risk model applied to real estate credit

In the case of mortgages, we denote the value of credit requested to fund real estate acquisition by *L,* and the value of the real estate good as the underlying asset. For this purpose, we consider total credit as the credit requested during the period ($\mathrm{CRV_t}$) plus any potential credit that could reduce the non-real estate financial endowment (CRV_0).

Hence, we have:

$$LTV = \frac{CRV_t + CRV_0}{P'_t V_t} \quad [37]$$

where P'_t is the volatility of real estate prices, once the real estate market has been cleared at P_t.

This implies that Loan to Value is the key driver to explain real estate backed credit default, which is in line with capital regulation and risk management practices. In addition, if default occurs, we will assume that losses are also linked to the difference between the credit amount and the underlying value of the collateral, conditioned to the default scenario (where the value of the real estate good is below total credit) plus a transaction cost, defined as a fixed percentage over credit.

Hence, following risk management practices and regulation, we express the credit loss as the product of the probability of default (PD) multiplied by the Loss Given Default (LGD).

$$Loss = PD \cdot LGD.$$

Then, the expected value of the credit losses will be:

$$Loss = m_v(CRV_t + CRV_0) = P(x < LTV - 1)[(CRV_t + CRV_0)(1 + c\%) - P_t V_t E[x]_{x<LTV-1}] \quad [38]$$

where c% is the transaction cost that the bank incurs in case of default for each unit of credit granted. Hence, assuming that *x,* which is the change in value of the real estate asset price and hence of the real estate asset value P_t follows a normal distribution, as per the Merton approach, then we have:

$$P(x < LTV - 1) = \Phi\left(\frac{LTV-1-\mu}{\sigma}\right) \quad [39]$$

$$E[x]_{x<LTV-1} = \mu - \sigma \frac{\phi\left(\frac{LTV-1-\mu}{\sigma}\right)}{\Phi\left(\frac{LTV-1-\mu}{\sigma}\right)} \quad [40]$$

where μ and σ are, respectively, the expected value and the volatility of the real estate prices. In turn, Φ and ϕ represent, respectively, the cumulative and density functions of a standard normal distribution. This leads to:

$$m_v = \frac{Loss}{(CRV_t + CRV_0)} = \Phi\left(\frac{LTV-1-\mu}{\sigma}\right)\left[(1 + c\%) - \frac{(1+\mu)}{LTV}\right] + \frac{(1+\mu)}{LTV}\ \phi\left(\frac{LTV-1-\mu}{\sigma}\right). \quad [41]$$

To investigate the impact of the decisions on the credit granted (CRV_t) into risk, we apply the chain rule to derive the previous expression by CRV_t:

$$\frac{\partial m_v}{\partial CRV_t} = \frac{\partial m_v}{\partial LTV}\frac{\partial LTV}{\partial CRV_t} \quad [42]$$

and denoting $\frac{LTV-1-\mu}{\sigma}$ by ltv, we obtain:

$$\frac{\partial m_v}{\partial LTV} = (1 + c\%)\phi(ltv) - \frac{(1+\mu)}{LTV}\ \phi(ltv) + \frac{(1+\mu)}{LTV^2}\ \phi(ltv) - \frac{ltv}{LTV}\ \phi(ltv) - \frac{\sigma}{LTV^2}\ \phi(ltv). \quad [43]$$

Given that

$$\frac{\partial \phi(ltv)}{\partial LTV} = -\frac{1}{\sigma} ltv\ \phi(ltv). \quad [44]$$

On the other hand, we have that

$$\frac{\partial LTV}{\partial CRV_t} = \frac{P_tV_t-(CRV_t+CRV_0)\left[1+\frac{\partial P_t}{\partial CRV_t}V_0\right]}{(P_tV_t)^2} = \frac{1}{P_tV_t}\left[1-LTV\left(1+\frac{\partial P_t}{\partial CRV_t}V_0\right)\right] \quad [45]$$

where, by Equation [26]

$$\frac{\partial P_t}{\partial CRV_t} = \frac{1}{(1+\gamma)V_t-V_0}.$$

It is important to reiterate the significant influence of credit on real estate prices. Credit plays a crucial role in mitigating the expected credit losses, which would naturally rise with the allocation of credit to the real estate sector. Notably, for specific low elasticities of the real estate supply, the expansion of real estate credit allocation may even lead to a reduction in risk. This aligns seamlessly with the observed pattern in the origin of real estate bubbles, where substantial growth in real estate lending is accompanied by remarkably low default rates, even when higher levels of risk are assumed. This, in turn, fuels a spiral of growth and unusually low default rates in real estate lending.

From a different perspective, from Equation [27]

$$\frac{\partial P_tV_t}{\partial CRV_t} = 1 + \frac{1}{(1+\gamma)\,V_t - V_0}V_0$$

meaning that the value of the real estate good grows more than proportionally than the credit granted to fund it, which is driven by the fact that the changes in the price of the real estate good impact the value of the stock already held by the households. Hence, this relationship will incentivize allocation of credit for real estate acquisition when banks have enough lending capacity.

Figures 13, 14 and 15 illustrate this idea, showing the impact of real estate credit growth on LTV, $\partial LTV/\partial CRV_t$ (i.e. the marginal risk incentive for banks to lend one further unit of credit to real estate) and the credit losses over credit granted (m_v), for different supply elasticities. For all of them we assume an expected real estate price growth of 5%, a volatility of 25% and a transaction cost of 5% for an initial debt level of CRV_0=70[5].

[5] Given that LTVs typically cluster around the 80% regulatory threshold at mortgage origination, a value that was well exceeded by some banks during the peak of the credit boom, starting at 70% helps analyzing the impact of credit on LTV and the credit loss for typical LTV ranges. Likewise, according to *Ionascu (2000)*, a 25% volatility is within the range of real estate price volatilities in European markets.

Figure 13. Impact of new real estate credit on LTV for different real estate supply elasticities.

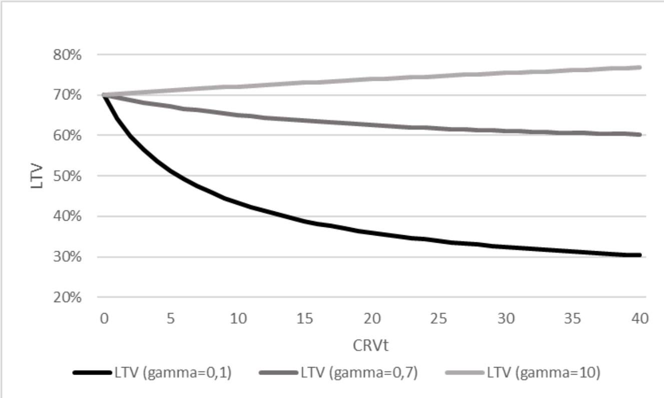


Figure 14. Marginal impact of real estate credit (CRV_t) on $\partial LTV / \partial CRV_t$ for different real estate supply elasticities.

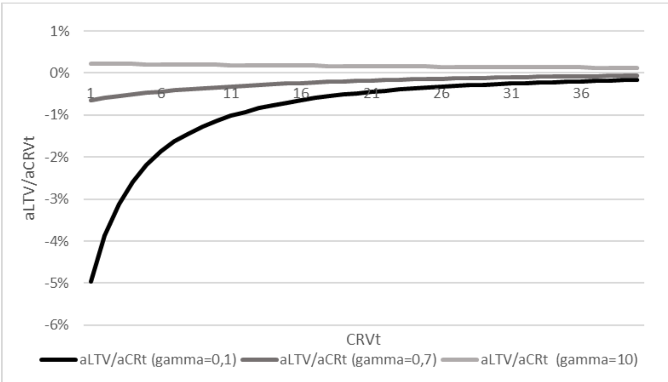
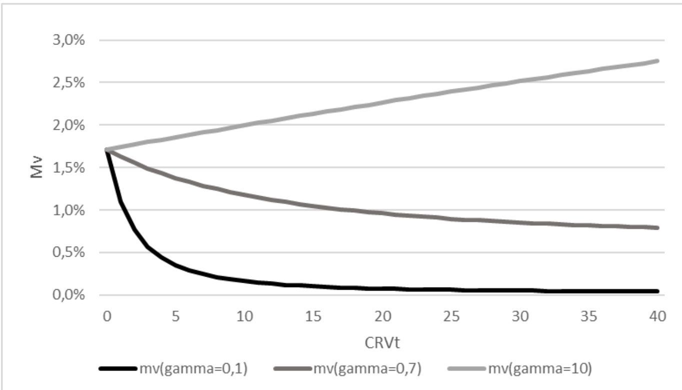


Figure 15. Impact of real estate credit (CRVt) on percentage credit losses (m_v) for different real estate supply elasticities.



As observed, further credit granted has a negative impact on the risk level. As we will illustrate in Section 5.4, this serves to amplify the proportion of credit allocated to the real estate sector, thereby increasing the value of real estate assets in contexts of banks' high lending capacity.

5.3. The risk model applied to companies' credit

To model the credit losses associated to credit to companies, we consider production as the underlying asset, so that default will occur when the production level falls below the amount of the credit lent. Similarly, for this purpose we assume that part of the capital held by companies has been funded by credit (i.e., $K_0 = CRK_0 + K'_0$) so that total level of credit, once banks have decided to grant CRK_t, will be equal to $CRK_0 + CRK_t$. Hence, denoting the random variable around a base level of production Y_t by y and assuming this random variable follows a N(μ_y,σ_y) distribution, we get:

$$PD_t = P(Y_t(1+y) < CRK_t) \ = P\left(y < \frac{CRK_0+CRK_t}{Y_t} - 1\right) = P\left(x < \frac{CRK_0+CRK_t}{A_t(CRK_t+K_0)^{\alpha_K}} - 1\right) \qquad [46]$$

where $\frac{CRK_0+CRK_t}{A_t(CRK_t+K_0)^{\alpha_K}}$ represents the leverage over sales or production (a crucial ratio very commonly used in risk management) that we denoted as $LevS$.

Consequently, we have that:

$$Loss_k = m_k(CRK_k + CRK_0) = P(y < LevS - 1)\left[(CRK_t + CRK_0)(1 + c_k\%) - Y_t E[y]_{y<LevS-1}\right] \qquad [47]$$

and then:

$$m_k = \frac{Loss}{(CRK_t+CRK_0)} = \Phi\left(\frac{LevS-1-\mu_y}{\sigma_y}\right)\left[(1+c_k\%) - \frac{(1+\mu_y)}{LevS}\right] + \frac{(1+\mu_y)}{LevS}\,\phi\left(\frac{LevS-1-\mu_y}{\sigma_y}\right). \qquad [48]$$

To understand the marginal impact of lending decisions to companies (CRK_t) over risk losses, applying the chain's rule yields:

$$\frac{\partial m_k}{\partial CRK_t} = \frac{\partial m_k}{\partial LevS}\frac{\partial LevS}{\partial CRK_t} \qquad [49]$$

and denoting $\frac{LevS-1-\mu_y}{\sigma_y}$ by $levs$ returns:

$$\frac{\partial m_k}{\partial LevS} = (1+c_k\%)\phi(levs) - \frac{(1+\mu_y)}{LevS}\,\phi(levs) + \frac{(1+\mu_y)}{LevS^2}\,\phi(ltvlevs) - \frac{levs}{LevS}\,\phi(levs) - \frac{\sigma_y}{LevS^2}\,\phi(levs)\ . \qquad [50]$$

Given that:

$$\frac{\partial\phi(levs)}{\partial LevS} = -\frac{1}{\sigma_y} ltv\ \phi(levs) \qquad [51]$$

we also have:

$$\frac{\partial LevS}{\partial CRK_t} = \frac{Y_t - \frac{CRK_0+CRK_t}{K_0+CRK_t}\alpha_K Y_t}{(Y_t)^2} = \frac{1}{Y_t}(1 - LevK\alpha_K), \qquad [52]$$

where $LevK$ is the leverage definition over capital, i.e.:

$$LevK = \frac{CRK_0+CRK_t}{K_0+CRK_t}. \qquad [53]$$

By definition both $LevK$ and α_K are less than one, which means that, conversely to the real estate funding case, any additional unit of credit granted to companies implies an increase in credit risk. This results from the fact that the funding to companies replaces the positive impact that an additional unit of credit has on the real state price (the loan to value denominator) by the impact that an additional unit of credit has on production. As production is subject to capital marginal decreasing returns, each additional unit of capital has a less than proportional impact on production and, hence, increases its risk.

Figures 16 and 17 illustrate this idea by showing the effect of companies' credit on the Leverage over Sales ratio and on companies' risk (m_k) for different levels of productivity growth. Simulations, assume production volatility of 25%, expected value of 5%, and an initial leverage of 20% ($CRK_0 = 2$ and $K_0 = 10$).

Figure 16. Impact of companies' credit growth (CRK_t) on Leverage over Sales (LevS).

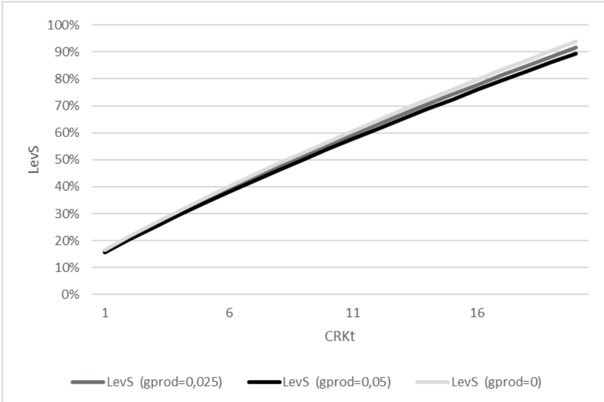
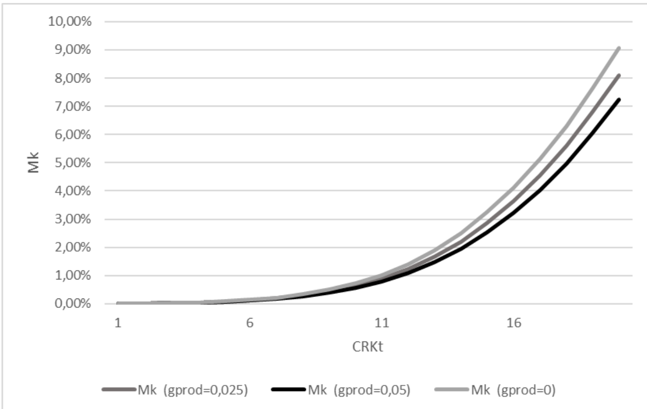


Figure 17. Impact of credit to companies on percentage credit losses (m_k).



5.4. Results and sensitivity analysis

In this section we analyze credit and real estate market equilibria under the same scenarios and hypothesis described in Sections 4.1 and 4.2, but with the credit risk framework embedded into banks decision making. With regard to Merton risk modelling parameters, a starting point LTV has been set at 50% for the real estate credit and a capital leverage of 20% for companies. Mathematically:

$$LTV_0 = \frac{\mathrm{CRV}_0}{P_0\mathrm{V}_0} \qquad ; \qquad LevK_0 = \frac{CRK_0}{K_0+CRK_0}.$$

A volatility of 25% and an expected return of 5% is set for both Merton model underlying default variables. Those values could fit into observed real estate price and equity market returns historical performance.

Figures 18, 19 and 20 summarize the results. As we did in Section 4.3, we compare the results obtained under the assumptions of banks considering its impact on the real estate market with those in which banks do not consider their secondary effects on the real estate market.

Figure 18. Credit and real estate equilibria characterization for different banks' lending capacity scenarios under the assumptions of banks not considering and considering their impact on the real estate market, once credit risk losses have been embedded into credit allocation decisions. a) Share of real estate credit under the assumption of banks considering their impact on the real estate market. b) Volume of credit allocated to real estate and consumer good's production capital under the assumption of banks considering (dotted lines) and non-considering (solid lines) their impact on the real estate market. c) Real Estate volumes, prices and credit volumes under different assumptions on credit lending.

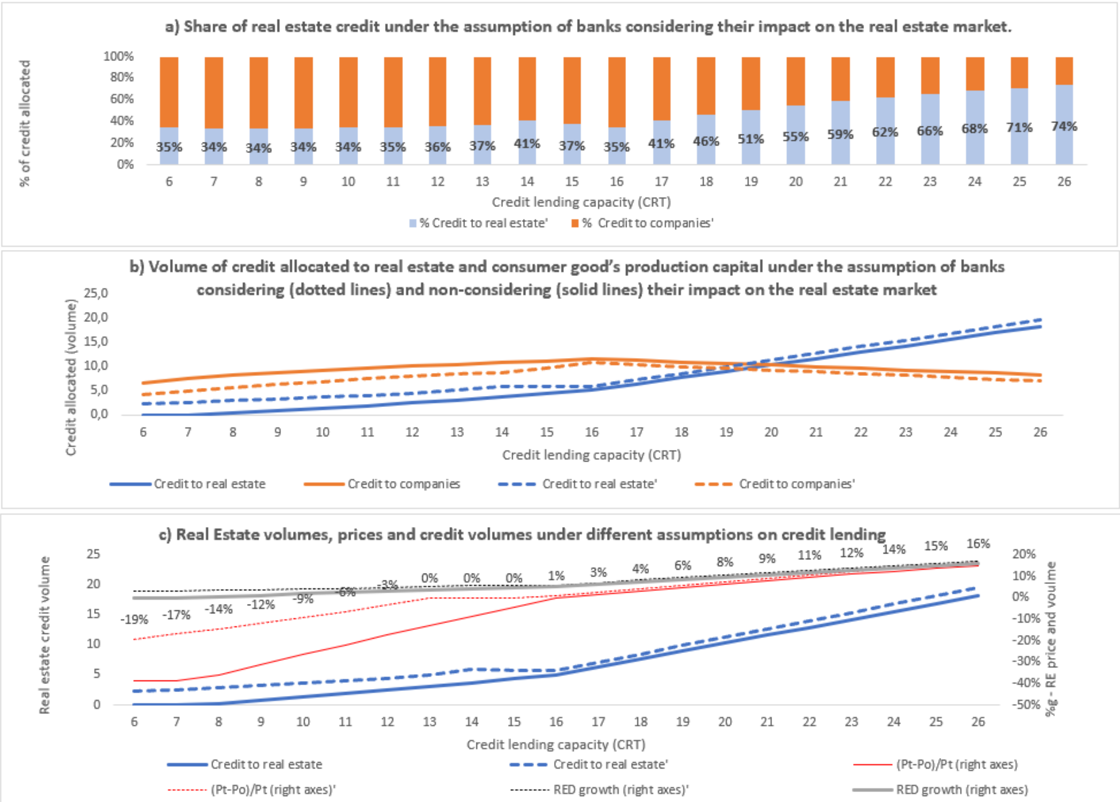


Figure 19. Increase in percentage allocated to credit and real estate prices by assuming banks consider their impact on the real estate markets (vs. non-considering that impact).

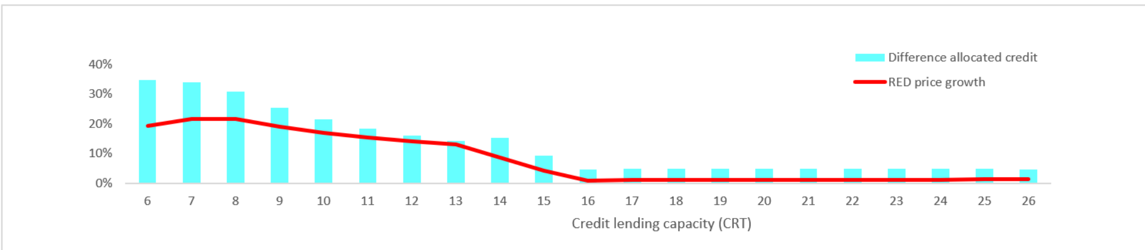
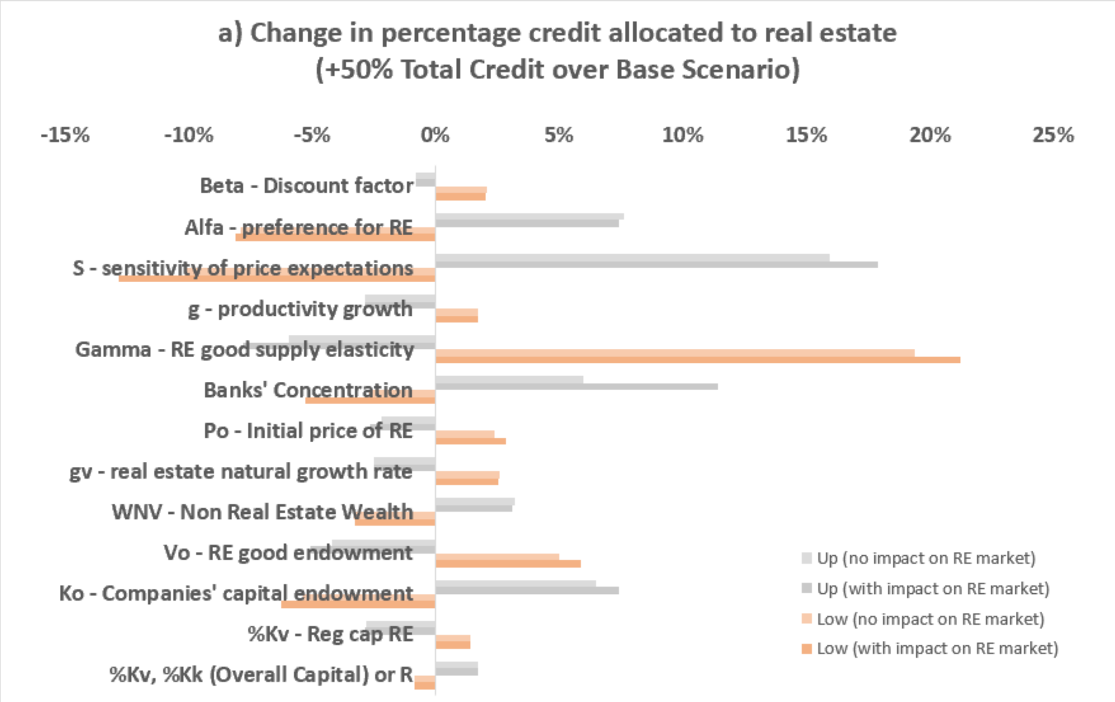
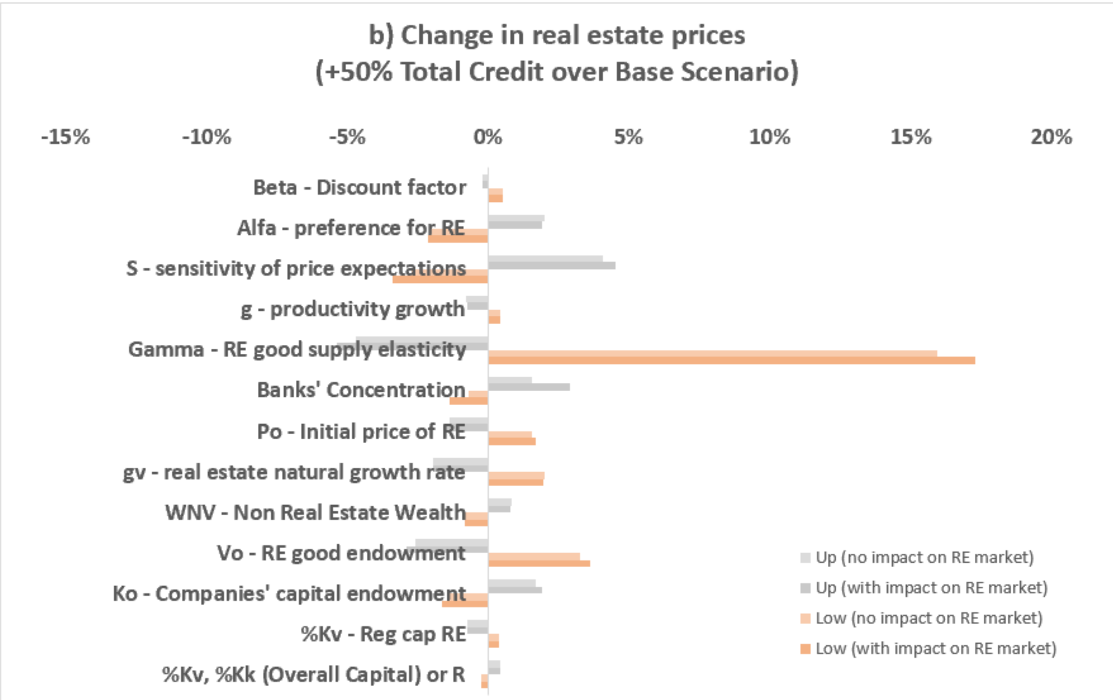


Figure 20. Real estate credit share (a) and real estate price (b) sensitivity analysis under changes in household preferences, consumer good production technology, real estate market and credit market and regulatory parameters for high lending capacity scenarios (+50% over base scenarios).





These results broadly are consistent with those observed before embedding credit risk. Interestingly, the risk increase associated with reduced volumes of real estate credit allocation discussed earlier implies that lower lending capacity scenarios set a higher credit allocation floor to real estate. This strategic move by banks serves to mitigate the raise of credit losses within this segment, by facilitating increased funding for real estate acquisition. Consequently, this action mitigates real estate price drops – which are still significant – and, therefore, attenuate credit risk losses.

Finally, the assumption of banks considering their impact on the real estate market in their credit granting decisions (which in this case also implies reducing their credit risk, as the credit allocated to real estate acquisition increases) significantly increase the real estate credit allocation bias and its price.

6. Conclusions and implications for banking regulation

The previous results show that the different characteristics of the real estate market (specifically supply inelasticity, household's use of this good as a form of savings and adaptative price expectations) compared to those of the consumer good market (perishable good, capital subject to diminishing returns unless counterbalanced by technology developments, internationally open markets) imply that, when banks have high lending capacity, they have incentives to skew credit to real estate acquisition, favoring the generation of real estate bubbles. There are concrete market characteristics where these incentives are particularly relevant.

First, a real estate market characterized by bigger i) households' preference for the real estate good, ii) households' non-real estate wealth, iii) inelasticity (or lower natural growth rate) of real estate supply, and iv) sensitivity of households' future real estate price expectations on current prices, favors real estate and credit bubble dynamics.

Second, concentration of the credit market significantly favors the generation of real estate and credit bubbles.

Third, a context of low productivity growth or bigger level of capital already available by companies also favors the generation of real estate and credit bubbles.

Finally, in contexts favorable to the origination of real estate bubbles, increasing the overall capital requirements (as in the case of Basel III, through the Countercyclical Capital Buffer (CCyB) and the Conservative Capital Buffer (CCB)) can even be counterproductive. In particular, when these capital requirement increases do not significantly mitigate banks' credit lending capacity, they might even contribute to increase the bias skew towards real estate lending. On the contrary, an increase of the capital requirements for real estate lending will be more effective to mitigate the credit allocation bias.

Interestingly, albeit the model has been developed focusing on the real state bubble case, the above conclusions also apply to other bubbles of similar nature, i.e., where the good potentially subject to bubble dynamics shares with real estate the properties of limited capacity to grow and future price expectations set based on its most recent price evolution. The equity share price boom dynamics generated during the Great Depression are a good example, where the spectacular growth in banks' lending for equity shares acquisition - a good with an obvious limited capacity to grow at the same speed than the credit - and population setting future price expectations on equity shares based on its most recent price evolution, sit at the core of the share price bubble generated before its later Crash. Furthermore, the cryptocurrencies market dynamics or even the dot-com bubble crash at the beginning of 2000, yet not being credit driven, also shared some of these characteristics.

These conclusions have clear implications for banking regulation.

First, while banks' portfolio risk has been rightly at the core of capital differentiation, from a macroprudential perspective there are conditions suggesting that, beyond banks' risk profile, the "*one-size fits all*" prudential capital buffers will fail in preventing real estate bubbles. There are many economy characteristics (some of them beyond the credit market) that, other things being equal, increase the risk of generating credit bias and real estate bubble dynamics. In particular, household preferences or more credit market concentration (something that has been increasing in Europe since the last financial crisis) favor these bubble dynamics, increasing the need for macroprudential preventing policies. Likewise, the prevention of financial crisis has to do with broader good functioning of the economy and markets beyond credit. In particular, good technology progress (which could be favored by, for instances, policies that premium the credit allocated to R&D) or lower real estate inelasticity (whilst this is limited by the specific nature of some of these assets) might favor longer term financial stability.

Second, the links between the credit market and the real estate market, and in particular the characteristics of the latter, generate a credit allocation bias in favor of real estate lending. This bias: i) undermines credit allocation to productive capital (unless this is counterbalanced by technology progress) even in less extreme scenarios than real estate bubbles; ii) generates an artificial, misleading and non-sustainable decrease in credit losses; and iii) creates an incentive for banks to allocate the credit in a way that favors bigger real estate, economy and financial markets volatility. This is not considered in the current capital requirements framework, that gives important capital benefits to mortgage lending based on its individual risk and the observed historical volatility. However, the abovementioned bias, which sits at the core of the incentives to increase this volatility aside of potentially sacrificing longer term sustainable growth, are not considered. This suggests that a reduction in the mortgage capital requirement premium should be considered.

Third, the sensitivity analysis of changes on regulatory capital requirements suggests that proportional changes on them, such as the ones implemented in Basel III through the Conservative and Countercyclical Capital buffers, might be counterproductive for the same level of banks' lending capacity. On the contrary, capital buffers focused on real estate acquisition funding ($\%K_v$) attenuate the credit and real estate boom dynamics.

Finally, the importance of credit market concentration implies that a market dominated by larger entities favors the origination of real estate and credit bubble dynamics, as larger entities credit decisions have a larger impact in the real estate market. This implies that, from this perspective, setting the grounds for lower credit concentrated markets will help mitigate the origination of this type of bubbles. At the same time, specific capital or capital buffer add-ons for domestic (vs. global) SIFIS could promote long term financial stability.

Hence, as summarized above, the conclusions of the theoretical model in this paper show a different perspective to understand and prevent financial crisis, with substantial implications for banking regulation and macroprudential supervision. Extending the model developed here towards a general equilibria dynamic framework, as well as undertaking its empirical parameterization, are natural future developments.

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