A Theory of Subprime Mortgage Lending*

Jaime Luque†
University of Wisconsin - Madison

Timothy Riddiough‡
University of Wisconsin - Madison

October 20, 2015

Abstract

We present a general equilibrium model of a subprime economy characterized by limited recourse mortgages, asymmetric borrower credit quality information, and mortgage lenders that either own or sell the loans they originate. Because portfolio lenders can acquire soft information at low cost and are capacity constrained, there is another potential funding source for consumers: the conduit loan market. Conduit lenders originate mortgages based on hard information only, but have access to the securitized investment market. This trade-off between adverse selection and secondary market liquidity determines the equilibrium size of the portfolio and conduit loan markets in our model. Our theory rationalizes the emergence of the subprime conduit mortgage market and subsequent collapse of the traditional lending model, and also the recent rise and fall of the subprime conduit mortgage market. In addition, the model sheds some light on the access to and fragmentation of the rental and owner-occupied segments of the housing market, and also illustrates how house prices respond to changes in the credit scoring technology and mortgage securitization rate, among other things.

Key words: subprime lending; credit scoring technology; portfolio lenders; conduit lenders; general equilibrium; endogenous mortgage market segmentation.

JEL Classification numbers: R21, R3, R52, D4, D5, D53.

---

*We thank for comments and suggestions Henrique Basso, Jan Brueckner, Briana Chang, Moussa Diop, Gonzalo Fernandez de Cordoba, Scott Frame, Bulent Guler, Barney Hartman-Glaser, Erwan Quintin, Steve Malpezzi, Thomasz Piskorski, Ricardo Serrano-Pardial, Abdullah Yavas, and the participants at the annual meetings of SAET (Cambridge, UK), Finance Forum (Madrid, Spain), EWGET (Naples, Italy), Singapore, DePaul conference in Economics and Finance (Chicago), UCLA Conference on Housing Affordability (Los Angeles), and seminars at the U. Wisconsin-Madison. We are particularly grateful to Xudong An and Vincent Yao for many discussions and their insights into the workings of the subprime secondary mortgage market. We also acknowledge contemporaneous work with them on certain empirical implications of our model, which has informed our work in this paper but which we do not cite at this point.

†jluque@wisc.edu

‡timothy.riddiough@wisc.edu

1 Introduction

The subprime crisis that started in 2007 and its aftermath has been coined as the Great Recession. Much of its discussion has focused on the problems around the secondary subprime mortgage market. This paper focuses instead on the changes that ocurred in the primary subprime mortgage market to rationalize the emergence of the subprime conduit mortgage market in mid-1990s, its subsequent dominance over the traditional relationship lending model in the early 2000s, and its posterior collapse in early 2007.

In particular, we show that a crude or even non-existent hard credit scoring technology was enough to explain why traditional relationship lenders, whose business model was to "originate-to-own", were the only ones that operated in the subprime mortgage market before mid-1990s. These lenders - also referred to as "portfolio lenders" - had cheap access to soft credit risk information, and this allowed them to screen between subprime borrowers of different default risk type. However, these traditional portfolio lenders were capacity constrained, and this left many potential high quality subprime borrowers out of the porfolio loan market. These leftovers preferred to rent than borrowing at a prohibitive high mortgage rate from other potential lenders who only relied on poor hard credit information. Thus, in this equilibrium regime only portfolio lenders were active, and a small number of high quality consumers were able to buy a house with a subprime mortgage.

We then show that the new and better hard credit scoring technologies that became available in the early to mid 1990s, such as FICO scores and consumer's credit history, was sufficient to trigger the emergence of the subprime conduit mortgage. With a better hard credit information, conduit lenders, who only relied on hard information and whose business model was primarily (but not exclusively) "originate-to-distribute", were able to attract good type consumers by offering them a better mortgage rate than before, but still at worse terms than portfolio lenders. We identify the parameter thresholds for this equilibrium regime where both portfolio lenders and conduit lenders actively lent to different pools of borrowers at different mortgage rates.

Afterwards, in the early 2000s, the conduit lender's "originate-to-distribute" business model became predominant: all higher quality borrowers preferred to migrate to the subprime conduit lending market leaving traditional portfolio lenders with a small market share of leftovers. In our model, this new equilibrium regime is generated by stronger investor's appetite for subprime mortgage-backed securities (MBS) together with a wider confidence in the existing hard credit scoring technology (the latter due to an increase in the fundamental proportions of higher quality borrowers in the conduit lenders' pool of borrowers). Since investors were effectively pricing conduit mortgage rates, the investors' new risk shifting behavior moved the conduit mortgage rate below what traditional portfolio lenders charged for their low default risk mortgages. In this equilibrium regime, there was a a lot of credit in the subprime economy because conduit lenders could accommodate any measure of borrowers as long as the hard credit scoring technology identified them as good borrowers. This boom of subprime credit is accompanied in our model by a jump in house prices and subprime home ownership rates.

Finally, the collapse of the conduit mortgage market in 2007 can be rationalized in terms of our model by a negative shock to the subprime borrowers' ability to repay their mortgage debt. This shock triggered defaults and foreclosures, and shook the confidence on the existing hard credit scoring technology. Lack of trust in the existing hard credit scoring technology was similar to the initial situation where this technology was crude or even non-existent. When this happened, the subsidy paid by the higher quality borrowers to support a pooling loan rate became so high that discouraged home ownership - renting was a preferred option. High credit quality consumers that were not able to borrow from portfolio lenders would then leave the conduit loan market, resulting in the collapse of this market. The drop in available subprime credit made house prices plummet and home affordability problems reappeared.

Our model is able to generate these different regimes and also explain the changes in subprime mortgage rates across regimes. While portfolio lenders incorporate soft information into the determination of a (borrower specific) risk-based subprime loan rate, conduit lenders recognize that their borrower-lending clientele is lower credit quality on average. Thus, the conduit mortgage rate contains an adverse selection component, captured by the lack of soft information, but also a liquidity component coming from the conduit lender's access to the securitized investment market. These two components move the conduit loan rate in opposite directions. On the one hand, securitization allows customization (conduit loans are priced using the investors' time discount rate), which lowers the cost of capital in the conduit loan market. On the other hand, adverse selection in the primary mortgage increases the cost of capital in the conduit loan market. This trade-off between secondary market liquidity and adverse selection is the key driver of the rise and fall of the subprime lending market in our model.

The theory proposed here relies on a general equilibrium model that incorporates important ingredients of a subprime economy: limited recourse mortgages, asymmetric borrower credit quality information, and two funding sources for consumers, the portfolio mortgage market and the conduit mortgage market. We allow consumers to choose between portfolio loans and conduit loans. This is important because it allows us to capture the migration of consumers from one mortgage market to another. Thus, the subprime mortgage market segmentation is endogenous in our the model. In addition, the loan amounts, the mortgage rates, the house prices, and the household's tenure choice (owning versus renting) are all endogenous determined in equilibrium. We also show that competitive equilibrium with endogenous segmented mortgage markets exists under mild conditions on the consumer's utility function.

Relationship with the literature: The literature on collateralized lending with asymmetric information is vast and has expanded rapidly in recent years in light of the subprime mortgage lending and financial crisis. In brief, and at a high level, this paper contributes to the literature that studies how both information frictions and mortgage securitization possibilities affect debt contract design, mortgage originations, securitization, and house prices. See Jaffee and Russell (1976), Stiglitz and Weiss (1981) and Akerlof (1986) for classic papers on the effects of information frictions on screening, sorting and borrower default. For recent work that focuses on how different lenders' information sets affect mortgage loan outcomes, borrowers' default, and market unraveling, see, e.g., Karlan and Zinman (2009), Adams et al. (2009), Edelberg (2004), Rajan, Seru and Vig (2010), and Einav et al. (2013). See Miller (2014) for a related analysis of the importance of information provision to subprime lender screening. More generally, see Stein (2002) for a description of how private information includes soft information, and how difficult is to communicate soft information to other agents at a distance.[1]

Our equilibrium analysis of the subprime mortgage market also contributes to the recent empirical literature that attempts to identify the pricing determinants of differences between portfolio loans and conduit loans, and also differences among different types of conduit loans themselves (see Keys, Mukherjee, Seru, and Vig (2010) and Krainer and Laderman (2014))[2]. Agarwal, Amromin, Ben-David, Chomsisengphet and Evano (2011) recognized the lack of a theoretical model. To this extent, our paper provides a theoretical framework that enables to decompose the conduit mortgage spread into a credit information component, a foreclosure recovery rate component, and a component that captures the access to liquidity in the securitized investment market. We then show how these different pricing components can drive the rise and fall of the subprime conduit mortgage market.

Our paper is also related to the literature of shadow banking and subprime lending. As in Gennaioli, Shleifer, and Vishny (2012), our model can also illustrate that investors' wealth drives up securitization, but in addition our model is able to generate the result that adverse selection in the loan origination market can be the only reason why the conduit loan market shuts down, even when there is investors' appetite for mortgage-backed securities. This provides a different angle to the role of adverse selection on the rise and fall of subprime mortgage lending, which so far has focused on adverse selection in the secondary mortgage market. Our paper also departs from Mayer, Piskorski, and Tchistyi (2013), Makarov and Plantin (2013), and Piskorski and Tchistyi (2011) by distinguishing between shadow bank and formal bank funding models, and relating their change in market share to different equilibrium subprime mortgage configuration regimes that result from changes in the credit scoring technology, securitization, foreclosure costs, or lenders' capacity constraints.[3]

Importantly, our model captures the ebbs and flows of shadow bank activity, often peaking just prior to a downturn. The peak corresponds with poor access to soft information acquisition by conduit lenders and high liquidity flowing from security investors to conduit lenders (which is their largest if not exclusive source of funds).[4] This is consistent with Purnanandam's (2010) evidence that lack of screening incentives coupled with leverage-induced risk-taking behavior significantly contributed to the current subprime mortgage crisis. Our equilibrium mechanism links subprime mortgage lending standards to the run-up and eventually collapse in home-prices (endogenously determined in our model), and thus fills a gap in the literature that studies mortgage leverage and the foreclosure crisis

[1] See also Inderst (2008) for a model that suggests a strong complementarity between competition and the adoption of hard-information lending techniques.

[2] See also Adelino, Gerardi and Willen (2013), Agarwal, Chang, and Yavas (2012), Agarwal, Amromin, Ben-David, Chomsisengphet and Evano (2011), Ambrose, Lacour-Little, and Sanders (2005), Bubb and Kaufman (2014), and Piskorski, Seru and Vig (2010)).

[3] Recent papers in the literature of shadow banking and subprime lending are Ashcraft and Schuermann (2008), Bernake (2008), European Central Bank (2008), Keys, Mukherjee, Seru and Vig (2010), Geanakoplos (2010a, 2010b), Mishkin (2008), Purnanandam (2011), Quintin and Corbae (2015), and Keys et al (2013); see also Calem, Covas, and Wu (2013) and Fuster and Vickery (forthcoming) for evidence of a collapse of the private label RMBS market during the financial crisis.

[4] As Ashcraft, Adrian, Boesky and Pozsar (2012) point out, at the eve of the financial crisis, the volume of credit intermediated by the shadow banking system was close to \$20 trillion, or nearly twice as large as the volume of credit intermediated by the traditional banking system at roughly \$11 trillion.

(Corbae and Quintin (2015)).[5] Our model also differs from Ordonez's (2014) theory that crisis appear when mortgage-backed security investors neglect systemic risks by focusing instead on the information problems that are specific to the conduit loan origination market.

Our interpretation of the credit scoring technology is similar to Chatterjee, Corbae, and Rios-Rull (2011) and Guler (2014) in that the technology dictates the fraction of borrowers of a given type. However, in their models they do not distinguish between hard information and soft information, and portfolio lender versus conduit lender, and also assume the same technology for all lenders. Also, we are unique in considering limited recourse mortgages, which are specific to subprime mortgages.[6] Another difference with Chatterjee, Corbae, and Rios-Rull (2011) is that they allow consumers to borrow multiple times to study the role of reputation acquisition where the individual's type score is updated every period according to some exogenous rule. These are characteristics of prime borrowers who build some credit reputation over time by borrowing in multiple occasions. In our paper we study subprime consumers whose access to credit is rather limited and in general can borrow only once. Thus, there is no reputation acquisition in our model, nor a need to update the individual's type score.

Our model is also unique in that it relates the activity in the financial market with the urban economy. First, the structural details underlying mortgage contract design and market organization consequently feed back to affect the rent versus own decision. Second, we can also rationalize the collapse of the subprime conduit market under the lens of land use regulations - unrelated to the recent financial crisis but still interesting from an urban economic point of view. This happens when land use regulations prevent subprime borrowers with small loans from buying houses with lot size above a minimum threshold. This result illustrates how housing regulations, in the form of costs associated with minimum lot and house size constraints, which are often imposed by local land use regulators, prevent the least well-endowed subprime consumers who cannot afford from purchasing a house with a minimum lot size.

Paper structure: The rest of this paper is as follows. In Section 2 we present the baseline model. Section 3 gives the equilibrium definition, states the equilibrium existence result, and discusses the pricing implicaitons on mortgage rates. Section 4 identify the different equilibrium regimes that our model can generate and also provide some simulations. In Section 5 we provide empirical support for the rise and fall of the subprime mortgage conduit market. Section 6 addresses several extensions of the model, such as allowing for endogenous soft information acquisition, introducing adverse selection into the secondary mortgage market, extending the baseline model to an stochastic economy and comparing the characteristics of the pooling and separating equilibrium, as well as a comparison between limited recourse loans and non-recourse loans.

[5] Other relevant papers that study foreclosure dynamics while taking exogenous house prices are Guler (2014) and Cambell and Cocco (2014).

[6] Guler (2014) considers non-recourse contracts, whereas Arslan, Guler and Taskin (2015), Chatterjee, Corbae, Nakajima and Rios-Rull (2007), and Chatterjee, Corbae, and Rios-Rull (2008), and Chatterjee, Corbae, and Rios-Rull (2011) consider unsecured consumer loans (see Chatterjee and Eyigungor (2012) for a departure from these models where long-maturity debt is issued against collateral which value may fluctuate over time).

2 The model

Our baseline model consists of a two-periods (periods 1 and 2) deterministic economy with asymmetric information in the primary conduit mortgage market and the following types of agents: subprime households (h), portfolio lenders (r), conduit lenders (k), and security investors (i). Subprime households are also called subprime consumers. By abuse of notation, we will write l to denote a lender independently of his type (portfolio lender or conduit lender).

We find convenient to denote an agent type by $a = h, r, k, i$, the set of agents of type a by $A(a)$, and the whole set of all agents in the economy by $\mathbf{A}$. The non-atomic measure space of agents in this economy is given by $(\mathbf{A}, \mathcal{A}, \lambda)$, where $\mathcal{A}$ is a σ-algebra of subsets of the set of agents $\mathbf{A}$, and λ is the associated Lebesgue measure. For simplicity, the measures of portfolio lenders, conduit lenders and investors are all set to be equal to 1, i.e., $\lambda(A(l)) = 1$ for both $l = r, k$ and $\lambda(A(i)) = 1$.

2.1 Main assumptions

The general equilibrium model we are about to describe has the following main assumptions:[7]

Two types of subprime households: In our economy all subprime households fall below some subsistence poverty line and have a subsistence income in period 1 equal to ω^{SR} units of the numeraire good (e.g., government subsidy). This income is fungible in the sense that it can be used to fund a down payment on a owner-occupied house should the borrower qualify for a sub-prime mortgage. In the second period some of the subprime consumers experience a positive income shock (e.g., get a better job) $\omega^{+} > \omega^{SR}$, while the rest of the pool remains at their current (poverty) income level ω^{SR}. Label the consumers that experience an increase in their second period endowment as a G-type (or good type) and those who don't as a B-type (or bad type). Consumers know their type in period 1, but G-type consumers are unable to verifiably convey their unrealized increase in income level to outside parties. This is an important aspect of our model with subprime consumers - as discussed below, the lenders' credit scoring technology that screens borrower types is coarse in absence of soft information, and, in general, considerably worse that the credit scoring technology in the prime lending market. The measures of types G and B households in the economy are $\lambda_G \equiv \lambda(A(G))$ and $\lambda_B \equiv \lambda(A(B))$, respectively. In the Appendix A we provide further details that characterize subprime consumers, subprime housing markets and subprime mortgage markets.

Limited recourse mortgages: Recourse mortgages are specific to the subprime market in the US and Europe, except few special cases such as purchase money mortgages in California and 1-4 family residences in North Dakota. In our model below we will consider recourse mortgage contracts, but subject to some ungarnishable minimum subsistence consumption

[7] The literature on general collateral equilibrium is vast. See Geanakoplos (1997, 2003) and Geanakoplos and Zame (2014) for leading models, and Fostel and Geanakoplos (2014) for a review of the theory of leverage developed in collateral equilibrium models with incomplete markets. See also Geanakoplos (2010) for a more applied view of the role of this models in the understanding of the recent credit crisis.

(ω^{SR}) by the borrower ("limited recourse").[8] This limited liability nature of the contract is similar to a mortgage exemption that protects the subprime borrower from consuming less than a subsistence rent (see Davila (2015) for an analysis of bankruptcy exemptions from a welfare point of view).[9] Under this contract a "good type" consumer (with no default risk) can credibly commit to pay back the loan even if the loan repayment is higher than the house value, but a "bad type" consumer (with default risk) cannot. Hence, the recourse nature of the contract introduces a potential for adverse selection in the primary subprime mortgage market. Also, this type of contract implies that bad type borrowers, who by assumption are only endowed with a subsistence rent at time of mortgage repayment, end up defaulting and giving their housing asset to the lenders. Hence, the limited recourse mortgage is effectively a non-recourse mortgage for the bad type borrowers. In Section 6 we elaborate on the details of limited recourse mortgage contracts, their implications for adverse selection, and also explain the differences if we were to consider non-recourse mortgages instead.

Two funding sources for consumers: Portfolio lenders (r) originate mortgages to be held in the entity's asset portfolio ("originate-for-ownership"). In contrast, conduit lenders (k) are transactional, specializing only in originating mortgages for sale to a third party ("originate-for-distribution"). This access to secondary mortgage markets can possibly reduce the cost of capital when secondary subprime mortgage markets are liquid and competitive. Another difference is that portfolio lenders and conduit lenders have different credit scoring technologies. Conduit lenders generally work out of a small office with computers, with no established presence in a community. Conduit lenders have access to hard credit information (e.g., credit history and FICO scores), which is always accurate, but it does not necessarily lead to a perfect assessment of consumer type. Portfolio lenders have soft information as a supplement to the available hard credit information, and by assumption this is enough to fully reveal the borrower's type (portfolio lenders know their borrowers and their communities and borrowers maintain checking and other personal accounts with them).[10] As such conduit lenders are not capable of resolving asymmetric information over and above what is available with hard information and their credit scoring technology. The lack of soft information by conduit lenders introduces asymmetric information in the conduit primary mortgage market. Later in the paper **(see Section 6)** we will allow lenders to choose their optimal amount of soft information and show that the assumed differences in soft information acquisition between lender types do not speak against optimality.

Capacity constrained portfolio lenders: Another assumption is that portfolio lenders cannot lend to more than $v(r)$ consumers. In particular, we assume $\lambda_G > v(r)$ (portfolio lenders can only lend to some but not all good type consumers). This assumption

[8] Lenders cannot take everything and leave a consumer homeless when he defaults and becomes bankrupt. In fact, bankruptcy is designed to shield consumers from too much recourse on mortgage loans. **See [law...]**

[9] See Poblete-Cazenave and Torres-Martinez's (2013) for a recent descriptive analysis of a model with limited liability mortgage loans.

[10] Soft information may include listening to and analyzing the borrower's explanation for past difficulties in making credit payments and determining whether the hard numbers for the borrower or property make sense given what a loan agent can perceive about them. For a discussion of how securitization discourages lenders from engaging in "soft" mortgage underwriting, see "Comments to the Federal Deposit Insurance Corporation" by the National Association of Consumer Advocates on February 22, 2010.

is motivated additional constrains faced by portfolio lenders, such as the time constraint to originate loans that require face-to-face contact between borrower and lender (one important source of soft information).[11] When portfolio loans are the first choice among consumers, the rest of good type consumers who did not get a portfolio loan have no other option but to go to the conduit loan market in order to get a mortgage. Also, bad type consumers, who are identified as such by the portfolio lender's additional soft credit information, only can get a mortgage if misrepresenting their type in the conduit mortgage market.

Table 1 summarizes the main distinctions between traditional portfolio lenders and conduit lendes.

	Soft information	Originate-to-distribute	Capacity constrained
Traditional portfolio lender	YES	NO	YES
Conduit lender	NO	YES	NO

Table 1

Adverse selection in the primary conduit mortgage market: Lenders cannot perfectly screen the type of borrowers using hard information only; only additional soft information can identify the type of borrower. In the baseline model investors rely on the same credit scoring technology than those lenders without soft information, thus leaving aside the possibility of adverse selection in the secondary market of mortgage backed securities. Later, in Section 6, we examine the implications of dropping this assumption. Below we will closely examine, together and separately, the effects of lenders' resolved (soft information acquisition) and unresolved (adverse selection) private information on borrower sorting outcomes.

Inelastic owner-occupied housing supply: The owner-occupied housing consumption space is $[0, \bar{H}]$ where $\bar{H}$ denotes the aggregate amount of owner-occupied housing in the economy.[12] For simplicity, we take the aggregate supply of owner-occupied housing in the first period and the aggregate demand of owner-occupied housing in the second period as exogenously given and equal to $\bar{H} = 1$.

2.2 Subprime households

Consumption can take two forms: owner-occupied housing and a numeraire good.[13] The latter can be thought as rental housing (e.g., subsistence rent can be used to live in a

[11] Alternatively, we could assume the that porfolio lenders have a dollar limit on subprime loans by regulation. For example, a portfolio lender may have $100,000,000 as endowment, and by regulation it cannot give loans larger than $100,000. Then, portfolio lenders can only lend to 1000 subprime consumers. Conduit lenders also have access to limited amounts of capital with which to fund mortgages, but it is their mortgage distribution business what provides them with enough capital to originate mortgages. Because conduit lenders do not have such limitation on the loan amount, they are effectively not capacity constrained.

[12] Below, in Section 4, we will study the impact of introducing a minimum housing consumption $H^{\min} > 0$ resulting from local land use regulation in the form of minimum quality standards for owner occupied houses.

[13] The numeraire good represents what is given up along consumer's budget constraint to consume more of the owner-occupied housing good.

shelter). In period 1 a household can buy a house of size H_1 at price p_1 per house size unit or buy an amount R_1 of the numeraire good at per unit price 1. House purchases are long term contracts - once signed the house can be "consumed" in both periods; if the consumer buys a house in period 1, the same house enters in period 2 budget constraint as an asset endowment evaluated at market price p_2. On the other hand, buying the (rental) numeraire good is a one-period contract: it only allows consumption of this good during one period only.

Once the second period starts, households expect to die at the end of the period. Thus, we refer to households in period 2 as old households, and households in period 1 as young households. When households are old, they can also choose to consume owner-occupied housing H_2 and the numeraire good R_2. Household h's preferences are represented by utility function: $u^h(R_1, H_1, R_2, H_2)$ that is continuous, concave and monotonic.

In period 1 (impatient) households can increase their consumption by borrowing from either a *portfolio lender* (r) or a *conduit lender* (k). Both types of lenders originate mortgages in a competitive environment, although they differ in the terms of their contracts. The matching between consumers and lenders is endogenous in our model and addressed later. Here, we describe the optimization problem of a consumer whose access to a primary mortgage market l has already been determined. We write $l = r$ for the portfolio loan market, $l = k$ for the conduit loan market, and $l = \emptyset$ if the consumer is not able to borrow from a portfolio lender or a conduit lender. By assumption, a consumer can only access one type of primary mortgage market l. Denote the consumer's loan amount in the subprime mortgage market l by $q^l\psi^l \geq 0$, where q^l and $\psi^l \geq 0$ denote the l-type mortgage discount price and loan repayment due at the beginning of the second period (when $l = \emptyset$, we have $\psi^l = 0$). Equilibrium existence requires an uppen bound $B > 0$ on ψ^l, but this bound can be arbitrarily chosen (in our characterization of equilibrium below we will choose this bound such that this short sale constraint is non-binding):

$$\psi^l \leq B \tag{1}$$

For simplicity, we normalize the loan interest rate to 0. The budget constraint in period 1 of a consumer consumer with access to a primary mortgage market l is:

$$p_1 H_1 + R_1 \leq q^l \psi^l + \omega^{SR} \tag{2}$$

The consumer's mortgage down payment is endogenous in this model (e.g., if $R_1 = 0$, then the downpayment is equal to $\omega^{SR}/p_1 H_1$).

Sub-prime loans are subject to a *limited recourse mortgage* contract that stipulates that a borrower is allowed to consume his subsistence income ω^{SR} if default occurs. Accordingly, we write the second period budget constraint as follows:

$$p_2 H_2 + R_2 \leq \max\{\omega^{SR}, \omega_2^t + p_2 H_1 - \psi^l\} \tag{3}$$

where ω_2^t denotes the period 2 endowment of a consumer of type $t = G, B$ and is such that $\omega_2^G = \omega^+$ and $\omega_2^B = \omega^{SR}$. The term $p_2 H_1$ in the right hand side of the inequality captures the value of the house purchased in the previous period and is interpreted as a sale at market price p_2. The consumer can then use the proceeds of this sale for consumption after repaying his mortgage.[14] The maximum operator in (3) allows the household to strategically default and consume at least the minimum subsistence income ω^{SR}.[15] There is no default if p_2, H_1, and ψ^l are such that $\omega^{SR} \leq \omega_2^t + p_2 H_1 - \psi^l$. Loan payment is (partially) enforced by the nature of the limited recourse loan in our model.

Households' optimization problem is as follows: each household maximizes his utility function subject to constraints (2), (1) and (3).

2.3 Lenders

We require that consumers with a mortgage are identified as G-type consumers, i.e., rating=G (this is done to simplify the analysis, but observe that the adverse selection problem in the mortgage market would not disappear if allow for a market of "bad ratings", since B-type consumers would still prefer to misrepresent their type and borrow a large loan amount as G-type consumers do). The lender l's credit scoring technology is described as follows. Denote by $\Pr^l(\text{rating=G}|\text{G})$ and $\Pr^l(\text{rating=G}|\text{B})$ the probabilities that a lender l gives a good rating to a G-type type borrower and a B-type type borrower, respectively. By assumption, conduit lenders only rely on hard information and thus $\Pr^l(\text{rating=G}|\text{G}) < 1$. Portfolio lenders have access to soft information on top of the hard credit information, and thus, by assumption, always assign a good signal to G-type consumers, i.e., $\Pr^l(\text{rating=G}|\text{G}) = 1$. Therefore, given the portfolio lenders' capacity constraint, portfolio lenders end up lending to a mass $v(r)$ of G-type consumers. The measure of consumers that receive a loan from conduit lenders is equal to

$$\mu^k(\text{rating=G}) = \Pr^l(\text{rating=G}|\text{G})\mu_G^k + (1 - \Pr^l(\text{rating=G}|\text{G}))\mu_B^k$$

where μ_G^k and μ_B^k denote the measure of G-type consumers and B-type consumers that try to borrow from conduit lenders (μ_G^k and μ_B^k are endogenous in the model, and so is $\mu^k(\text{rating=G})$).

We can use Bayes' rule and write the expected probability of lending to a G-type consumer given that the conduit lender's hard credit scoring technology assigns a good rating to that consumer as follows:

$$\Pr^l(\text{G}|\text{rating=G}) = \frac{\Pr^l(\text{rating=G}|\text{G})\hat{\pi}^l(G)}{\Pr^l(\text{rating=G}|\text{G})\hat{\pi}^l(G) + \Pr^l(\text{rating=G}|\text{B})\hat{\pi}^l(B)} \tag{4}$$

where $\hat{\pi}^k(G)$ denotes the fundamental proportion of G-type consumers available to the conduit lender.[16] For example, if a conduit lender's pool of borrower contains 60 B-type consumers and 40 G-type consumers who did not get a portfolio loan, then $\hat{\pi}^k(G) = 0.4$.

[14] A consumer with an owner-occupied house at the beginning of period 2 decides whether to sell it at market price, or to consume it. The latter is equivalent to the joint transactions of selling the house the consumer owns at the beginning of period 2 and then buying immediately after a house with same size.

[15] Strategic default is simply an optimality condition in which the borrower, subject to the relevant recourse requirements, decides whether mortgage loan payoff to retain ownership of the house or default with house forfeiture generates greater utility. For a discussion of the default option, see Deng, Quigley, and Van Order (2000). See Davila (2015) for an exhaustive analysis of exemptions in recourse mortgages.

[16] In the Appendix we show that $\Pr^l(\text{G}|\text{rating=G})$ can be expressed in a linear way as follows: $\Pr(G|\text{rating=G}) = 1 - \varepsilon\hat{\pi}(B)$, where ε denotes the amount of asymmetric information between the lender and the borrower and $\hat{\pi}^k(B) = 1 - \hat{\pi}^k(G)$.

To simplify notation, we write the lender's *belief* on the proportion of G-type consumers in its pool of borrowers as follows:

$$\pi^l \equiv \Pr{}^l(\text{G}|\text{rating=G})$$

Then, by assumption, we can write $\pi^r = 1$ and $\pi^k < 1$.

Lenders are subject to an "originate-to-distribute" type constraint, which says that a lender l cannot distribute more than a fraction d^l of his originated mortgages:

$$z^l \leq d^l \varphi^l \tag{5}$$

where $\varphi^l \geq 0$ denotes the total amount of mortgages originated by the lender, $z^l \geq 0$ is the amount of mortgages the lender sells to the investors, and d^l is the fraction of mortgages that are origintated for distribution.[17] φ^l and z^l are choice variables, and d^l is a parameter that takes value 0 if the lender is a portfolio lender ($l = r$), and $d^l \in (0, 1]$ if the lender is a conduit lender ($l = k$). In general, d^k is typically close to 1 for conduit lenders. A distribution rate smaller than 1 can be the result of a regulation or a self-imposed constraint due to reputation concerns (not modelled here).

Given the nature of the limited recourse mortgage contract, when there is borrower default, the lender garnishes all borrower's income above ω^{SR}. This includes repossessing the house and reselling it if the borrower happened to buy one in the first period. However, the foreclosure process is costly for the lender: foreclosure cost and other indirect costs associated with foreclosure delays result in a loss of $(1 - \delta)p_2 H_1$ units of the numeraire good to the lender, where $\delta \in [0, 1]$ denotes the foreclosure recovery rate.

Lenders are risk neutral with time discount factor $\theta^l > \theta^h$ and belief π^l on the fraction of G-type borrowers in the pool (π^l is a function of its credit scoring technology).[18] In particular, we consider the following linear separable profit function for a lender l:

$$\Phi^l(\varphi^l, z^l) = (\omega_1^l - q^l\varphi^l + \tau z^l) + \theta^l(1 - d^l)(\pi^l\varphi^l + (1 - \pi^l)\delta p_2 H_1^G), \tag{6}$$

where τ denotes the sale price of a mortgage in the secondary market. The lender's first period endowment is positive, $\omega_1^l > 0$ (for simplicity, we assumed $\omega_2^l = 0$). The lenders optimization problem is as follows. Each lender l chooses φ^l and z^l to maximize his profit function $\Phi^l(\varphi^l, z^l)$ subject to the originate-to-distribute constraint (5). Lenders are risk-neutral, and thus their first order conditions determine the competitive mortgage prices q^l, $l = r, k$.

Only a fraction $1-d^l$ of mortgages affect the lender's profit function in the second profit, as he distributes a fraction d^l of the mortgage payment proceeds to investors. Notice that the interaction between the originate-to-distribute constraint (5) and the profit function

[17] In our model, homogeneous loans are pooled and securitized into one asset (see Aksoy and Basso (2014) for a model with tranching). We also ignore agency issues regarding securitization and its implications on distressed loans (ssee Cordell, Dynan, Lehnert, Liang, and Mauskopf (2009), Piskorski, Seru, and Vig (2010), Agarwal, Amromin, Ben-David, Chomsisengphet, and Evano (2011), Ghent (2011), and Adelino, Gerardi, and Willen (2013) for a discusison of the role of securitization on residential mortgages).

[18] The assumption of lender's risk neutrality is common in the literature. See e.g. Arslan, Guler, and Taskin (2015), Chatterjee, Corbae and Rios-Rull (2011), Chatterjee and Eyigungor (2015), Guler (2015), and Fishman and Parker (2015).

(6) determines the two possible loan origination models. On the one hand, conduit lenders can distribute a fraction $d^k > 0$ of the originated mortgages, but lack soft information so $\pi^l < 1$. Portfolio lenders, on the other hand, have soft information ($\pi^r = 1$) but don't sell their mortgages ($d^r = 0$).

2.4 Investors

The investor's endowment in periods 1 and 2 is denoted by ω_1^i and ω_2^i, respectively. Again, for simplicity, we assume $\omega_2^i = 0$. First period endowment ω_1^i is positive, however. Investors assign a smaller weight to period 1 consumption than lenders do, and therefore we write $\theta^l < \theta^i$. We assume that both conduit lenders and investors only rely on hard credit information and their beliefs are such that $\pi^k = \pi^i < 1$. This assumption is convenient as it allows us to focus on the adverse selection problem in the primary mortgage market, leaving aside potential information problems that may arise between conduit lenders and secondary mortgage investors (later, in Section 6 we will discuss the implications of dropping this assumption).

The optimization problem of an investor i consists on choosing z^i to maximize the following profit function:

$$\Lambda^i(z^i) \equiv \omega_1^i - \tau z^i + \theta^i(\pi^i z^i + (1-\pi^i)d^l \delta p_2 H_1^G) \tag{7}$$

The term $\pi^i z^i + (1-\pi^i)d^l \delta p_2 H_1^G$ captures the investor's second period revenue from buying mortgages in the first period. The first term, $\pi^i z^i$, corresponds to the payment from the fraction π^i of G-type borrowers. The second term, $(1-\pi^i)d^l \delta p_2 H_1^G$, corresponds to the income from lending to a fraction $(1-\pi^i)$ of B-type borrowers. The term d^l stands for the percentage of mortgages that lenders sell and hence investors are entitled to that revenue. Because B-type consumers are not able to honor the loan payment correponding to a G-type loan contract, the investor only receives the depreciated value of the foreclosed house, $\delta p_2 H_1^G$, from these defaulted mortgages.

3 Equilibrium and Mortgage Pricing

Here we propose an equilibrium notion of a competitive economy with endogenous segmented markets, assert that an equilibrium exists, and examine its pricing implications. In the economy proposed here, borrowers match with lenders, and lenders match with investors. We will introduce restrictions on these matching possibilities that are consistent with the nature of the primary and secondary mortgage markets.

The notion of equilibrium proposed here relies on the definition of a group, which is no more than a finite set of matched agents that conform the different mortgage markets. If a lender matches with consumers, then we will refer to this set as a "primary mortgage group". If instead lenders match with investors, then we will refer to this group as a "secondary mortgage group". The primary portfolio mortgage market consists then on the aggregation of all primary portfolio mortgage groups. Similarly, the primary conduit mortgage market consists on the aggregation of all primary conduit mortgage groups. And the secondary mortgage market consists on the aggregation of all secondary mortgage groups. Because the theory developed here is intended as a competitive theory of lending relationships, we require that any group of agents to be small relative to the population as a whole. Since there is a continuum of consumers, lenders and investors in our economy, in equilibrium we will observe a continuum of negligible (measure zero) groups in this economy. Groups are comparable in size to agents but are negligible with respect to the society. The notion of matching between agents then requires consistency in terms of the aggregate of choices. For example, consistency means that if a third of the population are G-type borrowers in the conduit mortgage market where conduit lenders' belief is $\pi^k = 0.5$, then a third of the population must be B-type consumers in this market. This consistency condition must hold simultaneously for all types of groups. We proceed to formally define the different possible groups.

A "primary l-mortgage group" is consists on a triplet $g^l = (l, \upsilon(l), \pi^l)$, where the first coordinate indicates the type of lender (there is one lender in each group), and the second and third coordinates indicate the l-type lender's capacity constraint and belief on the proportion of G-type borrowers in its pool, respectively. The first coordinate can take three identities: $l = r$ (portfolio lender), $l = k$ (conduit lender) and $l = \emptyset$ (there is no lender to borrow from and thus $\psi^h = 0$). Group $g^\emptyset$ contains consumers who do not get a loan, or those consumers who prefer renting to owning. This notion of a primary mortgage group is also important because it permits us to control for the lender's capacity constraint by specifying the number of borrowers. At the same time, notice that we can choose two additional parameters in our model: the lender's first period endowment (ω_1^l) and the measure of lenders of each type.

In a "secondary mortgage group" lenders with $d^l > 0$ match investors to transact mortgage-backed securities given beliefs (π^i, π^l). Because $\lambda(A(k)) = \lambda(A(i)) = 1$ we find convenient to assume that matching is pair-wise (one lender and one investor) for each secondary mortgage group. This group is defined by the vector $g^s = (i, l, d^l, \pi^i, \pi^l)$. The universe of available group types in this economy is restricted to the discrete set $\mathbf{G} = \{g^r, g^k, g^\emptyset, g^s\}$.

When a primary mortgage group forms, the borrowers enter into a relationship with the lender described by a contract. In a pooling equilibrium, this contract specifies the discount mortgage price that results from the lender's first order optimality condition (lenders are risk neutral). Given this mortgage price, the borrowers demand a loan amount, which is then satisfied by the lender (market clearing holds). Notice that our concept of group allows for adverse selection by letting $\pi^l < 1$. When $\pi^l = 1$, the lender's pool of borrowers is only composed by G-type consumers. However, when $\pi^l < 1$ a fraction $1 - \pi^l$ of the pool of borrowers is of type B and the lender adjust the mortgage discount price accordingly.

In our model agents choose the type of group by choosing a "membership" in $\mathbf{G}$. A "membership" is agent-type (a $= G, B, r, k, i$) and group-type ($g \in \mathbf{G}$) specific, and is denoted by $m = (\mathrm{a}, g)$. The set of memberships is denoted by $\mathbf{M}$, while the maximum number of memberships that an agent a can choose is denoted by $M(a)$. The following concept is needed in our definitions below. A *list* is a function $\iota : \mathbf{M} \to \{0, 1, ...\}$, where $\iota(t, g)$ denotes the number of memberships of type (t, g). We then write $\mathbf{Lists} = \{\iota : \iota$ is a list$\}$ and define the agent's group-membership choice function by $\mu : \mathbf{A} \to \mathbf{Lists}$. We will need these definitions below.

3.1 Equilibrium definition and the existence result

The following concepts are necessary to characterize agents' choice sets. Denote the household h's consumption bundle by $x^h = (H_1^h, R_1^h, H_2^h, R_2^h) \in \mathbb{R}_+^4$. The pair (x^h, ψ^h) is feasible if it satisfies constraints (2), (1) and (3). The lender and investor consumption bundles are given by $x^l = (R_1^l, R_2^l) \in \mathbb{R}_+^2$ and $x^i = (R_1^i, R_2^i) \in \mathbb{R}_+^2$, respectively. The triplet (x^l, φ^l, z^l) is feasible if it satisfies (5). We find convenient to rewrite the consumer's utility function as a function of the his consumption and group type, e.g., $u^h(x^h, \mu^h(m))$. Similarly, we write $\Phi^l(\varphi^l, z^l, \mu^l(m))$ and $\Lambda^i(\varphi^i, z^i, \mu^i(m))$ for the lender and investor' profit functions, respectively.

The consumer h's choice set $\mathbf{X}^h \subset \mathbb{R}_+^5 \times \mathbf{Lists}$ consists of the feasible set of elements (x^h, ψ^h, μ^h) that this consumer can choose. Similarly, let the lender l's choice set $\mathbf{X}^l \subset \mathbb{R}_+^4 \times \mathbf{Lists}$ be the feasible set of elements $(x^l, \varphi^l, z^l, \mu^l)$ that that this lender can choose, whereas the investor i's choice set $\mathbf{X}^i \subset \mathbb{R}_+^3 \times \mathbf{Lists}$ stands for the set of elements (x^i, z^i, μ^i) that that this investor can choose. Also, let us define the set $\mathbf{Lists}(a) = \{\mu^a \in \mathbf{Lists} : \sum_m \mu^a(m) \leq M(a),\ \exists x^a \text{ s.t. } (x^a, \mu^a) \in \mathbf{X}^a\}$, which represents the agent a's restricted consumption set of memberships compatible with his consumption.

We make the following assumptions:

A1: The utility mapping $(h, x, \mu) \to u^h(x, \mu)$ is a jointly measurable function of all its arguments.

A2: The consumption set correspondence $a \to \mathbf{X}^a$ is a measurable correspondence, for $a = h, l$.

A3: If $(x^a, \mu^a) \in \mathbf{X}^a$ and $\hat{x}^a \geq x^a$, then $(\hat{x}^a, \mu^a) \in \mathbf{X}^a$, for $a = h, l$.

A4: Each agent $a \neq k$ chooses at most one group, while each conduit lender k can choose at most two groups, i.e., $M(a) = 1$ if $a \neq k$ and $M(a) = 2$ if $a = k$.

Lenders can only belong to their corresponding primary mortgage type (i.e., $\mu^l(l, g^l) = 1$ for $l = r, k$), and conduit lenders and investors belong to the secondary mortgage group (i.e., $\mu^a(a, g^s) = 1$ if $a = k, i$).

A5: The endowment mapping $(\omega_1, \omega_2) : a \mapsto (\omega_1(a), \omega_2(a))$, with $\omega_1(a), \omega_2(a) > 0$ for $a \in \mathbf{A}$, is an integrable function.

A6: The aggregate endowment is strictly positive, i.e., $\int_{\mathbf{A}} \omega(a) d\mu > E$, where $E > 0$.

Next, we proceed to define the concept of consistent matching in terms of the aggregate of choices.[19] For this, let us denote the aggregate of type (a, g)-memberships by $\hat{\mu}(\mathrm{a}, g) \equiv \int_{A(\mathrm{a})} \mu^a(\mathrm{a}, g) d\mu$. We say that the aggregate membership vector $\hat{\mu} \in \mathbb{R}^{\mathbf{M}}$ is *consistent* if, for every group type $g \in \mathbf{G}$, there is a real number $\gamma(g)$ such that $\hat{\mu}(\mathrm{a}, g) = \gamma(g) n(\mathrm{a}, g)$, $\forall \mathrm{a} = G, B, r, k, i$, where $\gamma(g)$ is the measure of type g groups, and $n(\mathrm{a}, g)$ is the (natural) number of type $\mathrm{a} = G, B, r, k$ agents in group g. Then, we say that the choice function $\mu : \mathbf{A} \to \mathbf{Lists}$ is *consistent* for $A \subseteq \mathbf{A}$ if the corresponding vector is consistent. We write $\mathbf{Cons} \equiv \{\hat{\mu} \in \mathbb{R}^{\mathbf{M}} : \hat{\mu} \text{ is consistent}\}$.

Definition 1: *Given (π^r, π^k, π^i), an equilibrium for this economy is a vector of memberships μ, prices $(p_1, p_2, q^r, q^k, \tau)$ and allocations $((x^h, \psi^h)_{h \in A(G) \cup A(B)}, (\varphi^l, z^l)_{l \in A(l), l=r,k}, (z^i)_{i \in A(i)})$ such that:*

[19] See also Ellickson et al. (1999).

(2.1) Each consumer h chooses $(x^h, \psi^h, \mu^h) \in \mathbf{X}^h$ that maximizes $u^h(x^h, \mu^h(m))$.
(2.2) Each lender l chooses $(R_1^l, R_2^l, \varphi^l, z^l, \mu^l) \in \mathbf{X}^l$ that maximizes $\Phi^l(\varphi^l, z^l, \mu^l(m))$.
(2.3) Each investor i chooses $(R_1^i, R_2^i, z^i, \mu^i) \in \mathbf{X}^l$ that maximizes $\Lambda^i(\varphi^i, z^i, \mu^i(m))$.
(2.4) $\hat{\mu}$ is consistent for $\mathbf{A}$.
(2.5) Market clearing:

$$\int_{A(G)} \psi^{h,r} \mu^h(t(h), g^r) dh = \int_{A(r)} \varphi^r \mu^r(r, g^r) dr, \tag{8}$$

$$\int_{A(G) \cup A(B)} \psi^{h,k} \mu^h(t(h), g^k) dh = \int_{A(k)} \varphi^k \mu^k(k, g^k) dk, \tag{9}$$

$$\int_0^1 z^l dl = \int_0^1 z^i di, \tag{10}$$

$$\sum_{g \in \mathbf{G}} \int_{A(G) \cup A(B) \cup A(r) \cup A(k)} R_1^a \mu^a(a, g) da + \int_{A(i)} R_1^i di = \int_{\mathbf{A}} \omega_1^a da, \tag{11}$$

$$\sum_{g \in \mathbf{G}} \int_{A(G) \cup A(B) \cup A(r) \cup A(k)} R_2^a \mu^a(a, g) da + \int_{A(i)} R_2^i di = \int_{\mathbf{A}} \omega_2^a da, \tag{12}$$

$$\sum_{g \in \mathbf{G}} \int_{A(G) \cup A(B)} H_1^h \mu^h(t(h), g) dh = \sum_{g \in \mathbf{G}} \int_{A(G) \cup A(B)} H_2^h \mu^h(t(h), g) dh = \bar{H} \tag{13}$$

Theorem 1 (Existence): *An equilibrium specified in Definition 1 exists.*

We leave the details of the existence proof for the Appendix B.

Remarks about the notion of equilibrium:

1. Our notion of equilibrium assumes that lenders and investors form beliefs about the composition of the lenders' pool of borrowers. These beliefs are common, degenerate and governed by the lender's credit scoring technology. Lenders and investors take their beliefs as given and optimize without taking into account the consumers' choice of mortgage market.[20] Thus, in our model all agents' beliefs about the prices of mortgages and goods, as well as about the composition of each mortgage market, are common and degenerate.

2. In our model default risk is the result of the conduit lenders' inability to perfectly screen between borrower types, and thus it can be attributed to the endogenous behavior of consumers with whom they are matched in equilibrium. We treat this risk as idiosyncratic in the sense we assume that the matching of lenders with consumers is independent and uniform, and that the law of large numbers applies.[21]

3. Given the portfolio lenders' capacity constraint and the conduit lenders' imperfect credit scoring technology, consumers of the same type may end up with different loan amounts, and thus different realized housing consumption and ex-post utility (e.g., there will be an equilibrium configuration where some G-type consumers are lucky and obtain a portfolio loan, some G-type consumers obtain a conduit loan, and the remaining G-type consumers cannot borrow and must rent). Our approach to equilibrium existence is consistent with this interpretation.

[20] This is similar to Zame (2007) where agents optimize without taking the supply of jobs into account.
[21] See Zame (2007) and Duffie and Sun (2007, 2012).

4. Also, notice that the continuum of consumers allows us to deal with two types of non-convexities: those associated with the maximum operator in the consumer's second period budget constraint, and those associated with the consumer's choice of loan type (portfolio loan, conduit loan, or no loan).

5. Incorporating the consumers' mortgage market discrete choice into a two-periods general equilibrium economy with a continuum of agents brings new subtleties to the existence proof, which we discuss in the Appendix. Extending this setting to a fully dynamic infinite-horizon general equilibrium economy with a continuum of agents would considerably be more complicated from a technical point of view. To understand the evolution of the subprime mortgage market in our analysis below, we will consider a sequence of two-period economies where parameters, and hence the equilibrium regime, may change.

Next, we derive asset pricing conditions that any equilibrium in this economy must satisfy using the lender and investor's optimality conditions.

3.2 Mortgage Discount Prices

Using the lender and investor's first order conditions we obtain the following conduit loan discount price:

$$q^k = \frac{\bar{\pi}\bar{\theta}}{1 - \delta(1 - \bar{\pi})\bar{\bar{\theta}}} \tag{14}$$

where $\bar{\pi} \equiv \pi^k = \pi^i$, $\bar{\theta} \equiv d^l\theta^i + (1 - d^l)\theta^l$, and d^l is the lender l's mortgage distribution rate. Since $\theta^i > \theta^l$, a higher distribution rate implies a higher q^k. A $\bar{\pi}$ smaller than 1 captures the negative effect of adverse selection on the mortgage discount price. The term $1 - \delta(1 - \bar{\pi})\bar{\theta}$ in (14) is the "default loss" that the conduit lender incurs when its pool of borrowers contains an expected fraction $1 - \bar{\pi}$ of B-type borrowers: the higher is the default loss, the lower is the discount price that the conduit lender offers to its borrowers. We can rewrite expression (14) in a more intuitive way as follows:

$$q^k = \frac{\textit{hard info predictive power} \ * \ d^l\textit{-weighted discount factor}}{\textit{default loss}}$$

The inability of conduit lenders to fully resolve information asymmetries with their the hard information-based screening technology ($\bar{\pi} < 1$) implies that some borrowers in their pool are of bad type. Since bad type borrowers (endogenously) fail to comply with mortgage payment contract terms and conditions, with the net post-foreclosure sales proceeds less than the promised payment (as $\delta > 0$), the conduit lender incurs in a "default loss". As a result, based on observables and expectations at the time of mortgage loan origination, the lender finds it optimal to tack on a pooling rate premium to the base loan rate to account for adverse selection risk. However, the loan rate may move indirectly with the credit risk of its borrowers if the lender's access to liquidity in the secondary market is sufficiently high (i.e., high $\bar{\theta}$). Roughly speaking, securitization allows customization, which lowers the cost of capital ($1/q^k$) in a conduit loan market where lemons are present.

The discount price that investors pay for the subprime mortgages is

$$\tau = \frac{\bar{\pi}\theta^i}{1 - \delta(1 - \bar{\pi})\bar{\bar{\theta}}} \tag{15}$$

Finally, the portfolio lender, who by assumption has $d^r = 0$ and $\pi^r = 1$, finds optimal to set the mortgage price equal to its discount factor θ^l, i.e.,

$$q^* = \theta^l \tag{16}$$

Since $\pi^r = 1$ implies no default, q^* can be thought as a *risk free discount price* that does not incorporate liquidity gains from distribution of originated loans to investors. We see that, when the fraction of lemons in the conduit lender's pool of borrowers converges to zero - that is, when its hard credit scoring technology is such that $1 - \bar{\pi} \to 0$ -, q^k converges to q^* if it is not possible to distribute mortgages to investors ($d^k = 0$) or if there are no investors that buy subprime mortgage securities (e.g., if $\omega_1^i = 0$).

Pricing conditions (14) and (16) are compared as follows:

$$q^k < q^* \text{ if } \pi^k < \pi_2 \equiv \frac{\theta^l(1-\delta\bar{\theta})}{\bar{\theta}(1-\delta\theta^l)}.$$

Threshold π_2 defined in the above expression will appear again in the next section when we characterize the different equilibrium regimes. Interesting, as the distribution rate d^k increases, threshold π_2 decreases, and hence more information is needed to sustain an environment where the conduit mortgage rate is below the risk free rate.

By excess premium EP (or credit spread) we mean the difference between the rate of return of conduit loans and the risk free rate of portfolio loans, i.e.,

$$EP \equiv (1/q^k) - (1/q^*) \tag{17}$$

Proposition 1: *The excess premium increases with default losses and decreases with the predictive power of hard credit information, a higher distribution rate of mortgages to investors, and a higher risk free rate.*

Figure 1 portraits the excess premium as a function of the conduit lender's belief π^k (driven by the predictive power of the hard credit score technology). We set $\theta^l = 0.7$, $\theta^i = 0.9$, $\delta = 0.5$, $v(r) = 1$, $\lambda_G = 1.5$, and $\lambda_B = 0.5$. In this figure we observe two lines. The first one computes EP when $d^k = 0.8$, and changes from positive to negative at $\pi^k = \pi_2 \equiv 0.71$. At this point the conduit lender's gains from intermediation exactly offset its loss from bad type (defaulted) loans, and the EP coincides with the risk-free rate. When $\pi^k > 0.71$ the conduit lender's mortgage rate is smaller than the portfolio lender's rate, and G-types consumers prefer conduit loans to portfolio loans in equilibrium (we will show this in the next Section). When that happens, the conduit lender's fundamental proportions of G-type consumers, $\hat{\pi}(G)$, increases from 0.5 to 0.75,[22] and this jump creates the discontinuity on the EP function at $\pi_2 = 0.71$ in Figure 1 (we will discuss this discontinuity effect later in the next Section). The second line in Figure 1 computes EP when conduit lenders cannot distribute mortgages to investors ($d^k = 0$). We see that in this case the conduit mortgage rate is always above q^*, so $EP > 0$. However, EP decreases when the hard credit scoring technology improves.

[22] The discountinuity occurs because consumers start preferring conduit loans to portfolio loans. When this happens the fundamental proportion of G-type changes because the measure of G-type consumers jumps from 0.5 to 1.5. To see this notice that the measure of G-type consumers that attempts to borrow from conduit lenders increases from 0.5 to 1.5, whereas the measure of B-type consumers is 0.5.

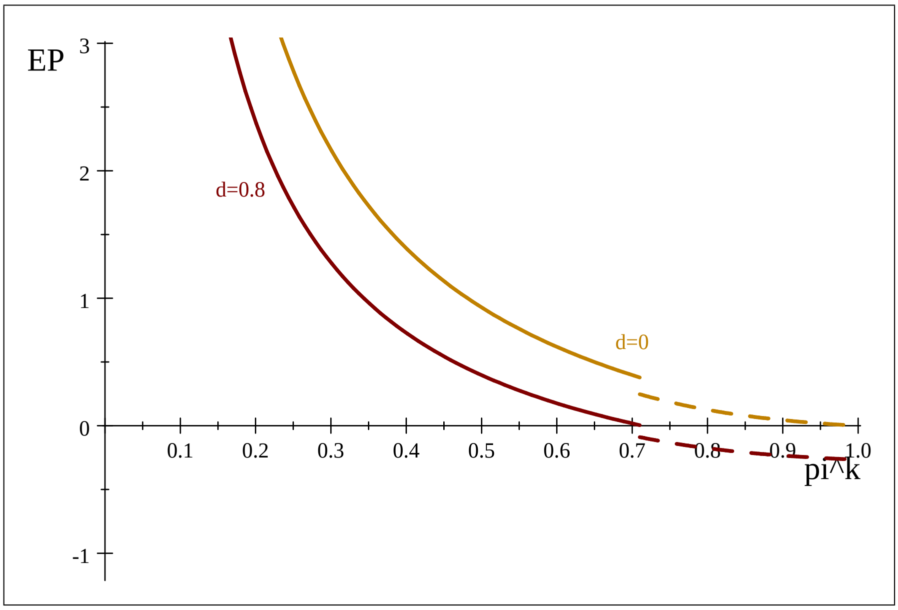

Figure 1

Remark: Our pricing results have some analogies with Sato's (2015) analysis of transparent versus opaque assets. Sato shows that transparent firms own transparent assets and opaque firms own opaque assets in equilibrium. This is analogous to us showing portfolio lenders hold only higher quality loans and conduit lenders own a mix. The reasons for such holdings are different in the two models, however. In our model, conduit lenders are intermediaries that transform a set of assets into opaque subprime MBS. Sato also shows that opaque assets trade at a premium to transparent assets. This is primarily due to agency distortions in the opaque firm. For us a premium in opaque asset prices comes through the investors' demand for subprime MBS. For a similar result in the commercial mortgage market, see An, Deng and Gabriel (2011), who find that conduit loans enjoyed a 34 basis points pricing advantage over portfolio loans in the CMBS market.

4 Equilibrium regimes

So far we have assumed that consumer preferences were described by a concave utility function. In Section 3 we showed that an equilibrium for this economy exists under quite mild conditions. In order to streamline our analysis, we focus on a more analytically tractable setting where owner-occupied housing (H) and rental housing (R) are perfect substitutes and consider the following linear separable utility function:

$$u^h(R_1, H_1, R_2, H_2) = R_1 + \eta H_1 + \theta^h(R_2 + H_2),$$

where $\theta^h < 1$ denotes the consumer's discount factor and $\eta > 1$ denotes a preference parameter that captures that, all else equal, in the first period young households prefer to consume owner-occupied housing over rental housing (this can be possibly due to a better access to schools, for example; see Corbae and Quintin (2015) for a model with also an "ownership premium" in preferences, and Hochguertel and van Soest (2001) for empirical evidence). When households are old, the utility from consumption of owner-occupied housing H_2 and the utility from consumption of rental housing R_2 are the same.

Also, to get simple closed form solutions, we assume $\omega_2^+ = 1$, $\omega^{SR} = 1/2$, $v(r) = 1$, and $\lambda_G = 1.5$.

4.1 House prices and local land use regulations

This subsection discusses the effect of the owner-occupied housing price on consumers' housing choices, and then examines the role of land use regulations on the exclusion of subprime consumers from mortgage markets.

First, recall that the aggregate demand of owner-occupied housing consumption in the *first* period and the aggregate supply of owner-occupied housing consumption in the *second* period are inelastic, both equal to $\bar{H} = 1$. A constant stock of owner-occupied housing is convenient to get simple closed form equilibrium solutions because the market clearing house prices are such that $p_1 = p_2 = p$.[23] Defaults occur in our model due to the imperfect hard credit scoring technology used by conduit lenders, and not due to house price movements.[24]

Secondly, in equilibrium $p > 1$, which implies that old households with a mortgage will sell their house in the second period and move to rental housing, as the benefits to owning go away as the younger household transitions to older age.[25] In the first period, however, young consumers with a mortgage will find it optimal to buy a house, provided that the credit scoring technology parameter π^k exceeds a certain threshold, as argued below.

Thirdly, portfolio lenders can in general lend to G-type consumers or to B-type consumers. Recall that portfolio lenders know the borrower's type, and hence can charge a risk-based mortgage loan rate. So far we have assumed that portfolio lenders only lend to G-type consumers (say, because of regulation on formal banks or stigma). Here we explore a different reason. In particular, G-type consumers may end up crowding out B-type consumers from the portfolio mortgage market if there is a local policy that requires a minimum house (lot) size $H^{\min}$ equal to[26]

$$H^{\min} \equiv \omega^{SR}/p(1 - \delta\theta^l)$$

[23] The owner-occupied market clearing equations in periods 1 and 2 and the households' optimal choice $H_2^h = 0$ (shown in the Appendix) imply that $p_1 = p_2 = p$.

[24] For a model where default is triggered by a fall in house prices, see Chatterjee and Eyigungor (2015) and Arslan, Guler and Taskin (2015) where mortgages are non-recourse.

[25] Also, as households get older, their needs may change and may prefer independent living, assistance living, or even nursing care than living by their own in a big owner-occupied house. See Hochguertel and van Soest (2001) for evidence that young households buy a house to accommodate the new family members and possibly to get access to better schools, but when they are old and the family size decreases, these households sell their houses and move to smaller rental houses.

[26] The porfolio mortgage contract $(q^{B,r}, \psi^{B,r})$ specific for B-type consumers must satisfy budget constraints $pH_1^{B,r} = \omega^{SR} + q^{B,r}\psi^{B,r}$ and $\omega^{SR} = \omega^{SR} - \psi^{B,r} + pH_1^{B,r}$ (the latter coming from the limited recourse requirement), which implies $\psi^{B,r} = pH_1^{B,r}$ and $\psi^{B,r} = \omega^{SR}/(1 - q^{B,r})$. Porfolio lender's optimization implies that $q^{B,r} = \theta^l\delta$. Thus, $\psi^{B,r} = \omega^{SR}/(1 - \theta^l\delta)$ and using again equation $\psi^{B,r} = pH_1^{B,r}$ we get $H_1^{B,r} = \omega^{SR}/p(1 - \theta^l\delta)$. Then, set $H^{\min} = \omega^{SR}/p(1 - \theta^l\delta)$.

Local land use regulation typically imposes minimum quality standards for owner occupied houses.[27] This creates a fixed cost that puts a lower bound on house size (in order for the builder's profit margin to at least pay for the cost of regulation).[28] In terms of our model, this policy implies that those subprime consumers that don't get a loan have no other option but to rent in the first period as they can only afford buying a house of size ω^{SR}/p, which is certainly below $H^{\min}$ with $p > 1$. This illustrates how local land regulations, in the form of a minimum lot size, affects the bottom of the housing market by excluding subprime borrowers from the mortgage market.

4.2 Mortgage market collapses

This section identifies three thresholds, π_0, π_1 and π_2, for the conduit lender's belief π^l on the proportion of good type borrowers in its pool. These thresholds determine different subprime mortgage market configurations, and all can be expressed as a function of the parameters of our economy, including $\theta^l, \theta^i, \delta, d^l$ and η.

1. In presence of land regulation constraints, the conduit market can collapse if conduit lenders' lending standards, captured by π^k, sufficiently deteriorate. In particular, there is a threshold π_0 that solves the following equation:

$$H_1^{G,k}(\pi_0) = H^{\min} \tag{18}$$

   such that when $\pi^k < \pi_0$ conduit loans are so small that borrowers with these loans cannot afford to buy a house with size above $H^{\min}$.[29]

2. There is a conduit mortgage market as long as G-type consumers prefer to borrow from conduit lenders than renting in the first period. When π^k decreases below a given threshold π_1, the implicit conduit mortgage rate is so high that G-type consumers prefer to rent in both periods ($R_1 = \omega^{SR}$ and $R_2 = \omega_2^+$) than borrowing from conduit lenders and buying a house in the first period. Threshold π_1, at which indifference between buying a house with a conduit loan and renting in both periods occurs, solves the following equation:[30]

$$\eta H_1^{G,k}(\pi_1) + \theta^h \omega^{SR} = \omega^{SR} + \theta^h \omega^+ \tag{19}$$

   When $\pi^k < \pi_1$, conduit loans are so small that G-type consumers prefer to rent in both periods.

Lemma 1: *The conduit lender market collapses when* $\pi^k < \max\{\pi_0, \pi_1\}$.

[27] Local land use regulations can be embedded in our model by modifying the owner-occupied housing consumption space as $\{0\} \cup [H^{\min}, \bar{H}]$.

[28] See Malpezzi and Green (1996) and NAHB Research Center (2007) for empirical evidence and further explanations, and also the Wharton Housing Regulation Index for measures of housing regulation.

[29] The housing market clearing price p, which decreases in π^k as the conduit loan gets smaller, will not decrease any further when π^k is below π_0.

[30] In the left hand side term of equation (19) both portfolio loan and conduit loan markets are active and the market clearing house price is computed accordingly.

3. Consumers may prefer to borrow from conduit lenders if the conduit loan is larger than the portfolio loan. Formally, there is a threshold π_2 at which the G-type consumer is indifferent between a conduit loan and a portfolio loan. This threshold solves the following expression:[31]

$$\eta H_1^{G,k}(\pi_2) + \theta^h \omega^{SR} = \eta H_1^{G,r} + \theta^h \omega^{SR} \tag{20}$$

Observe that when $\pi^k > \pi_2$, consumers prefer conduit loans even when conduit lenders risk-price the presence of lemons and their subsequent default into the mortgage discount price. In this case, the conduit lender's fundamental proportions of G-type consumers, $\hat{\pi}(G)$, improves as now conduit loans are the first best option for G-type consumers. Also interestingly, when the mortgage distribution rate increases, π_2 decreases and the conduit mortgage market expands.

Lemma 2: *The portfolio loan market becomes the first choice for G-type consumers when $\pi^k > \pi_2$.*

Below we summarize the different possible market configurations in terms of the conduit lender's belief π^k and indicate the size of the portfolio and conduit mortgage markets for each of these configuration. We find convenient to distinguish between

$$\pi^k \equiv \Pr\left(\text{rating=G}|\text{G}\right) \text{ and } \tilde{\pi}^k \equiv \Pr\left(\text{rating=G}|\text{B}\right).$$

For simplicity, we assumed that conduit lenders are not capacity constrained[32], so whenever a G-type is not able to borrow from a portfolio lender, he can always try to borrow from a conduit lender. However, not all G-type consumers that attempt to borrow from a conduit lender end up with a loan. This is because the conduit lender's credit scoring technology identifies a G-type consumers as a bad consumer with positive probability.

Proposition 2 (Mortgage market configurations)**:**

- *If $\pi^k < \max\{\pi_0, \pi_1\}$, the conduit mortgage market collapses and only a mass $v(r)$ of G-type consumers can borrow to buy a house. The rest of consumers, with mass $\lambda_G - v(r) + \lambda_B$, rent in both periods.*
- *If $\pi^k > \pi_2$, G-type consumers prefer the conduit mortgage market. A mass $\pi^k\lambda_G + \tilde{\pi}^k\lambda_B$ of consumers receive a good rating and are able to borrow at the conduit loan rate and buy a house. Those G-type consumers without a conduit loan, with mass* $\min[(1-\pi^k)\lambda_G, 1]$, *will borrow from their second best option, the portfolio loan market. The rest of consumers, with mass $(1-\pi^k)\lambda_G + (1-\tilde{\pi}^k)\lambda_B - \min[(1-\pi^k)\lambda_G, 1]$, will rent in both periods.*

[31] The left hand side term in equation (20) represents the G-type consumer's utility from buying a house in the first period with a conduit loan and then renting (in a setting where only the conduit loan market is active). The right hand side term in equation (20) represents the G-type consumer's utility from buying a house in the first period with a portfolio loan and then renting (in a setting where both portfolio loans and conduit loans markets are active).

[32] Alternatively, $v(k) > \pi^k\lambda_G + \tilde{\pi}^k\lambda_B$.

- *When $\pi^k \in [\max\{\pi_0, \pi_1\}, \pi_2]$, portfolio lenders lend to a mass $v(r)$ of G-type consumers, whereas conduit lenders lend to a mass $\pi^k(\lambda_G - v(r)) + \tilde{\pi}^k \lambda_B$ of consumers. The rest of consumers (those who receive a bad rating by the conduit lender), with mass $(1 - \pi^k)(\lambda_G - v(r)) + (1 - \tilde{\pi}^k)\lambda_B$, will rent in both periods.*

The proof follows immediately from our previous analysis and is thus omitted. Next, we explain the effect of changes of key parameters on π_0, π_1 and π_2. First, when the predictive power of the hard credit scoring technology worsens (π^k decreases), there is more asymmetric information between borrowers and conduit, and all else equal, the conduit market is closer to its collapse (or enters in the collapse region). Second, when the consumer's discount factor θ^h increases and the owner-occupied preference parameter η decreases, consumers find renting in the first period relatively more attractive than borrowing-to-own, and thus the conduit loan market shrinks as π_1 increases. Third, when the investor's discount factor θ^i and/or the distribution rate d^k increase, all else equal, the conduit loan market expands (as threshold values π_0, π_1 and π_2 decrease). This is because conduit mortgages become more attractive due to the higher investors' willingness to pay for mortgages. Fourth, a higher foreclosure cost expands the region where both portfolio and conduit loan markets are active, as a lower δ^k decreases the value of thresholds π_0, π_1 and increases the value of π_2.

4.3 Simulations

For the sake of brevety, we present in the Appendix D the closed form solutions for the house price, the different types of loan amounts, and the amount of securitized mortgages sold to investors. Here we illustrate how the equilibrium house price and loan amounts change as a function of the conduit lender's credit scoring technology across the different regimes identified above. We will assume that $d^k = 0.8$, $\theta^h = 0.4$, $\theta^l = 0.7$, $\theta^i = 0.9$, $\eta = 4$, $\delta = 0.5$, $v^k = 1$, $\lambda_G = 1.5$, $\lambda_B = 0.5$ and $v(r) = 1$. For these parameters, the π-thresholds are $\pi_0 = 0.15$, $\pi_1 = 0.50$ and $\pi_2 = 0.71$.[33] For simplicity, we make $\pi^k = 1 - \tilde{\pi}^k$.[34] As before, we assume $\pi^k < 1$ and $\pi^r = 1$.

4.3.1 Loan amounts, house prices, and house size

Figure 2 portraits the portfolio loan, conduit loan and mortgage securitization' equilibrium values ($q^r\psi^r$, $q^k\psi^k$ and τz^k, respectively) as a function of π^k; Figure 3 illustrates the equilibrium owner-occupied housing price p as a function of π^k; and Figure 4 portraits the equilibrium house sizes for different borrowers ($H^{G,r}$ for borrowers with portfolio loans and $H^{G,k}$ for borrowers with conduit loans) as a function of π^k. These figures capture the following dynamics.

When $\pi^k < \max\{\pi_0, \pi_1\}$, there are only portfolio lenders in the subprime mortgage market, whose loan amount is independent on the conduit lender's belief π^k. For this domain of parameter values of π^k, we see that the house price is low and constant, as well

[33] Observe that threshold π_2 that solves equation (20) exactly coincides with the threshold that solves equation $q^* = q^k$ (or equivalently, $EP = 0$) and also equation $q^r\psi^r = q^k\psi^k$.

[34] i.e., $\Pr^l$(rating=G|G) = $\Pr^l$(rating=B|B) = 1− $\Pr^l$(rating=B|G) = 1-$\Pr^l$(rating=G|B).

as the equilibrium house size in the owner-occupied segment of the housing market. When $\pi^k > \pi_1$, the conduit mortgage market emerges as now conduit lenders offer loan amounts that are sufficiently attractive to G-type households that did not get a loan from portfolio lenders. Thus, in this regime there are more consumers with a mortgage than in the previous regime with $\pi^k < \max\{\pi_0, \pi_1\}$, and this higher demand for houses increases the price of owner-occupied houses. Because housing supply is inelastic, more credit coming from the conduit loan market decreases the equilibrium house size that consumers with portfolio loans can buy. On the other hand, consumers with conduit loans can buy a larger house size when π^k keeps increasing.

Once $\pi^k = \pi_2$, the portfolio loan amount and the conduit loan amount coincide, whereas when $\pi^k > \pi_2$ the conduit loan is larger than the portfolio loan due to the conduit lender's access to high liquid from the secondary mortgage market. At $\pi^k = \pi_2$, the conduit lender's fundamental proportion of G-type consumers, $\hat{\pi}^k(G)$, jumps from 0.5 to 0.75, and hence belief π^k jumps too (see (4) expression). As we indicate in the Appendix D, the conduit lender's loan amount $q^k\psi^k$ and the value of securitizated mortgages τz^k jump at π_2, and increase thereafter as π^k increases above π_2.[35] The more credit in the subprime economy, the higher is the demand for owner-occupied houses, and thus the higher is the house price p (Figure 3).

Also notice that when π^k goes beyond π_2, the house size of a conduit borrower becomes larger than the house size of a portfolio borrower. This also according to our result that portfolio mortgage market is not the consumers' first option once the credit scoring technology goes beyond π_2. We also see that the equilibrium house size of consumers with portfolio loans plummets again when the conduit loan size jumps at π_2, as the expansion of the conduit loan market injects more credit in the economy. However, the discontinuity in the equilibrium values of house sizes purchased with conduit loans is small at π_2 . This is because the jump of the conduit loan amount compensates the fall in the equilibrium house price at that point. Once π^k increases above π_2, the equilibrium size of houses purchased with conduit loans decreases, as the convex effect of the house price dominates the concavity of the conduit loan in that region.

4.3.2 The size of the rental market

Next, we illustrate how the sorting of borrowers into the different types of mortgage lending markets determines the size of the rental market. Figure 5 depicts the measure of tenants that rent in both periods for the different regimes. First, notice that portfolio lenders exhaust their lending capacity constraint $v(r) = 1$ by lending to a mass 1 of G-type borrowers. Hence, when $\pi^k < \pi_1 = 0.50$, there are only portfolio loans issued, and therefore a mass

$$\lambda_G + \lambda_B - 1 \tag{21}$$

of households have no other option but to rent. Second, since conduit lenders can absorb all excess demand of consumers with a good rating, we have that, when $\pi^k \in [\pi_1, \pi_2]$, a

[35] Market clearing in the conduit loan market requires that $\varphi^k = \mu^k(\text{rating=G})\psi^k$, and ψ^k jumps when $\pi^k > \pi_2$). The equilibrium closed form solution for τz^k is given by expression (**??**) in the Appendix. There we can see how τz^k is no more than a fraction d^k of the value of mortgages originated by conduit lenders ($\tau z^k = \tau d^k \varphi^k$).

mass $\mu^k(\text{rating=G}) = \pi^k(\lambda_G - 1) + (1-\pi^k)\lambda_B$ of consumers are able to get a conduit loan, whereas the remaining consumers, with mass

$$\underbrace{(\lambda_G - 1) + \lambda_B}_{\text{Remaining consumers without a portfolio loan}} \quad - \quad \underbrace{(\pi^k(\lambda_G - 1) + (1-\pi^k)\lambda_B)}_{\text{Mass of consumers with a conduit loan } (\mu^k(\text{rating=G})) \text{ when } \pi^k \in [\pi_1, \pi_2]} \tag{22}$$

have no other option but to rent. Third, when $\pi^k \geq \pi_2 = 0.71$, all consumers attempt to get a conduit loan first. However, only a mass $\mu^k(\text{rating=G}) = \pi^k\lambda_G + (1-\pi^k)\lambda_B$ of consumers get a conduit loan. Those G-type consumers without a conduit loan, with mass $(1-\alpha^k)\lambda_G$, attempt to get a portfolio loan, their second option. The remaining consumers, with mass

$$\lambda_G + \lambda_B - \underbrace{(\pi^k\lambda_G + (1-\pi^k)\lambda_B)}_{\text{Mass of consumers with a conduit loan } (\mu^k(\text{rating=G})) \text{ when } \pi^k > \pi_2} - \underbrace{\min[(1-\pi^k)\lambda_G, 1]}_{\text{G-type consumers wih a conduit loan}}, \tag{23}$$

have no other option but to rent. In Figure 5 we see equilibrium values (21), (22) and (23) when $\lambda_G = 1.5$ and $\lambda_B = 0.5$, plotted against π^k. The size of the rental market is largest when $\pi^k < \pi_1$. Above π_1 the rental market shrinks as new consumers get (conduit) loans. Then, we see how the rental market shrinks again at π_2 as the conduit mortgage market absorbs a substantial larger fraction of G-type and B-type consumers, while the portfolio mortgage market also absorbs those G-type consumers without a conduit loan. At $\pi^k = \pi_2$ a mass $(1-\pi^k)\lambda_B$ of B-type consumers are able to get a conduit loan. However, as α^k gets closer to 1, the mass of B-type consumers without a conduit loan that have no other option than to rent increases and converges to λ_B.

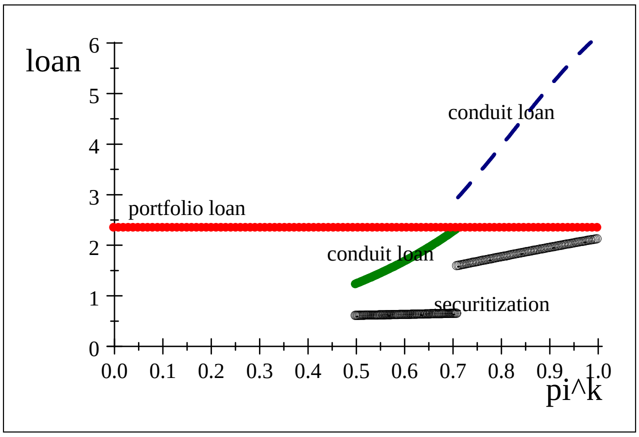

Figure 2

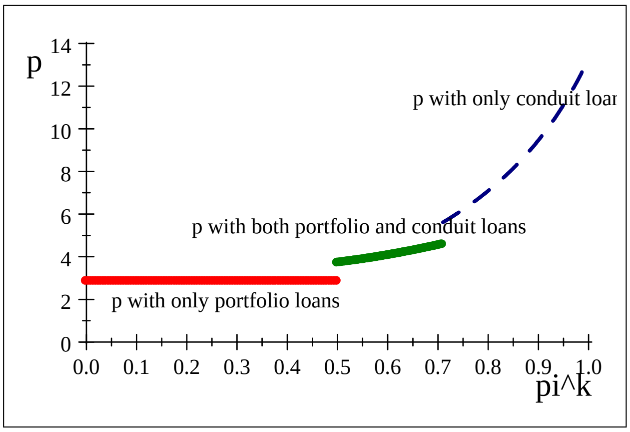

Figure 3

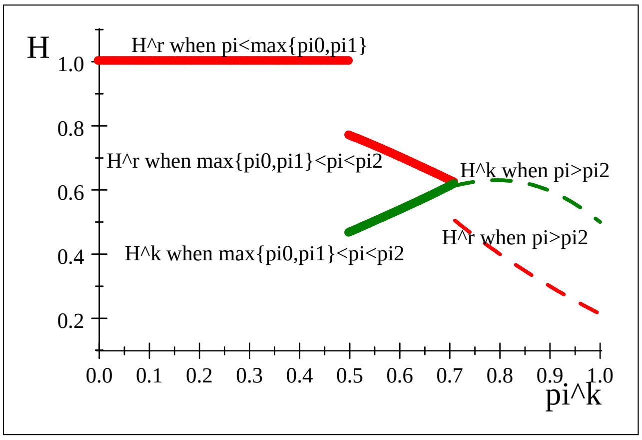

Figure 4

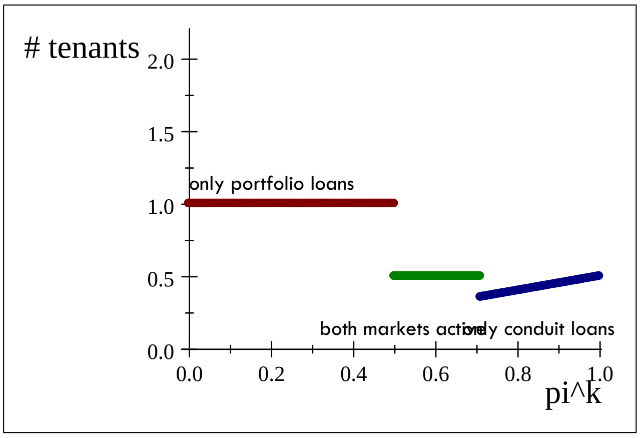

Figure 5

5 Empirical support for the rise and fall of subprime mortgage lending

In this section we show how our model can generate different equilibrium regimes depending on the predictive power of the credit scoring technology (hard information) and the liquidity from the secondary MBS market. We first provide a short narrative for each of the equilibrium regimes, and then illustrate the behavior of key equilibrium variables.

- **Only portfolio lenders** ($\pi^k < \pi_1$)

Consider a world (pre-middle 1990s) in which subprime loan credit scoring technology was crude and there did not exist powerful summary statistics on consumer credit quality (FICO score). This meant that it was very difficult for subprime loan originators to reliably distinguish between good and bad credit borrowers based on hard information ($\pi^k < \pi_1$).

If transaction-based lending were to occur based on hard information only, the high likelihood to confusing good and bad types in underwriting decisions would increase loan rates substantially due to adverse selection concerns, thus potentially pricing all borrowers out of the market. But relationship lenders (local depository financial institutions) are capable to soliciting soft information to improve their underwriting decision outcomes. Potentially based on regulatory requirement (e.g., CRA), localized relationship lenders are the only available source of subprime loans, but are subject to capacity constraints that result in the rationing of credit (to good types) in subprime neighborhoods.

In addition to adverse selection concerns as related to loan pricing with transaction-based lending, in this world there was also little demand for subprime loans packaged as securities. There are not strong regulatory or tax reasons to invest in pooled-tranched securities backed by mortgage or other types of loans. Capital flows into bond markets are "normal" and are not distorted by factors such as foreign capital flows looking for dollar denominated low-risk investments. This implies that a private-label subprime MBS market is non-existent, since the high cost of loan sales is not offset by any other benefits that might be associated with subprime loan securitization.

- **Conduit lenders enter into the subprime mortgage market** ($\pi^k \in [\pi_1, \pi_2]$)

Now consider an evolved world (say from the middle 1990s to early 2000s) in which credit information is now available to improve credit scoring decisions (FICO is introduced and provides accurate assessments of borrower credit quality), and where credit scoring models themselves improve ($\pi^k \in [\pi_1, \pi_2]$). This creates a foundation where it is now possible to more credibly distribute subprime loans into a secondary market. Concurrent with this is the introduction of capital reserve regulation (Basel II) that increases the attractiveness of owning low credit risk (AAA-rated) securities. There has also been shocks (the Asian and Russian financial crises) that have shifted foreign capital flows towards dollar-denominated U.S. Treasuries and close substitutes. This shift in demand has decreased yields of riskless and near riskless bonds, causing fixed-income investors to move further out the credit risk curve in search for higher yields. The search for higher yields and favorable capital treatment causes demand for AAA-rated securities to skyrocket. But these securities are not in sufficient supply to meet all of the demand. The subprime mortgage market represents a vast untapped market, where the pooling of such loans can then be converted (in part, but large part) into AAA-rated securities in large quantities to help satisfy the demand.

Improved credit scoring technology along with a high demand for manufactured AAA-rated securities sets the stage for the rise of the subprime mortgage market. A reduction in the pooling rate on subprime loans due to better (perceived if not actual) sorting of good and bad types makes it feasible for low-cost transaction-based lenders (brokers and other conduit lenders) to set up shop to apply automated underwriting based on hard information only.

- **Conduit lenders dominate the subprime lending market** ($\pi^k > \pi_2$ & $\uparrow \theta^i$).

By the early to middle 2000s, demand for AAA-rated securities has intensified ($\uparrow \theta^i$). With this intensified demand and increasing confidence in the basic conduit loan business model ($\pi^k > \pi_2$), conduit loans rates decline to the point where the pooled conduit loan rate falls below the portfolio loan rate, and the traditional portfolio loan market shrinks (relative to the total size of the subprime mortgage market) as good subprime borrower types migrate to the conduit loan market to take advantage of the low rates. There is a housing market boom.

- **The collapse of the conduit loan market** ($\pi^k < \pi_1$ & $\downarrow \theta^i$ & $\downarrow \hat{\pi}^k(G)$)

Finally, starting in 2006, with the start of a sustained increase in unemployment ($\downarrow \hat{\pi}^k(G)$) and decline in house prices and also concerns about the performance of subprime MBS, confidence in the credit scoring based conduit loan business model is shaken ($\pi^k < \pi_1$). This causes investors to increase the pooling loan rate as the credit scoring classification system is scrutinized, and a fall-off in demand for credit-risky MBS occurs ($\downarrow \theta^i$). This causes the conduit loan market to collapse as conduit loan rates spike. Subprime home ownership rates stall and the housing boom ends (badly).

- **The conduit loan market reemerges** ($\pi^k \in [\pi_1, \pi_2]$ & $\uparrow \hat{\pi}^k(G)$)

Lastly, as a post-script, imagine it is 2018 and the U.S. economy is now "normalized". The "broken" securitized lending business model is declared to be "fixed" as improved scoring variables are introduced and mechanisms are put into place to improve the quality of credit model assessments ($\pi^k \in [\pi_1, \pi_2]$). The percentage of good types in the subprime population increases due to an improved job outlook and increasing wages at the low end of the labor market ($\uparrow \hat{\pi}^k(G)$). Demand for highly rated securities has persisted, and once again a conduit subprime mortgage market emerges to provide financing for the lower end of the housing market.

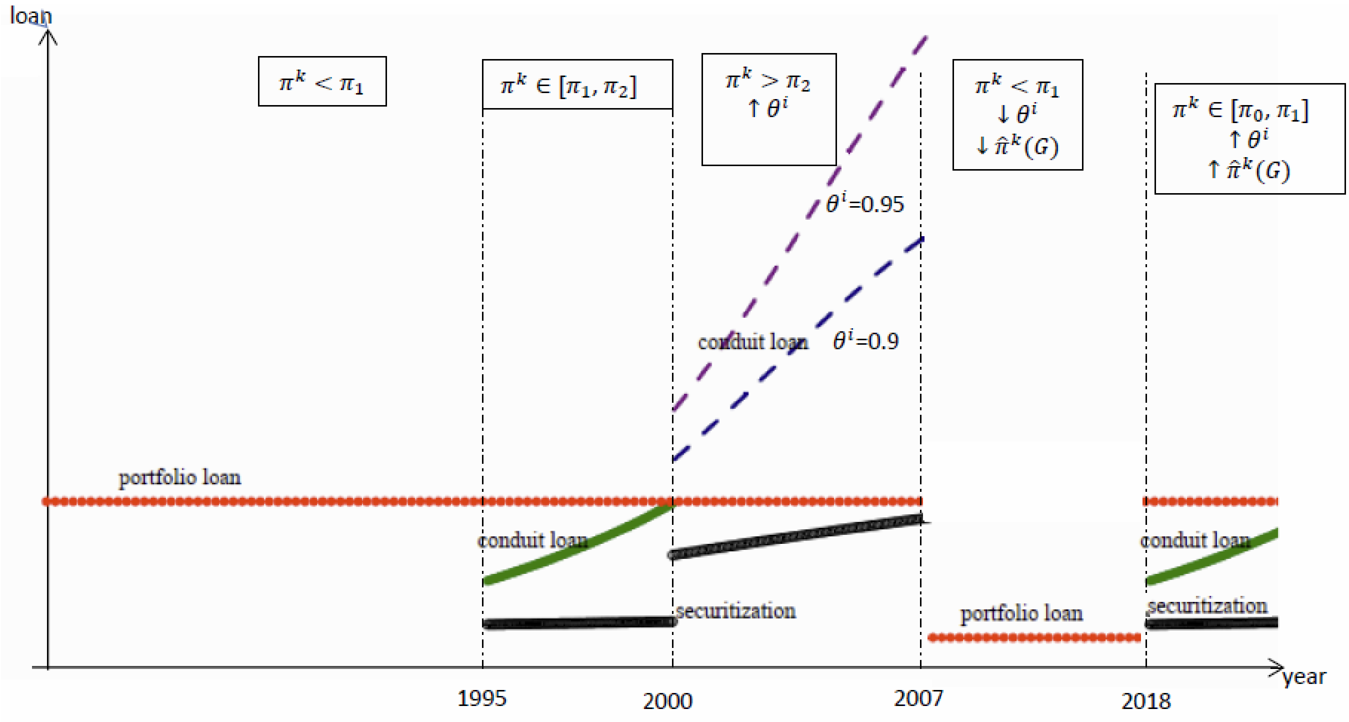

Figure 6

6 Extensions

Here we consider a the following extensions of the baseline model to assess its robustness: 1) we allow lenders to choose the amount of soft information; 2) we introduce adverse selection in secondary mortgage market; 3) we extend our economy to an stochastic economy with uncertainty in the second period endowment realization and study the characteristics of the pooling and separating equilibria in that setting; and 4) we examine the implications of considering non-recourse mortgage contracts instead.

6.1 Endogenous soft information acquisition

So far, we have assumed that conduit lenders only relied on hard credit information, captured by parameter $\pi^k < 1$. Here we allow lenders to choose the amount of soft information acquisition, and give support to the assumption that lenders with a higher mortgage distribution rate (e.g., conduit lendes vs. porfolio lenders) rely less on soft information to screen between borrowers. For this, let us modify the profit function $\Phi^l(\varphi^l, z^l)$ as follows:

$$\Phi^l(\varphi^l, z^l) = (\omega_1^l - s - q^l\varphi^l + \tau z^l) + \theta^l(1 - d^l)(\pi^l(s)\varphi^l + (1 - \pi^l)\delta p_2 H_1^G),$$

where s denotes the cost to acquire soft information in the first period, and $\pi^l(s)$ is a continuous, increasing and concave function of s. Taking the partial derivative with respect to s, with (5) binding and writing $D^l = \varphi^l - \delta p_2 H_1^G$ to denote the lender's default loss, we get:

$$[s] : 1 = \theta^l(1 - d^l)\frac{\partial \pi^l(s)}{\partial s}D^l \qquad \text{(FOC[s])}$$

From first order condition (FOC[s]) we can see that the conduit lender finds optimal to acquire more soft information the higher is his discount factor θ^l, the lower is the mortgage distribution rate d^l, the higher is the default loss $D(\varphi^l)$, and the stronger is the effect of s on $\pi^l(s)$.

The following figure plots the marginal cost (MC) and marginal benefit (MB) functions - corresponding to the left hand side and right hand side of (FOC[s]) equation, respectively - as a function of the amount of soft information acquisition when $\pi^l(s) = 0.3 + \sqrt{s}$, where the first and second components correspond to hard and soft information, respectively. We set $s \in [0, 0.49]$, $\omega_2^+ = 1$, $\omega^{SR} = 1/2$, and $\delta = 0.5$. In this figure MC is constant and equal to 1, while MB is decreasing with slope $-1/(4s^{3/2})$. The intersection between MC and MB pins down the optimal amount of soft information acquired by conduit lenders.[36] In Figure 7 we plot two marginal benefit curves, one with low distribution rate ($d^k = 0.1$) and another with high distribution rate ($d^k = 0.8$). As expected, when the mortgage distribution rate increases from 0.1 to 0.8, the amount of soft information acquired by conduit lenders decreases from 0.32 to 0.02 (and hence π^l decreases from $\pi^l(0.32) = 0.86$ to $\pi^l(0.02) = 0.34$), as conduit lenders pass default risk to the investors.

Therefore, this result points out that when lenders increase their mortgage distribution rate to investors, they choose to acquire less soft information, and thus screen less. Because in our model less soft information leads to a higher percentage of secturized mortgages that end up defaulting, we can rationalize the Keys, Mukherjee, Seru, and Vig's (2010) result that conditional on being securitized, the portfolio with greater ease of securitization defaults by around 10% to 25% more than a similar risk profile group with a lesser ease of securitization (their results are confined to loans where intermediaries' screening efforts may be relevant and soft information about borrowers determines their creditworthiness).[37]

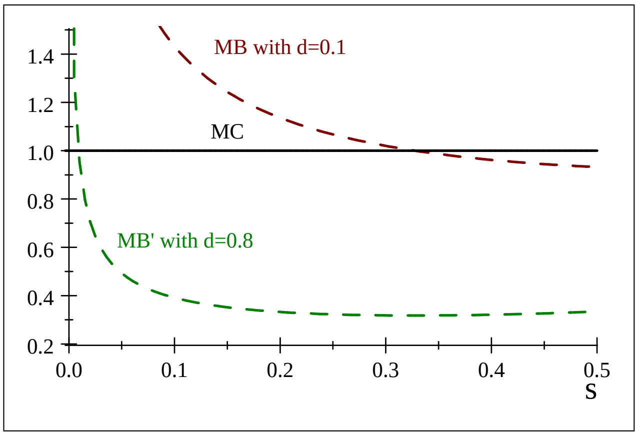

Figure 7

[36] In equilibrium default losses can in turn be expressed as a function of the parameters of our economy as follows: $D^l(\omega_2^+, \delta, d^k, \pi^k, \theta^i, \theta^l) = \frac{\omega_2^+(1-\delta\bar{\theta})}{1-\bar{\theta}(\pi^k(s)(1-\delta)+\delta)} - \frac{\delta\omega^{SR}}{2}$.

[37] Bubb and Kaufman (2014), on the other hand, study the effect of the moral hazard of securitization on lenders creening, and conclude that securitization *did not* lead to lax screening.

6.2 Adverse selection in the secondary mortgage market

So far we have assumed in the baseline model that conduit lenders only rely on hard information and that investors rely on the same credit scoring technology than conduit lenders, i.e., $\pi^i = \pi^k$. Moreover, portfolio lenders, who by assumption have access to soft information, are not allowed to sell their originated mortgages to investors. This set of assumptions eliminates the possibility of adverse selection in the secondary mortgage markets. Adverse selection in secondary markets may arise if investors who only rely on hard information buy mortgage-backed securities from lenders that have superior (soft) information. This section explores this possibility and its implications on the equilibrium regime, mortgage spreads and realized defaults.

For this, let us consider a setting where the conduit loan market is dominant and the portfolio loan market is relative small, similar to the one we characterized in our previous analysis when $\pi^k > \pi_2$. Now consider a change in the business model of portfolio lenders to gain market quote. In particular, assume that portfolio lenders also originate-to-distribute subject to some distribution rate $d^r = d^k > 0$. Thus, in this setting, portfolio lenders are similar to conduit lenders, with the only advantage that portfolio lenders can acquire soft information at no (low) cost ($\pi^r = 1$). We will call them "sophisticated portfolio lenders". Investors, on the other hand, cannot rely on soft information and thus π^i is such that $\pi^i = \pi^k < \pi^r = 1$. Accordingly, assuming that the sophisticated portfolio lender's capacity constraint is smaller than λ_G (for simplicity), we can rewrite the sophisticated portfolio lender's profit function as follows:

$$\Phi^r(\varphi^r, z^r) = (\omega_1^r - q^r\varphi^r + \tau d^r\varphi^r) + \theta^r(1 - d^r)\varphi^r$$

whereas investors maximize $\Lambda^i(z^i)$ function (7) defined in Section 2:

$$\Lambda^i(z^i) \equiv \omega_1^i - \tau z^i + \theta^i(\pi^i z^i + (1 - \pi^i)d^l\delta p_2 H_1^G)$$

We can then show that the sophisticated portfolio lender's discount price is given by the following expression:[38]

$$q^r = \frac{\pi^i d^l\theta^i + (1 - d^l)\theta^l}{1 - \delta(1 - \pi^i)d^l\theta^i} \tag{24}$$

Discount price (24) is always higher than the corresponding discount price found for conduit lenders in the baseline model. This is because in a competitive framework sophisticated portfolio lenders, who do not face any default risk, can also benefit from the gains from distribution. Thus, when sophisticated portfolio lenders enter into the secondary mortgage market, the sophisticated portfolio loan rate is always smaller than the conduit loan rate, and therefore sophisticated portfolio lenders are always the first choice for borrowers. However, the conduit loan market can be still active when portfolio lenders are subject to regulation and capacity constraints that limit the number of loans originated.

[38] From the first order condition with respect φ^r we obtain $q^r = \tau d^r + \theta^r(1 - d^r)$, where $p_2 H_1^G$ is a function of z^i in equilibrium (we can write $p_2 H_1^G = d^r\omega^{SR} + q^r z^i$ using consumer's budget constraints and market clearing $z^r = z^i$). Now, taking the partial derivative of $\Lambda^i(z^i)$ with respect to z^i we obtain $\tau = \theta^i(\pi^i + (1-\pi^i)\delta q^r)$. We susbtitute τ into the q^r expression and get $q^r = \theta^i(\pi^i + (1-\pi^i)\delta q^r)d^r + \theta^r(1-d^r)$. After some algebra we get the desired price function.

Another interesting extension is to introduce sophisticated portfolio lenders together with relatively naive secondary market investors. In that case, investors are selected against by informed mortgage originators and, as a result, investor's default expectations are lower than their realized default. In the Appendix F, we explore this possibility.

6.3 Stochastic economy with uncertainty

To demonstrate the robustness of our model we have included in the Appendix E the technical details of extending the baseline deterministic economy with one state of nature in the second period to an stochastic economy with uncertainty in the consumer's second period endowment realization. In the first state the consumer's endowment, irrespective of his type, is ω_2^+, whereas in the second state his endowment is ω^{SR} and thus defaults on the loan payment. Subprime consumers differ in their probabilities attached to each of these two states. For G-type consumers the probability of s_1 is β^G, whereas the probability is β^B for B-type consumers. We assume that $0 < \beta^B < \beta^G$. In the Appendix we show that the baseline model is in fact a particular case of the extended model and that the predictions of the model do not change in qualitative terms. Also, we examine the possibility of a separating equilibrium for the extended model with $0 < \beta^B < \beta^G$, and find that our predictions for the rise and fall of subprime mortgage lending are qualitatively similar to the described dynamics of the pooling equilibrium of our baseline model.

6.4 Recourse v. non-recourse mortgage contracts

So far we have assumed that mortgage contracts are recourse but subject to limited liability (see Davila (2015) for an exhaustive analysis of "mortgage exemptions" in subprime recourse mortgages). This is according to common practice in the US and Europe. In the US most states have recourse loans in subprime mortgages, with only few exceptions, such as purchase money mortgages in California and 1-4 family residences in North Dakota. Some states also *limit deficiencies* if a creditor proceeds through a non-judicial foreclosure.[39] It is in the subprime borrowers group where one expects most limited deficiencies judgments. Here we analyze the equilibrium implications of considering non-recourse mortgages instead than (limited) recourse mortgages.[40]

In a recourse mortgage the borrower can credibly commit to pay back the loan even if the house value is below the debt amount (until the point where paying the promise would involve consuming below the subsistence rent).[41] Adverse selection then arises for (limited) recourse contracts because subprime consumers have different probabilities of receiving a high endowment in the second period. In the good state both consumer types honor the promise, and in the bad state both types default. The probability of occurrence of each state is different between the two types of consumers though.

In a non-recourse mortgage, if the house does not sell for at least what the borrower owes,

[39] See Li and Oswald (2014) and also Ghent and Kudlyak's (2011) table 1 for a summary of different state recourse laws.

[40] See Kobayashi and Osano (2012) for further insights of non-recourse financing on securitization.

[41] The way bankruptcy/foreclosure law works is that non-payment results in wage garnishment.

the lender must absorb the difference and walk away.[42] Notice that if we were to modify the baseline model and consider instead non-recourse mortgage contracts, the adverse selection problem is absent in both the pooling and the separating equilibria because both types of consumers would be always able to repay their debt using part or all of the proceeds from the house sale, and still consume the subsistence rent ω^{SR} (see Appendix G for more elaborated argument).

Notice also that in both types of equilibrium the non-recourse contract does not need to include a limited liability clause, which allows the borrower to consume at least the subsistence rent in the second period, since when $\psi \leq pH_1$, the borrower always have means to repay the loan by selling his house and, therefore, does not need to use his own endowment to satisfy the mortgage payment.

Finally, observe that a non-recourse contract may prevent the consumer to borrow against all the second period income that is above ω^{SR}, as the promise cannot be larger than the house value (pH_1) in the baseline model. Non-recourse, by eliminating adverse selection, causes the G-type to delay some consumption until the second period. This is welfare decreasing, since households prefer to consume more in the first period. This is both because the household is impatient and because the younger household derives more utility from owning a house than renting.

References

[1] Acharya, V., P. Schnabl, and G. Suarez (2013), "Securitization without Risk Transfer", *Journal of Financial Economics* 107, 515–536.

[2] Acharya, Viral, Matthew Richardson, Stijn Van Nieuwerburgh, and Lawrence White (2011), "Guaranteed to Fail: Fannie Mae, Freddie Mac, and the Debacle of Mortgage Finance", Princeton University Press, March.

[3] Adams, W., Einav, L., and J. Levin, (2009), "Liquidity Constraints and Imperfect Information in Subprime Lending", *American Economic Review* 99, 49–84.

[4] Adelino, M., K. Gerardi, and P. S. Willen (2013), "Why Don't Lenders Renegotiate More Home Mortgages? Redefaults, Self-Cures and Securitization", *Journal of Monetary Economics* 60, 835-853.

[5] Agarwal, S., G. Amromin, I. Ben-David, S. Chomsisengphet, and D. Evano (2011), "The Role of Securitization in Mortgage Renegotiation", *Journal of Financial Economics* 102, 559-578.

[6] Agarwal, S., Y. Chang, and A. Yavas (2012), "Adverse Selection in Mortgage Securitization", *Journal of Financial Economics* 105, 640-660.

[7] Akerlof, G. (1986), "The market for 'lemons': Qualitative Uncertainty and the Market Mechanism", *Quarterly Journal of Economics* 84, 488–500.

[42] Notice that in both recourse and non-recourse mortgages, the lender would be able to seize and sell the house to pay off the loan if the borrower defaults.

[8] Aksoy, Y. and H. Basso (2015), "Securitization and Asset Prices", mimeo.

[9] Ambrose, B. W., M. Lacour-Little, and A. B. Sanders (2005), "Does Regulatory Capital Arbitrage, Reputation, or Asymmetric Information Drive Securitization?", *Journal of Financial Services Research* 28, 113-133.

[10] An X., Y. Deng, and S. Gabriel (2011), "Asymmetric Information, Adverse Selection, and the Pricing of CMBS", *Journal of Financial Economics* 100, 304–325.

[11] Araujo, A., J. Fajardo, and M. Pascoa (2005), "Endogenous Collateral", *Journal of Mathematical Economics* 41, 439-462.

[12] Arslan, Y., B. Guler and T. Taskin (2015), "Joint Dynamics of House Prices and Foreclosures", *Journal of Money, Credit and Banking* (forthcoming).

[13] Ashcraft, A. and A. Tobias (2012), "Shadow Banking Regulation", *Annual Review of Financial Economics* 4, 99-140.

[14] Ashchraft, A., H. Boesky, T. Adrian, and P. Zoltan (2012), "Shadow Banking", Federal Reserve Bank of New York, Staff Report No. 458.

[15] Ashcraft, A. and T. Schuermann (2008), "Understanding the Securitization of Subprime Mortgage Credit", Staff reports, Federal Reserve Bank of New York.

[16] Barlevy, G. and P. Veronesi (2000), "Information Acquisition in Financial Markets", *Review of Economics Studies* 67, 79-90.

[17] Bernanke, B.S. (2008), "Remarks on Mortgage Crisis: Speech Delivered to the National Community Reinvestment Coalition", March14.

[18] Bottazzi, J.M., J. Luque, and M. Pascoa (2012), "Securities Market Theory: Possession, Repo and Rehypothecation", *Journal of Economic Theory* 147, 477-1500.

[19] Bubb, R., and A. Kaufman (2014), "Securitization and Moral Hazard: Evidence from Credit Scoring Cuto Rules", *Journal of Monetary Economics* 63, 1-18.

[20] Calem, P., F. Covas, and J.Wu (2013), "The Impact of the 2007 Liquidity Shock on Bank Jumbo Mortgage Lending", *Journal of Money, Credit and Banking* 45, 59-91.

[21] Campbell, J. and J. Cocco (2015), "A Model of Mortgage Default", *Journal of Finance* (forthcoming).

[22] Chatterjee, S., D. Corbae, and V. Rios-Rull (2011), "A Theory of Credit Scoring and Competitive Pricing of Default Risk", mimeo.

[23] Chatterjee, S., D. Corbae, M. Nakajima and V. Rios-Rull (2007), "A Quantitative Theory of Unsecured Consumer Credit with Risk of Default", *Econometrica* 142, 149-177.

[24] Chatterjee, S., D. Corbae and V. Rios-Rull (2008), "A Finite-Life Private-Information Theory of Unsecured Debt", *Journal of Economic Theory* 142, 149-177.

[25] Chatterjee, S. and B. Eyigungor (2014), "A Quantitative Analysis of the U.S. Housing and Mortgage Markets and the Foreclosure Crisis", *Review of Economic Dynamics* (forthcoming).

[26] Corbae, D. and E. Quintin (2015), "Leverage and the Foreclosure Crisis", *Journal of Political Economy* 123, 1-65.

[27] Cordell, L., K. Dynan, A. Lehnert, N. Liang, and E. Mauskopf (2009), "The Incentives of Mortgage Servicers: Myths and Realities", *Uniform Commercial Code Law Journal* 41, 347-74.

[28] Davila, E. (2015), "Using Elasticities to Derive Optimal Bankruptcy Exemptions", mimeo.

[29] Deng, Y., J. Quigley, and R. Van Order (2000), "Mortgage Terminations, Heterogeneity, and the Exercise of Mortgage Options", *Econometrica* 68, 275-307.

[30] Duffie, D. and Y. Sun (2007), "Existence of Independent Random Matching", *Annals of Applied Probability* 17, 386-419.

[31] Duffie, D. and Y. Sun (2012), "The Exact Law of Random Matching for Independent Random Variables", *Journal of Economic Theory* 147, 1105–1139.

[32] Edelberg, W. (2004), "Testing For Adverse Selection and Moral Hazard in Consumer Loan Markets", Finance and Economics Discussion Series 2004-9, Board of Governors of the Federal Reserve System, Washington.

[33] Einav, L., Jenkins, M., and J. Levin (2013), "The Impact of Credit Scoring on Consumer Lending", *RAND Journal of Economics* 44, 249–274.

[34] European Central Bank (2008), "The Incentive Structure of the "Originate and Distribute" Model", Report, European Central Bank, Frankfurt, Germany.

[35] Fishman, M. J. and J. A. Parker (2015), "Valuation, Adverse Selection, and Market Collapses", *Review of Financial Studies* 28, 2575-2607.

[36] Fostel, A. and J. Geanakoplos (2012), "Endogenous Collateral Constraints and The Leverage Cycle", Annual Review of Economics 33, 1-29.

[37] Fuster, A., and J. Vickery (2015), "Securitization and the Fixed-Rate Mortgage" *Review of Financial Studies* (forthcoming).

[38] Geanakoplos, J. (1997), "Promises, Promises," In The Economy as an Evolving Complex System II, ed. W. Brian Arthur, Steven N. Durlauf, and David A. Lane, 28–320. Reading, MA: Addison-Wesley.

[39] Geanakoplos, J. (2003), "Liquidity, Default, and Crashes: Endogenous Contracts in General Equilibrium," In Advances in Economics and Econometrics: Theory and Applications, Eighth World Congress, Vol. 2, ed. Mathias Dewatripont, Lars Peter Hansen, and Stephen J. Turnovsky, 170–205. Cambridge, UK: Cambridge University Press.

[40] Geanakoplos, J. (2010a), "The Leverage Cycle," In NBER Macroeconomics Annual 2009, ed. Daron Acemoglu, Kenneth Rogoff, and Michael Woodford, 1-65. Chicago: University of Chicago Press.

[41] Geanakoplos, J. (2010b), "Solving the Present Crisis and Managing the Leverage Cycle," Federal Reserve Bank of New York Economic Policy Review, 16(1): 101–31.

[42] Geanakoplos, J, and W. Zame (1997), "Collateral Equilibrium," Unpublished.

[43] Geanakoplos, J, and W. Zame (2011), "Collateralized Security Markets," Unpublished.

[44] Geanakoplos, J, and W. Zame (2014), "Collateral Equilibrium: A Basic Framework", *Economic Theory* 56, 443-492.

[45] Gennaioli, N., A. Shleifer, and R. Vishny (2013), "A Model of Shadow Banking", *Journal of Finance* 68, 1331-1363.

[46] Ghent, A. C. (2011), "Securitization and Mortgage Renegotiation: Evidence from the Great Depression", *Review of Financial Studies* 24, 1814-1847.

[47] Ghent, A. and M. Kudlyak (2011), "Recourse and Residential Mortgage Default: Evidence from US States", *Review of Financial Studies* 24, 3139-3186.

[48] Ghent, A. and R. Valkanov (2014), "Comparing Securitized and Balance Sheet Loans: Size Matters", mimeo.

[49] Green, R. and S. Malpezzi (1996), "What Has Happened to the Bottom of the US Housing Market?", *Urban Studies* 33, 1807-1820.

[50] Gorton, G. and G. Ordonez (2014), "Collateral Crises", *American Economic Review* 104, 343-378.

[51] Guler, B. (2014) "Innovations in Information Technology and the Mortgage Market", *Review of Economic Dynamics* (forthcoming).

[52] Hochguertel, S. and A. van Soest (2001), "The Relation between Financial and Housing Wealth: Evidence from Dutch Households", *Journal of Urban Economics* 49, 374-403.

[53] Inderst, R. (2008), "Loan Origination under Soft- and Hard-Information Lending", mimeo.

[54] Jaffee, D. and T. Russell (1976), "Imperfect Information, Uncertainty, and Credit Rationing", *Quarterly Journal of Economics* 90, 651–666.

[55] Karlan, D. and J. Zinman (2009), "Observing Unobservable: Identifying Information Asymmetries With a Consumer Credit Field Experiment", *Econometrica* 77, 1993–2008.

[56] Keys, B.J., T. Mukherjee, A. Seru, and V. Vig (2010), "Did Securitization Lead to Lax Screening? Evidence From Subprime Loans", *Quarterly Journal of Economics* 125, 307–362.

[57] Keys, B.J., T. Piskorski, A. Seru, and V. Vig (2013), "Mortgage Financing in the Housing Boom and Bust", in Housing and Financial Crisis edited by Edward Glaeser and Todd Sinai, NBER and University of Chicago Press.

[58] Kobayashi, M. and H. Osano (2012), "Nonrescourse Financing and Securitization", *Journal of Financial Intermediation* 21, 659-693.

[59] Krainer, J., and E. Laderman (2014), "Mortgage Loan Securitization and Relative Loan Performance", *Journal of Financial Services Research* 45, 39-66.

[60] Li, W. and F. Oswald (2014), "Recourse and Residential Mortgage Market: the Case of Nevada", mimeo.

[61] Makarov, I. and G. Plantin (2013), "Equilibrium Subprime Lending", *Journal of Finance* 68, 849-879.

[62] Mayer, C., A. Tchistyi, T. Piskorski (2013), "The Inefficiency of Refinancing: Why Prepayment Penalties are Good for Risky Borrowers", *Journal of Financial Economics* 107, 694-714.

[63] Mishkin, F.S. (2008), "Leveraged Losses: Lessons From The Mortgage Meltdown", Speech delivered at the US Monetary Policy Forum, New York, February 29.

[64] Miller, S. (2014), "Information and Default in Consumer Credit Markets: Evidence From a Natural Experiment", *Journal of Financial Intermediation*, in press.

[65] Muendler, M.-A. (2008), "Risk Neutral Investors Do Not Acquire Information", *Finance Research Letters* 5, 156-161.

[66] NAHB Research Center (2007), *Study of Subdivision Requirements as a Regulatory Barrier*, prepared for U.S. Department of Housing and Urban Development Office of Policy Department and Research.

[67] Ordonez, G. (2014), "Sustainable Shadow Banking", NBER Working Paper 19022.

[68] Tchistyi, A. and T. Piskorski (2011), "Stochastic House Appreciation and Optimal Mortgage Lending", *Review of Financial Studies* 24, 1407-1446.

[69] Piskorski, T., A. Seru, and V. Vig (2010), "Securitization and Distressed Loan Renegotiation: Evidence from the Subprime Mortgage Crisis", *Journal of Financial Economics* 97, 369-397.

[70] Poblete-Cazenave, R. and J.P. Torres-Martinez (2013), "Equilibrium with Limited-recourse Collateralized Loans", *Economic Theory* 53, 181-211.

[71] Purnanandam, A.K. (2011), "Originate-to-distribute Model and The Sub-prime Mortgage Crisis", *Review of Financial Studies* 24, 1881-1915.

[72] Rajan, U., A. Seru and V. Vig. (2010), "Statistical Default Models and Inentives", *American Economic Review, Papers and Proceedings*, 100, 506-510.

[73] Sato, Y. (2014), "Opacity in Financial Markets", *Review of Financial Studies,* forthcoming doi: 10.1093/rfs/hhu047

[74] Shin, H. S. (2009), "Securitization and Financial Stability." *Economic Journal* 119, 309-332.

[75] Stein, J.C. (2002), "Information Production and Capital Allocation: Decentralized Versus Hierarchical Firms," *Journal of Finance* 57, 1891-1921.

[76] Stiglitz, J. and A. Weiss, (1981), "Credit Rationing in Markets with Imperfect Information", *American Economic Review* 71, 393–410.