House prices, lending standards, and the macroeconomy

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Abstract

This paper studies the link between house prices, lending standards, and aggregate over-investment in housing. I develop a model of the housing market where the mortgage loan market is affected by an adverse selection problem. The selection is towards less creditworthy mortgage borrowers. I show that lending standards are loose and the incentives for less-than-creditworthy borrowers to apply for a mortgage are particularly strong first, when future house values are expected to be high, which leads to high sales prices of housing and high leverage of borrowers; and second, when safe interest rates are relatively low, which implies low costs of borrowing. There are strong non-linearities however: rising house values first drive out the least-creditworthy borrowers, as sales prices of housing increase, but attract them back as expectations on future values become high enough to counter-act risks inherent in high leverage. The results shed light on incentive mechanisms which can explain the developments in the U.S. housing market in the early 2000s that led to the subprime crisis.

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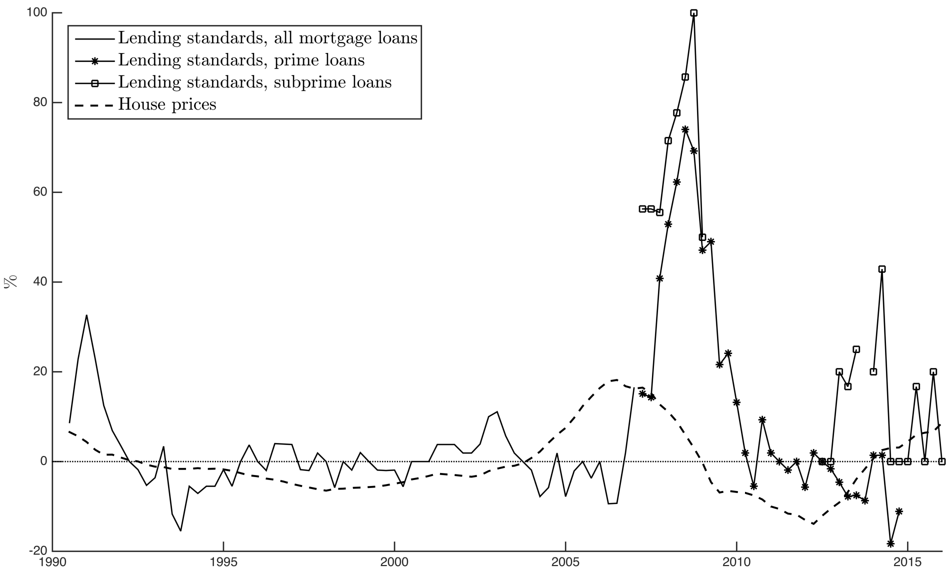

Figure 1: Lending standards and the house price cycle. Lending standards on mortgage loans measure net lending standards: the percentage of lenders who have tightened standards less those who have relaxed them. A positive value indicates tightening. House prices are measured as %-deviations from trend. Source: Senior Loan Officer Opinion Survey on Bank Lending Practices; S&P Case-Shiller U.S. National Home Price index.

1 Introduction

It has become clear in the aftermath of the 2007–2009 subprime crisis in the U.S. that there are important links between the housing market and the rest of the economy, and that house prices can be an important driver of aggregate consumption especially in downturns.

A key observation is that lending standards are counter-cyclical: lenders relax their standards in expansions and tighten them in recessions. This phenomenon is illustrated in Figure 1, which shows movements in lending standards on mortgage loans together with the house price cycle in the U.S. in 1990–2016. Lending standards have typically relaxed in times when house prices have been increasing, which correspond to periods of general economic expansion. This phenomenon is documented among others by Mian and Sufi (2009) and Bassett et al. (2014).

This negative correlation between lending standards and house prices could be explained by a causality that runs in either direction. On the one hand, when house prices are rising, lenders expect that less borrowers default on their loans and the losses on defaults are smaller, which allows them to relax their standards. On the borrower side, the expectations of rising house prices make it attractive even for riskier borrowers to demand loans. Relaxing standards to accommodate the increasing demand may also allow lenders to charge higher interest rates and make larger profits, if they accept the increasing riskiness of the borrower pool. On the other hand, as lending standards relax, the increased demand for loans bids up house prices, if housing supply is not very elastic. These two mechanisms are also very likely to feed back into each other. Disentangling them from observed data is particularly challenging; a theoretical framework is vital to understanding the underlying behaviour.

In this paper, I analyse the first of these mechanisms. I take fundamental house values as exogenous, and study the impact of changes in house values — which are then reflected in actual sales prices — on lending standards, the composition of the borrower pool, foreclosure rates, and the ultimate impact of these factors on aggregate consumption.

Understanding the incentives of households to take on debt in the first place, and consequently to possibly choose to default on it, is of great importance in understanding the drivers of the subprime crisis. However, in order to talk about potentially harmful *over*-borrowing, there has to be a market failure which allows households to take on too much debt from a social perspective. In such a context, over-borrowing is naturally defined as a deviation from a socially efficient equilibrium. Similarly, a loosening or tightening of lending standards can be understood as a deviation from the first-best in lenders' optimal decisions in terms of to whom, and at what price, loans should be granted.

In the model presented in this paper, households face two fundamental choices. First, they must decide whether to buy or rent their home; they must borrow to finance housing purchases, but their future incomes are uncertain at the time of purchase. Second, after income uncertainty is resolved, they can choose to default on their debt if they have any. Default acts as a form of insurance against adverse shocks, induced by market incompleteness and limited liability, but carries a deadweight loss cost.

I model the housing market in a setting where the intermediation of mortgage loans is inefficient because of an adverse selection problem, modelled after the classic framework of De Meza and Webb (1987, 1990). All households are subject to two shocks: a shock to house value, and an income shock. The former is observable by all agents, whereas the latter is private information to the borrower. Optimal default decisions are however affected by the joint probability of these two shocks. Consequently, borrowers differ by their default risk in a way that is unobservable to lenders. This particular information structure leads to over-investment in equilibrium, and "subprime" borrowers are defined as the set of borrowers who do get a loan, but would not in a first-best equilibrium.

First, I show that, despite its relative simplicity, the model can replicate some long run average statistics of the housing market, including the default rate, homeownership rate and loan-to-income ratio in the period before the subprime crisis. This suggest that although the model is not meant to be quantitative in nature, it does adequately capture some key aspects of households' behaviour in the housing market.

Using a comparative statics exercise, I show that there is a non-linear relationship between expected house values and participation in the credit market. When future house values are expected to be low, participation is high because prices are low. Because of low leverage, there is no incentive to default despite households with high income risk also participating in the market. As expected house values rise, the types with the lowest expected income first opt out of the market because housing becomes more expensive.

At some point expected capital gains become so attractive that the risky types enter the market again as expected future house values rise further. However, current house prices also rise with the increasing expectations on future values, and because of higher leverage, default becomes optimal if the borrower is hit by an adverse combination of income and house value shocks. The relationship between safe interest rates and mortgage market participation is monotone: lower interest rates attract more borrowers, as outside returns and borrowing costs are both low.

This mechanism is in line with the evidence in a series of influential empirical studies by Mian and Sufi (2009, 2011) and Mian et al. (2013). The authors find evidence for a credit supply driven mortgage lending boom, where lenders expanded their supply of mortgage lending and relaxed their lending standards in the run-up to the subprime crisis of 2007–2009. The shift in supply was tightly connected to the expansion of mortgage securitisation since the early 2000's. In Mian and Sufi (2011) and Mian et al. (2013), the authors conclude that the contraction in aggregate consumption that followed the sharp decline in house prices starting in 2006 was due to de-leveraging by households who had borrowed heavily against home equity.

The goal of this paper is to explore the micro-foundations of a financial friction that can cause over-investment in housing and link these foundations to a macroeconomic setting. Understanding the underlying incentive mechanisms linking credit supply and demand to aggregate consumption will help determine the types of policies that can mitigate the over-investment problem and suppress inefficient cycles in the housing market.

This research is linked to a growing body of literature on the interactions of asset prices and aggregate consumption. Iacoviello (2005), Kiyotaki et al. (2011), Iacoviello and Pavan (2013), and Guerrieri and Iacoviello (2014) study aggregate housing debt and the interaction between house prices and consumption. However, these papers do not explain or motivate *why* the borrowers are constrained. Kaplan and Violante (2014) and Gorea and Midrigan (2015) look at the aggregate implications of wealth and liquidity heterogeneity and the marginal propensity to consume out of housing wealth. In contrast to these papers, my focus is on formulating an explicit micro-foundation for inefficiencies in the mortgage credit market that have implications for aggregate consumption.

It also connects to recent quantitative models of the housing market where mortgage borrowers can strategically default, such as Corbae and Quintin (2015) and Elenev et al. (2015). My model differs from them in that the default decision is founded in an adverse selection problem.

The paper also contributes to the study of risk-averse agents and adverse selection in macroeconomic literature. A recent strand of literature has attempted to found micro-foundations for inefficiencies in aggregate investment by exploiting an adverse selection framework. Eisfeldt (2004), House (2006), Morris and Shin (2012), and Bigio (2015) look at investment in entrepreneurial projects, or the financing of capital production, in general equilibrium when the financing is affected by asymmetric information on project quality. Takalo and Toivanen (2012) and Kurlat (2013) examine the same problem, but in a partial equilibrium setting. Benhabib et al. (2015) formulate a general equilibrium model where the quality of final goods is unknown to the consumer prior to purchase.

The model presented in this paper applies the adverse selection framework of De Meza and Webb (1987, 1990), and is closest in spirit to the general equilibrium model of House (2006), although he focuses on risk-neutral entrepreneurs who invest in investment projects. Guler (2015) studies an economy with adverse selection and strategic default in the housing market, but contrary to this paper, argues that adverse selection has lead to credit rationing rather than over-lending in the housing market, and that the run-up to the subprime crisis can be explained with an increase in information symmetry and thus an increase in efficiency of credit intermediation, rather than an exacerbation of a market failure.

The remainder of the paper is organised as follows. Section 2 describes the model economy. Section 3 solves for the mortgage market equilibrium under symmetric and asymmetric information. Section 4 describes the timing of events and characterises the equilibrium of the aggregate economy. Section 5 explores the link between house prices, interest rates, and the selection into the housing market through a comparative statics exercise, and discusses and the general equilibrium implications of the selection problem. Finally, Section 6 concludes.

2 The model

2.1 Description of the economy

The economy consists of three types of agents: consumers, lenders, and real estate agents. The consumers have a finite lifetime, and they consume housing services and other consumption goods and receive an endowment income. The lenders extend mortgage loans to consumers in a perfectly competitive loan market. The real estate agents buy housing from exiting consumers as well as from lenders who acquire foreclosed housing, refurbish them, and re-sell them to newborn consumers.

There is a continuum of mass one of households which consist of consumers, who are risk averse. Each consumer only lives for two periods. Each period, a new generation of consumers enters as the previous one exits, so that the total mass of consumers stays constant. Each consumer receives an exogenous income in both periods of her life. In the first period, she must make a tenure choice of either buying or renting a unit of housing. In order to buy a house, she needs a mortgage loan from a banker. In the second period, she consumes housing services and other consumption goods.

In the second period of their life, each consumer faces an idiosyncratic probability of receiving either a high or a low endowment; housing is also subject to i.i.d. valuation shocks. The combination of these two sources of uncertainty may trigger a default by homeowners. The joint distribution of y_1 and q_1 is shown in Table 1.

Consider a consumer who lives for two periods, $t = 0, 1$. A consumer who wishes to become a home-owner buys housing h in $t = 0$ at a unit price q_0. At the time of the purchase, the value of the house in $t = 1$ is uncertain. It can be $q_1 = q_H$ with probability ϕ, or $q_1 = q_L$ with probability $1 - \phi$, with $q_H > q_0 > q_L \geq 0$.

Similarly, the endowment of the consumer in period $t = 1$ is $y_1 \in \{y_H, y_L\}$ with $y_H > y_L$. The probability of receiving y_H and y_L are π and $1 - \pi$, respectively.

The consumers differ by their probability of realising a high endowment y_H: there is a continuum of types $\pi \in [0, 1]$. This means that different borrowers face a different risk of low income y_L, and thus, a higher risk of potential default. The consumers only differ in the probability π they face; otherwise, they have the same preferences, and the same support for the income distribution $y_1 \in \{y_H, y_L\}$, and the same stochastic process and support for the housing value shock on q_1.

	y_H	y_L
q_H	$\pi\phi$	$(1-\pi)\phi$
q_L	$\pi(1-\phi)$	$(1-\pi)(1-\phi)$

Table 1: Joint distribution of endowment y_1 and house value q_1 in $t = 1$

The type is private information observed only by the consumer herself, and not by other agents in the economy. Lenders and real estate agents know the distribution of π, $F(\pi)$, which is time-invariant.

There is also a continuum of mass one of lenders, who are risk neutral. They have access to an infinitely elastic supply of funds (for example, through the international financial market). The lenders grant mortgage loans to borrowers, collect loan repayments, and consume their profits. The mortgage market is perfectly competitive and anonymous, and the loans are non-recourse one-period loans.

2.2 The credit market

There is a competitive credit market where households can apply for mortgage loans from a continuum of atomistic lenders. The loan contract consists of a loan l and a repayment schedule given by $\min\{(1+r)l, q_1 h + \xi y_1\}$. The lender observes the realisation of the house value q_1 and the income y_1 after the contract has been agreed upon, but before the loan repayment is scheduled to be made. In the event of default, the borrower goes into foreclosure and the lender acquires the house. The lender may also have recourse to a fraction $0 < \xi < 1$ of the borrower's income, y_1. If there is no default, the lender collects the loan repayment $(1+r)l$.

The optimal contract is described in Section 3.

2.3 The household problem

Assume that there is a fixed stock of housing h. Each individual must occupy one unit of housing, which provides a flow of housing services; each unit is ex-ante identical. The individual problem is to make the tenure choice over owning or renting a house. Given this choice, the consumption pattern in the second period is determined. I abstract from the choice over how much housing to acquire.

Consider a generation of individuals born in period $t = 0$. The ex-post budget constraints of the household in the second period of their life, $t = 1$, are:

Home-owner	
No default	$c_1 + \delta h = y_1 + q_1 h - (1 + r) l_0$
Default	$c_1 + s_1 h = (1 - \xi) y_1 - \kappa$
Tenant	$c_1 + s_1 h = y_1 + (1 + \bar{r}) a_0$

In the first period, there is no consumption; the endowment received in $t = 0$ is invested either into housing or a safe deposit:

Home-owner	$q_0 h = y_0 + l_0$
Tenant	$a_0 = y_0$

Both a home-owner and a tenant receive an exogenous income y_t in both periods. If the individual chooses to rent, she can earn the market rate $\bar{r}$ on her savings a_0, while paying a rent s_t per unit of housing in the second period.

In contrast, a home-owner in the first period takes out a loan l_0 to acquire housing h at a unit price q_0. At the beginning of the second period, the income y_1 is realised, and the home-owner makes the decision of whether or not to default. If there is no default, she pays a maintenance cost δ per unit of housing instead of rent. However, if she chooses to default on the loan, the lender seizes the house and the fraction ξy_1 of the income, and the borrower must convert into a tenant, paying rent s_1 on housing. A defaulting borrower also faces a deadweight loss cost of foreclosure $\kappa \geq 0$.

If the individual chooses to rent a house, she pays a unit rent s_1 in $t = 1$, and can save or borrow a_0 in period 0 with the market interest rate $\bar{r}$. In the second period, she consumes her endowment and her savings.

The price of consumption goods acts as numeraire and is normalised to unity.

The consumer derives utility from consuming housing services and other goods in the second period of her life, captured by the utility function $u(c) + \chi_i v(h)$, where $i = h, r$ designates a home-owner (h) or tenant (r). The utility function is separable in housing services and other goods, and I assume $u(\cdot)$ increasing and concave: $u'(\cdot) > 0, u''(\cdot) < 0$. In addition, home-owners enjoy a utility premium on housing services: χ_h is normalised to 1 for $i = h$, and $\chi_r = \chi < 1$ for tenants.

The value function of a consumer of type π in t_0 who becomes a home-owner is:

$$
\begin{aligned}
V_H(\pi) &= \beta E[u(c_1) + v(h)|\pi] \\
&= \beta\{p(\pi)E[u(c_{nd}) + v(h)|\pi] + (1 - p(\pi))E[u(c_d) + \chi v(h)|\pi]\} \\
\text{s.t.} \quad & q_0 h = y_0 + l_0 \qquad (1) \\
& c_{nd} = y_1 + q_1 h - (1 + r)l_0 - \delta h \qquad (2) \\
& c_d = (1 - \xi)y_1 - \kappa - s_1 h \qquad (3)
\end{aligned}
$$

where c_{nd} denotes period 1 consumption in case of no default, and c_d period 1 consumption in case of default.

$p(\pi)$ is the individual probability of not defaulting in $t = 1$, given the home-owners type π. It is an equilibrium object, for which the expression is derived in Section 3.1.

Substituting the period 0 budget constraint (1) into the no-default budget constraint (2) and rearranging yields the intertemporal budget constraint

$$c_{nd} = y_1 + (1 + r)y_0 + \Delta q h - (r_0 q_0 + \delta)h \qquad (4)$$

where $\Delta q \equiv q_1 - q_0$ equals the capital gain on the house. The term $r_0 q_0 + \delta$ is the user cost of housing borne in the second period.

The value function of a consumer who becomes a tenant is:

$$
\begin{aligned}
V_R(\pi) &= \beta E[u(c_r) + \chi v(h)|\pi] \qquad (5) \\
\text{s.t.} \quad c_r &= y_1 + (1 + \bar{r})y_0 - s_1 h \qquad (6)
\end{aligned}
$$

An individual chooses to buy a house and become a home-owner if and only if $V_H(\pi) \geq V_R(\pi)$. The trade-off that the individual faces is the higher income in the good state, in the form of the risky capital gain on housing, as well as enjoying the utility premium on housing services, as a home-owner, versus the less risky consumption granted by the safe return on savings as a tenant.

2.4 The real estate market

There is also a competitive real estate market, where a continuum of atomistic real estate agents act. In each period, a representative real estate agent buys housing both from successful exiting home-owners in the second period of their lifetime, and from lenders who have seized the houses of defaulting home-owners. The real estate agents refurbishes the housing stock at no cost, and sells it to the new, entering generation.

I assume that the whole housing stock, both owner-occupied and rental housing, are subject to the same distribution of value shocks. Then, in any given period, a fraction ϕ ends up as high value (q_H), and a fraction $1-\phi$ is low value (q_L).

Competition drives the profits of the real estate agents to zero, so that the sales price of the refurbished housing to a generation entering in period t is:

$$q_t = \phi q_H + (1-\phi) q_L. \tag{7}$$

The real estate agents also rent part of the housing stock to the defaulting homeowners whose houses have been foreclosed, and households who have chosen to rent, at a rental rate of s_t, and bear the user cost $\delta + r_{t-1} q_{t-1}$ per unit of housing. Perfect competition drives the rental rate down to equal the use cost of housing:

$$s_t = \delta + r_{t-1} q_{t-1}. \tag{8}$$

3 Credit market equilibrium

3.1 Optimal default decision

In the second period, a home-owner will choose not to default if and only if:

$$u(c_{nd}(y1, q1)) + v(h) \geq u(c_d(y1)) + \chi v(h) \tag{9}$$

for a given realisation $(y1, q1)$. Then, the ex-ante probability of no default, conditional on the borrower type π, is:

$$\Pr\{\text{'no default'} \mid \pi\} = \Pr\{u(c_{nd}(y_1, q_1)) + v(h) \geq u(c_d(y_1)) + \chi v(h) \mid \pi\} \equiv p(\pi). \tag{10}$$

This is equivalent to:

$$\Pr\{\text{'no default'} \mid \pi\} = \Pr\{(1 - \chi)v(h) \geq u(c_d(y_1)) - u(c_{nd}(y_1, q_1)) \mid \pi\}. \tag{11}$$

In other words, the homeowner will not borrow if the utility premium from owner-occupied housing relative to tenant-occupied housing is greater than the utility in terms of consumption acquired by defaulting.

Because utility is increasing in consumption, but more so in the no-default state (because only a fraction $1 - \xi$ can be consumed in the default state), the right hand side of this inequality is decreasing in y_1. Thus the probability of no default, $p(\pi)$, is increasing with the likelihood of high income, π.

Correspondingly, the conditional default probability is $1 - p(\pi)$, which is decreasing in π.

3.2 Credit market equilibrium under symmetric information

Each potential borrower will demand a loan of equal size: $l_0 = q_0 h - y_0 \equiv l$. Assume that there is symmetric information about borrower types, and a lender can observe each individual borrower's type π, and subsequently, also their individual ex-ante default probability $p(\pi)$. Then, he will offer a different loan contract $\mathcal{C}_\pi$ characterised by an interest rate $r(\pi)$ to each type π. The expected return on such a loan is

$$E\Pi(\pi) = p(\pi)[1 + r(\pi)]l + (1 - p(\pi))E[q_1 h + \xi y_1 \,|\, \text{'default'}], \tag{12}$$

where in case of no default, the lender receives the repayment of the loan amount and interest, and in case of default, recovers the house and the fraction ξ of income of the borrower.

Perfect competition ensures that the expected return on each individual loan is equal to the opportunity cost of the funds, $1 + \bar{r}$:

$$p(\pi)[1 + r(\pi)]l + (1 - p(\pi))E[q_1 h + \xi y_1 \,|\, \text{'default'}] = (1 + \bar{r})l \tag{13}$$

$$\Leftrightarrow \quad 1 + r(\pi) = \frac{1 + \bar{r}}{p(\pi)} - \frac{1 - p(\pi)}{p(\pi)} \frac{E[q_1 h + \xi y_1 \,|\, \text{'default'}]}{l}. \tag{14}$$

The no-default probability is increasing in the probability of a favourable income realisation, π, so that the individual rate $1 + r(\pi)$ is decreasing in π.

Given the offer $r(\pi)$, a borrower accepts the loan if $V_H(\pi) \geq V_R(\pi)$ and becomes a homeowner; otherwise, she becomes a tenant. High π borrowers enjoy lower interest rates on their loans: $\frac{\mathrm{d}r(\pi)}{\mathrm{d}\pi} < 0$. At the limit, the borrower with $\pi = 1$ faces no risk of low income, but only of the house losing its value.

Given the rate $r(\pi)$ and using the budget constraints (3) and (4), the first-best consumption of a type-π homeowner in the no-default (*nd*) and default (*d*) states, respectively, are:

$$c_{nd}^{FB}(\pi) = (1 + r(\pi))y_0 + y_1 + \Delta q h - (\delta + r(\pi)q_0)h \tag{15}$$

$$c_d^{FB} = (1 - \xi)y_1 - \kappa - s_1 h, \tag{16}$$

and the consumption of a tenant is:

$$c_r^{FB} = y_1 + (1 + \bar{r})y_0 - s_1 h. \tag{17}$$

Proposition 1 *The credit market equilibrium under symmetric information is characterised by a set of contracts $\mathcal{C}_\pi = \{l, r(\pi)\}$ and a cut-off type $\hat{\pi}^e \in [0, 1]$ such that all individuals with $\pi \geq \hat{\pi}^e$ accept $\mathcal{C}_\pi$ and become home-owners, and* *all individuals with $\pi < \hat{\pi}^e$ become tenants, and the lenders break even in expectation for every type π.*

The efficient cutoff type $\hat{\pi}^e$ is just indifferent between buying and renting, and is characterised by:

$$\begin{aligned}
& V_H^{FB}(\hat{\pi}^e) = V_R^{FB}(\hat{\pi}^e) \\
\Leftrightarrow \quad & \beta E[p(\hat{\pi}^e)[u(c_{nd}^{FB}(\hat{\pi}^e)) + v(h)] + (1 - p(\hat{\pi}^e))[u(c_d^{FB}) + \chi v(h)] \mid \hat{\pi}^e] = \\
& \beta E[u(c_r) + \chi v(h) \mid \hat{\pi}^e] \\
\Leftrightarrow \quad & p(\hat{\pi}^e) = \frac{E[u(c_r^{FB}) - u(c_d^{FB}) \mid \hat{\pi}^e]}{E[u(c_{nd}^{FB}(\hat{\pi}^e)) - u(c_d^{FB}) + (1-\chi)v(h) \mid \hat{\pi}^e]}. \qquad (18)
\end{aligned}$$

Sketch of the proof. The homeowner consumption in the no-default state c_{nd}^{FB} is increasing in π: $\frac{\partial c_{nd}^{FB}}{\partial \pi} = -\frac{\partial r(\pi)}{\partial \pi} l > 0$, as:

$$\frac{\partial r(\pi)}{\partial \pi} = \underbrace{\left[\frac{q_L h + \xi y_L}{l} - (1 + \bar{r})\right]}_{<0} \underbrace{\frac{p'(\pi)}{p(\pi)^2}}_{>0} < 0.$$

The value $V_R^{FB}(\pi) = \beta E[u(c_r^{FB}) + \chi v(h)|\pi]$ is linearly increasing in type π:

$$\begin{aligned}
\frac{\partial V_R^{FB}(\pi)}{\partial \pi} &= u(c_r^{FB}(y_H)) - u(c_r^{FB}(y_L)) > 0 \\
\frac{\partial^2 V_R^{FB}(\pi)}{\partial \pi^2} &= 0.
\end{aligned}$$

The value $V_H^{FB}(\pi)$ is increasing in p:

$$\begin{aligned}
\frac{\partial V_H^{FB}(\pi)}{\partial \pi} = \beta & \underbrace{p'(\pi) E\left[(u(c_{nd}^{FB}) - u(c_d^{FB})) + (1-\chi)v(h) \mid \pi\right]}_{>0} \\
& + \beta \underbrace{\left[p(\pi) \frac{\partial E[u(c^{nd} + v(h)) \mid \pi]}{\partial \pi}\right]}_{>0} > 0.
\end{aligned}$$

Then, there exists a parametrisation for which the value functions $V_R^{FB}(\pi)$ and $V_H^{FB}(\pi)$ intersect at most once in the interval $\pi \in [0, 1]$. If no intersection exists in this interval, if $V_R^{FB}(\pi) < V_H^{FB}(\pi) \, \forall p$, define $\hat{\pi}^e = 0$, and if $V_R^{FB}(\pi) > V_H^{FB}(\pi) \, \forall \pi$, define $\hat{\pi}^e = 1$. I rule out cases where the value functions could intersect twice.

The credit market equilibrium under symmetric information is efficient and establishes a first-best benchmark.

3.3 Credit market equilibrium under asymmetric information

Now return to the assumption that a borrower's type is unobservable to the lender. Low-π borrowers have the incentive to mimic high-π borrowers in order to get a loan because of the limited liability in case of default. There exists now an equilibrium, characterised by a cut-off, in which the banker lends to all borrowers above the cut-off, and charges an common interest rate r from all borrowers, such that he makes a non-negative expected profit in expectation on the pool of loans l.

Proposition 2 *The credit market equilibrium under asymmetric information is characterised by a pooling contract $\mathcal{C} = \{l, r^*\}$ and a cut-off type $\hat{\pi} \in [0,1]$ such that all individuals with $\pi \geq \hat{\pi}$ accept $\mathcal{C}$ and become home-owners, and all individuals with $\pi < \hat{\pi}$ become tenants, and the lenders break even in expectation given $\hat{\pi}$.*

Sketch of proof. Similarly to the symmetric information case, the value of a tenant $V_R(\pi)$ is linearly increasing in π:

$$\frac{\partial V_H(\pi)}{\partial \pi} = \beta\left[u(c^r(y_H)) - u(c^r(y_L))\right]$$

The value of a home-owner $V_H(\pi)$ is increasing in π:

$$\frac{\partial V_H(\pi)}{\partial \pi} = \beta\left\{p'(\pi)E[u(c^{nd}) - u(c^d) + (1-\chi)v(h)|\pi] + p(\pi)\frac{\partial E[u(c^{nd})]}{\partial \pi}\right\} > 0.$$

Then, there exists a parametrisation for $V_R(\pi)$ and $V_H(\pi)$ such that they intersect at most once in the interval $\pi \in [0,1]$. If no intersection exists in this interval and $V_R(\pi) < V_H(\pi)\,\forall\pi$, define $\hat{\pi} = 0$, and if $V_R(\pi) > V_H(\pi)\,\forall\pi$, define $\hat{\pi} = 1$.

The equilibrium interest rate is determined by the break-even condition of the lenders. The expected return of a banker who charges an interest rate r, given the pool of loan applicants characterised by the cutoff $\hat{\pi}$, is given by:

$$E\Pi(r) = E[p(\pi)|\pi \geq \hat{\pi}](1+r)l + E[(1-p(\pi))(q_1 h + \xi y_1)|\pi \geq \hat{\pi}]. \quad (19)$$

In equilibrium, the competition drives the return on the loan down to equal the market rate, or the opportunity cost of the funds. The equilibrium interest rate offered to all loan applicants, r^*, is then given by:

$$\begin{aligned} & E\Pi(r^*) = (1+\bar{r})l \\ \Leftrightarrow \quad & 1 + r^* = \frac{1+\bar{r}}{E[p(\pi)|\pi \geq \hat{\pi}]} - \frac{E[(1-p(\pi))(q_1 h + \xi y_1)|\pi \geq \hat{\pi}]}{E[p(\pi)|\pi \geq \hat{\pi}]}. \end{aligned} \quad (20)$$

Given the offered rate r^*, an individual accepts the contract $\mathcal{C}$ if $V_H(p, r^*) \geq V_R(\pi)$. The cutoff type $\hat{p}$ is implicitly determined by:

$$\begin{aligned} & V_H(\hat{\pi}, r^*) = V_R(\hat{\pi}) \\ \Leftrightarrow \quad & p(\hat{\pi}) = \frac{E[u(c^r) - u(c^d(r^*))|\hat{\pi}]}{E[u(c^{nd}(r^*)) - u(c^d) + (1-\chi)v(h)|\hat{\pi}]}, \end{aligned} \quad (21)$$

where c^{nd}, c^d and c^r are given by equations (4), (3) and (6), respectively.

4 Equilibrium and model solution

4.1 Timing

The timing of the model is as follows. In every period t, a new generation enters. A generation indexed by its entry period $t = \tau$. Each generation lives for two periods, t and $t+1$. The timing within the two periods of a generation entering in $t = 0$ is outlined in Table 2.

4.2 Equilibrium and aggregation

The equilibrium is an allocation $\{c^\tau_{t+1}, \hat{\pi}_t, h_t, r^*_t, q_t, s_t\}_{t=0}^\infty$ is such that given the interest rate r^*_t, the cut-off $\hat{\pi}_t$ satisfies (21) and the household consumption plan is given by $c^\tau_{t+1} = \{c^{nd}, c^d, c^r\}$, defined by equations (4), (3) and (6); the loan interest rate r^*_t satisfies (20) given $\hat{\pi}_t$; the house sales price

Period 0
• The generation $\tau = 0$ is born and receives the first-period endowment y_0. • The preceding generation $\tau = -1$ sells their housing stock to the real estate agents, consume, and exit. • The new generation observes the house price q_0 and the income y_0, and make its housing choice. The cutoff type $\hat{\pi}_0$ is determined.
Period 1
• The house values $q_1 \in q_H, q_L$ as well as the income realisations $y_1 \in y_H, y_L$ are realised and observed by all agents. • The homeowners make their optimal default choice. • The successful homeowners sell their housing to the real estate agents at the price q_1 and consume $c^{nd}(y_1, q_1)$. • The renters consume $c^r(y_1)$ and the foreclosed homeowners consume $c^d(y_1)$. • The generation $\tau = 0$ exits while a new one enters.

Table 2: Timing of events

q_t satisfies (7); the rental rate s_t satisfies (8); and the following conditions hold:

$$Y^\tau = C^\tau + H^\tau \tag{22}$$

$$\bar{h} = \int_0^1 h \, \mathrm{d}p, \tag{23}$$

where equation (22) is the aggregate consistency condition, and (23) is the housing market clearing condition. C^τ is the aggregate consumption of goods, H^τ is the aggregate consumption of housing services, and Y^τ is the aggregate income of generation τ, born in period $\tau = t$. They are defined as:

$$C^\tau = \int_0^1 c^\tau_{t+1} \, \mathrm{d}p \tag{24}$$

$$H^\tau = \int_0^1 s^\tau_{t+1} \, \mathrm{d}p \tag{25}$$

$$\begin{aligned} Y^\tau = & \int_0^{\hat{p}_\tau} [(1+\bar{r})y_t + y_{t+1}] \, \mathrm{d}p + (1-\gamma_\tau) \int_{\hat{p}_\tau}^1 (y_{t+1} - \kappa) \, \mathrm{d}p \\ & + \gamma_\tau \int_{\hat{p}_\tau}^1 [(1+r)y_t + y_{t+1} + \Delta q_{t+1}] \, \mathrm{d}p \end{aligned} \tag{26}$$

where $\hat{\pi}_\tau$ denotes the cutoff type in generation τ, and γ_τ the fraction of non-defaulting home-owners in generation τ in the second period of their life. By the law of large numbers, $\gamma_\tau \to E[p(\pi)|\pi \geq \hat{\pi}]$.

4.3 Functional forms

I assume log utility $u(\cdot) = v(\cdot) = \log(\cdot)$ and a uniform distribution of types $\pi \sim Uniform(0,1)$. These simple functional forms allow for an analytical solution of the equilibrium default probability and the equilibrium interest rate.

In particular, the optimal default choice (9) is given by the condition:

$$\begin{aligned} & u(c_d(y_1)) + \chi v(h) \geq u(c_{nd}(y_1, q_1) + v(h) \\ \Leftrightarrow \quad & \log(c_d(y_1)) + \chi \log(h) \geq \log(c_{nd}(y_1, q_1) + \log(h) \end{aligned}$$

By substituting in the budget constraints (3) and (2), this condition can be solved for:

$$y_1 + \Phi q_1 h \leq \Phi \left((1+r^*)l_0 - \frac{\kappa}{h^{1-\chi}} \right)$$

where $\Phi \equiv \left(1 - \frac{1-\xi}{h^{1-\chi}}\right)^{-1} > 0$.

Therefore, the ex-ante optimal default probability of a type π is given by

$$\Pr\{\text{'default'} \mid \pi\} = \Pr\left\{ y_1 + \Phi q_1 h \leq \Phi \left((1+r^*)l_0 - \frac{\kappa}{h} \right) \mid \pi \right\} \equiv 1 - p(\pi).$$

Then, the borrower optimally defaults if and only if in the event that the sum of his income y_1 and house value q_1 is low enough, or in other words, in the joint event that y_1 and q_1 both realise a low enough value. In the calibration I use, optimal default occurs only when $y_1 = y_L$ and $q_1 = q_L$, i.e. when the home-owner suffers both an adverse income and an adverse house value shock at the same time. In other states of the world, the borrower has no incentive to default.

In this case, the default probability of a type π is $1 - p(\pi) = (1-\phi)(1-\pi)$, which is the joint probablity of the event $(y_1, q_1) = (y_L, q_L)$.

Then the ex-ante default probability of a borrower from a lender's point of view, given the borrower cut-off type, is:

$$\begin{aligned} E[(1-\phi)(1-\pi)|\pi \geq \hat{\pi}] &= 1-\phi-(1-\phi)E[\pi|\pi \geq \hat{\pi}] \\ &= 1-\phi-(1-\phi)\frac{\int_{\hat{\pi}}^{1}\pi f(\pi)\,\mathrm{d}\pi}{1-F(\hat{\pi})} \\ &= \frac{1}{2}(1-\phi)(1-\hat{\pi}). \end{aligned}$$

and correspondinly the no-default probability is $E[1-(1-\phi)(1-\pi)|\pi \geq \hat{\pi}] = \frac{1}{2}(1+\phi+(1-\phi)\hat{\pi})$. Finally, the equilibrium pooling interest rate (20) in this case is:

$$1+r_t^* = \frac{1+\bar{r}}{\frac{1}{2}(1+\phi+(1-\phi)\hat{\pi})} - \frac{1-\phi-(1-\phi)\hat{\pi}}{1+\phi+(1-\phi)\hat{\pi}}\frac{q_L h+\xi y_L}{l}. \tag{27}$$

4.4 Numerical calibration and solution

The parameter values used in the numerical model solution and simulation are given in Table 3. They are chosen to mach some key housing market statistics from the U.S. data. The data moments are based on the figures given in Corbae and Quintin (2015) and on the author's own calculations based on the Case-Shiller index and the Survey of Consumer Finances. The first two columns of the table list the baseline values of the parameters being calibrated. Each parameter is chosen to pin down a given target statistic. These data targers and their model counterparts are shown the right-most columns in Table 3.

Furthermore, Table 4 shows some statistics from the U.S. data that were not explicitly targeted, but which the model nonetheless matches reasonably well.

In order to study the behaviour of the model, I solve for the equilibrium numerically using iteration methods. Taken together, the figures in Tables 3 and 4 show that the model, while simple, can replicate some of the long-run averages in the U.S. housing market data. In the next section, I look at some comparative statistics to gauge further how the selection into homeownership depends especially on the safe interest rate $\bar{r}$ and on the housing value risk ϕ.

Parameter	Value	Target	Data	Model
Discount rate β	0.96	Safe interest rate	1.04	1.04
Utility from owner-occ. h $v_R(h)$	0.2	Homeownership rate	0.66	0.66
Lender appropriation rate ξ	0.288	Average recovery rate	0.5	0.48
High house value prob. ϕ	0.915	Mortgage default rate	0.01	0.03
Default DWL cost κ	2.08	Default only when (y_L, q_L)		
$\frac{q_0}{y_0}$	2.93	Loan-to-value ratio	-	0.7
$\frac{q_H}{q_0}$	1.07	Case-Shiller 1999-2006	1.85	1.72
$\frac{q_L}{q_0}$	0.24	Case-Shiller 2007-2010	0.59	0.33
$\frac{y_H}{y_0}$	1.43			
$\frac{y_L}{y_0}$	0.71			

Table 3: Baseline parameter calibration

Target	Data	Model
Loan spread	300 bp	162 bp
Loan-to-income ratio	-	1.94
Rent-to-income ratio	0.40	0.38

Table 4: Data targets and model counterparts

5 Equilibrium characteristics

In this section, I describe some equilibrium features of the model: over-investment in mortgages, the source of this inefficiency, and the links between default rates, house prices, and interest rates.

5.1 The over-investment externality

The key feature of models of the credit market with a De Meza and Webb (1987) type of information structure, such as here, is that the equilibrium in the credit market equilibrium is inefficient in the sense that there is over-investment in mortgages compared to the first best whenever there is a non-zero possibility of borrower default. Moreover, the marginal type $\hat{\pi}$ is the riskiest type in the loan pool, meaning that the loan pool is riskier than it would be under symmetric information.

Equivalently, as the pooling interest rate r^* is decreasing in $\hat{\pi}$, this implies that $\hat{\pi} \leq \hat{\pi}^e$ for all $\hat{\pi}$. The share of borrowers that are able to get a mortgage under asymmetric information, but would not do so under

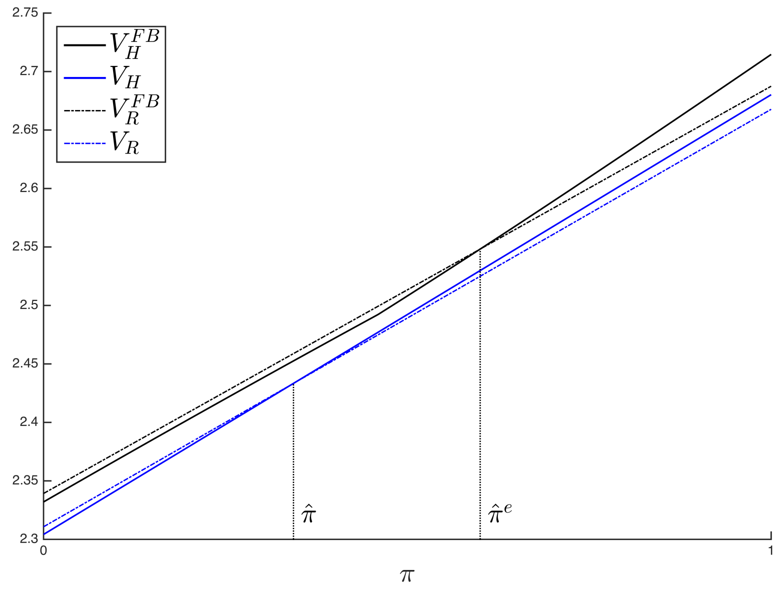

Figure 2: Value functions under symmetric and asymmetric information

symmetric information, defined as the share $\hat{\pi}^e - \hat{\pi}$, can be called *subprime* borrowers. They are borrowers whose mortgage loans are not socially optimal.

This is illustrated in Figure 2, which shows the value functions of a tenant $V_R(\pi)$ and a home-owner $V_H(\pi)$ as a function of type π, together with their respective first-best counterparts. All value functions are increasing in the type: a high type has, on expectation, a higher consumption in the second period because of the lower income risk.

However, in the asymmetric information economy, there is an externality associated with entry into the credit market. If an agent of type π enters the market and takes a mortgage loan, it yields her an expected marginal utility of consumption $u'(c_{nd})$ with probability of $p(\pi)$, i.e. if she does not default. This expectation is the higher, the higher the type. The cost of entry however does not depend on type: the pooling interest rate $1 + \bar{r}$ is the same for all entrants. However, by entering the market, the marginal borrower makes the pool marginally riskier, and thus increases the interest rate faced by all other agents in the credit market as well.

It is this change in the interest rate r^* induced by entry, which affects the consumption available in the no-default state for every borrower, that the

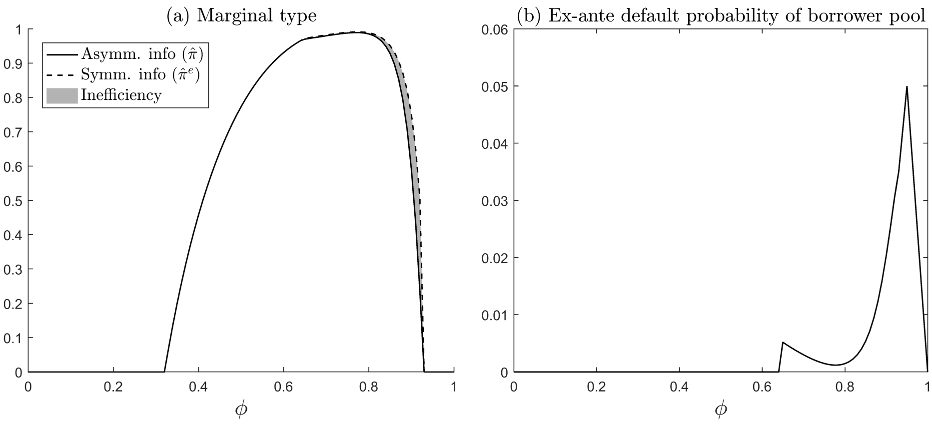

Figure 3: Equilibrium cut-off types and default probability of the borrower pool as a function of the house price risk ϕ

marginal borrower does not internalise under asymmetric information. In the symmetric case, the interest rate $1 + r(\pi)$ correctly reflects each type's riskiness, so that the externality disappears.

The implications of an increase in credit supply, i.e. a decrease in the cut-off $\hat{\pi}$, on aggregate consumption are more subtle. There are two effects that move in different directions. As more households gain access to the mortgage market and can consume capital gains on their housing, aggregate consumption increases. But as the borrower pool expands, it also becomes riskier, so the interest rate on mortgages rises. This increases the user cost of housing, which includes the interest payments on the mortgage loan. This mechanically increases the value of consumption of housing services, but reduces resources left for the consumption of goods other than housing services. The aggregate effect depends on which component dominates, but for plausible parameter values, it is positive when house prices are increasing. Conversely, when house prices decline, capital gains are eroded, which contracts aggregate consumption.

5.2 Comparative statics

The extent of the externality is quantified in Figures 3 and 4. They show how the marginal type $\hat{\pi}$ and the ex-ante default probability of default in the borrower pool observed by the lender, $E[1 - p(\pi)|\pi \geq \hat{\pi}]$, change as two key parameters of the models change: the probability of a high house value realisation ϕ, and the safe interest rate $1 + \bar{r}$.

As Figure 3 shows, the model exhibits an interesting non-linear relationship between the probability of a high house value realisation ϕ and the marginal type, all other parameter being fixed at their benchmark values. Strikingly, the homeownership rate is 100 % (i.e. the marginal type is 0) both when a high house value is very unlikely and very likely.

At the limit, when the high house value y_H will never occur, i.e. when $\phi = 0$, the purchase price of the house is equal to the low value: $q_0 = q_L$. Then, buying a house is very cheap, and there is no price risk involved. As a consequence, owning is very attractive to all types, even those with low expected income. Even as ϕ becomes positive, for low values, $q_0 = \phi q_H + (1 - \phi) q_L$ remains low. Because loan amounts are low and homeowners derive a utility bonus from owning rather than renting, default is never optimal for any type π when ϕ is low.

As ϕ increases, also the purchase price q_0 and loan amounts increase. At first, the worst types who have the lowest expected income start opting out and renting instead. However, default remains non-optimal for all types in the borrower pool. Eventually, as q_0 keeps rising, default becomes optimal for some types. There is a discontinuous jump of the ex-ante default probability of the borrower pool away from zero at around $\phi = 0.63$. At this point, as defaults become a non-zero probability event, the over-investment externality kicks in and the asymmetric information equilibrium is no longer efficient: the efficient marginal type is higher than the actual one under asymmetric information.

As the probality of the high house value and therefore the purchase price q_0 keep rising, the worst types keep opting out of the mortgage market, and thus the borrower pool becomes safer. Although defaults still happen, the pool becomes less risky.

However, as the high house value becomes likely enough, at around $\phi = 0.80$, riskier types with worse income expectations are drawn back to the mortgage market. Consequently, the ex-ante default rate sharply increases, peaking at $\phi = 0.95$.

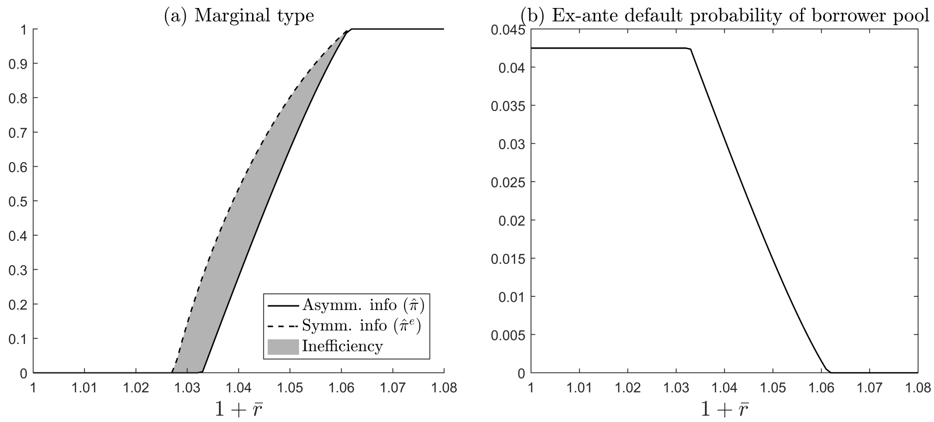

Figure 4: Equilibrium cut-off types and default probability of the borrower pool as a function of the outside interest rate $1 + \bar{r}$

For very high values of ϕ in the range 0.95–0.99, homeowners actually default whenever they are hit by a low house value, regardless of their income realisation, because they are so highly levered. Then the ex-ante default probability is no longer dependent of the composition of the borrower pool. In this region, the inefficiency thus disappears. This behaviour is ruled out in the benchmark calibration, where $\phi = 0.915$.

It is in this region of increasing market participation that the over-investment inefficiency is at its worst. For a given value of ϕ, the vertical distance of the two curves measures the extent of this inefficiency. This distance can also be interpreted to measure the looseness of lending standards relative to first-best: it shows that lending standards are loose exactly when high house values are relatively likely.

Figure 4 shows a similar exercise of comparative statics for the interest rate $1 + \bar{r}$, all other parameter being fixed at their benchmark values. The relationship between the safe interest rate and the marginal type is monotone and increasing. When $\bar{r}$ is low, the cost of lending is low on the one hand, and the outside return for savings is low as well. Therefore purchasing a house is very attractive. As the safe interest rate is increased, borrowing becomes more expensive and the outside return better; thus worst types opt out of the mortgage market. The inefficiency is worst at low values of $\bar{r}$: since in the symmetric information economy each agents' cost of funding reflects their true riskiness as borrowers, it increases faster for low types than when they face the pooling interest rate, and hence these marginal types choose to opt out for lower values of $\bar{r}$.

These two exercises highlight that the over-investment externality is particularly big first, when house values are relatively high on expectation, which is reflected in high purchase prices; and second, when interest rates are relatively low.

6 Conclusions

This papers outlines a model of the housing market where the intermediation of mortgage loans is affected by an adverse selection problem. The selection is towards less creditworthy borrowers, which implies equilibrium overborrowing with respect to the first-best. Overborrowing must then be understood as a macroeconomic problem, not an individual-level one: each household chooses optimally to take on debt, and lenders choose optimally their loan offers, but the market failure caused by hidden borrower types can lead to too much debt in aggregate from a social point of view.

The first goal of this paper is to shed light on the micro-level mechanisms and incentives that can cause equilibrium over-investment and endogenous fluctuations in lending standards, captured by the endogenous share of subprime borrowers in the market.

The model presented in this paper, while simple, succeeds in replicating some key statistics of long-run averages in the U.S. housing market before the subprime crisis, such as the default rate, homeownership rate, and loan-to-income ratio.

Using two examples of comparative statics, I show that lending standards are loose and there is a lot of overborrowing first, when future house values are expected to be high, which leads to high purchase prices of housing; and second, when safe interest rates are relatively low, which implies low costs of borrowing as well as a low opportunity cost on housing investment. In these circumstances, the incentives of not-very-creditworthy borrowers to enter the mortgage market are the strongest: their outside returns are low, expected capital gains on housing are high, and the cost of borrowing is low. These are also the conditions which correlate with the greatest inefficiency in the credit market, or in other words, with very loose lending standards. These are exactly the circumstances which prevailed in the U.S. prior to the subprime crisis in the early 2000s; the results are consistent with a substantial market failure in housing finance in the years prior to the crisis.

However, increasing expectations on future house values per se are not enough to create inefficient levels of borrowing, and debt is not always undesirable from a social perspective. The incentives of households are affected by many interlinked factors. It is remarkably difficult to disentagle these incentives from observed data; this justifies why a micro-founded model is vital in distinguishing when the aggregate amount of debt in an economy is excessive and when not.

The key mechanism driving the dynamics of the model is the endogenous composition of the borrower pool, which derives from the household's tenure choice. Increasing house values increases the demand for mortgage loans on the one hand; on the other hand, lenders are happy to increase their credit supply, as long as they are able to compensate for the increased riskiness of the borrower pool by charging higher interest rates. This relaxation of lending standards worsens the composition of the mortgage loan pool, which in turn increases borrower default rates.

Understanding the incentive mechanisms that lead to inefficient credit and over-borrowing will help think about effective policy measures that can mitigate this inefficiency in credit intermediation. Any policy that aims at curbing overborrowing by home-buyers should target these incentives directly.

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