The Amplification Effects of Adverse Selection in Mortgage Credit Supply*

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Abstract

This paper studies how information frictions in the securitization market amplify the response of mortgage credit supply to house price shocks. We model securitization as an optimal contracting problem between investors and banks. Banks are better informed than investors about the quality of mortgages they originate, leading to adverse selection in securitization. Investors use the quantity sold as a screening device to induce banks to reveal truthful information. We find that adverse selection amplifies the response of a bank's mortgage credit to house price shocks. The degree of amplification is also a function of the technological differences in managing portfolios between banks and investors. The model is informative on how information frictions can induce large fluctuations in mortgage credit supply.

Keywords: Securitization, screening, banking, information frictions, liquidity.
JEL codes: D82, E51, G21, G28, R31

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1 Introduction

The mortgage securitization market in the United States has grown considerably since the 1970s, becoming the main source of mortgage credit for the housing market. However, this source of liquidity is volatile and can rapidly expand or collapse abruptly, as observed during the credit cycle of the 2000s. These are known characteristics of markets that feature Adverse Selection problems. Extensive empirical research has documented agency problems arising from information frictions in this market (Adelino et al. (2019), Keys et al. (2010), and Downing et al. (2008)). Specifically, that mortgage originators (sellers) are better informed about the quality of mortgages than investors (buyers). On the theoretical side, extensive literature shows that this agency problem can induce high volatility in asset trading markets.[1] Yet, we have less understanding of the role of information frictions in accounting for aggregate credit dynamics. Given the close connection between these markets, this paper addresses the following questions: how do information frictions in securitization affect credit supply to households? Does adverse selection amplify credit fluctuations? If so, what is the magnitude of this amplification?

To answer these questions, we develop a banking model with an endogenous securitization market to study banks' lending and loan securitization decisions jointly. The model features mortgage originators, called banks, and security investors interacting in a securitization market affected by information frictions about the quality of loans sold. Investors optimally screen mortgage originators' pools of loans, which endogenously leads to market segmentation like the one observed in the mortgage-backed security (MBS) market. Dynamics in securitization affect the supply of credit through a securitization liquidity channel. A quantitative application indicates that adverse selection in securitization can amplify the response of credit supply to house price shocks by a factor between 1.5 to 2.0. These results are consistent with other studies of the aggregate effects of adverse selection in asset markets (Krishnamurthy (2010), Kurlat (2013), Bigio (2015)) and with the magnitudes documented at the micro-level in the mortgage market (Calem et al. (2013)).

The model's characterization shows that a bank's lending volume is a nonlinear function of the volume of securitized mortgages. House price shocks affect the structure of securitization contracts through nonlinear price and quantity effects, which induce nonlinear dynamics in a bank's liquid funds. Consequently, mortgage lending fluctuates with the volume of mortgage securitization and experiences quick rises and falls. The fraction of securitized mortgages is an endogenous function of the spread in mortgage returns, the differences in portfolio management costs between originators

[1] Theoretical work starting with Akerlof (1970) and Bernanke and Gertler (1989) have studied how asymmetries of information about asset qualities have the potential to generate market breakdowns(Guerrieri and Shimer (2014), Kurlat (2013), and Chari et al. (2014), Bigio (2015)).

and investors, and the growth rate of house prices.[2]

Motivated by the empirical evidence, we assume that banks are better informed about the quality of mortgages than investors. Such information asymmetry creates incentives for banks to sell low-quality mortgages and retain high-quality ones. Investors are aware that such incentives are in place. Consequently, they design incentive-compatible contracts that induce banks to reveal their portfolio's underlying quality. These contracts offer higher prices for mortgage pools with higher retention rates. Retention rates work as a skin-in-the-game mechanism to separate high-quality mortgage sellers from low-quality ones. In equilibrium, no one is taken advantage of because investors learn the underlying quality of the mortgages backing MBSs. Nevertheless, the asymmetric-information equilibrium contracts are less efficient than those under the complete information because banks with high-quality mortgages cannot sell all of them to investors who can hold them more efficiently.

The model features securitization contracts with investors playing in pure and in mixed strategies. The pure strategies equilibrium contracts resemble some features of the *specified pool market* for MBSs in the U.S., where quality-specific pools of mortgages sell at differentiated prices, there is low liquidity, and originators face high loan-retention rates. In like manner, the mixed strategies equilibrium contracts capture some characteristics of the *to-be-announced (TBA) market*, where pools of mortgages of heterogeneous qualities sell at similar prices, the market is highly liquid, and originators face lower levels of loan retention. The model shows that banks trade off the benefits of liquidity and savings in management costs against the adverse selection discount associated with information frictions.

The main quantitative exercise simulates the model's aggregate stationary distribution of mortgage lending and studies how house price shocks affect aggregate mortgage lending through the securitization liquidity channel. We find that adverse selection amplifies the response of a bank's lending to house price shocks by a factor of 1.5 to 2. The model is informative on how information frictions and differences in portfolio management technology can induce large fluctuations in credit supply. This observation is relevant for designing macroprudential policies in the mortgage market that alleviate these vulnerabilities and keep a stable credit supply to households.

The paper is structured as follows: Section 2 presents the model, Section 3 the theoretical results, Section 4 presents the quantitative exercise, and Section 5 concludes. The rest of this section briefs on the related literature and institutional details of the U.S. mortgage market.

Related Literature. There is extensive literature studying the drivers of credit cycles in the housing market, especially the last episode that led to the Great Financial Crisis (GFC) of 2008.

[2] The theory presented does not aim to explain the 2000s boom-bust cycle but rather to show how information frictions may contribute to amplifying credit cycles. A more general approach would need to account for the feedback effects of house price appreciation on default rates.

This paper is related to quantitative models (Iacoviello (2005); Elenev et al. (2016); Justiniano et al. (2015, 2019)) who argue that credit supply forces—such as lending constraints that restrict a lender's available funds for mortgage credit—are quantitatively more important than credit demand forces in explaining fluctuations in mortgage debt and the housing market (Justiniano et al. (2015, 2019)). Our work provides a microeconomic foundation for such lending constraints by modeling the dynamics of securitization as a major source of liquidity for mortgage lenders.[3]

In this line, the paper fits within the "Credit Supply View" as coined by Mian and Sufi (2009, 2017), which puts mortgage credit supply at the center of the 2000s housing and household debt cycle in the U.S. The credit supply view states that higher credit availability leads to house price growth through expansive housing demand (Mian and Sufi (2009, 2017); Di Maggio and Kermani (2017); Favara and Imbs (2015); Adelino et al. (2016)).[4] Our paper contributes to understanding the feedback effects between credit and house price growth by providing a precise mechanism by which exogenous increases in house price growth lead to a credit expansion through the liquidity securitization channel (Loutskina (2011); Calem et al. (2013); Vickery and Wright (2013); Fuster and Vickery (2014)). The model provides theoretical support for the relevance of mortgage securitization dynamics as a key driver of credit supply (Levitin and Wachter (2012)). The model's mechanism predicts fluctuations of credit supply without taking a stance on whether credit expands (or contracts) more towards prime (Albanesi et al. (2022)) or subprime borrowers (Mian and Sufi (2009, 2017)).[5] Such a general approach is supported by Adelino et al. (2016); Foote et al. (2020) and Conklin et al. (2022) who document that mortgage debt expanded homogeneously across the income distribution of borrowers during the 2000s housing debt cycle, challenging the initial narrative about a credit expansion towards subprime borrowers only.

Our work also shows how information frictions about mortgage quality play a relevant role in determining liquidity in the securitization market. Information frictions are motivated by a vast body of literature that documents the presence and relevance of private information in the mortgage issuance and securitization chain. Downing et al. (2008), Keys et al. (2010), Calem et al.

[3]In the model, lenders trade off efficiency gains versus information costs. Securitization can loosen lending constraints and expand mortgage credit. The setup captures some of the advantages of securitization in financial intermediation: lower funding costs; the creation of safe assets by pooling risk; and gains from financial specialization; see Gorton and Metrick (2013) for an in-depth analysis.

[4]Among the main documented driving factors of credit supply are: the development of the securitization market (Levitin and Wachter (2012)), regulatory changes in the banking system (Favara and Imbs (2015)), and changes in originators' screening practices (Griffin and Maturana (2016); Keys et al. (2010)) and lending standards (Choi and Kim (2021)). Kaplan et al. (2020) and Cheng et al. (2014) have also shown that agents' expectations about house price dynamics played an important role in driving mortgage credit supply.

[5]Such analysis would require modeling credit demand as arising from heterogeneous borrowers and possibly segmented markets which are beyond the scope of this paper.

(2011), Park (2016), and Adelino et al. (2019) consistently find that mortgage originators retain mortgages that are, on average, of better quality than mortgages sold and securitized in the agency and non-agency MBS segments, thereby generating an adverse selection problem.[6] On theoretical grounds, this paper is closely related to the literature that studies the effects of adverse selection in asset market trading—a tradition that dates back to Akerlof (1970). Cutts et al. (2001) study the role of securitization in the evolution of financial markets where agents trade off efficiency costs against adverse selection due to asymmetric information. Cutts and Van Order (2005) study the securitization market structure—prime and subprime—through the lens of asymmetric information models where investors design incentive-compatible contracts for loan sellers to reveal information. Chari et al. (2014) show that adverse selection and traders' reputational concerns can play an important role in accounting for sharp fluctuations in the volume of securities traded in asset markets. We build upon Chari et al. (2014) static framework, extend it to account for a bank's mortgage origination decision, and use it to study the effects of house price shocks on aggregate credit supply. Our model also shares elements present in Eisfeldt (2004); Bigio (2015); Vanasco (2017); Caramp (2019), and Asriyan (2020). These papers show that adverse selection can generate large fluctuations in the volume of traded assets by amplifying the effects of exogenous shocks in the economy.

Motivating Empirical Observations. The mortgage finance system in the U.S. has experienced significant changes since the development of the securitization market of mortgages with the creation of the Government Sponsored Enterprises (GSEs) in the 1970s.[7] Their main objective was to fund mortgages through a combination of deposits and capital markets instead of deposits only. To do so, GSEs issued and guaranteed MBSs—in what is known as the agency segment—effectively shielding market investors from borrowers' credit risk. Later, in the 1980s, the private MBS segment took off when private securitizers started issuing private-labeled securities (PLS), which carried none or minimal credit guarantees.[8] The remarkable change in mortgage funding is shown in Figure 12 (see the Appendix); from 1985 onwards, non-depository institutions have held more than 50% of

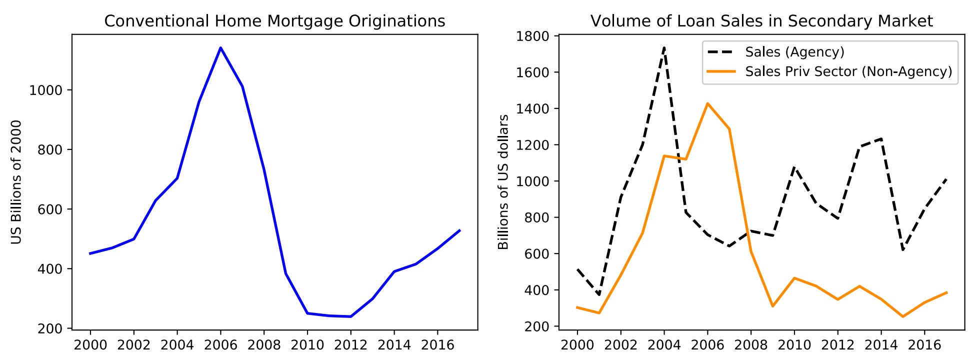
[6] Sellers usually make available to buyers vast data describing many characteristics about loans and borrowers—such as credit scores, loan-to-value ratios, income, owner-occupancy status, among others. Despite this, there are several margins along which an originator may still have superior information than MBS's investors. To name a few: low levels of documentation, the incapacity and the cost of processing soft information, and data misrepresentation by borrowers of which originators may not be aware.

[7] In 1968, the Federal National Mortgage Association (FNMA) was partitioned into a private corporation, Fannie Mae, and a publicly owned institution, Ginnie Mae. This event marks the start of the pass-through securitization era (1970-1984) as defined by Campbell and Hercowitz (2005).

[8] Due to their government-sponsored nature, investors perceived GSEs credit guarantees as having the implicit backing of the U.S. government. In September 2008, these views became explicit when the Federal Finance Housing Administration (FHFA) placed Freddie Mac and Ginnie Mae in conservatorship.

all residential mortgages as assets in their portfolios. This new mortgage finance system is known as the originate-to-distribute model as opposed to the traditional originate-to-hold model of the 1960s.[9] We represent these non-depository institutions in our model as investors. Most of these investors are financial institutions that manage large pools of savings, such as pension funds, mutual funds, insurance companies, and sponsors of structured products.

The securitization market is characterized by fast growth and high volatility. Mortgage securitization grew from 207 US$ billions in 1970 to 2.97 US trillions in 2016, and more than half of this growth corresponds to the housing boom period.[10] From 2000 to 2007 the annual growth rate of total MBS issuance averaged 12%. However, from 2007 to 2011, the securitization market shrank considerably, with growth averaging -29% per year. Figure 1 shows the flows of mortgage originations and mortgage securitized since 2000. Both variables follow each other closely and experience sharp fluctuations. These fluctuations are in line with fluctuations in the value of houses that serve as collateral for mortgages and with the observed path for delinquency rates in residential mortgages. The theoretical model in Section 2 provides a mechanism—microfounded in information frictions— capable of replicating high volatility episodes in the aggregate volumes of mortgage originations and MBS issuance in response to house price shocks dynamics.



Source: Home Mortgage Disclosure Act (HMDA) database. Figures correspond to National Aggregates. Conventional Home Mortgage Originations corresponds to mortgages on 1-to-4 family dwellings only. Sales (Agency) corresponds to Government Sponsored Enterprises (GSE's). Sales Private Sector (Non-Agency) corresponds to sales to any other commercial institution that purchases mortgages and it is not a GSE.

Figure 1: Volume of Mortgage Originations and Mortgage Sales

A relevant institutional feature for our work is that mortgage pools for MBS trade in two segmented submarkets. One of them is a futures market known as the 'to-be-announced' (TBA)

[9] During the traditional banking system (1952-1969), banks funded mortgages mostly with deposits and kept them in their portfolio until maturity.

[10] See Shimer (2014) for detailed documentation of these observations using Securities Industry and Financial Markets Association (SIFMA) data.

market. In the TBA market, the seller of MBSs agrees upon price and delivery date when trading but does not specify the identity of securities.[11] Pools of mortgages of heterogeneous qualities sell at similar prices, the market is highly liquid, and originators face lower levels of loan retention. The other submarket is the 'specified-pool' (SP) market, where sellers agree upon specific characteristics of the mortgages backing MBSs at the trading date. In this segment, pools of different qualities trade at different prices, the market enjoys low liquidity and mortgage originators feature high retention rates. The TBA market trades mostly agency MBSs backed by conforming mortgage pools, i.e., loans conforming to GSE's standards (loan limits, credit scores, among others). In contrast, the SP market trades mostly non-agency MBSs without government credit guarantees. These securities are usually backed by mortgage pools with less standard features, like jumbo mortgages (loans exceeding the GSE's conforming limits).[12] The model presented in the following section takes a general perspective and abstracts from modeling the agency and non-agency segmentation, which arises from specific GSE's policies. Instead, the model shows how market segmentation arises endogenously from an optimal contracting problem when investors screen the bank's portfolio quality. Also, while our model is silent about the sources of loan quality on a bank's portfolio, it highlights the economic forces of loan heterogeneity in determining equilibrium outcomes in the securitization market and its feedback on credit supply.[13]

[11] Participants agree upon general parameters for the underlying pool of mortgages; coupon rate, bonds face value, originator, and delivery date. The details about TBA trading are outlined in the "good delivery guidelines" developed by SIFMA; see also Vickery and Wright (2013).

[12] Investors are aware of the scope for private information when dealing in these markets, and various mechanism have been implemented to ameliorate the impact of information asymmetries. For instance, warranties to MBS buyers impose that sellers repurchase or replace loans identified as defective. Credit ratings for MBSs intend to provide an independent assessment of the asset's quality. Also, tranching and repurchase agreements intend to shield MBS investors against unexpected defaults. These mechanisms show that information asymmetries are a significant concern in these markets, Shimer (2014) performs a comprehensive review of empirical studies documenting major shortcomings of the above mentioned mechanisms in the mortgage market.

[13] We assume loan quality on a bank's portfolio follows an exogenous process. Modeling loan quality determination (bank's screening loans) will add an extra layer of complexity to the model without changing our main conclusions. Vanasco (2017) explores the interactions between asset quality determination and market liquidity in secondary markets. The author shows that screening improves asset quality but leads to asymmetric information, leading to adverse selection.

2 The Model

2.1 Environment

Time is discrete and has an infinite horizon, v denotes a variable at the current period, and v' denotes variables at the next period.[14] There is a continuum of mass one of two types of agents: banks and investors. Both are risk-neutral.

Banks

Each bank can be thought of as a financial firm that, at every period, has access to deposits d at cost R^d. A bank uses deposits to originate mortgages. A mortgage is a debt contract between the bank and a non-modeled borrower. It is assumed that there is an exogenous household demand that takes on any amount of mortgages originated. The mortgage contract has two parts: $(R^l l, \phi p_{-1} h_{-1})$: l represents the dollar amount lent to a borrower the previous period, which matures today.[15] Then, $R^l l$ is the gross dollar amount owed by the borrower to the bank. It is assumed that at the time of issuance, the mortgage amount is restricted to a fraction ϕ of the market value of the collateral: $l = \phi p_{-1} h_{-1}$, where ϕ denotes the loan-to-value ratio. Hence, the second term represents the fraction of the pledged housing collateral a bank can claim when the mortgage defaults. Both the amount of collateral, h_{-1}, and its price, p_{-1}, are taken as given by banks.

There are three prices of interest to the bank: the gross interest rate it pays on deposits, R^d, the lending rate it charges on mortgages it originates, R^l, and the change in house prices between origination p_{-1} and maturity p, which we define as $\pi = \frac{p}{p_{-1}}$. For simplicity, it is assumed that these prices, $\{R^d, R^l, \pi\}$, are exogenous and deterministic over time.[16]

Partial Default. There is partial default at maturity, meaning every period, only a fraction θ of the amount owed gets repaid, and the remaining fraction $1-\theta$ is recovered by selling the foreclosed housing collateral. The repayment rate θ is stochastic and governed by an exogenous process, it is a source of idiosyncratic risk to a bank. We assume $\theta \sim i.i.d. \in \{\theta_h, \theta_l\}$, with probabilities $\mu = \Pr(\theta = \theta_h)$, and $1-\mu = \Pr(\theta = \theta_l)$, and that $1 > \theta_h > \theta_l > 0$. Let y denote the gross cash payout of a mortgage:

$$y = \theta R^l l + (1-\theta)\zeta\phi p h_{-1}, \tag{1}$$

[14] All variables within the period respect this notation.

[15] We can think each bank issues one mortgage, which amounts to l, or interpret l as a bank's portfolio size.

[16] The focus of this paper is on the interactions between banks and security investors. This assumption keeps movements in the mortgage rate isolated from the dynamics of the deposit rate and the markup a bank sets on a particular mortgage. The quantitative section studies the effect of house price fluctuations on credit supply.

where $\zeta \in [0,1)$ represents the recovery value of housing at foreclosure.[17] From a bank's perspective, the payoff of its portfolio has two components: the mortgage payments and the recovery value from the foreclosed housing collateral. Then, the gross cash payout is:

$$\begin{aligned} y &= l\left[\frac{\theta R^l l + (1-\theta)\zeta\phi p h_{-1}}{l}\right] \\ &= l\left[\theta R^l + (1-\theta)\zeta\pi\right] \\ &= lM(\theta), \end{aligned} \tag{2}$$

where $M(\theta) \equiv M(\theta; R^l, \pi)$ is the net rate of return of a mortgage which is a function of the stochastic repayment rate θ, the lending interest rate R^l, and the growth rate of housing prices $\pi = \frac{p}{p_{-1}}$. The market value of the collateral is public information, every agent observes π. The repayment rate θ is a bank's private information. Given that we have assumed the repayment rate takes on two values only, high and low, it effectively translates into the mortgage's return rate being $M(\theta) \in \{M(\theta_h),\ M(\theta_l)\}$. Banks with high-return mortgages are referred to as high-type banks, and banks with low-return mortgages as low-type banks.[18]

Technology. A bank faces three types of costs that capture the main features of the mortgage lending industry.

$$o(l) = \nu l^2 \tag{3}$$

$$c \in [0,1) \tag{4}$$

$$\kappa(div) = \kappa(div - \bar{div})^2 \tag{5}$$

First, a mortgage origination cost (3) is represented by a convex and increasing function in the amount of the mortgage. The bank pays this cost as part of the mortgage origination process. It captures potential borrowers' administrative and screening costs, which grow with the client base. Second, a bank faces a portfolio management cost (4). This cost is paid after the mortgage has matured and yielded a return, and it represents non-interest costs faced by banks when managing a portfolio. This portfolio management cost can be avoided if the bank sells its mortgage to a third party. Additionally, each bank faces a dividends adjustment cost (5). This cost captures the tendency of banks to smooth dividend payments to shareholders.[19]

[17] Bank incurs in costs when selling the foreclosed housing collateral, moreover, foreclosed houses may sell at a discount because financial institutions usually want to sell them quickly, see Campbell et al. (2011).

[18] The function $M(\cdot)$ is indexed on θ to highlight the nature of the differences in returns due to differences in repayment rates, and because banks' private information about θ plays a central role in determining the equilibrium contracts in the securitization market.

[19] Banks are assumed risk-neutral; hence a quadratic adjustment cost on dividends introduces concavity on its objective function, guaranteeing the recursive problem of the bank is well defined. Additionally, dividends are restricted to be positive.

2.1.1 Investors

There is a unit mass of risk-neutral investors. Investors cannot issue mortgages or take deposits, but they have a comparative advantage in managing mortgages; their management cost c is normalized to zero. This assumption captures the technological differences between originators and investors in performing liquidity transformation, bearing prepayment risk, and (for the private label MBS) credit risk. Such technological differences motivate trading between them. Investors know θ's stochastic process and understand the payoff structure of mortgages, given by (2). However, they do not observe θ, and hence they are uncertain about the mortgage's net return $M(\theta)$.

Securitization market. We model a securitization market where banks can sell a pool of mortgages, partially or completely, to deep-pocket investors. Banks are offered a menu of contracts by investors. A contract is an equilibrium object that specifies a fraction $x_i \in [0, 1]$ of a bank's portfolio to be purchased and an associated per-unit loan price q_i intended for each bank type $i \in \{h, l\}$. Since at any point in time, there can be two types of banks selling high or low-return mortgages, a contract z is a quadruple (x_h, q_h, x_l, q_l) that contains two pairs of offers, (x_i, q_i).

2.2 Bank's Decisions

The timeline is as follows: a bank starts each period with a stock of mortgages and a stock of deposits; $\{l, d\}$ are a bank's endogenous state variables at the start of the period. The only exogenous state variable is the realization of the repayment rate θ. A period has two stages; a securitization stage and an origination stage. At the securitization stage, a bank privately observes its mortgage repayment rate and has the option to sell its portfolio, partially or entirely. At the origination stage, a bank decides on the volume of new originations based on the securitization cash proceeds and on the payments from maturing mortgages. Mortgages not sold in the securitization stage mature at the beginning of the origination stage. Figure 2 shows the timeline of the model.

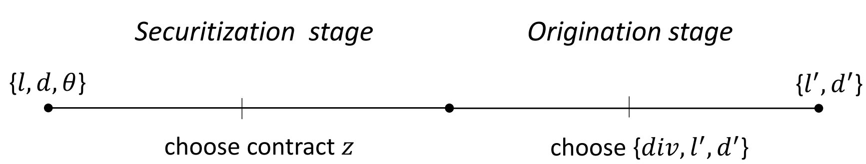


Figure 2: Timeline of the Model

Securitization stage. A bank meets with a potential investor in the securitization market. The investor understands that a bank has incentives to sell low-quality loans first and retain high-quality ones; hence, she offers an incentive-compatible contract z to induce the bank to truthfully reveal the quality of mortgages sold. Meaning that if a bank accepts a contract, it chooses its intended offer. The problem of a bank type θ in the securitization stage, given states $\{l, d; \theta\}$ is to choose a contract z that maximizes the intra-period linear payoff function:

$$\max_{(x,t)} \quad l \cdot [q_i x_i + (1 - x_i)(M(\theta) - c)] \tag{6}$$
$$z = (x_h, q_h, x_l, q_l) \in \mathbb{Z},$$

where the first term, $lq_i x_i$, is the payment a bank obtains from selling fraction x_i of its portfolio. The second term, $l(1 - x_i)(M(\theta) - c)$, corresponds to a bank's net return from the retained portfolio.[20]

Origination Stage. After choosing a contract $z \in \mathbb{Z}$ in the securitization market, a bank type θ enters the origination stage with stock of mortgages, $l(1 - x_i)$, and liabilities, $R^d d - lq_i x_i$. Let $\tilde{y}$ be the net cash holdings (liquid funds) available to a bank type θ after securitization:

$$\tilde{y}(l, d; \theta, z) \quad = \quad l(1 - x_i)(M(\theta) - c) + lq_i x_i - R^d d, \tag{7}$$

then, taking prices $\{R^l, R^d, \pi\}$ as given, the Recursive Problem of a bank type θ in the origination stage is:

$$V(l, d; \theta) \quad = \quad \max_{\{l', d', div\}} \; div + \beta \mathbb{E}_{\theta'} V(l', d'; \theta') \tag{8}$$
$$l' + o(l') + div + \kappa(div) \quad = \quad \tilde{y}(l, d; \theta, z) + d' \tag{9}$$
$$\tilde{y}(l, d; \theta, z) - div - \kappa(div) \quad \geq \quad b \tag{10}$$
$$\theta' \sim i.i.d \in \{\theta_h, \theta_l\}, \qquad l' \geq 0, \; d' \geq 0, \; div \geq 0,$$

where β is the bank's discount rate. A bank maximizes the value of dividends by choosing new mortgage originations l', deposits for the next period d', and dividends payouts div subject to its flow of funds constraint (9), and to a capital requirement constraint (10).

The flow of funds constraint represents all cash-relevant transactions. A bank's uses of funds are shown on the left-hand side; a bank allocates its resources to new mortgages l', payment of origination costs $o(l')$, and distributes dividends to shareholders, div, net of adjustment costs $\kappa(div)$. A bank's sources of funds show on the right-hand side; net cash proceeds from its operations in the securitization stage plus new deposits d'. The capital requirement constraint (10) restricts net cash holdings after dividends payout to be above a level $b \in R^+$, which is effectively a restriction on the amount of lending a bank can make.

[20] In this setup, given that repayment rates are i.i.d. across time, investors only care about a bank's current payoff from selling mortgages when designing the incentive-compatible contracts. This assumption delivers persistent adverse selection. Chari et al. (2014) shows that adverse selection can also persist over time when investors take into account the bank's reputational concerns.

2.3 Stationary Equilibrium

An individual bank's recursive problem is characterized by the states vector $s = (l, d, \theta)$. The aggregate state of the economy is the distribution of banks across states $\lambda(l, d, \theta)$. Here, We define the appropriate mathematical structure for λ to be a probability measure.

Let $D \equiv [\underline{d},\ \overline{d}]$ and let $L \equiv [\underline{l},\ \bar{l}]$ be the set of admissible values for deposits and mortgage originations respectively.[21] The state space is defined by $S = L \times D \times \{\theta_h, \theta_l\}$ with Borel σ algebra $\mathcal{B}$ and typical subset $\mathcal{S} = \mathcal{L} \times \mathcal{D} \times \theta$. Then, the space $(S, \mathcal{S})$ is a measurable space, and for any set $\mathcal{S} \in \mathcal{B}$, $\lambda(\mathcal{S})$ is the measure of banks in the set $\mathcal{S}$. Finally, let Λ denote the set of all probability measures over $(S, \mathcal{B})$. Next, define $Q(s, \mathcal{S})$ as the probability that a bank with current state vector $s = (l, d, \theta)$ transits to the set $\mathcal{S} = \mathcal{L} \times \mathcal{D} \times \theta$ next period, formally: $Q : S \times \mathcal{B} \rightarrow [0, 1]$, and

$$Q(s, \mathcal{S}) = \sum_{\theta' \in \Theta} \mathcal{I}\{l'(l, d, \theta) \times d'(l, d, \theta) \in \mathcal{L} \times \mathcal{D}\} \cdot \mu(\theta', \theta) \tag{11}$$

where $\mathcal{I}$ is the indicator function, $l'(l, d, \theta)$ is the optimal mortgage origination policy and $\mu(\theta', \theta)$ is the transition probability function.[22] Then Q is the transition function and the associated operator Γ defines the law of motion of the transition function,

$$\lambda'(\mathcal{S}) = \Gamma(\lambda) = \int_S Q(s, \mathcal{S}) d\lambda(s) \tag{12}$$

which indicates the measure of banks that move to the set $\mathcal{S}$ from across the entire state space S, from the current to the next period.

Definition of Stationary Equilibrium. A Stationary Recursive Equilibrium in this environment is a value function $V : S \rightarrow \mathbb{R}_+$; policy functions for the bank $l' : S \rightarrow L$, and $d' : S \rightarrow D$, a stationary measure $\lambda^* \in \Lambda$, a vector of prices $\{R^d, R^l, \pi\}$, and an equilibrium contract z^* from the securitization market, such that:

1. given prices $\{R^d, R^l, \pi\}$, and an equilibrium contract z^* from the securitization market, policy functions $\{l', d'\}$ solve the bank's problem in (8) and V is the associated value function.

2. for all $\mathcal{S} \in \mathcal{B}$, the invariant probability measure λ^* satisfies:

$$\lambda^*(\mathcal{S}) = \int_{L \times D \times \{\theta_h, \theta_l\}} Q(s, \mathcal{S}) d\lambda^*(s), \tag{13}$$

   where Q is the transition function defined in (11).

[21] Bounds $\underline{d}$ and $\overline{d}$ define the lower and upper bounds for deposits. $\underline{l}$ is derived from (10) after setting values for $b \in R^+$ and $d = \underline{d}$, and $\bar{l}$ is the maximum amount of lending allowed in the economy.

[22] Thanks to the assumption of $\theta \sim i.i.d.$ the transition probability function $\mu(\theta', \theta)$ is the vector $(\mu, 1 - \mu)$.

3 Characterization

There are two main parts to the model characterization. First, we characterize a bank's lending decisions in the origination stage. Then, we characterize a bank's mortgage sales decisions in the securitization stage.

3.1 Origination Stage

The origination problem is characterized by backward induction. Origination decisions are a function of the equilibrium contract outcomes from the securitization stage. We can rewrite a bank's flow of funds constraint as:

$$l' + \nu l'^2 + div + \kappa(div - \bar{div})^2 = \tilde{y}(l, d; \theta, z) + d',$$

solving for dividends obtains:

$$div \;=\; a_0 + \kappa^{-1/2}\left[a_1 + \tilde{y}(l, d; \theta, z) + d' - l' - \nu l'^2\right]^{1/2},$$

where $a_0 = \bar{div} - \frac{1}{2\kappa}$, and $a_1 = \frac{1}{4\kappa} - \bar{div}$. Which indicates that dividend payouts are an increasing and concave function of a bank's cash holdings and a decreasing function in new originations. A bank's problem in the origination stage can be re-expressed as:

$$\begin{aligned} V(l, d; \theta) &= \max_{\{l', d', div\}} a_0 + \kappa^{-1/2}\left[a_1 + \tilde{y}(l, d; \theta, z) + d' - l' - \nu l'^2\right]^{1/2} + \beta \mathbb{E}_{\theta'} V(l', d'; \theta') \\ b &\leq \tilde{y}(l, d; \theta, z) - div - \kappa(div) \\ & \theta' \sim i.i.d \in \{\theta_h, \theta_l\}, \quad l' \geq 0,\ d' \geq 0,\ div \geq 0 \end{aligned}$$

Proposition 1. *A high-type bank originates more mortgages than a low-type bank.*
This result is derived from the liquidity value of drawing a high repayment rate on a bank's portfolio; the liquidity associated with it is higher than that of a lower repayment rate.

Proposition 2. *Mortgage securitization increases a bank's mortgage credit supply.*
By trading in the securitization market, a bank saves resources in management costs. And transform the current mortgage portfolio into liquid funds. These extra resources are then channeled into a higher credit supply. A securitization market allows for a more efficient allocation of resources. This endogenous connection between securitization and the credit markets is known as the securitization liquidity channel (Loutskina (2011); Calem et al. (2013); Vickery and Wright (2013)). Section C in the appendix illustrates the stationary distribution of mortgage credit supply in economies with and without access to a securitization market.

3.2 Securitization Stage

The characterization first focuses on the contract that an individual investor offers to a bank and then extends the analysis to aggregate outcomes. Investors engage in Bertrand-style price competition, simultaneously offering contracts to banks to screen their portfolio types. As mentioned before, a contract z is a quadruple (x_h, q_h, x_l, q_l) that contains two pairs of offers specifying the fraction and the price intended for each type of bank. Since a bank can freely choose which offer to accept, We restrict attention to incentive-compatible contracts, meaning that at any period, a bank's payoffs from contracts must satisfy:

$$q_h x_h + (1 - x_h)(M_h - c) \geq q_l x_l + (1 - x_l)(M_h - c), \tag{14}$$

$$q_l x_l + (1 - x_l)(M_l - c) \geq q_h x_h + (1 - x_h)(M_l - c), \tag{15}$$

where $M_h \equiv M(\theta_h)$, and $M_l \equiv M(\theta_l)$ to avoid notation cluttering. Rothschild and Stiglitz (1976) have shown that in this type of adverse selection model, equilibria under pure strategies might not exist. However, mixed strategy equilibria have been proven to exist (Dasgupta and Maskin (1986); Rosenthal and Weiss (1984)). As in Rosenthal and Weiss (1984) and Chari et al. (2014), we allow investors to play in mixed strategies and banks in pure strategies and follow their refinement strategy. Define $\mathbb{Z}$ as the set of incentive-compatible contracts. A strategy for an investor $j = 1, 2$ is a distribution function $F_j(z)$ over $\mathbb{Z}$, as we assume investors competing in prices a la Bertrand, it suffices to restrict the number of investors to two. A strategy for the bank is an action $\delta_j(z_1, z_2; M) \in [0, 1]$ for $j = 1, 2$, where δ_j represents the probability that contract from investor j is accepted. Given the mixed strategy by the other investor, F_{-j}, and the strategy of the bank, δ, the profits earned by an investor offering contract z are given by:

$$\Pi = \int \left[\mu\delta_j(z, z_{-j}; M_h)\,(M_h x_h - q_h x_h) + (1 - \mu)\delta_j(z, z_{-j}; M_l)\,(M_l x_l - q_l x_l)\right] dF_{-j}(z_{-j}) \tag{16}$$

Equilibrium in the securitization market. An equilibrium consists of strategies for investors $F_j(z)$ for $j = 1, 2$, strategies for banks $\delta_j(z_1, z_2; M) \in [0, 1]$ for $j = 1, 2$, such that:

1. for all z_j in the support of F_j no other contract $\hat{z}_j$ earns strictly higher profits,

2. bank's strategy specifies that its choice maximizes its payoff.

We further refine the equilibrium, requiring it to be monotone in the sense that a low-quality bank prefers a contract $\hat{z}$ to a z if and only if a high-quality bank also prefers $\hat{z}$ to a z. Hence in any monotone equilibrium $\delta_j(z, z_{-j}; M_h) = 1$ if and only if $\delta_j(z, z_{-j}; M_l) = 1$. As it is standard, we assume tie-breaking rules in which if contracts offered by both investors give the same payoff to a bank of a given quality, the bank accepts either offer with probability 1/2. In equilibrium, a bank always chooses some offer as even (0,0,0,0) is a feasible contract. Additionally, any *monotone equilibrium outcome* satisfies four key properties: i) for all z in the support of F, the low-type bank sells all its newly originated mortgages, $x_l = 1$; ii) the incentive constraint (15) binds for a low-quality bank; iii) investors make zero profits (16) for every contract z in the support of F; and iv) offers to low-types do not yield positive profits: $q_l x_l \geq M_l x_l$.

3.3 Equilibrium Contracts

The main result of this section is the derivation of specific functional forms for mortgage securitization contracts as a function of the probability of trading with a high-type bank, μ.

Proposition 3. *Contracts in the securitization market correspond to a separating equilibrium. If $\mu \leq \tilde{\mu}$, the equilibrium outcome has banks and investors playing pure strategies under the contract:*

$$\begin{aligned} z &= (x_h, q_h, x_l, q_l)\,. \\ &= \left(\frac{1}{1+\rho}, M_h, 1, M_l\right), \end{aligned} \tag{17}$$

where $\rho = \frac{1}{c}(M_h - M_l)$ is defined as the adverse selection discount. If $\mu \geq \tilde{\mu}$, then the equilibrium outcome has mixed strategies by investors and the distribution of contracts is given by

$$F(q_l) = \left(\frac{(q_l - M_l)}{\mu(M_h - M_l)}\right)^{\frac{\mu}{(1-\mu)\rho} - 1} \tag{18}$$

with support $[M_l, \hat{p}(\mu)]$. Hence, given any payment $q_l \in [M_l, \hat{p}(\mu)]$, we obtain a contract $z(q_l;\mu)$. The threshold is defined by $\tilde{\mu} = \frac{\rho}{1+\rho}$. And $\hat{p}(\mu)$ is the pooling price obtained from accepting a zero-payoff pooling contract: $\hat{p}(\mu) = \mu M_h + (1-\mu)M_l$.

Proposition 3 states that the model always has a *separating equilibrium*. An equilibrium is *separating* if the offers accepted by low and high-quality banks are different. In terms of players' strategies, banks and investors, there are two possible equilibrium outcomes; the pure strategies equilibrium outcome (PSEO) and the mixed strategies equilibrium outcome (MSEO).[23] Hence, there are two regions defining two types of equilibrium contracts for the space of values of $\mu \in [0, 1]$. Figure 3 shows a diagram summarizing this result.

[23] An equilibrium outcome refers to a contract that is the result of trade between banks and investors, each playing their set of strategies. The PSEO contract is known as the least-cost separating outcome (Spence (1973); Rothschild and Stiglitz (1976)). The proof of Proposition 3 is provided in Appendix A.3.

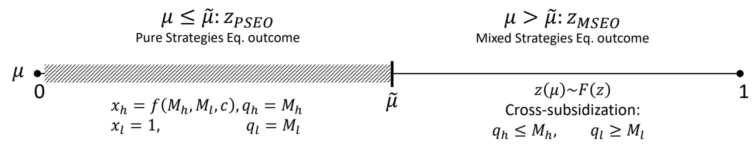


Figure 3: Equilibrium outcome regions

Separating Equilibrium with Pure Strategies. In this case, investors and banks play pure strategies. Rothschild and Stiglitz (1976) show that any pure strategy equilibrium must have investors breaking even on each type of bank i.e., payments for each type must equate its corresponding returns: $q_l = M_l$ and $q_h = M_h$. Substituting q_l and q_h in the binding incentive constraint for low-type bank (15) yields the fraction of loans securitized by the high-quality bank

$$x_h = \frac{1}{1 + \frac{M_h - M_l}{c}} = \frac{1}{1+\rho}, \tag{19}$$

which leads to (17). In this environment, the intensity of the adverse selection problem is measurable and maps into an endogenous *adverse selection discount* ρ defined in Proposition 3. Its size depends on the size of frictions faced by banks, the portfolio management cost, and the spread of the mortgage's payoff. Which further depends on the underlying risk of a bank's portfolio and the performance of the collateral based on house price dynamics.

Next, we determine the range of values of μ for which we can obtain the above pure strategy equilibrium outcome. This range is expressed in terms of a threshold, $\tilde{\mu}$, which defines the maximum value of μ for which the model yields a pure strategy equilibrium outcome. To determine this threshold, we compare the payoffs of the high-quality bank under the PSEO against the payoffs it would receive from accepting a zero-payoff full trade pooling contract, in which $x_h = x_l = 1$ and $q_h = q_l = \hat{p}(\mu)$, where $\hat{p}(\mu)$ is derived from the zero profit condition for investors:

$$\hat{p}(\mu) = \mu M_h + (1-\mu) M_l. \tag{20}$$

The idea is to associate a bank's payoffs to μ. Thus, we look for the value of μ that leaves the high-quality bank indifferent between choosing the PSEO contract or the full-trade pooling contract.[24] Straightforward algebra obtains:

$$\tilde{\mu} = \frac{\rho}{1+\rho}. \tag{21}$$

Separating Equilibrium with Mixed Strategies. Above $\tilde{\mu}$, the high-quality bank strictly prefers a zero-profit pooling contract to the PSEO. If offered a PSEO contract, investors have

[24] The threshold is derived by equating the payoffs a high-type bank obtains from the PSEO offer to the payoff it would obtain under the pooling contract.

incentives to deviate to an allocation near the pooling outcome since such deviation would be profitable. However, it is possible to construct mixed strategies that preclude deviations, so any deviation attracts low-quality banks with disproportionate probability. In Appendix A.3, we show that there is a continuum of contracts satisfying such an approach, known in the mechanism design literature as the *best deviation approach* (Rosenthal and Weiss (1984); Chari et al. (2014)). Since investors are allowed to play in mixed strategies, i.e., assign probabilities to the continuum of offers to the high and low-type banks that define the above contracts, the MSEO is characterized by a cumulative distribution function $F(q_l)$ given by (18) over the support $[M_l, \hat{p}(\mu)]$ of possible q_l prices. A relevant feature of this type of contract is the cross-subsidization between bank types. An investor's offers to the low-type bank are such that $q_l \geq M_l$, and payment to the high-type bank are such that $q_h \leq M_h$ which imply investors make zero profits in expectation. Intuitively, $\mu \geq \tilde{\mu}$ indicate that the probability of meeting a high-type bank is relatively high; hence, it becomes more costly to separate low from high-type banks, and it is necessary to provide a higher payment to the low-type bank to induce her to choose the offer intended for her.

Contracts in (17) and (18) show that investors understand that banks have incentives to securitize low-quality mortgages and retain high-quality ones. Consequently, they design incentive-compatible contracts that pay higher prices for mortgage pools with higher retention requirements—as a signal of quality. Contracts let the low-type bank securitize the entire portfolio at lower prices than those offered to high-type banks. Nevertheless, this asymmetric-information equilibrium is less efficient than the complete-information equilibrium, because the originators of high-quality mortgages cannot sell all of them to investors who can hold them more efficiently.

These contracts also capture key dynamics observed in the MBS market; when house prices rise, the spread between the returns of high and low-type mortgage pools falls. Investors become less concerned about information asymmetries on mortgage qualities and increase their purchases of high-type pools. Also, the pure strategies equilibrium contracts resemble some features of the *specified pool market* for MBSs in the U.S., where quality-specific pools of mortgages sell at differentiated prices, there is low liquidity, and originators face high loan-retention rates. In like manner, the mixed strategies equilibrium contracts capture some characteristics of the *to-be-announced (TBA) market*, where pools of mortgages of heterogeneous qualities sell at similar prices, the market is highly liquid, and originators face lower levels of loan retention. The model shows that banks trade off the benefits of liquidity and savings in management costs against the adverse selection discount associated with information frictions.[25]

[25] Fusari et al. (2022) document how mortgage heterogeneity affects prices and volumes in both TBA and SP markets. Garcia (2022) develops a general equilibrium model with TBA securitization to study the effects of information frictions and the role of GSE's policy in smoothing credit cycles.

Contracts under Complete Information. Absent information asymmetries, the equilibrium contract between banks and investors is trivial. Investors can easily identify between high-and low-type mortgage pools. Thus, they make type-specific offers to buy a bank's entire portfolio $x_h = x_l = 1$, paying exactly their return $q_h = M_h$, and $q_l = M_l$, leading to:

$$z_{CI} = (1, M_h, 1, M_l). \tag{22}$$

Such contract is attractive for banks since, by selling their mortgages, they can avoid the portfolio management cost, and it respects the investor's zero profit condition (16).

Proposition 4. *Mortgage credit volumes are lower in the asymmetric information economy than in the complete information economy but larger than in the absence of securitization.*

The complete information economy is also useful to understand the possibilities of credit expansion in this class of models; access to a securitization market will lead to an expansion of credit (Proposition 2). However, the magnitude of credit expansion is a function of the severity of asymmetries of information affecting the securitization market. Proposition 4 summarizes this insight. See also Section C for a numerical illustration of the stationary distribution of credit between economies with different securitization market structures.

Aggregate Securitization and Credit Volumes. Given the equilibrium contracts defined in Proposition 3 and policy functions that solve a bank's recursive problem (8) we can define the aggregate volume of securitized mortgages T and the aggregate volume of credit L as:

$$\begin{aligned} T &= \mu x_h + (1-\mu)x_l, \qquad (23) \\ L &= \int l_{\theta_h} d\lambda + \int l_{\theta_l} d\lambda. \qquad (24) \end{aligned}$$

Our setup delivers an equilibrium relation between mortgage credit supply and securitization volumes. Exogenous shocks that cause the volume of mortgage securitization to contract (expand) will also spill over into the credit market as a contraction (expansion) of credit, which matches the positive correlation between both aggregates observed in the data (Figure 1). Shocks to house prices (π) or to the spread between repayment rates ($\theta_h - \theta_l$) affect the equilibrium securitization contracts, and consequently, the liquid funds (7) available to a bank to fund new credit. This is the essence of the securitization liquidity channel, the main channel of transmission of shocks in our model.

The next quantitative section studies the effects of a house price shock on aggregate securitization and credit volumes. We rely on the theoretical structure of the securitization contracts developed here and on a numerical simulation to show the transmission and amplification of shocks to the aggregate credit supply.

4 Quantitative Outcomes

We perform a numerical simulation to illustrate how information asymmetries amplify banks' mortgage credit supply and securitization volumes in response to house price shocks.[26] The model's parameters, presented in Table 2, are calibrated based on annual targets for 1990 to 2007. We defer the details of the calibration to Appendix B. The interested reader is also referred to Appendix B.2 for descriptive and numerical examples of the equilibrium contracts that can arise in the model.

4.1 The Effect of House Price Shocks on Banks Cash Holdings

House price shocks affect securitization contracts z by changing the return of mortgages $M(\theta;\pi)$. A positive π shock increases the recovery rate from foreclosing the housing collateral in (2) by factor $(1-\theta)\zeta$ with $\theta \in \{\theta_h, \theta_l\}$, proportionally increasing mortgage returns. This further affects a bank's cash holdings as securitization prices and quantities are endogenous functions of the mortgage returns. Additionally, since the threshold $\tilde{\mu}$ in (21) is a decreasing function of house price shocks, changes in π affect the equilibrium threshold and can induce the model to switch between the PSEO and the MSEO contracts, another essential source of nonlinearities in the model.[27] Figure 4 illustrates a positive house price shock $\pi' > \pi$ that expands the MSEO region.

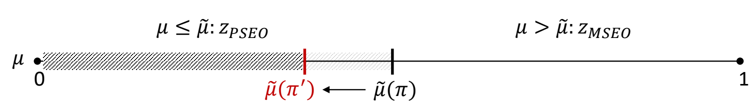


Figure 4: Change in equilibrium outcome regions due to a house price shock

Securitization contracts are affected in three possible ways: (i) the economy initially operates with securitization contracts in the PSEO region and remains in the same region after the shock, (ii) the economy initially operates with securitization contracts in the MSEO region and remains in the same region after the shock, or (iii) the economy transitions from PSEO to MSEO securitization contracts as the latter region expands.

In the first case, since PSEO contracts (17) feature break-even prices, the house price shock will proportionally increase the price paid to both bank types and their cash holdings. These dynamics

[26] The model is stylized and abstracts from various institutional details of the U.S. mortgage market. This simulation aims to show the model's mechanism for a reasonable calibration.

[27] To see that the function $\tilde{\mu}$ is decreasing in π, replace the definition of the adverse selection discount ρ on (21), which obtains: $\tilde{\mu} = \left[1 + \frac{c}{(\theta_h-\theta_l)(R^l-\zeta\pi)}\right]^{-1}$. The dynamics are similar for a shock that reduces the spread in repayment rates, $\theta_h - \theta_l$. Both cases will induce changes in the adverse selection discount ρ and into the equilibrium outcomes regions in Figure 4.

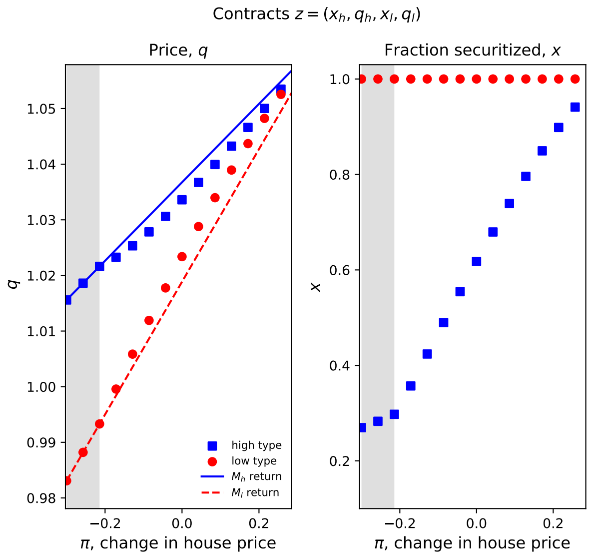
are illustrated in the left panel of Figure 5 where securitization prices (square-blue and circle-red markers) are the same as mortgage returns (solid-blue and dashed-red lines) in the PSEO region. We call this the *price effect*. Additionally, cash holdings for a high-type bank rise due to a *quantity effect* derived from an increased securitized fraction of her portfolio, as x_h in the PSEO contract (19) is an increasing function of π. In sum, a positive house price shock increases the inflows of liquid funds to both bank types through price and quantity effects.[28] From Propositions 1 and 2, it follows that the aggregate credit supply for both banks expands accordingly.

In the second case, since MSEO contracts (18) feature cross-subsidization in prices between bank types, the house price shocks will increase a low-type bank's cash holdings more than proportionally to her mortgage returns. Hence, a low-type bank experiences a substantial price increase. On the other hand, high-type banks experience a less-than-proportional price increase. The white area in Figure 5 shows these dynamics; notice that securitization prices paid to the low-type (circle-red markers) are above their mortgage returns (dashed-red lines), while the opposite occurs for the high-type banks. Although the price effect is smaller for the high-type banks, the quantity effect is large as the fraction securitized rises significantly when housing price increases—see the slope of the fraction securitized in the MSEO compared to the PSEO on the left panel of Figure 5. The total impact of the positive house price shocks on both bank types' cash holdings is positive and larger for the high-type bank. However, cash holdings for the low-type bank grow faster than those of the high-type bank as the house price shock increases, as Figure 6 shows.

In the third case, the positive house price shock shifts the securitization equilibrium contracts offered to banks from the PSEO to the MSEO region. This transition induces another nonlinear change in a bank's securitization cash holdings. Figure 6 compares the pattern of securitization cash holdings obtained in an economy with asymmetric information to those obtained in an economy with complete information for a sequence of π shocks. In the latter, shocks to housing prices affect a bank's cash holdings linearly only through a price effect. In contrast, bank cash holdings from the asymmetric information economy display a nonlinear pattern derived from a compounded effect of changes in securitization prices, quantities, and contract structure. These cash-holding dynamics are transmitted to a bank's loan origination decisions and generate a nonlinear response of the aggregate credit supply to exogenous shocks.

Figure 6 also shows relevant differences in cash holdings across banks. Cash holdings for the high-type bank are always lower in the asymmetric information economy as the high-type cannot securitize her entire portfolio. In contrast, the low-type cash holdings can be as low as the complete information economy or higher due to cross-subsidization in prices. Whenever house price shocks

[28] Gete and Reher (2020) document that securitization price effects—in their case, out regulatory changes—can lead to credit expansions in the U.S. mortgage market.



The left panel shows prices q and mortgage returns M for each type of bank for a sequence of house price shocks π. The right panel shows the fraction securitized x for the same sequence of house price shocks. The gray shaded area corresponds to the region of the equilibrium contracts under pure strategies, and the white area to the mixed strategy equilibrium contracts. Markers in the white area represent the expected (average) prices and fractions securitized according to the probability distribution of contracts F.

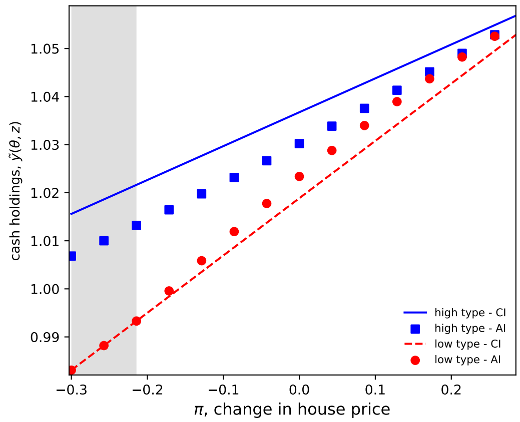
Figure 5: Simulated contracts for a sequence of house price shocks, π

are positive and large, the cross-subsidization in the MSEO contracts reduces the cash holding differences across bank types and allows them to supply similar volumes of credit.[29] On the other hand, negative house price shocks amplify differences in cash holdings across bank types and increase the dispersion in the volume of mortgage lending across banks. In the next section, we show that these cash-holding dynamics are at the center of the amplification effect of information asymmetries on aggregate credit supply.

4.2 The Amplification Effect on Aggregate Credit Supply

We simulate the model for a positive and a negative house price shock of 7% magnitude to show how the aggregate credit supply is amplified in an economy with asymmetric information. Figure 7 displays the stationary cross-sectional distribution of aggregate credit for the baseline calibration, and for a negative and positive house price shock, in the asymmetric information (left panel) and complete information (right panel) economies. A positive house price shock changes the aggregate distribution in two ways; first, it shifts it to the right, implying an increase in the aggregate

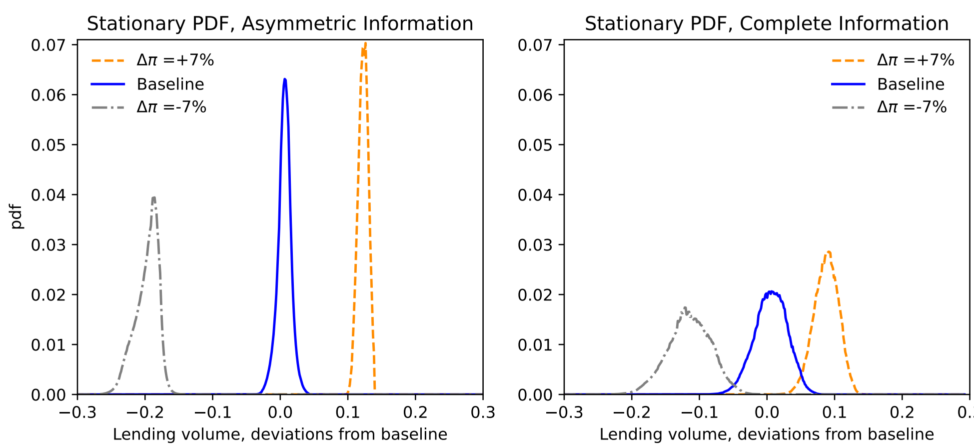
[29] Taking into account asymmetries of information obtains a structure of securitization contracts in which rising collateral values can support higher production of low-quality MBSs as low-type securitizers benefit from higher market prices.



Simulated expected cash holdings after securitization for a sequence of house price shocks, π. Lines represent expected cash holdings in the complete information (CI) economy, and markers correspond to asymmetric information (AI) for each type of bank. The gray shaded area corresponds to the pure strategies, and the white area to the mixed strategy equilibrium contracts.

Figure 6: Banks' cash holdings after securitization

level of credit. Second, it reduces the dispersion of the distribution. Both changes—in level and dispersion—are larger for the asymmetric information than for the complete information economy. Negative house price shocks produce opposite effects; a contraction in the level and an increase in the cross-sectional dispersion of aggregate credit. As explained in the previous section, these dynamics arise endogenously from the heterogeneity in cash holdings across bank types, which embeds the compounded nonlinear effects of shocks on securitization prices, quantities, and the contract structure.



Each density represents the cross-sectional distribution of credit. Baseline is the benchmark calibration. $\Delta\pi$ refers to the new steady state distribution after introducing a positive and negative house price shock of 7% to the benchmark economy.

Figure 7: Cross-sectional distributions of aggregate credit

Table 1 reports the quantitative effects of house price shocks. In the complete information economy, a positive shock increases mortgage credit per-unit of deposits by 8.2% and reduces dispersion by 15%. The same shock in an economy with asymmetric information increases the aggregate credit 1.5 times more and reduces the dispersion of the distribution 2.1 times more. In the context of the credit market, this result states that an expansive (contractive) shock on house prices will amplify a credit expansion (contraction). The amplification effect is not symmetric, showing larger effects on contractionary shocks. Similar dynamics arise for shocks of different magnitudes. In the appendix, figure 11 compares the growth rate of credit supply with information asymmetries to its counterpart with complete information for a sequence of house price shocks.[30]

	Asymmetric Information		Complete Information		Amplification	
House price shock	Level	Dispersion	Level	Dispersion	Level	Dispersion
Expansive $\Delta\pi = +7\%$	12.2	-32.0	8.2	-15.0	1.5	2.1
Contractive $\Delta\pi = -7\%$	-20.5	84.9	-10.5	31.9	2.0	2.7

Statistics obtained from simulating the stationary distribution of credit across banks for different scenarios of a shock to the growth rate of house prices. Level and Dispersion refer to the percentage changes in the mean and the standard deviation of the distribution, respectively. Amplification is the ratio of the percentage change of asymmetric to that of complete information.

Table 1: Percentage change in aggregate credit from a house price shock

5 Conclusion

This paper provides a theoretical connection between a bank's mortgage lending and securitization decisions. It shows that adverse selection in securitization (Downing et al. (2008); Calem et al. (2011); Keys et al. (2010); Adelino et al. (2019)) amplifies fundamental shocks and their transmission to banks' credit supply. A quantitative application of the theory indicates that the response of lending to house price shocks can be amplified by a factor that ranges between 1.5 to 2.0 with respect to an economy that abstracts from information frictions. These results are consistent with other studies of the aggregate effects of adverse selection in asset markets (Krishnamurthy (2010), Kurlat (2013), Bigio (2015)) and with the magnitudes documented at the micro-level in the mortgage market (Calem et al. (2013)). This observation is relevant for designing macroprudential policies in the mortgage market that alleviate these vulnerabilities and keep a stable credit supply to households.

[30]Large amplification effects from the securitization liquidity channel have also been documented at the micro-level. Calem et al. (2013) find that the contraction in mortgage credit by commercial banks that were highly exposed to securitization liquidity was six times greater than that of similar banks that were not dependent on securitization during the collapse of the non-agency MBS market.

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Online Appendix for The Amplification Effects of Adverse Selection in Mortgage Credit Supply

A Proofs to Propositions

A.1 Proof to Proposition 1

Proposition 1. *A high-type bank originates more mortgages than a low-type bank.*

We start by taking first order conditions (FOC) from problem (8) with respect to $\{l', d'\}$:

$$\begin{aligned} l': \quad & g_{div}(\theta)(-1-2\nu l') + \beta\left[\mu\frac{\partial V(l',d';\theta^h)}{\partial l'} + (1-\mu)\frac{\partial V(l',d';\theta^l)}{\partial l'}\right] + \lambda(1+2\nu l') &= 0 \\ d': \quad & g_{div}(\theta)(1) + \beta\left[\mu\frac{\partial V(l',d';\theta^h)}{\partial d'} + (1-\mu)\frac{\partial V(l',d';\theta^l)}{\partial d'}\right] - \lambda &= 0 \end{aligned}$$

where λ is the Lagrange multiplier associated to the capital requirement constraint and g_{div} represents the marginal change in dividends,

$$g_{div}(\theta) = -\frac{\kappa}{2}^{-1/2}[a_1 + \tilde{y}(l,d;\theta,z) + d' - l' - \nu l'^2]^{-1/2}$$

Suppose $d = d' = 1$, then

$$\tilde{y}(l;\theta,z) = l(1-x)[M(\theta)-c] - (R^d - qxl)$$

and

$$g_{div}(\theta) = -\frac{\kappa}{2}^{-1/2}[a_1 + l(1-x)[M(\theta)-c] - (R^d - qxl) + 1 - l' - \nu l'^2]^{-1/2}$$

consider the case in which there are no sales $z{=}(x_h, t_h, x_l, t_l) = (0,0,0,0)$:

$$g_{div}(\theta) = -\frac{\kappa}{2}^{-1/2}[a_1 + l[M(\theta)-c] - R^d + 1 - l' - \nu l'^2]^{-1/2}$$

notice that since $M(\theta^h) \geq M(\theta^l)$:

$$g_{div}(\theta^h) \leq g_{div}(\theta^l)$$

This difference in the marginal change of dividends implies a difference in the level of originations between high and low type i.e., it translates in the policy functions being parallel arrays with the policy function for high type above that of the low type.

A.2 Proof to Proposition 2

Proposition 2. *Mortgage securitization increases a bank's mortgage credit supply.*

Using envelope condition, we obtain the Euler equation for deposits:

$$g_{div} - \lambda = \beta \left[R^d \mu g_{div'}(\theta^h) + R^d(1-\mu) g_{div'}(\theta^l) \right]$$
$$g_{div} - \lambda = \beta \mathbb{E}_{\theta'} g_{div'}(\theta')$$

and the Euler equation for loans:

$$\underbrace{(1+2\nu l')(g_{div} - \lambda)}_{\text{marginal cost}} = \beta \underbrace{\mathbb{E}_{\theta'} g_{div'}(\theta') \left[(1 - x(\theta'))[M(\theta') - c] + x q(\theta') \right]}_{\text{marginal benefit}} \tag{25}$$

Notice that the right-hand-side of the above equation depends on the securitization contract, $z{=}(x_h, q_h, x_l, q_l)$ which is a function of the model's fundamentals.

For instance if there are no securitization, the contract is $z = (0, 0, 0, 0)$, hence:

$$(1+2\nu l')(g_{div} - \lambda) = \beta \mathbb{E}_{\theta'} g_{div'}(\theta') \left[M(\theta') - c \right]$$

A.3 Proof to Proposition 3

We follow the same strategy proposed in Rosenthal and Weiss (1984) and Chari et al. (2014) to reproduce a similar proof for Proposition 3 as the environments are similar. We break down the proof into two parts; first, we prove that the contract in (17) is a unique separating pure strategies equilibrium in the region $\mu \leq \tilde{\mu}$. Second, we show that for the region $\mu \geq \tilde{\mu}$, a mixed strategy equilibrium exists where the distribution of contracts $F(z)$ is given by $F(q_l)$ in (18).

For the first part, we proceed in three steps. The first step is to show that in any pure strategies equilibrium $q_l = M_l$. Suppose by contradiction that a pure strategy equilibrium has $q_l \geq M_l$. It is immediate to see that if $x_h = 0$, this contract produces negative profits for the investor. Recall that one of the properties of monotone contracts implies $x_l = 1$, then an investor's profits would be $(1-\mu)(M_l - q_l)x_l < 0$. So it must be that $x_h > 0$. Now, consider a deviating contract $\hat{z} = (z_h, q_h - \epsilon, 1, q_l)$ with ϵ small. This deviating contract keeps the high-quality bank indifferent to our initial equilibrium contract and relaxes the low-quality bank's incentive constraint. Conditional on attracting the high-quality bank, profits from this bank rise by $c x_h \epsilon$, and profits from the low-quality bank are unchanged. Implying strictly positive profits, so we have a contradiction. This result and the four properties of monotone contracts imply that the pure strategies outcome must coincide with the least-cost separating outcome (Spence (1973)).

The second step shows that the least-cost separating outcome is a unique pure strategy equilibrium. First, we establish a preliminary result regarding the high-quality bank's payoffs. Consider the set of offers (x_h, q_h) to the high-quality bank im plied by a binding incentive constraint for the low-quality bank,

$$q_l = q_h x_h + (1 - x_h)(M_l - c), \tag{26}$$

and zero profits as functions of q_l,

$$\mu\left(M_h x_h - q_h x_h\right) + (1-\mu)\left(M_l - q_l\right) = 0. \tag{27}$$

Since both the profit function and the incentive constraint are linear functions of q_h, x_h, and q_l, it follows that q_h and x_h are linear functions of q_l. Since the payoff function to the high-quality bank in (7) is linear in x_h and q_h, this payoff $\tilde{y}_h(q_l)$ is also linear in q_l. Then, let $\tilde{y}_h(M_l)$ represent the high-quality bank's payoff in the least-cost separating outcome and $\tilde{y}_h(\hat{p}(\mu)) = \hat{p}(\mu)$. Since $\mu < \tilde{\mu}$, we obtain $\tilde{y}_h(M_l) > \hat{p}(\mu)$, indicating that the high-quality bank prefers the least-cost separating offer to any offer associated with $q_l > M_l$ that breaks even and in which the incentive constraint for the low-quality bank holds with equality. Suppose now that another investor offers the least-cost separating contract. Consider a deviation by the first investor to contracts of the form $\hat{z} = (\hat{x}_h, \hat{q}_h, 1, \hat{q}_l)$ with $\hat{q}_l > M_l$. Since we showed that high-quality banks always prefer the least-cost separating offer among break-even contracts, $\hat{z}$ does not attract high-quality banks. So if the $\hat{z}$ contract somehow attracts high-quality banks, it must be that it yields negative profits. The last step shows that $\mu < \tilde{\mu}$ the model has no mixed strategy equilibrium. By contradiction, suppose it did. Note that we have established that the high-quality bank strictly prefers the least-cost separating outcome to any other offer in the support of the offer distribution, and the low-quality bank strictly prefers any offer with a price greater than M_l to the least-cost separating contract. We've also shown that any break-even contract with $q_l > M_l$ yields negative profits. Then, any deviation by an investor to a pure strategy contract close to the least-cost separating outcome that offers higher profits to the investor attracts high-quality banks with a probability close to 1 and low-quality banks with a probability of zero. Hence, for the region $\mu < \tilde{\mu}$ investors offer the least-cost separating contract, which we presented in (17), with probability 1, i.e., the distribution is degenerate at this contract, and there is no mixing by investors. Appendix B.2 provides a graphic illustration and a numerical example of this pure strategy equilibrium outcome in our model.

For the second part, we want to show that a mixed strategy equilibrium exists in the region of $\mu \geq \tilde{\mu}$ where the distribution over the contracts $F(z)$ is given by (18). This part of the proof consists of several standard steps, which for convenience, we outline here and refer the interested reader to the exposition of the best-deviation approach by Rosenthal and Weiss (1984) or the online appendix in Chari et al. (2014). First, show that the best deviations $\hat{z}$ have the property that for some contracts z in the support of F, the high-quality bank is indifferent between z and $\hat{z}$, meaning:

$$\hat{q}_h \hat{x}_h + (1-\hat{x}_h)(M_h - c) = q_h x_h + (1-x_h)(M_h - c) \tag{28}$$

and with z satisfying the low-quality bank's incentive constraint with equality,

$$\hat{q}_l \hat{x}_l + (1-\hat{x}_l)(M_l - c) = q_h x_h + (1-\hat{x}_h)(M_l - c). \tag{29}$$

The dashed-blue line of panel (b) in Figure 8 depicts this set of offers to the high-type bank. Second, evaluate an investor's profits for a deviation of the form $\hat{x}_h + \epsilon$ for small ϵ and $\hat{q}_h$ and $\hat{q}_l$ given by (28) and (29). Third, show that profits are globally concave and attain a maximum at ϵ, which leads to a first-order differential equation. Fourth, solve the first-order differential equation under the assumption that the distribution F is continuous, has no mass point, has a connected subset of $[M_l, \hat{p}(\mu)]$, and $F(q_l) < 1$ and $q_l < \hat{p}(\mu)$. Fifth, check that the solution to the differential equation in the previous step with the boundary condition $F(\hat{p}(\mu))$ coincides with (18).

A.4 Proof to Proposition 4

The statement regarding credit volumes follows from a straightforward comparison of a bank's Euler equation for loans in each scenario. First, for the complete information economy, the corresponding Euler equation for a generic bank type θ is:

$$(1 + 2\nu l')(g_{div} - \lambda) = \beta \mathbb{E}_{\theta'} g_{div'}(\theta') M(\theta)'.$$

The concavity of bank's preferences over dividends, implies an interior solution for the level of credit. Let l^*_{CI} be the optimal average level of credit for a generic bank in the complete information economy. Next, for the economy with asymmetries of information, since $c > 0$ and some banks do not get to securitize their entire portfolio $x(\theta) < 1$, on average, the marginal benefit of originating a loan will be lower than the complete information economy but higher than the case of no securitization, i.e.

$$\begin{aligned} \mathbb{E}_{\theta'} g_{div'}(\theta') M(\theta') &\geq \mathbb{E}_{\theta'} g_{div'}(\theta') \left[(1 - x(\theta'))[M(\theta') - c] + xq(\theta') \right] \\ &> \mathbb{E}_{\theta'} g_{div'}(\theta') \left[M(\theta') - c \right], \end{aligned}$$

and given that the marginal cost of origination is independent of the securitization outcome, the level of credit supply is the highest for the complete information economy, the lowest for the economy with no securitization, and the level of credit for the economy with asymmetric information is bounded above and below by those cases:

$$l^*_{CI} > l^*_{AI} \geq l^*_{NS},$$

where l^*_{AI} and l^*_{NS} represent the optimal level of credit in the economy with asymmetric information economy and the no securitization economy, respectively.

A.5 Aggregate Securitization Volumes

In Section 3 we showed that our model features multiple equilibria in the securitization market. This implies that the aggregate securitization volume (23) changes accordingly. Here we derive closed form expressions for each equilibrium outcome. Consider the case $\mu \leq \tilde{\mu}$, the equilibrium outcome is the PSEO, then (17) implies that the expected aggregate volume of mortgage securitization (security issuance) is:

$$\begin{aligned} T_L(\mu) &= \mu x_h + (1-\mu)x_l \\ &= \mu \frac{1}{1+\rho} + (1-\mu) \end{aligned} \tag{30}$$

On the other hand, if the probability μ of observing a high type is such that $\mu \geq \tilde{\mu}$, the equilibrium contracts are determined by mixed strategies, and the expected aggregate volume of mortgage securitization is:

$$\begin{aligned} T_H(\mu) &= \mu x_h + (1-\mu)x_l \\ &= \mu \left[1 - \frac{1-\mu}{\mu} \left[\frac{1}{\rho} + \frac{1}{\rho^2} \right]^{-1} \right] + (1-\mu). \end{aligned} \tag{31}$$

Note that both aggregate functions are decreasing on the adverse selection discount ρ. An increase in the spread between repayment rates will increase the mortgages' return spread between banks, increasing the adverse selection discount and reducing security issuance in the aggregate. Furthermore, shocks to the spread that induces a switch from the mixed strategies to the pure strategies equilibrium contract also imply a reduction in aggregate securitization. To see this, note that the threshold $\tilde{\mu}$ increases as ρ increases (21). Then, suppose μ is initially slightly above $\tilde{\mu}$. In that case, the increase in the threshold induces a switch to the PSEO, causing expected aggregate security issuance for banks to fall. Thus, in all three different cases, the volume of mortgage securitization falls when the adverse selection discount increases.

B Appendix to the Quantitative Section

B.1 Calibration

Table 2: Parameters of the model

Parameter	Description	Value	Target
β	Bank discount factor	0.985	Real 1YT-bill rate: 1.56% (90-07).
$\{\theta_l, \theta_h\}$	Repayment rates	$0.91, 0.84$	Default rates in MBS pools (01-07). Adelino et al. (2019).
μ	Prob. of high type	0.70	Prime, subprime MBS pools (01-07). Adelino et al. (2019).
ζ	Foreclosure recovery rate	0.75	Mortgage severities of 25% (Elenev et al. (2016)).
κ	Dividends adj. cost	10	Dividends to assets ratio (0.7%) U.S. Call Reports (84-07).
ν_l	Loan origination cost	0.00033	Scale parameter.
R^l	Gross lending rate (pp)	6.26	30Y FRM plus fees. Freddie Mac and Fannie Mae (90-07).
R^d	Gross deposits rate (pp)	0.50	Overnight deposits rate. St Louis FRED (90-07).
π	House price growth (pp)	5.00	Growth rate of FHFA's house price index (90-07).
c	Bank's operation cost (pp)	1.20	Fraction of all securitized mortgages: 70%, HMDA (90-07).

All parameters are calibrated based on annual targets for the U.S. mortgage market from 1990 to 2007, a period in which the private label securitization segment accounted for a significant fraction of the market.

Here we present the calibration strategy. The bank's discount rate β is set to 0.985 to target an average real rate of 1.56% from the one-year treasury bill. Repayment rates $\{\theta_h, \theta_l\}$ are set to $\{0.906, 0.841\}$, based on estimates of the average default rates for mortgage pools acquired by GSEs (Fannie Mae and Freddie Mac) and privately securitizers as reported by Adelino et al. (2019).[31] The probability of observing a high repayment rate μ does not have a direct counterpart in the data; we set μ to 0.7, which resembles the fraction of all prime mortgages traded from 2002 to 2007 according to the McDash sample reported by Adelino et al. (2019). The foreclosure recovery rate ζ is set to 0.75 to target mortgage severities of 25% (Elenev et al. (2016)). The real lending rate is set to 6.26% to match the 30-year fixed mortgage rate from 1990 to 2007, including fees, as reported by Freddie Mac Primary Mortgage Market Survey 2018. The real interest rate on deposits is set to 0.5% based on the overnight deposit rate from the Federal Reserve Economic Data. Average house price inflation, $\pi = 5\%$, corresponds to the average growth rate of the all-transaction house price index from 1990 to 2007, as reported by the FHFA. The portfolio management cost is set to $c = 1.2\%$ to target the average fraction of all mortgages sold every year from 1990 to 2007

[31] Adelino et al. (2019) define a default as a mortgage delinquent 90 days or more in a horizon of 60 months after origination. They report average default rates for a sample of 20 million mortgages (covering about 80% of all mortgages issued in the U.S.) from McDash Analytics for 2002 to 2007.

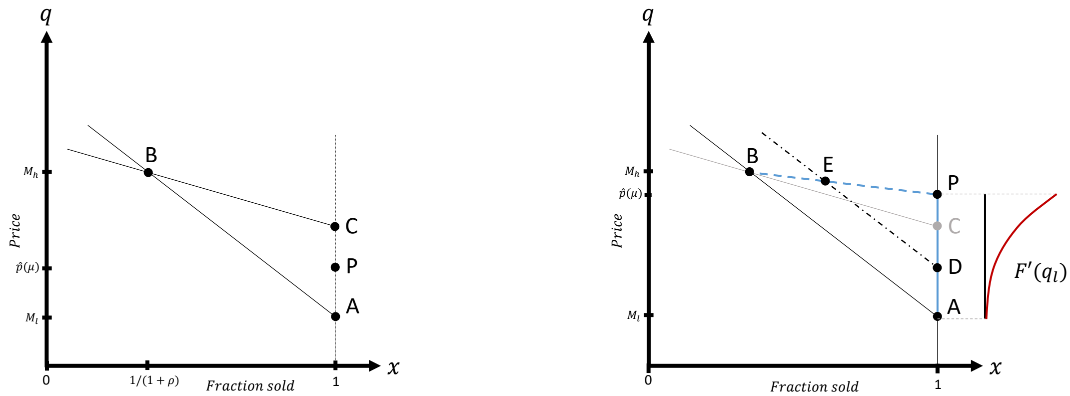
according to HMDA. Dividend adjustment costs are calibrated to target a dividend payout of 0.7% of a bank's assets from the U.S. Call Report data (84-07). The minimum requirement is to set $b = 0$, which lets a bank operate as long as its net cash proceeds from operations are not negative, these also captures the minimum restrictions faced by non-bank mortgage originators. These calibrated parameters imply a return's spread between the high and low type of $M(\theta_h) - M(\theta) = 1.79\%$, an average securitization rate of 73% for the entire market, with high type banks retaining on average 30% of new mortgage in their portfolio, which is in line with HMDA data reports for the period of analysis.

B.2 An Illustration of Equilibrium Contracts

This section provides descriptive and numerical examples of the equilibrium contracts that can arise in the model. As shown in Proposition 3, there are two possible types of equilibrium outcomes (see Figure 3). We start by illustrating contracts in the pure strategies equilibrium in the non-negative orthant of (x, q) space.

Pure Strategies. The PSEO contract (17) is a quadruple containing an offer for each bank type. In Figure 8, Panel (a), the offer to the low-type bank $(x_l, q_l) = (1, M_l)$ is labeled A, and the offer to the high-type bank $(x_h, q_h) = (\frac{1}{1+\rho}, M_h)$ is represented by point B. Straight-line indifference curves with negative slopes represent banks' preferences over offers; these are derived from each bank's linear payoffs function in the securitization stage, equation (7). The low-type bank indifference line runs through points B and A, indicating that the low-type is indifferent between her offer and the offer to the high-type. Let C represent the point at which the high-type indifference line through B intersects the vertical line denoting $x = 1$. Let the point P illustrate a pooling contract containing the same offer $(1, \hat{p}(\mu))$ to each bank-type with pooling price $\hat{p}(\mu) = \mu M_h + (1-\mu) M_l$. The point P may be below (as in panel (a)), on, or above C (as in panel (b)). In panel (a), we have illustrated P for a value of μ that satisfies $\mu \leq \tilde{\mu}$ (See Proposition 3). More generally, whenever P is below C, there is a unique pure strategy separating equilibrium: all investors offer the contract (B,A) to banks. This contract is known as the least-cost separating outcome (Spence (1973); Rothschild and Stiglitz (1976)). Notice that although the low type might prefer the pooling contract, such an offer is not attractive to the high type. Hence, contract (B, A) dominates the pooling contract P and constitutes a unique equilibrium (see Appendix A.3 for the proof).

According to the model's baseline calibration (Table 2), the threshold defining the equilibrium regions takes a value of $\tilde{\mu} = 0.598$. For example, consider the probability of observing high-type banks to be $\mu = 0.50$, so it's equally probable to observe low and high types. Since $0.5 < \tilde{\mu}$, this would imply steady-state securitization contracts in the PSEO region, with the following values $z = (1/(1+\rho), M_h, 1, M_l) \equiv (0.402, 1.037, 1.00, 1.019)$ obtained from equation (17). In this case,



(a) Pure Strategy Equilibrium

(b) Mixed Strategy Equilibrium

Figure 8: Illustration of Equilibrium Contracts

the optimal contract requires almost sixty percent portfolio retention from the high type as a screening (skin-in-the-game) device to separate them from the low types. Intuitively, whenever the probability of observing high-type banks is low ($\mu \leq \tilde{\mu}$) it is possible to separate between types by offering a contract requiring high retention levels to the high-type.

Mixed Strategies. On the other hand, for values of μ above $\tilde{\mu}$, whenever banks and investors play in pure strategies, a (separating) equilibrium does not exist.[32] In our environment, the non-existence of equilibrium means that the pair of offers (B, A) intended to separate banks are dominated by the pooling contract, as both bank types strictly prefer such contract if available—represented by point P in the panel (b) of Figure 8. In this case, Rosenthal and Weiss (1984) have shown that a (separating) equilibrium in the region $\mu > \tilde{\mu}$ exists if investors are allowed to play in mixed strategies. In the Appendix A.3, we follow Rosenthal and Weiss (1984) and Chari et al. (2014)'s approach to derive the set of mixed strategies equilibrium contracts. The main idea is to design contracts that pay low-types a price above their break-even return (for instance, point D in panel (b) of Figure 8 offers a price $q_l > M_l$) and find the corresponding offer to the high-type (point$E$) by riding along the low-type indifference line that crosses the line connecting B and P. An example of a possible contract in the MSEO is given by the pair of offers (E, D). In general, these class of contracts feature the following properties: (i) contract payments to the low type are chosen from the support $[M_l, \hat{p}(\mu)]$, (ii) contracts are incentive compatible, and (iii) investors make zero profits in expectation. Panel (b) in Figure 8 shows the continuum of contracts satisfying these properties, offers to the high-type—represented by the dashed blue array BP—feature some level

[32]See Rothschild and Stiglitz (1976); Dasgupta and Maskin (1986) for the formal proof and arguments in the classical insurance market model, Rosenthal and Weiss (1984) extend the exposition to a signaling model of education.

of loan retention ($x_h < 1$) and lower prices than the break-even return $q_h < M_h$. Offers to the low-type—represented by the solid blue vertical array AP—feature zero loan retention ($x = 1$) and prices $q_l \in [M_l, p(\mu)]$ higher than their break-even return M_l. Since investors are allowed to play in mixed strategies, i.e. assign probabilities to the continuum of offers to the high and low types that define the above contracts, the MSEO is characterized by the cumulative distribution function $F(q_l)$ with support $[M_l, \hat{p}(\mu)]$ given by (18). In the baseline calibration (Table 2), we set μ to 0.7. This implies steady-state securitization contracts in the MSEO region given that μ is above the threshold $\tilde{\mu} = 0.598$. Straight forward computation—using the cdf in (18) and following the steps in Appendix A.3—yields the expected contract $z = (x_h, q_h, x_l, q_l) \equiv (0.618, 1.034, 1.00, 1.023)$. Such contract corresponds to our benchmark economy with asymmetric information and can be identified in the Figure 5.

B.3 Computational Algorithm

The algorithm to solve the steady state of this model follows the structure presented in the timeline in section 2.2. Given a set of parameters that characterize the economy $\Omega = \{\theta^h, \theta^l, c, \zeta, \nu_l, \kappa, d\bar{i}v, \beta, \mu\}$, and prices $\{R^d, R^l, \pi\}$:

- First, solve for the equilibrium contracts from the Securitization Stage,
- Second, given prices $\{R^d, R^l, \pi\}$ and equilibrium contract $z^* = (x_h, q_h, x_l, q_l)$, solve the Recursive Problem of each bank in the origination stage, which yields policy and value function is $\{l'(l, d; \theta, z),\ d'(l, d; \theta, z),\ V(l, d; \theta, z)\}_{\theta \in \{\theta^h, \theta^l\}}$for every type of bank.
- Third, obtain the stationary distribution (13) by iterating over the law of motion of the transition function (12) until convergence.

C Comparing Different Economies

C.1 Opening the securitization market

In this section we analyze the Stationary Distribution of loans before and after opening the securitization market for the complete information economy. Figure 9 shows the cross-section of the aggregate stationary distribution of lending (mortgage credit) across banks normalized for 1 unit of deposits

Securitization allows for a significant expansion of mortgage credit (Proposition 2). The lending distribution shifts to the right, both low-and high-type banks expand their loan originations by

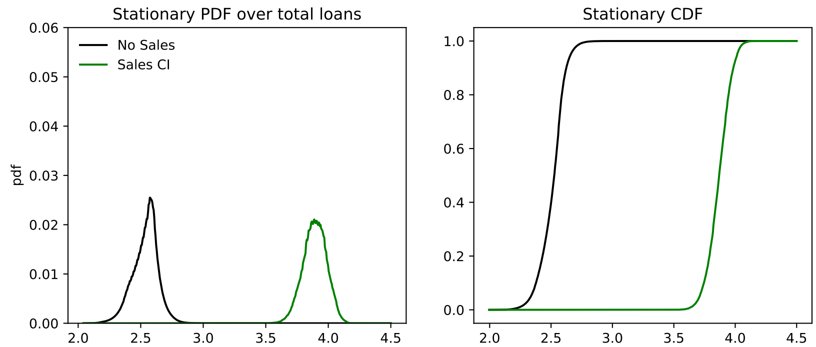


Figure 9: Distribution of lending with and without securitization

selling their entire portfolios and saving on management costs. This is consistent with the idea securitization was a key economic driver of credit supply in the 2000s and can account for fluctuations in mortgage debt and the housing market (Justiniano et al. (2015, 2019))

C.1.1 Securitization with asymmetric information

Figure 10 adds to the previous figure the stationary distribution of lending for the asymmetric information case (blue line). There are two results in this figure: first, under asymmetric information, there is less lending than under complete information. This result is consistent with the literature on asymmetries of information frictions, see Bernanke and Gertler (1989), Kurlat (2013).

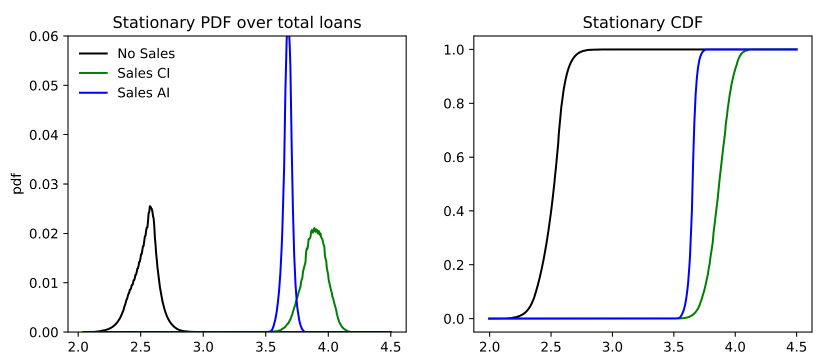
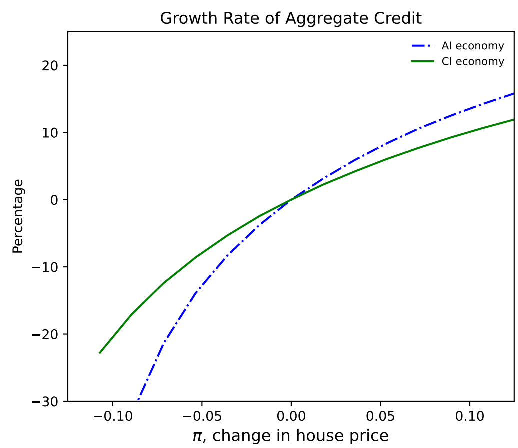


Figure 10: Distributions of lending for different economies

Under asymmetric information, the distribution of lending becomes more concentrated around its mean, the second moment of the distribution is half the magnitude of the complete information economy. This reduction in dispersion comes from the structure of contracts in the model (Proposition 3). Given the calibration in Table 2, the equilibrium contracts correspond to the Mixed

Strategies Equilibrium contract from (18), which means that profits from high-type banks are used by investors to subsidize low-type banks.

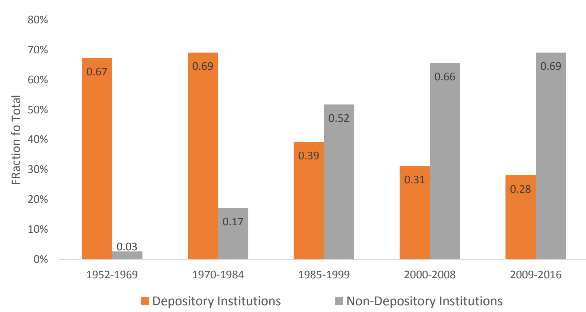
C.2 The Amplification Effect of Asymmetric Information on Credit Supply



The growth rate is the percentage change of aggregate credit supply with respect to the benchmark calibration. The dashed and solid lines show the credit growth rate for the asymmetric information economy and the complete information economy.

Figure 11: Growth rate of the aggregate credit supply for a sequence of house price shocks, π

D Additional Figures



Source: Flow of Funds Accounts, March 2017 release. Table L.218. Home Mortgage Loans, amounts outstanding by the end of the period. Depository institutions include Chartered US Banks; Foreign Banking Offices in the US, Bank in US affiliated areas, and Credit Unions. Non-depository institutions include Government Sponsored Enterprises (GSEs), ABS issuers, Finance Companies, and Real Estate Investment Trusts. Bins in years follow Campbell and Hercowitz (2005), and Landovigt (2016) classification of the stages of mortgage finance in the U.S.

Figure 12: Stock of Residential Mortgages Loans, by holder