Mortgage Securitization and Information Frictions in General Equilibrium*

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Abstract

How do aggregate fluctuations in mortgage credit respond to liquidity and information frictions in the securitization market? I answer this question by developing a general equilibrium model in which heterogeneous banks interact in an endogenous securitization market that features adverse selection. During the Great Recession, I find that the liquidity dry up arising from the collapse of the securitization market accounted for about thirty percent of the contraction of mortgage credit in the United States. Fluctuations in mortgage credit and security issuance are amplified by the severity of information frictions. A welfare analysis of the policy changes introduced after the Great Recession shows positive but unequal welfare gains among borrowers and lenders.

Keywords: Banking, DSGE, heterogeneous agents models, private information, liquidity frictions, securitization.
JEL codes: D5, D82, G21, G28

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1 Introduction

Securitization has become the largest source of funding to mortgage originators in the United States. From 2000 to 2019, mortgage originators sold or securitized on average 70 percent of all residential mortgages during the first year of origination.[1] However, this source of liquidity is volatile and sometimes collapses abruptly, and when this happens, the supply of mortgage credit to households follows in tandem. These large fluctuations have been associated to the presence of information frictions along the mortgage origination and securitization chain. Particularly relevant for the securitization market is the well documented adverse selection problem between better informed mortgage originators and security investors.[2] However, there are a number of key questions that remain unanswered: how important are these frictions to account for aggregate credit fluctuations? What is the channel of transmission of shocks from the securitization to the primary market? what policies can avoid collapses in the securitization market?

In this paper, I tackle these questions by developing a novel dynamic stochastic general equilibrium model in which heterogeneous banks interact in a dual mortgage market. I explicitly model a securitization market that features adverse selection as arising from information frictions between seller and buyers of mortgage-backed securities. I find that liquidity and information frictions in the securitization market accounted for twenty seven percent of the total mortgage credit contraction during the Great Recession. The model's success in generating large fluctuations in both markets rests on two important forces: (i) the severity of information frictions, which is an endogenous function of borrowers default risk; and (ii) the cross-sectional characteristics of the U.S. mortgage market, which I discipline using cross-sectional data on mortgage originators.

The model features two types of agents: borrowers and lenders, and two markets: a primary mortgage market and a securitization market. In the primary mortgage market, lenders extend long-term loans(mortgages) to borrowers. In the securitization market, lenders can sell their portfolio of outstanding loans and buy securities. Borrower households are standard, they borrow to smooth their consumption of non-durable and housing goods in the presence of aggregate income risk and idiosyncratic housing risk, and can default on their mortgages.

Lenders have three main characteristics. First, they are heterogeneous in their loan origination costs. Second, lenders are financially constrained by having limited sources of income: cash payments from their maturing portfolio, and cash inflows from selling loans in the securitization market.

[1] According to the Home Mortgage Disclosure Act (HMDA) database which accounts for almost the universe of mortgage originators in the United States.

[2] Adelino et al. (2019), Keys et al. (2010), Downing et al. (2008) are among the large body of literature documenting that sellers of mortgage loans are better informed than prospective buyers about the quality of the loans. Furthermore, mortgage originators actively take advantage of such information asymmetry.

Third, lenders have private information about the probability of default of loans in their portfolio. Private information gives rise to an adverse selection problem, as in Akerlof (1970). The securitization market is modelled as an anonymous and non-exclusive market in which all traded loans are pooled into securities, akin to the theoretical framework proposed in Kurlat (2013). Lenders that buy securities understand that a fraction of those turns out to have a low value because all lenders have incentives to sell non-performing loans and to selectively hold on to good-outstanding loans when the market price is lower than their individual valuation. Consequently, the private information friction reduces trade in the securitization market and lowers the liquidity available to lenders.

To capture government's involvement in the securitization market, I map existing government policies to a subsidy provided to buyers that compensates them for the losses associated to default risk when purchasing securities. The government finances this policy by imposing a fee (tax) on mortgage originators over the interest rate contracted with borrowers. The subsidy is a tractable way of capturing the role of the insurance provided by the Government Sponsored Entities (GSEs) to buyers of mortgage-backed securities (MBS).[3] This government policy encourages demand for securities, increasing both security issuance in the securitization market and mortgage credit to households in the primary market.

The model's feedback mechanism between the credit market and the securitization market is as follow: episodes of high—housing or income—risk induce borrower households to default on their mortgages which aggravates the adverse selection problem by discouraging some lenders from buying securities and others from selling their portfolio of good-outstanding loans. As a consequence, securities trade at a low price and the volume of security issuance falls. In the primary market, a large mass of lenders face a liquidity shock derived from the inability to cash their portfolio, which is further transmitted into a contraction of credit supplied to households. In equilibrium, prices adjust leading to a higher mortgage rate and lower demand of credit from households which feeds back into lower issuance of securities and a prolonged liquidity cycle for mortgage originators.

The model is able to replicate the dynamics observed in the data. I calibrate the model to match key moments of the cross section and time series of the U.S. mortgage market from 1990 to 2006. To study the role of this frictions during the Great Recession, I simulate the model using—as exogenous drivers— the sequences of income and housing depreciation shocks observed in the data. The model successfully replicates the deep and prolonged contractions observed in the volumes of mortgage credit and security issuance from 2008 to 2012. Performing a decomposition of forces on the contraction of aggregates in the mortgage market, I find that information frictions account for

[3] In practice, GSEs, specifically Freddie Mac and Fannie Mae, buy mortgages from originators, pack them into mortgage-backed securities, and insure MBS buyers against the default risk from borrower households.

twenty seven percent, housing depreciation shocks account for about half, and household's income shocks account for about five percent of the dynamics.

The transmission of fluctuations from the securitization to the primary market depends on the cross-sectional distribution of volume of lending across lenders. I use granular data from the Home Mortgage Disclosure Act database to discipline the distribution of lending in the model. In the data, the main feature of the mortgage market is the high level of concentration among mortgage originators.[4] Given this high levels of concentration, contractions in the volume of security issuance in the securitization market generate large contractions in the volume of credit in the primary market when some of the large originators are unable to securitize their portfolio.

To understand the role of policy in stabilizing mortgage credit to households, I evaluate two major policy changes introduced in the securitization market after the Great Recession. First, the expansion of the market share of GSEs, which, starting from 2009 has accounted for close to the entire MBS market. Second, starting in 2012, the guarantee fee charged by GSEs to mortgage originators increased threefold. I find that these policy changes were effective in stabilizing the mortgage market by reducing the volatility of quantities and prices in both the primary and securitization markets compared with the benchmark economy. However, the cost of financing these policies increases substantially, leading to higher taxes on borrowers and lenders. An analysis of the welfare effects derived from these policy changes shows unequal gains among borrowers and lenders. Lenders benefit more than borrowers compared with the benchmark economy.

While a substantial amount of research has focused on the moral hazard cost of expanding GSEs—and finds little scope or no role for policy interventions—my analysis focuses on the interaction of liquidity and information frictions arising from adverse selection in securitization markets. I find that expanding government policy can have an important stabilization role. In particular, this paper contributes by highlighting two aspects of the benefits of government policy: the increase in liquidity to mortgage originators who actively participate in the securitization market and the reduction in lending costs from better reallocation of resources in the economy.

Related Literature. My work fits within the strand of literature that introduces financial frictions into dynamic stochastic general equilibrium (DSGE) models to account for large fluctuations in macroeconomic aggregates. I contribute to this literature by quantifying the role of information and liquidity frictions in accounting for the joint dynamics of mortgage credit and mortgage-backed security issuance in a tractable DSGE model. In this line, Justiniano et al. (2019) argue that fluctuations in the supply of mortgage credit are quantitatively more important than fluctuations on the demand side—when borrowers are credit constrained—in explaining large fluctuations in the

[4] The mortgage market is highly concentrated among a few large originators: 10 percent of originators account for 90 percent of all new loan issuance to households in the primary residential mortgage market.

mortgage debt and in the housing market. Landvoigt (2016) introduces securitization in a DSGE model by allowing a representative lender to sell a fraction of her stock to a more patient investor. My approach goes one step further by introducing heterogeneity in lenders' origination costs which endogenously give rise to a securitization market. The securitization market not only provides liquidity but leads to an efficient allocation of resources among lenders, financial specialization, and lowers the cost of credit to households.[5]

On the empirical side there is also a literature quantifying information frictions in lending markets. Crawford et al. (2018) do so by estimating a structural model of credit demand that focuses on the interaction of market power and asymmetric information. Darmouni (2020) estimates the magnitude of informational frictions limiting credit reallocation to firms during the 2007-2009 financial crisis. While these works focus on the relation between borrowers and lenders, my paper focuses on the information frictions between lenders and investors in the securitization market and shows that the aggregate effects on lending markets can be sizeable in general equilibrium. Also relevant is the work by Calem et al. (2013), which quantifies the liquidity shock to banks derived from the collapse of the private-label RMBS market. They find that banks that had sold all of its jumbo loans in the securitization market reduced its jumbo lending by 6 times more than those banks that did not sell any of its jumbo loans.[6] Looking at the Great Recession, I find a similar amplification arising from the liquidity banks obtain from the securitization market.

A large body of literature documents the presence and relevance of adverse selection and moral hazard problems in the mortgage issuance and MBS market.[7] Downing et al. (2008) find that in their portfolios, mortgage originators retain mortgages that are, on average, of better quality than mortgages sold and securitized in the agency segment of the MBS market. Keys et al. (2010) find evidence that when mortgage originators expect to retain rather than sell a loan, they screen it more carefully. Elul (2011) looks at prime mortgages traded in the private segment of the market and finds that the rate of delinquency for a typical prime loan is 20 percent higher if it is privately

[5]Securitization has several advantages as a technology to enhance financial intermediation as it is associated with: i) a lower cost of capital; ii) the creation of high-quality safe assets by pooling risk, lowering bankruptcy, and lowering tax-related costs; and iii) gains from financial specialization (see Gorton and Metrick (2013) for an in-depth analysis).

[6]Using HMDA and Call-Report data Calem et al. (2013) find that for a bank that sold all of its jumbo loans to the securitization market, and had an 8% tier 1 capital ratio immediately preceding the liquidity shock, reduced its jumbo lending relative to all conventional mortgage lending by 7.9 percentage points as a result of the collapse of the private-label RMBS market. In contrast, a bank with the same tier 1 capital ratio that did not sell any of its jumbo loans to the securitization market experienced a reduction in jumbo lending of only 1.3 percentage points.

[7]The adverse selection problem is, of course, not new in the mortgage market. The industry has developed numerous strategies for screening private information and reducing the losses associated with it. Among them are warranties, credit ratings, reputation effects, tranching, and repurchase agreement haircuts. See Shimer (2014) for a review of how the market deals with private information.

securitized. More recently, Adelino et al. (2019) study the private segment of the MBS market during the period 2002-2007 and document that mortgage originators consistently retained the better-performing loans and sold those with poorer performance first. These findings show that adverse selection is an economically relevant friction in the securitization mortgage market.

I build on an extensive theoretical literature that studies adverse selection in financial markets, a tradition that dates back to Akerlof (1970). In particular, my framework for modeling adverse selection draws on the work of Kurlat (2013) and shares elements present in Eisfeldt (2004), Bigio (2015), Vanasco (2017), Caramp (2019), Neuhann (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. Other models of adverse selection consistent with this feature are those developed by Chari et al. (2014), which incorporate reputation concerns, and Guerrieri and Shimer (2012); both works relax the assumption of non-exclusive markets. My paper builds on the insights of these theoretical frameworks to introduce information frictions in tractable way within a DSGE framework. Furthermore, I model a novel mechanism by which liquidity shocks are amplified and transmitted from the securitization market to the primary mortgage market.

This paper also contributes to the literature that studies the effects of government policies in the mortgage and housing markets. Along this line, Elenev et al. (2016) develop a general equilibrium model of the mortgage market that also emphasizes the role of the financial sector and the government. They focus on the moral hazard incentive created by under-priced mortgage default insurance that encourages the banking sector to take on higher leverage. My paper provides a complementary view of the effects of policies in the presence of adverse selection when abstracting from moral hazard and shows that policy has an enhanced role in the presence of such frictions.

Layout. The paper is structured as follows. Section 2 presents motivating empirical observations. Section 3 introduces the model. Section 4 presents the theoretical analysis and Section 5 the quantitative analysis and main results, and Section 6 concludes.

2 Motivating Empirical Observations

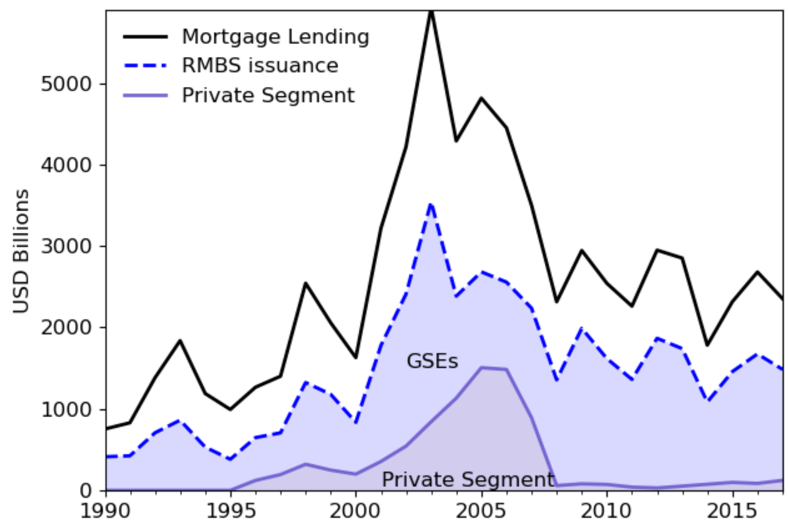
This section documents time series and cross-sectional patterns of the mortgage market that are relevant for the theory exposed in Section 3. This analysis is based on the Home Mortgage Disclosure Act (HMDA) data set, see the Appendix A for details about data treatment and constructions of variables.

2.1 Fluctuations in the Primary and Securitization Markets

The mortgage market in the United States comprises two markets: a primary mortgage market, where mortgage originators issue mortgage loans to households, and a securitization market, where mortgages are sold, bundled, and transformed into mortgage-backed securities, a process known as securitization. The primary market links home buyers and mortgage originators, while the securitization market brings together mortgage originators and investors.[8]

The volume of mortgage-backed securities issuance in the securitization market experiences large fluctuations. Figure 1 shows how the volume of issuance of mortgage loans and the volume of issuance of residential mortgage backed securities (RMBS) move in tandem.

Figure 1: Primary and securitization mortgage markets



Source: Mortgage lending comes from aggregating volume of new mortgage issuance during the first year of origination across all reporter institutions in the HMDA databbase. RMBS issuance is from SIFMA (Securities Industry and Financial Markets Association). “GSE” corresponds to RMBS issuance by Freddie Mac and Fannie Mae. “private segment” corresponds to issuance by private institutions apart from GSEs. Magnitudes are in USD real terms, base year 2015.

This close connection is grounded on mortgage originators’ reliance on securitization as a source of liquid resources to fund new mortgages, rather than funding them through equity or deposits. The fraction of new loans sold, or securitized, in the securitization mortgage market during the first year of origination has steadily increased from around 50 percent in the 1990s to close to 80 percent in 2016, as shown in Figure 8 in the Appendix. During this period, on average, mortgage

[8]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.

originators sold close to 70 percent of all mortgage loans within the first year of origination, see Table 1.

The high and positive correlation in the volume of issuance in both markets lends support to the idea of financially constrained mortgage originators. Expansions in demand for securities in the securitization market induce expansions of mortgage credit to households in the primary market because originators can securitize loans immediately after origination, which frees up resources to originate new loans. Securitization market downturns represent a negative liquidity shock to originators; lower sales of mortgages and securities imply that originators must hold mortgages on their balance sheets for longer periods, which can induce contractions in new issuance of mortgages to households if banks do not hold enough capital or are unable to access other sources of funding.

GSEs have played a major role in purchasing loans and issuing MBS. Following the Great Recession the private segment of the RMBS issuance market collapsed, as shown in Figure 1, effectively increasing the market share of GSEs.

Table 1: Selected statistics

Mortgage market	90-06	09-16	90-16
Sales of loans[1] (%)	61.8	77.0	66.7
Corr[2] (sales, lending)	0.96	0.98	0.97

GSEs market shares[3]	90-06	09-16	90-16
Loan purchases	0.62	0.74	0.66
RMBS issuance[4]	0.69	0.95	0.81

Source: HMDA LARs and Reporter Panel 1990-2016. 1. The percentage of sales corresponds to the average dollar amount of loan sales divided by the total dollar amount of loans originated in a year by a mortgage-reporter institution. 2. The correlation reported is the average correlation of the volume of loans originated and of sold(or securitized) in the cross section. 3. Data on RMBS issuance market share are from SIFMA. 4. Data on RMBS issuance market share are only available starting in 1996.

Fluctuations of aggregates in the mortgage market are negatively correlated with fluctuations in households' default risk, which depends on households' fundamentals, namely, fluctuations in the value of the collateral—induced by house prices—and households' income. I perform a dynamic panel data estimation to document that the volume of mortgage lending and the volume of mortgage sales in the securitization market at the level of the originating institution are negatively associated with aggregate measures of households' default rate on their mortgage obligations, as well as households' aggregate disposable personal income. I include controls for originating institution asset's size and funding costs, which have the predicted sign. Table 14 and Table 15 in Appendix B show these results. The model developed in Section 3 captures this negative correlation by endogenously establishing an inverse relationship between the quality of securities and households' default risk.

2.2 Cross Sectional Distribution of Mortgage Lending

A high market concentration is the main characteristic of the mortgage industry in the United States. From 1990 to 2016, a small number of mortgage originators—although different over time—has dominated the lending market. Table 2 summarizes average moments that describe the cross-sectional distribution of mortgage originators based on their dollar amount of lending.[9] On average over the period of analysis, the top 1 percent of mortgage originators accounted for 62 percent and the top 10 percent for 89 percent of mortgage lending in the market.[10] Figure 7 in Appendix B shows that starting in the mid-1990s, the market became progressively more concentrated, peaking at the height of the 2006 housing market boom and slightly decreasing following the aftermath of the Great Recession.[11]. I calibrate the model to internally match these cross-sectional moments. The theory developed in Section 4.2 shows how these moments are crucial to informing equilibrium prices and quantities. Which in turn defines the degree of amplification of information frictions presented in the quantitative exercise performed in Section 5.

Concentration is even higher if the definition of loan origination is based on the sources of funds, that is, the retail and the wholesale channel. Stanton et al. (2014) find that the top 40 lenders accounted for 96 percent of all residential mortgage origination in 2006 when using Inside Mortgage Finance data and a definition of loan origination based on an originator's funding channel. Hence, the HMDA estimates in Table 2 represent a lower bound for the levels of concentration observed in the mortgage market.

2.3 Sources of Funding

Based on their sources of funding, mortgage originators are categorized into two main groups: banks and savings institutions (including traditional banks, thrifts, and credit unions), which have

[9]These results are very similar if one restricts the set of loans to those that are home purchase, conventional, one-to-four family property, and owner-occupied.

[10]This observation also holds when breaking down originators by type of mortgage institutions. A small fraction of banks, thrifts, and mortgage companies issue the bulk of mortgages in the market.

[11]Another interesting observation is that the number of lenders has declined over time, going from more than 9,000 in the early 1990s to less than 6,000 by 2017. Most of the reduction in the number of originators is due to a reduction in the number of small banks and credit unions reporting home mortgage lending activity. This is consistent with the findings of Corbae and D'Erasmo (2020), McCord and Prescott (2014), and Janicki and Prescott (2006), who document a decline in the number of commercial banks and an increase in the market concentration of large banks as the main trends in the commercial banking industry during the last three decades.

Table 2: Moments of the distribution of mortgage lending

Moments	90-06
Market share top 1%	0.62
Market share top 10%	0.89
Market share top 25%	0.96
Lending top 10% to bottom 90%	9.22
Mean/median	18.5
Average number of institutions	8,596

Source: HMDA LARs and Reporter Panel, 1990-2006

access to deposits, and mortgage companies, which do not. This breakdown is relevant because it is informative about originators' reliance on the securitization market as a source of capital, and their likelihood of being financially constrained in their ability to fund mortgage lending when demand for mortgage-backed securities dries up.

Mortgage companies sources of funding depend crucially on the securitization market's demand for mortgage-backed securities. Stanton et al. (2014) document that mortgage companies' portfolio of mortgages represents a large fraction of their assets, whereas most of their liabilities are short-term—repurchase agreements and warehouse lines of credit with maturities commonly between 30 to 45 days—which limits their ability to delay mortgage sales.[12] Using HMDA data I document that from 1990 to 2016, mortgage companies sold on average close to 90 percent of their portfolio within the first year of origination, see Figure 9 in Appendix B. Moreover, mortgage companies account for an important share of mortgage lending to households. Figure 7 in Appendix B shows that their market share averaged 30 percent from 1990 to 2006 and has steadily increased since then, surpassing 50 percent in 2016.

Banks, on the other hand, have the option to hold mortgages for longer periods than mortgage companies according to their balance sheet capacity. If the demand in the securitization market dries up, they can still meet households' demand for credit in the primary market by drawing from other sources of funding. However, there is evidence that many banks that operate in the mortgage market also behave like financially constrained institutions. Loutskina and Strahan (2009) and Loutskina (2011) use call-report data to show that securitization enhances bank lending potential but also makes a bank vulnerable to a shutdown of the securitization market, which can induce

[12]These patterns have also been documented by Jiang et al. (2020) for a larger set of non-depository financial institutions. Moreover, the authors find that this type of financial intermediaries finances themselves with twice as much equity as equivalent commercial banks.

strong contractions in their provision of credit. Calem et al. (2013) document that the collapse in the private segment of the securitization market removed a major source of funding for banks. In response to this collapse, financially constrained banks reduced the supply of mortgages, thereby amplifying the response of lending growth to the liquidity shock experienced during the Great Recession.[13] Based on these observations, in the model that I present in section 3, lenders are assumed to have limited access to outside equity.

3 The Model

3.1 Environment

Time is discrete and infinite. There are three types of agents: a borrower household, a continuum of lenders of mass one, and a government. Borrowers discount time (β^B) at a higher rate than lenders (β^L): $\beta^B < \beta^L$.

Borrowers

Preferences and Endowments. The borrower household has preferences over a final numeraire consumption good C_t, and over the housing services from owning a housing stock H_t given by:

$$U(C_t, H_t) = (1-\theta)\log C_t + \theta \log H_t,$$

where θ represents the valuation of housing services relative to other non-housing consumption goods. The household receives an stochastic income endowment Y_t every period. In order to finance house purchases, the household take on long-term debt (mortgages) extended by banks. Each period t, the household begins with outstanding stock of liabilities or mortgage debt B_t, and a total stock of housing H_t.

Mortgage Loans. Mortgages are modeled as long-term debt contracts with a fixed-rate and perpetual geometrically declining payments. This assumption is motivated by the fact that the most prominent mortgage contract in the United States is the fixed-rate 30 year mortgage. Under this type of contract, a fraction ϕ of the remaining principal balance becomes due each period, so that the next period's principal balance and payment decay by a factor $(1-\phi)$.[14] New mortgage

[13] This is also consistent with patterns in the securitization market of corporate loans documented by Ivashina and Scharfstein (2010). They find that during downturns, *lead banks* are required to hold larger shares of the loans they originate, which is associated with reductions in the amount of loans banks are willing to originate. The authors argue that this pattern is expected from financially constrained institutions.

[14] This representation has the advantage that the face value of all the coupon payments is $F_t = \sum_{t=0}^{\infty} \phi(1-\phi)^t = 1$. After making the first coupon payment ϕ, the amount of outstanding debt next period is $F_{t+1} = \sum_{t=1}^{\infty} \phi(1-\phi)^t = 1-\phi$.

loans N_t are priced competitively at the discounted price q_t. Every period at origination, a lender gives the borrower q times N units of the numeraire good, with face value N_t, which accumulates according to the aggregate law of motion of outstanding loans given by (1).

Mortgage Credit Risk and Default. I assume a family construct for the borrower household—as in Elenev et al. (2016), and Faria-e Castro (2018)–to model partial default in a tractable manner. Under this setup the household is split into a continuum of members indexed by $i \in [0, 1]$. The household provides perfect consumption insurance against idiosyncratic shocks so all members have the same allocations, they only differ in their default decisions. At the beginning of every period, each member owns the same amount of housing stock h_t such that $\int_0^1 h_t di = H_t$ and the same stock of liabilities or mortgage debt b_t such that $\int_0^1 b_t di = B_t$. Then, each member draws an idiosyncratic housing depreciation shock $\omega_t^i \sim G_\omega$ which proportionally lowers the value of their housing holdings to $\omega_t^i p_{h,t} h_t$ with $\omega_t^i \in [0, \infty)$. The mean, $\mu_\omega = \mathbb{E}[\omega_t^i]$, is assumed constant over time. While the standard deviation, $\sigma_{\omega_t} = Var[\omega_t^i]^{\frac{1}{2}}$, is assumed to vary over time. σ_{ω_t} represents mortgage credit risk in the economy and it is an exogenous state variable in the model. Household members optimally decide to default or repay their mortgage debt b_t according to the default function $\iota(\omega^i) : [0, \infty) \to \{0, 1\}$. When a member defaults, $\iota(\omega^i) = 1$, she also loses her stock of housing good h_t, so that default does not represent a windfall. This captures the loss of housing equity that a borrower experiences upon default by entering into foreclosure.[15] Appendix E.1 shows that the household's optimal default decision is characterized by a threshold $\bar{\omega}_t$, such that only members with $\omega_t^i \leq \bar{\omega}_t$ default on their mortgages. For a given threshold $\bar{\omega}_t$ we can define the household's aggregate default rate $\lambda(\bar{\omega}_t) = Pr[\omega_t^i \leq \bar{\omega}_t]$.

The maturity structure and the aggregate default rate imply the following law of motion for the stock of mortgage debt in the economy:

$$B_{t+1} = (1 - \phi)(1 - \lambda(\bar{\omega}_t))B_t + N_t. \tag{1}$$

Notice that going forward, a loan originated $t \geq 1$ periods in the past has exactly the same payoff structure as another loan originated $t' > t$ periods in the past. Thus, we only need to keep track of total debt B_t.

Budget and Borrowing Constraints. The household's budget constraint is given by:

$$C_t + p_{h,t}H_{t+1} = Y_t + T_t^B + (1 - \lambda(\bar{\omega}_t))\mu_\omega(\bar{\omega}_t)p_{h,t}H_t - (1 - \lambda(\bar{\omega}_t))\phi B_t + q_t N_t \tag{2}$$

where $\mu_\omega(\bar{\omega}_t) = \mathbb{E}[\omega_{i,t}|\omega_{i,t} \geq \bar{\omega}; \chi]$ represents the expected valuation of the aggregate housing good among the household's members that repaid their mortgage. T^B is a lump-sum tax imposed

[15]We abstract from other consequences of default for a borrower like reputation concerns and its effects to access credit over the long-term.

on borrowers by the government to balance its budget. Notice that the aggregate default rate impacts household's financial conditions in three ways: first, it reduces current mortgage payments $(1-\lambda(\bar{\omega}_t))\phi B_t$; second, it reduces the remaining aggregate stock of liabilities in (1); and third, it also reduces the current aggregate stock of depreciated housing good in (2), so borrowers internalize the effects of their default decisions.

The household faces a borrowing constraint that restricts the total amount of debt B_{t+1} at the end of the period to a fraction π of the new level of next's period choice of housing stock valued at current market prices $p_{ht}H_{t+1}$. This constraint captures regulatory loan-to-value π requirements.

$$B_{t+1} \leq \pi p_{ht} H_{t+1} \tag{3}$$

Housing Market. The housing market is segmented in the sense that only the borrower household purchases housing assets and derives utility from housing services.[16] Consequently, house prices are determined by the borrower's stochastic discount factor as shown by equation (27) in Appendix E.1. House price dynamics impact household's balance sheet through their holdings of housing stock. It also impacts household's leverage which, in equilibrium, is key to determine household's default rates. For simplicity, I assume that the recovery value of foreclosed houses is zero so borrowers' default represent a direct deadweight loss for lenders.[17] I also assume that the supply of housing is fixed to an amount $\bar{H}$ at every point in time.

Borrowers' Recursive Problem. The endogenous states that characterize the problem of the borrower family are $\{B_t, H_t\}$. The recursive formulation is:

$$V^B(B_t, H_t; X_t) \quad = \quad \max U(C_t, H_t) + \beta^B \mathbb{E}_{X'|X} V^B(B_{t+1}, H_{t+1}; X_{t+1}) \tag{4}$$

where X_t denotes the set of exogenous states in the economy to be defined later. The borrower family's problem consist in choosing sequences $\{C_t, N_t, H_{t+1}, \{\iota_t(\omega)\}_{\omega\in[0,\infty)}\}$ to maximize (4) subject to (1)-(3).

Lenders

Preferences and Funding. Lenders are denoted by lowercase letters with superscript j, and each lender j has preferences only over the final consumption good:

$$u(c_t^j) = \log c_t^j.$$

[16]The assumption of housing market segmentation is standard in macro models with housing markets, see Greenwald (2016) and Faria-e Castro (2018). This formulation is equivalent to assuming a rigid housing demand by lenders that derive services from a constant housing stock as in Elenev et al. (2016) and Justiniano et al. (2019).

[17]This assumption can be easily relaxed to include the recovery value of foreclosing houses–household's housing collateral–in a lender's payoff function.

Lenders operate only with private equity given by their ownership of the household's mortgages. A lender j's stock of loans is denoted by b_t^j. I assume that each lender holds a diversified loan portfolio across members of the household such that each of them is equally exposed to the aggregate default rate $\lambda(\bar{\omega}_t)$. Every period a lenders' income comes from borrowers' loan payments, i.e. fraction ϕ of their performing portfolio matures and pays cash. This setup implies that lenders have limited sources of funding and act as financially constrained intermediaries–one of the main features of financial institutions operating in the U.S. mortgage market as documented in section 2.

Loan Origination Technology. At the beginning of each period t, a lender draws a loan-origination cost z_t^j, which is independent and identically distributed across lenders and time, and follows a continuous cumulative distribution function $F(z)$ in the bounded support $[z_a, z_b]$. The loan origination technology is linear, and each lender j originates new loans of size n_t^j at a gross cost of $n_t^j z_t^j$. This stochastic cost represents a source of idiosyncratic risk for each lender, it captures the heterogeneity in costs, lending opportunities, and expertise of a wide variety of mortgage originators.

Private Information. I assume that every period, each lender privately knows which loans within her portfolio are non-performing after observing the aggregate household's default rate. More precisely, the information friction rests on the ability of a lender j to identify the defaulting loans in her portfolio $\lambda(\bar{\omega}_t)b_t^j$. An outsider cannot make such a distinction. By the end of the period, this information becomes public, and every lender can identify the non-performing loans in the economy. This assumption captures the asymmetries of information, between originators and buyers of mortgages, that allow an originator to better predict a borrower's default. Such asymmetries often–although not exclusively–arise during the borrower's screening stage.[18] For instance, originators may have soft information about a borrower's credit quality often retained to their advantage. Or originators may observe borrowers misreporting on loan applications or actively misrepresent their profiles, which carry over to MBS buyers.[19] I abstract from modeling the specific sources of these information asymmetries and instead take them as part of the environment.[20]

[18] Asymmetries of information can arise even if both parties observe the same information. For example, originators developing superior valuation models than MBS buyers–to predict a borrower's default based on fundamentals–can give rise to such asymmetries, see Shimer (2014) and Krainer and Laderman (2014).

[19] Soft information is referred to as *soft* because it is difficult to quantify–for instance, the originator's expectation about a borrower's income stability– as opposed to hard information usually reflected in quantitative borrowers' profiles (e.g. LTV, income, credit scores). There is compelling evidence of this information asymmetries, mainly in low-documentation loans, see Keys et al. (2010) and Demiroglu and James (2012). Misrepresentation of borrowers' profiles is an important determinant of their default risk see Jiang et al. (2014) and Piskorski et al. (2015).

[20] The problem of asset screening is relevant due to the scope for a moral hazard problem on the side of the originator (Downing et al. (2008) Keys et al. (2010)), Adelino et al. (2019)). For recent models with microeconomic foundations for this problem see Vanasco (2017), Neuhann (2019), Caramp (2019).

Additionally, it is assumed that a lender's loan-origination cost remains private so that other lenders cannot use this information to infer her trading decisions in the securitization market.

Securitization Market. Securitization is modeled to capture key features of the to-be-announced (TBA) forward market, the largest liquid market for mortgage-backed-securities (MBS) in the U.S.[21] In the model, lenders have access to a securitization market where they can buy securities and sell their stock of outstanding–previously originated–loans. A lender j makes trading decisions $\{s^j_{Gt}, s^j_{Bt}, d^j_t\}$ where s^j_{Gt} represents sales of good-outstanding (high quality) loans, that is those loans not affected by borrowers default, s^j_{Bt} represents sales of non-performing (low quality) loans, and d^j_t represents purchases of securities. As in practice, the securitization process consists in pooling loans of heterogeneous qualities to form securities. A security is a representative bundle of all loans traded, that features the same coupon payment and maturity structure as the loans that comprise it.

A TBA trade has two main features. First, a buyer learns the exact characteristics of the securities just before delivery rather than at the time of the trade. Meaning that sellers choose which assets in their portfolio will be delivered to buyers–at settlement–after information about the assets' quality has been realized. Second, TBA securities trade on a "cheapest-to-deliver basis". Under this arrangement, buyers understand that sellers have incentives to sell the lowest-value assets that satisfy the terms of trade.[22] To capture these features in a tractable manner, I assume that trades in the securitization market are non-exclusive and anonymous. Non-exclusivity implies that all loans and securities trade at a competitive pooling price p_t–endogenously determined in equilibrium. Anonymity implies that buyers and sellers cannot identify each other.[23] These two assumptions coupled with the private information friction allow the model to resemble the key features of TBA trades.

In this environment, just as in practice, a classic adverse selection problem–as in Akerlof (1970)–

[21]The TBA forward market accounts for more than 90 percent of the agency mortgage-backed-security trading. The other type of agency MBS trading is known as "specified pool" trading because the identity of the securities to be delivered is specified at the time of the trade.

[22]Securities from a TBA trade are known as pass-through securities. Each security in the pass-through pool represents a large and diverse number of mortgages. The underlying mortgage principal and interest payments are collected by a pass-through structure and forwarded to security holders on a pro-rata basis. There is no tranching or structuring of cash flows. In a TBA trade the actual identity of the securities to be delivered at settlement to a buyer is not specified on the trade date. Instead, participants agree upon only general parameters for the underlying pool of mortgages. The details about TBA trading are outlined in the "good delivery guidelines" developed by the Securities Industry and Financial Markets Association (SIFMA), see Vickery and Wright (2013) for an in-depth description.

[23]This assumption is a tractable way of ensuring the adverse selection problem persist over time in this simplified environment. Chari et al. (2014) show that adverse selection persists over time when lenders' anonymity is relaxed and reputational concerns about their trading actions are considered.

between loan sellers and security buyers naturally arises. Buyers are well aware of sellers' incentives to sell low-quality loans, and they expect to receive securities valued possibly below the average stated quality. Hence, buyers of securities will face a discount–over the competitive price–that would not emerge in the absence of information frictions. Let μ_t represent the per-unit discount arising from the adverse selection problem. This is an endogenous equilibrium object, and it is defined as the aggregate fraction of non-performing loans traded in the securitization market:

$$\mu_t = \frac{S_{B_t}}{S_t} \tag{5}$$

where S_{Bt} is the aggregate supply of non-performing loans, S_{Gt} denotes the aggregate supply of good-outstanding loans, and $S_t = S_{Gt} + S_{Bt}$ the aggregate supply of all loans traded.

Portfolio's Law of Motion. The law of motion of a lender's portfolio of loans is given by:

$$b^j_{t+1} \quad = \quad (1-\phi)(1-\lambda(\bar{\omega}_t))b^j_t - s^j_{Gt} + n^j_t + (1-\mu_t)d^j_t \tag{6}$$

The next period's portfolio comprises the current period's outstanding portfolio net of default, minus any loan sales, plus new loans. The last term, $(1-\mu)d^j_t$, corresponds to new purchases of securities net of the adverse selection discount imposed by information frictions.

Flow of Funds Constraint. A lender's flow of funds constraint is given by:

$$c^j_t + z^j_t n^j_t(q_t + \gamma_t) + p_t d^j_t(1-\tau_t) \quad \leq \quad (1-\lambda(\bar{\omega}_t))\phi b^j_t + p_t(s^j_{Gt} + s^j_{Bt}) \tag{7}$$

The right-hand side shows the sources of funding for a lender j: current mortgage payments net of losses from households' default, and cash receipts from sales of good-outstanding and non-performing loans in the securitization market. The left-hand side shows lender j's outflows: consumption c^j_t, origination of new lending n^j_t using her idiosyncratic origination cost z^j_t. As introduced in the borrower household problem, q_t is the discounted price of new loans. The additive term γ_t represents an insurance fee the government charges on originators to partially finance a subsidy τ_t provided to buyers of securities d^j_t. Both $\{\gamma_t, \tau_t\}$ are state-contingent government policy tools that capture current policy interventions in the market and are explained below in more detail.

Notice that s^j_{Bt} shows up in the flow of funds constraint because a lender can sell non-performing loans in the current period. However, it does not show up in a lender's portfolio law of motion (6). This is because non-performing loans are assumed to have a recovery value of zero; if a lender keeps them, these become current losses as those loans do not accumulate over the next period. A lender also faces portfolio restrictions over loan sales:

$$s^j_{Gt} \in [0, (1-\lambda(\bar{\omega}_t))(1-\phi)b^j_t] \tag{8}$$

$$s^j_{Bt} \in [0, \lambda(\bar{\omega}_t)(1-\phi)b^j_t] \tag{9}$$

and it is assumed that new loans and security purchases are non-negative, $n^j \geq 0$ and $d^j \geq 0$.

Recursive Problem of a Lender. The set of individual endogenous states that characterize the problem of a lender j is $\{b_t^j, z_t^j\}$. The recursive representation is the following:

$$V(b_t^j, z_t^j; X_t) \quad = \quad \max u(c_t^j) + \beta^L \mathbb{E}_{X_{t+1}|X_t} V(b_{t+1}^j, z_{t+1}^j; X_{t+1}) \tag{10}$$

where X_t denotes the same set of aggregate exogenous states faced by the borrower household. A lender's recursive problem consist in choosing sequences $\{c_t^j, b_{t+1}^j, d_t^j, s_{G,t}^j, s_{B,t}^j\}$ to maximize (10) subject to (6), and (7)-(9).

Government

In the U.S. mortgage-backed securities market, the GSEs insure loans against default risk and finance this insurance by charging a fee to the originator, known as the guarantee fee. The fee is a surcharge, in basis points, added to the loan interest rate contracted with the borrower.

I model government interventions as a set of exogenous state-contingent policies. There are two policy instruments: (i) a fee (or tax) on loan originators, and (ii) a subsidy (state contingent compensation) to lenders that buy securities. Let γ_t represents the insurance fee in units of the discounted price for loans. Then a lender must give up

$$\tilde{q}_t = q_t + \gamma_t \tag{11}$$

in order to lend a unit of resources to a borrower.

The subsidy on security purchases is denoted by $\tau_t > 0$. It is aimed at compensating buyers of securities for the losses derived from borrower's default and the adverse selection problem captured by the function μ. It naturally follows to set $\tau_t = \alpha^G \mu_t$, where $\alpha^G \in [0, 1]$ corresponds to the degree of compensation provided by the government policy. When $\alpha^G = 1$, the policy completely offsets buyer's losses associated to default risk and adverse selection, $\tau_t = \mu_t$ can be interpreted as an insurance policy. When $\alpha^G = 0$, there is no government intervention, i.e. $\tau_t = 0$. The government budget constraint is given by

$$\gamma_t N_t + T_t^B = \tau_t p_t \int d_t^j \; d\Gamma_t(b, z). \tag{12}$$

$\gamma_t N_t$ represents aggregate government revenue from collecting the origination fee. T_t^B is a lump-sum tax charged to borrowers so that the government balances its budget each period. The right-hand side represents government expenditures from providing subsidy τ_t in the securitization market.

Aggregate Resource Constraint

State Variables. The set of aggregate states in the economy is given by $X_t = \{Y_t, \sigma_{\omega_t}, \Gamma_t, B_t, H_t\}$. As introduced before, $\{Y_t, \sigma_{\omega_t}\}$ are exogenous states representing the borrower household's income endowment, and the volatility of the housing depreciation shocks, respectively. $\Gamma_t(b, z)$ is the joint distribution of the stock of loans and origination costs across lenders.[24] $\{B_t, H_t\}$ are the aggregate stock of loans and the aggregate stock of housing in the economy, respectively. The aggregate resource constraint is given by:

$$C_t + \int c_t^j \; d\Gamma_t(b, z) + p_{ht} H_{t+1} - \mu_\omega(\bar{\omega}_t) p_{ht} H_t + \zeta(N_t) \leq Y_t, \tag{13}$$

where $\zeta(N_t) = q_t \int (z_t^j - 1) n_t^j \; d\Gamma_t(b, z)$ represents the aggregate cost of lending in the economy.

3.2 Competitive Equilibrium

From here on, I suppress the subscript j and time indexing for ease of notation. A recursive competitive equilibrium given government policy $\{\gamma, \tau, T^B\}$ consists of the following functions: prices $\{q, p, p_h\}$, adverse selection discount $\{\mu\}$, allocations for the borrower household $\{C, N, B', H'\}$, and allocations for lenders $\{c^j, n^j, d^j, s_G^j, s_B^j\}_{j \in J}$ such that given initial endowments $\{B_0, \{b_0^j\}_{j \in J}\}$, a law of motion Γ', its transition density $\Pi(X'|X)$, and value functions $\{V^B, \{V^j\}_{j \in J}\}$:

1. Borrowers' allocations solve the problem in (4), taking as given $\{q, p, p_h\}$.

2. Lenders' allocations solve the problem in (10), taking as given $\{q, p, \mu\}$.

3. The housing price p_h clears the housing market:

$$H' = \bar{H} \tag{14}$$

4. The price of lending $q > 0$ clears the credit market:

$$N(q, p; X) = \int n(q, p) d\Gamma. \tag{15}$$

5. Whenever $p > 0$, the securitization market clears:

$$D(p, q; X) = S(p, q; X). \tag{16}$$

   and the adverse selection discount μ is determined in equilibrium by (5).

[24] In the presence of aggregate shocks, market-clearing prices change every period; thus agents need to know Γ to forecast prices. The distribution becomes a state variable because prices are a function of aggregates, which are computed by integrating the joint distribution.

6. The law of motion of Γ is consistent with lender's individual decisions:

$$\Gamma'(b,z) = \int_{b'(\hat{b},\hat{z},X)\leq b} d\Gamma(\hat{b},\hat{z}).$$

7. The government budget constraint, (12), is satisfied every period.

8. The resource constraint, (13), holds every period.

The notation for aggregates in the securitization market is as follows: S_G denotes the aggregate supply of good-outstanding loans, S_B the aggregate supply of non-performing loans, and S the aggregate supply of all loans sold. Each of these objects is defined by $S_G = \int s_G(b,z;X)\ d\Gamma(b,z)$, $S_B = \int s_B(b,z;X)\ d\Gamma(b,z)$ and $S = S_G + S_B$, and the demand of loans is $D = \int d(b,z;X)\ d\Gamma(b,z)$.

4 Theoretical Analysis

This section first presents the characterization of lender's decisions. Then, I study the main properties of the model, by focusing on the mechanism by which information and financial frictions amplify and transmit household's shocks between the primary and securitization markets.

4.1 Characterization of a Lender's Decisions

The dynamic problem in equation (10) has characteristics that allows for a closed form characterization of lender's decisions, as shown in Kurlat (2013).[25] I follow Kurlat's strategy and reproduce similar results. First, I show that all lenders' policy functions are linear in their stock of loans b. Second, I show that given choices of c and b', decisions $\{n, d, s_{G,}, s_B\}$ are obtained by solving a linear problem that leads to corner solutions. Third, I transform the problem of the lenders into a relaxed problem that allows for a simple characterization of consumption-lending decisions, and for deriving analytical expressions for the aggregate demand and supply of securities in the securitization market. Fourth, I show how the dynamics in the securitization market are connected to the primary market and borrowers' decisions.

Aggregate States

Aggregate states X follow a joint distribution $\Theta(X) \equiv \Theta(\sigma_\omega, Y, \Gamma, B, H)$ with law of motion $\Theta'(X') = \int \Pi(X'|X) d\Theta(X)$, where $\Pi(X'|X)$ is the transition density associated with the law

[25] Different to Kurlat's, in the present environment, lenders must also take into account the price of loans and borrower's endogenous default rate to compute their policy functions.

of motion. Additionally, the law of motion of Γ needs to be consistent with individual decisions $\Gamma'(b,z)(X) = \int_{b'(\tilde{b},\tilde{z},X)} d\Gamma(\tilde{b},\tilde{z})$.

Under the assumption that $z \sim i.i.d.$ across lenders, the joint distribution of debt holdings and idiosyncratic shocks $\Gamma(b,z)$ at time t can be written as the product of the distribution of idiosyncratic shocks F and the distribution of stock of loans G across lenders: $\Gamma(b,z) = G(b)F(z)$. This means that the stock of a lender's loans is independent of the probability of obtaining a particular realization of z. Furthermore, assuming that $z \sim i.i.d.$ across time implies that z does not correlate with $\{\sigma_\omega, Y\}$. Then $\Theta(\sigma'_\omega, Y', \Gamma'|\sigma_\omega, Y, \Gamma) = \Theta(\sigma'_\omega, Y', \Gamma'|\sigma_\omega, Y)$ and

$$\begin{aligned} \Theta(\sigma'_\omega, Y', \Gamma'|\sigma_\omega, Y) &= \Pi(\sigma'_\omega, Y'|\sigma_\omega, Y)\Gamma(b', z') \\ &= \Pi(\sigma'_\omega, Y'|\sigma_\omega, Y)G(b')F(z'). \end{aligned}$$

Thus, the joint law of motion of aggregate states is determined by the product of the law of motion for the exogenous states, origination costs, and the endogenous states.

Linearity of Policy Functions

The recursive problem in equation (10) has two main properties: first, the constraint set is linear in the stock of loans b, and second, preferences are homothetic, given the assumption of log-preferences. The first implies that a lender's consolidated wealth is proportional to her stock of loans; the second implies that her consumption and investment decisions are a constant fraction of her wealth. Hence, the policy functions for all lenders' decisions $\{c, b', s_G, s_B, d\}$ are linear in their stock of loans b. This is summarized in Lemma 1.

Lemma 1. Aggregate debt B is a sufficient statistic to predict prices and aggregate quantities. In particular, these do not depend on the distribution of debt holdings across lenders only on aggregate debt B.

Furthermore, Lemma 1 implies that the minimum relevant set of states needed to predict aggregate debt holdings next period is $X = \{B, H; \sigma_\omega, Y\}$.

Origination and Trading Policy Functions

In the securitization market, trading decisions can be characterized separately from consumption and investment decisions $\{c, b'\}$. Taking portfolio investment decisions b' as given, the problem of lender j, equation (10), consists of maximizing consumption c by choosing $\{d, n, s_G, s_B\}$, which implies solving a linear problem. This can be seen by combining her budget constraint (7) and the law of motion of her portfolio (6), which together yields

$$c = (1 - \lambda(\bar{\omega}))b\left[\phi + (1-\phi)z\tilde{q}\right] + s_B\, p + s_G\left[p(1-\tau) - z\tilde{q}\right] - d\left[p - z\tilde{q}(1-\mu)\right] - z\tilde{q}b'.$$

Since each lender j takes as given prices and the adverse selection discount: $\{p, \tilde{q}, \mu\}$, trading decisions are derived by comparing static payoffs. For sales of non-performing loans s_B: if $p > 0$ a lender has no incentive to keep a non-performing loan with zero recovery value. She chooses to sell all of them, hitting the corner in (9): $s_B = (1-\phi)\lambda(\bar{\omega})b$. The decision to sell good-outstanding loans s_G is based on how a lender's origination cost $\tilde{q}z^j$ compares with the price of selling loans p. Taking into account the portfolio constraint in (8) yields:

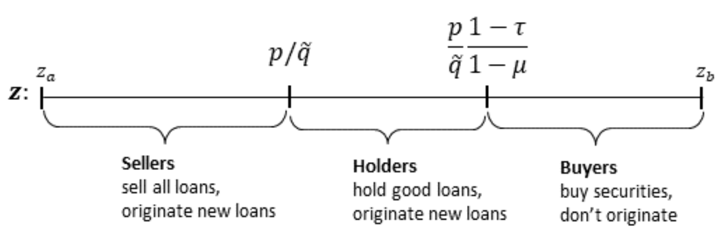
$$s_G = \begin{cases} (1-\lambda(\bar{\omega}))(1-\phi)b & \text{if} \quad z < \frac{p}{\tilde{q}} \\ 0 & \text{if} \quad z \geq \frac{p}{\tilde{q}} \end{cases}$$

The decision to purchase securities d depends on how a lender's origination cost $\tilde{q}z^j$ compares with the effective cost of buying a security $\frac{p(1-\tau)}{1-\mu}$. Notice, a lender understands that she is buying a bundle of all the loans supplied in the securitization market, and because all participants have incentives to sell all their non-performing loans, a fraction μ of them default with a zero payoff. Consequently, the effective cost of buying securities taking into account the subsidy to buyers, $\frac{p(1-\tau)}{1-\mu}$, is at least as high as the market price p:

$$d = \begin{cases} > 0 & \text{if} \quad z > \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu} \\ 0 & otw \end{cases}$$

Figure 2 summarizes a lenders' trading decisions in the securitization market according to cutoffs $\{\frac{p}{\tilde{q}}, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}\}$. The support for z is divided into three intervals.

Figure 2: Lenders' trading decisions in the securitization market



In equilibrium, lenders self-classify into three groups: sellers, holders, and buyers. Sellers are lenders with a low-z, $z \in [z_a, p/\tilde{q})$. They can originate new loans at a low cost, because of this, they have incentives to sell their entire outstanding portfolio in the securitization market and use the proceeds to originate new loans. Buyers are lenders with a high-z, $z \in (\frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}, z_b]$. For them, originating new loans is very costly, the market allows them to buy securities (bundle of loans) from other lenders at a lower price—after considering the adverse selection discount—relative to their origination cost. Thus, they choose to buy securities instead of originating new loans. Holders are lenders that fall between the cutoffs, $z \in [p/\tilde{q}, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}]$. Given their origination cost, the market price is not high enough to induce them to sell good-outstanding loans, and due to the adverse selection discount, the effective price they must pay for buying securities is too high, so they don't buy securities neither sell their good-outstanding loans. They end up holding their illiquid portfolio of outstanding loans and originate fewer loans at a high cost.

Lemma 2 summarizes trading and lending decisions for lenders. Trade in the securitization market is essentially an alternative investment technology to loan origination. When the securitization market is active, some lenders can specialize in originating loans and others in holding existing securities, meaning that they find it profitable to invest through the market instead of investing using their own technology. If the securitization market is not active, this alternative technology is not available to any lender. Consequently, all lenders invest according to their idiosyncratic draw of origination cost z.

Lemma 2. Given a lender's investment b', if there exists a positive market price for loans $p > 0$, the optimal trading decisions $\{n, d, s_G, s_B\}$ are shown in Table 3

Table 3: Trading and lending decisions

	$z < p/\tilde{q}$	$z \in [p/\tilde{q}, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}]$	$z > \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}$
d	0	0	$\frac{b'-(1-\lambda(\bar{\omega}))(1-\phi)b}{1-\mu}$
s_G	$(1-\lambda(\bar{\omega}))(1-\phi)b$	0	0
s_B	$\lambda(\bar{\omega})(1-\phi)b$	$\lambda(\bar{\omega})(1-\phi)b$	$\lambda(\bar{\omega})(1-\phi)b$
n	b'	$b'-(1-\lambda(\bar{\omega}))(1-\phi)b$	0

where the second cutoff is well defined for $\tau \leq \mu$. If there is no positive price that clears the securitization market, trading decisions are $d = s_G = s_B = 0$, and a lender origination decision is $n = b' - (1-\lambda(\bar{\omega}))\phi b$, taking into account the non-negativity constraints $n \geq 0$ and $d \geq 0$.

Consumption and Investment Policy Functions

Different trading decisions imply different budget sets for a lender. In particular, the budget set for lenders that decide either to buy or to hold is not convex. This non-convexity arises because the marginal rates of substitution are not only different across lenders but also different between possible equilibrium outcomes in the securitization market. In this environment, Kurlat (2013) shows that it is possible to characterize consumption-investment policy functions by defining an extended convex budget set that captures a lender's virtual wealth before trading decisions are taken. This approach allows for (i) setting up a relaxed problem for any lender type j and deriving consumption-investment policy rules as functions of an agent's virtual wealth before the realization of the agent's idiosyncratic origination cost z, and (ii) obtaining an analytical characterization of aggregate supply and demand in the securitization market.

Furthermore, the solution to the relaxed problem coincides with the solution of the original problem whenever the securitization market is active. That is, there is a positive price p that clears the market. If there is no such positive price, the relaxed problem can also be used to obtain consumption-investment policy functions without trade in the securitization market.

A lender's virtual wealth is defined as

$$W(b,z;X) = b\left[(1-\lambda(\bar{\omega}))\phi + \lambda(\bar{\omega})(1-\phi)p + (1-\lambda(\bar{\omega}))(1-\phi)\tilde{q}\max\{p/\tilde{q}, \min\{z, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}\}\}\right]. \tag{17}$$

The virtual wealth represents a lender's consolidated wealth as a generic function of her origination cost z, prices $\{\tilde{q}, p\}$, and lending and trading decisions $\{n, d, s_G, s_B\}$. It consolidates the lender's sources income: cash payments from her maturing portfolio, cash from selling non-performing loans, and the virtual valuation of her outstanding portfolio of loans—at either the market price or at the lender's internal valuation rate. Using (17) we can define a convex budget set that is weakly larger than the original budget set in problem (10). The problem of a lender under this relaxed budget set is given by

$$\begin{aligned} V(b,z;X) \quad &= \quad \max_{\{c,b'\}} \; \log(c) + \beta^L \mathbb{E}_{X'|X} V(b',z';X') \\ s.t. \quad & \\ & \qquad c + b'\tilde{q}\min\{z, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}\} \leq W(b,z;X). \end{aligned} \tag{18}$$

Given the choice of lender's utility function, the optimal consumption-investment decision rule will be to invest a constant fraction β^L of his wealth and consume the rest. Lemma 3 presents the policy functions for a lender j as a function of her virtual wealth.

Lemma 3. The optimal consumption and investment policy functions that solve problem (18) are given by:

$$c = (1-\beta^L)W(b,z;X) \tag{19}$$

$$b' = \frac{\beta^L}{\tilde{q}\min\{z, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}\}}W(b,z;X). \tag{20}$$

Equilibrium in the Securitization Market

The supply of loans in the securitization market is obtained by integrating the policy functions of sales of good-outstanding loans and non-performing loans, presented in Lemma 2, across the distribution of lenders:

$$\begin{aligned} S(p,q;X) &= S_B + S_G \\ &= \int s_B(b,z;X)\ d\Gamma(b,z) + \int s_G(b,z;X)\ d\Gamma(b,z) \end{aligned}$$

The adverse selection discount $\mu(p,q;X)$ was defined in equation (5). Demand for loans is obtained by integrating security purchases. For this we use the lender's investment policy function (20) and purchasing decisions from Lemma 2:

$$\begin{aligned} D(p,q;X) &= \int d(b,z;X)\ d\Gamma(b,z) \\ &= \int_{\frac{p}{q}\frac{1-\tau}{1-\mu}}^{z_b} \int_{b} \frac{b' - (1-\lambda)(1-\phi)b}{1-\mu(p,q;X)}\ dG(b)dF(z). \end{aligned}$$

Notice that demand is only well defined for $\mu < 1$; when $\mu = 1$ demand is zero. Market clearing requires that

$$S(p,q;X) \geq D(p,q;X) \text{ holding strict whenever } p > 0. \tag{21}$$

Lemma 4. $D > 0$ only if the solutions to problem (10) and problem (18) coincide for all lenders.

The solutions to problem (10) and problem (18) will differ whenever a lender chooses an allocation outside her budget set in (10). In this case, demand for securities in the securitization market will be zero, and the price must also be zero.

Equilibrium in the Primary Credit Market

Lemma 5. Credit supply in the primary credit market is contingent on the equilibrium outcome achieved in the securitization market. The credit supply function is given by

$$N^S(p,q;X) = \int_{z_a}^{\bar{z}(p,q)} n\ d\Gamma(b,z). \tag{22}$$

where the cutoff $\bar{z}(p,q)$ is given by

$$\bar{z}(p,q) = \begin{cases} \frac{p}{q}\frac{1-\tau}{1-\mu} & p > 0 \\ \min\left\{z_b, \frac{1}{q}\frac{\beta^L\phi}{(1-\beta^L)(1-\phi)}\right\} & p = 0 \end{cases}$$

The equilibrium in the primary market is determined by the market clearing condition (15), which equates borrower's demand for credit to lenders' supply of credit. The aggregate supply of credit is derived by aggregating the lender's lending decisions as given by Lemma 2. Lending policy functions are defined for two possible scenarios in the securitization market: one in which loans and securities trade at a strictly positive price; and another in which the price of these assets is zero. In the first case, only lenders that become sellers and holders originate new loans, and the total mass of originators is given by the integral over the interval $[z_a, \frac{p}{\tilde{q}}\frac{1-\tau}{1-\mu}]$, see Figure 2. Hence, when the securitization market is active the total supply of credit is given by (22). In the second case, when the securitization market is not active, aggregate supply will be given by the integral of lending decisions over all lenders in the interval $[z_a, \bar{z}(q)]$, where $\bar{z}(q) = \min\{z_b, \frac{1}{q}\frac{\beta^L \phi}{(1-\beta^L)(1-\phi)}\}$.

The aggregate demand for credit depends on the policy function of aggregate debt $B'(B, H; X)$, which is obtained by numerically solving problem (4). Once we solve borrower's problem we derive the aggregate demand for credit using the law of motion for borrower's aggregate debt:

$$N^D(q; X) = B'(B, H; X) - (1 - \lambda(\bar{\omega}))(1 - \phi)B. \tag{23}$$

Market clearing in the primary market satisfies

$$N^D(q; X) = N^S(p, q; X). \tag{24}$$

Notice that the price of securities in the securitization market also affects the market clearing equilibrium condition in the primary lending market.

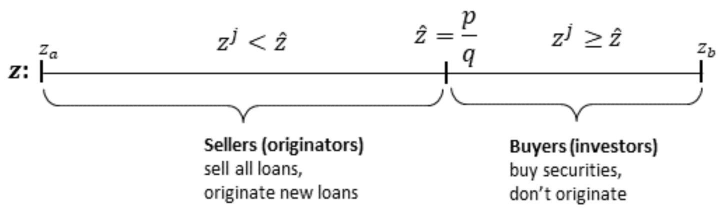
The model is fully characterized by the solution to the problem of the family of borrowers (4); the policy functions for each individual lender problem (19)-(20); the market clearing conditions for each market (15)-(16); and the aggregate resource constraint of the economy (13). Equilibrium prices $\{p(X), q(X)\}$ and adverse selection discount $\mu(X)$ for state space X, and borrower's policy functions are jointly solved using global solution methods. The computational algorithm is presented in Appendix D.

4.2 Model Properties

Securitization under Complete Information

To isolate the effects of information frictions, first consider the case of complete information. That is, assume that all lenders in the economy can identify the loans affected by borrowers default. Given that we have assumed non-performing loans pay zero upon default with certainty, their market value is zero. In this case, there is no adverse selection in the securitization market, only good loans are traded at a price different from zero if there is a positive equilibrium price. The market discount from adverse selection is zero and there is no wedge between the price a lender received and the cost to a buyer from purchasing securities. Figure 3 shows lenders' trading decisions under complete information. If there is an equilibrium in the securitization market, it is associated to only one cutoff $\hat{z}$, and trading and origination decisions are as in Lemma 2. All lenders with origination cost below $\hat{z}$ sell their entire portfolio in the securitization market to obtain cash and originate new loans. All lenders with origination cost $\hat{z}$ retain their portfolio, buy securities and do not originate new loans.[26]

Figure 3: lenders' trading decisions under complete information



The securitization market serves two primary purposes in this economy: first, it provides additional liquidity to lenders and, second, it allows for an efficient reallocation of resources among lenders. A lender can obtain liquidity by selling—partially or completely—her portfolio of outstanding loans instead of collecting payments until portfolio's maturity. Without a securitization market to trade these illiquid assets the liquidity available to a lender every period is limited to the cash payments from the lender's maturing portfolio.

The reallocation of resources among lenders occurs because of lenders' heterogeneous valuation of their outstanding portfolio.[27] This heterogeneity gives raise to gains from trading assets. The most efficient lenders—those hit with a low z—have a low valuation of their outstanding portfolio and want to sell it because they can invest at a higher return by origination new loans. The least efficient lenders—those hit by a high z—have a high valuation of their outstanding portfolio because originating new loans is expensive. For them holding illiquid assets through the purchase of securities is a more profitable strategy. In this sense, the securitization market allows the reallocation of illiquid assets from low-z lenders to high-z lenders.

Proposition 1. *Under complete information, in the steady state, an economy with trade in the securitization market features lower mortgage rates than in the absence of trade in this market, i.e. the discounted price of mortgage debt satisfies:* $q^{CI} > q^{NSM}$.

Credit intermediation is a costly process. By accessing a securitization market, lenders can trade away their differences in intermediation costs and reduce their individual cost of investment. Now, since lenders consume and invest in fixed proportions, a fraction of those extra resources—gained

[26]This specialization by activity captures the specialization observed in the mortgage market, that is, some financial institutions specialize in issuing loans but while others specialize in holding and investing in mortgage-backed securities.

[27]The assumption of idiosyncratic shocks generates heterogeneity in origination costs and introduces motives for trade among lenders.

through an efficient reallocation—increases their investment. In the aggregate, higher investment is reflected in an expansion of the credit supplied to borrowers, ceteris paribus, this translates into lower interest rates to borrowers. This intuition is formalized in Proposition 1.

The Role of Private Information

The impossibility of publicly identifying non-performing loans in the securitization market creates an adverse selection problem. Sellers are better informed about the default risk of the loans they sell, and they use this information advantage on their benefit. By always selling the non-performing loans and retaining the good-outstanding loans, whenever the market price is below their valuation, sellers adversely affect buyers in the securitization market. Although a buyer pays p for one security, she only ends up obtaining $1-\mu$ units because of the adverse selection discount. Hence, information frictions introduce a wedge between the price that a seller receives and the cost that a buyer faces.

Proposition 1 states that the aggregate cost credit intermediation depends on the extent to which the reallocation of resources among lenders is carried over. In other words, information frictions reduce the level of trade achieved in the securitization market, which has implications for the level of credit supplied in the primary market and for the price of credit (interest rate) that borrowers face.

An important property of the model is that adverse selection in the securitization market becomes more severe when household default rates increase. This is because the average quality of loans traded falls compared with the quality of loans retained in a lender's portfolio.[28] Notice that when the default rate is low, the effects of private information in disrupting trade can be small. However, as default rate shocks increase, the adverse selection problem becomes very acute, which can lead to a complete disruption of trade in securitization markets.

Comparative Statics

Here, I establish how aggregate shocks to the default rate affect aggregate outcomes in the securitization market and the credit market. First, let $\hat{z}$ be a market cutoff in equilibrium $\hat{z} \equiv \frac{p}{q}$.

Lemma 6. In steady state, consider an exogenous increase in the volatility of G_ω so that the new distribution G'_ω is a mean preserving spread. Ceteris paribus, borrowers default rate, $\lambda(\bar{\omega})$, under G'_ω will be higher than under G_ω.

[28] Elul (2011) presents empirical support for this idea, finding that in 2005, the average quality of retained loans was not significantly different from that of loans sold, whereas starting in 2006, the average quality of loans sold worsened compared with those retained. Agarwal et al. (2012) also document that starting in 2007, the strategy of prime mortgage originators moved towards an unwillingness to retain higher-default-risk loans in return for a lower prepayment risk, which coincides with the beginning of the foreclosure crisis in the primary mortgage market.

Lemma 6 establishes that volatility shocks that preserve the mean of the individual housing valuation shocks, that members of the borrower family experience, are associated to higher default rates. This is a way of capturing episodes of high credit risk arising from borrowers.

Lemma 7. In steady state, the proportion of non-performing loans in the market $\mu(\lambda, \hat{z})$ is increasing in borrowers default $\lambda(\bar{\omega})$, and decreasing in the market cut-off $\hat{z}$.

Lemma 7 indicates that in times of high borrowers default, if there is an equilibrium price which defines the cutoff $\hat{z}$, the proportion of non-performing loans in the market is also high. This is the case because at any positive price for securities all lenders sell their non-performing loans, as established in Lemma 2.

Assumption A1: $\forall\ \hat{z} \in [z_a, z_b]$:

$$m(\hat{z}) > \frac{1}{\hat{z}}\left[1 + \frac{1-\lambda}{\lambda}F(\hat{z})\right]$$

where $m(\hat{z}) = \frac{f(\hat{z})}{F(\hat{z})}$ is the inverse Mills ratio of $\hat{z}$.

Lemma 8. Under Assumption A1, the second equilibrium cutoff $\frac{\hat{z}}{1-\mu(\hat{z})}$ is decreasing in $\hat{z}$.

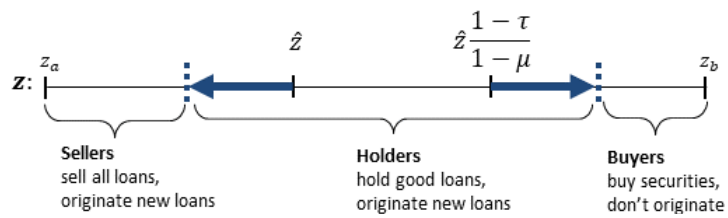
Lemma 8 states that as securitization market conditions improve the cutoff that indicates the real price paid by buyers gets closer to first cutoff, in other words, the private information wedge become lower. As explained before, this wedge represents the extent to which information frictions in the market impede trade.

Shocks that increase the default rate disrupt the functioning of the securitization market by increasing the proportion of non-performing loans, which follows from Lemma 6 and Lemma 7. In the securitization market a higher discount per security will, in turn, increase the real cost of buying securities which contracts demand; that is the second cutoff moves to the right in Figure 4. Then, the price must fall in order for the securitization market to clear. Consequently, the volume of trade is lower because at a lower price, more lenders retain good-outstanding loans instead of selling them, i.e. more lenders become holders.

Proposition 2. *In steady state, consider an exogenous increase in the volatility of G_ω so that the new distribution G'_ω is a mean preserving spread. Then, if there is price that clears the securitization market in the new steady, this has the following characteristics:*

1. *a higher proportion of non-performing loans are traded.*
2. *a lower volume of trade.*
3. *lower price of securities.*

Figure 4: Effects of episodes of high default



Furthermore, the aggregate cost of lending increases when the default rate is high because a larger mass of holders originate new loans at a higher cost. In the primary market, borrowers' needs for credit also increases due to lower housing stock.

Proposition 3. *A sufficient condition for a shutdown of the securitizaton market is:*

$$\min_{p}\left\{\frac{p(1-\tau)}{1-\mu}\right\} > \frac{\beta\phi}{(1-\beta)(1-\phi)} \tag{25}$$

then:

1. *there is no trade in the securitization market, and each lender uses her own technology to originate new loans.*

2. *the aggregate cost of lending and the interest rate are higher than when the securitization market operates.*

This proposition establishes that market shutdowns are possible in this economy, this is a well known result in models with adverse selection shown by Akerlof (1970), and Stiglitz and Weiss (1981), among others. Kurlat (2013) derives a similar sufficient condition to (25). Notice that even when the securitization market ceases to operate the credit market continues functioning. Hence, the economy can transition between states of nature in which the securitization market is inactive. The magnitude of changes in quantities and prices depend on the model's calibration. In Section 5.1, I calibrate the model by matching key characteristics of the U.S. mortgage market data.

5 Quantitative Analysis

5.1 Calibration

The model is calibrated at annual frequency for the period 1990-2006. The calibrated parameters are presented in Table 4.

Preferences Parameters. For borrowers, the discount rate β^B is set to 0.97 to match the ratio of consumption of non-durables and services to disposable personal income from the national income and product accounts (NIPA), which equals 0.79. The housing preference parameter θ is set to 0.13 to match the ratio of non-durable consumption to housing, C/H, to the ratio of consumption of non-durables and services to residential real estate: 0.4 in NIPA. The parameter governing the borrowing constraint π is set to 0.425 to match the ratio of households' mortgage debt to the stock of residential real estate in the flow of funds accounts. For lenders, the discount rate β^L is set to 0.985 to match the average real risk-free rate obtained from a one-year Treasury bill, which is 1.6% for 1990-2006.[29]

Technology Parameters. The distribution of lending cost shocks across lenders, $F(z)$, is calibrated using microdata from the HMDA database.[30] I aggregate the volume of mortgage origination in dollar amounts for every lender and for every year in the database from 1990 to 2017. Refer back to Table 2 for the average moments of the cross-sectional distribution. In order to match key moments of the lending distribution, $F(z)$ is modeled as a beta distribution characterized by shape parameters (α, β) in a bounded support $[z_a, z_b]$. Shape parameters (α, β) are estimated by methods of simulated moments to match the market share of the top 25 percent of originators, which is 0.96, and the ratio of the average volume of mortgage origination of the top 10 percent of originators to the bottom 90 percent in dollar amounts.[31] The bounds in the support of the distribution $[z_a, z_b]$ are the result of calibrating the scale, $sc = z_b - z_a$, and location, $lc = z_a$, parameters. I normalize the scale sc to 1, and set the location parameter to match the average real mortgage rate of 5.3 percent for the period 1990-2006. The mortgage bond is characterized by parameter ϕ, which governs the duration of the bond. I use the estimations from Elenev et al. (2016), who estimate this parameter by matching the Macaulay's duration and the coupon payments structure of a representative mortgage bond given by the Barclays MBS index.

Government Policy Parameters. The government's vector of policy instruments is given by $\{\gamma, \tau, T^B\}$. In practice, GSEs charge a guarantee fee to mortgage originators—quoted over the interest rate contracted with the borrowers—and provide a level of insurance to buyers of securities.

[29] In the model lenders do not have access to a risk-free bond; however, it is possible to compute the risk-free rate corresponding to a one period risk-free bond by computing the stochastic discount factor based on the aggregate consumption that the family of lenders obtains: $\frac{1}{1+r^f} = \beta^L \mathbb{E}_{X'|X}[U_{c'}/U_c]$, where $U_c = \frac{1}{\int c^j \, d\Gamma(b,z)}$.

[30] The HMDA requires covered depository and non-depository institutions to collect and publicly disclose information about applications for, originations of, and purchases of home purchase loans, home improvement loans, and refinancing.

[31] The choice of moments is motivated by the analysis in Section 2.2 where I argue that a high degree of concentration is one of the main features of the cross-sectional distribution of mortgage lending.

This policy can be mapped to the model, using the following equation:

$$r^*(q_t) = r(\tilde{q}_t) + g_f,$$

where $r^*(q_t)$ is the interest rate implied by the discounted price q_t that borrowers face, $r(\tilde{q}_t)$ is the net interest rate obtained by the lender, and g_f is the guarantee fee. Using the definition of lenders discounted price with government policy (11), obtains the following relation between γ and the g_f:

$$\gamma = \tilde{q} - \left(\frac{g_f}{\hat{\phi}} + \frac{1}{\tilde{q}}\right)^{-1}.$$

In the benchmark the guarantee fee is set to 20 basis points, since this was the average for the period 1990 to 2006, as reported by Fannie Mae. The parameter governing the degree of subsidy in the securitization market, α^G, is set to the average market share of GSEs of all sales of mortgages in the securitization market, which was 69 percent for the period 1990 to 2006.

Aggregate Exogenous Processes. Borrower households' income Y and the variance of the housing valuation shocks σ_ω are the two exogenous aggregate states in the economy. I assume they follow a first-order joint Markov process, characterized by state space $(Y_t, \sigma_{\omega_t}) \in \mathcal{Y} \times \mathcal{S}$ and transition matrix Π. For income, I use the cyclical component of disposable personal income from the flow of funds account. The mean of housing valuation shocks is set to match the average depreciation rate in the housing market, and the variance is calibrated to replicate the national delinquency rate for mortgage loans that are 90 or more days delinquent or went into foreclosure from the National Mortgage Database from the Federal Housing Finance Agency (FHFA). I set $(\sigma_\omega^H, \sigma_\omega^L) = (5.7\%, 17.5\%)$ which obtains default rates $(\lambda^H, \lambda^L) = (1.8\%, 7.9\%)$ and unconditional default rate of 2.6%

5.2 Model's Fit

This section shows the model's performance in terms of targeted moments and non-targeted moments, and shows the results from a simulation with the same sequence of shocks, as observed during the Great Recession. Table 4 shows the benchmark calibration and the targeted moments.

Table 4: Model vs Data Moments

Parameter		Target, period 1990-2006	Data	Model
Preferences				
β^L	0.985	risk free rate (pp)	1.6	1.7
β^B	0.97	C/Y, consumption to disposable personal income	0.79	0.80
θ^B	0.13	C/K, consumption to real state stock	0.40	0.40
π	0.43	B/K, households mortgage debt to real estate ratio	0.43	0.43
ν	2.0	I/K, residential real estate investment ratio	0.04	0.04
μ_ω	0.975	B/K, residential housing depreciation	0.03	0.03
ϕ	0.21	Average maturity of mortgage bond index	3.7	3.7
Lenders technology, $F(z)$				
α	4.20	Market share top 25% originators	95.7	95.9
β	2.25	Average lending top-10 to top-90	9.3	9.2
lc	0.63	30 years FRM real (pp), Freddie Mac	5.0	5.1
Government policy				
α^G	0.69	GSEs market share of mortgage sales in SM, 90-03 & 90-16		
g_f	20	Avg insurance fee (bps), Freddie Mac & Fannie Mae, 90-06		

The model fits the data well. In the primary market, the model does a good job in matching the market share of the top 25 percent originators in the cross-sectional distribution. In terms of non-targeted moments, Table 5 shows that in the securitization market, the model has a good fit with the correlation between the volume of sales and the volume of loan originations to households. However, the model predicts a higher fraction of loan sales in the securitization market than in the data and falls short in accounting for the value added of the credit intermediation sector. Also, the model fits very well the distribution of market shares in quartile groups across mortgage originators.

Table 5: Non-targeted moments. Model's benchmark calibration

Description	Model	Data	Description. Period 90-06
Fraction of loan sales(pp)	73.9	61.8	% average sales of loans, HMDA
Corr (sales, lending)	0.86	0.90	Time series, HMDA
mortgage spread (bps)	178	330	Avg 30y FRM compared to 10y t-bill.

Distribution of lending $F(n)$				
Market share by quartile group	Q1	Q2	Q3	Q4
Data	0.002	0.008	0.030	0.959
Model	0.006	0.007	0.030	0.957

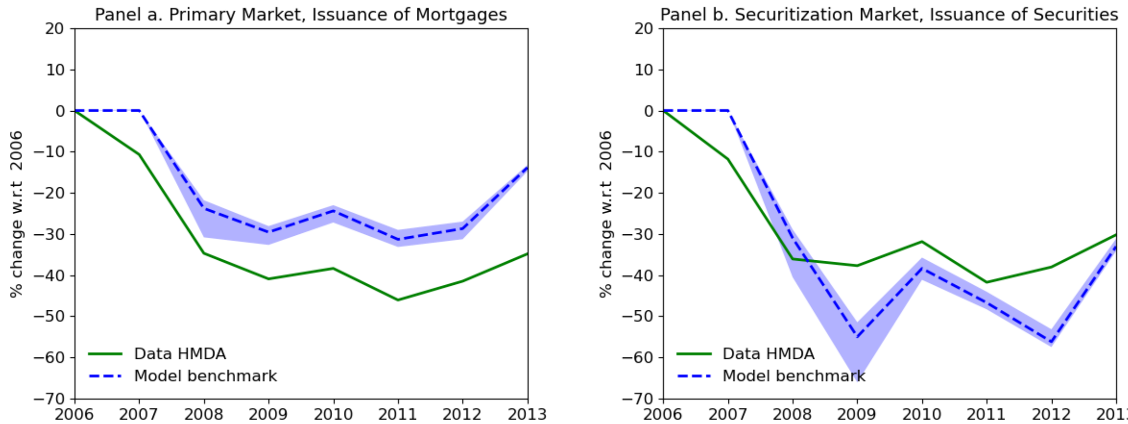
5.3 Dynamic Responses

This section studies the model's predictions on aggregates in the mortgage market during the Great Recession. The baseline calibration corresponds to the period 1990-2006 as described in the previous section. A sequence of realized shocks for aggregate households' income; and a sequence of housing depreciation shocks that endogenously matches the default rate observed from 2006 to 2016 are introduced in the model as exogenous processes. Figure 10 in Appendix B, shows the entire sequence since 2000.

The model accounts for two-thirds of the 41 percent contraction in aggregate residential mortgage lending experience from 2008 to 2013 during the Great Recession, i.e the model predicts a contraction of 25 percent of aggregate mortgage lending during the same period. Figure 5 shows percentage changes of the volume of new mortgage lending and the volume of issuance of MBS (right panel) with respect to 2006. The volume of MBS issuance fell by 37 percent on average between 2008 and 2013, and the model predicts an average decline of 40 percent during the same period. Figure 13 in Appendix C shows percentage changes with respect to 2006 for households' default rates and for the spread on mortgage interest rates. Both follow closely the observed patterns of their data counterparts during the period of analysis.

The model success is generating large fluctuations rests on two factors. First, the endogenous response of the adverse selection discount to borrowers default risk, and second, the shape of the distribution of lending costs estimated in the calibration. To illustrate the importance of the latter, Figure 12 in Appendix C shows the model's implied distribution of lending costs across lenders. The cutoffs are obtained for the mean default rate and the mean income shock. The density shows that there is a small mass of lenders that originate loans to households at a low cost—those below

Figure 5: The mortgage market during the Great Recession



Panel a: Data is the aggregate volume of new mortgage issuance in a given year in dollar amounts. Source: HMDA database. Panel b. Data, Sales corresponds to the aggregate volume of sales of mortgage loans in the securitization market in a given year in dollar amounts. Source: HMDA database. All data series have been deflated to 2015 prices.

the first cutoff $\hat{z}$—and a large mass of lenders with high origination costs. According to the model, those lenders below the first cutoff sell their entire portfolio to take advantage of their low lending cost. This large inflow of cash allows them to issue a large number of new loans to households compared with those lenders that hold on to their portfolio of good-outstanding loans—the mass of lenders between the two cutoffs—which only originate new loans using the proceeds from the fraction of their portfolio that matures.

In line with the patterns of the U.S. mortgage market, the calibration replicates a small mass of lenders accounting for a large fraction of lending in the market. The model predicts that the liquidity benefits of trading in the securitization market are large: the left panel in Figure 12 shows a large discontinuity in the volume of lending of the last marginal seller compared with the next marginal holder, about four times as large. Based on this market structure, the model predicts that fluctuations in the aggregate default rate induce changes in the distribution of sellers, holders, and buyers, which in turn induces large fluctuations in the supply of credit in the primary market. In particular, times in which the default rate is high result in large contractions of the volume of new loan originations because some of the most efficient lenders switch from selling to holding their portfolio. The degree of concentration plays a key role in the quantitative magnitude of the induced fluctuations.

5.4 Quantifying Information Frictions

How important are information frictions in the securitization market to account for fluctuations in aggregate credit? To answer this question, I perform a decomposition of the forces underlying the contraction. First, I simulate the model for the same sequence of aggregate shocks observed during the Great Recession for an economy under complete information. In this economy, non-performing loans are immediately identified by all lenders in the economy and hence are not traded in the securitization market. Still, security investors face aggregate default risk associated to the pool of loans that conform the security.

Figure 6: Shock Decomposition during the Great Recession

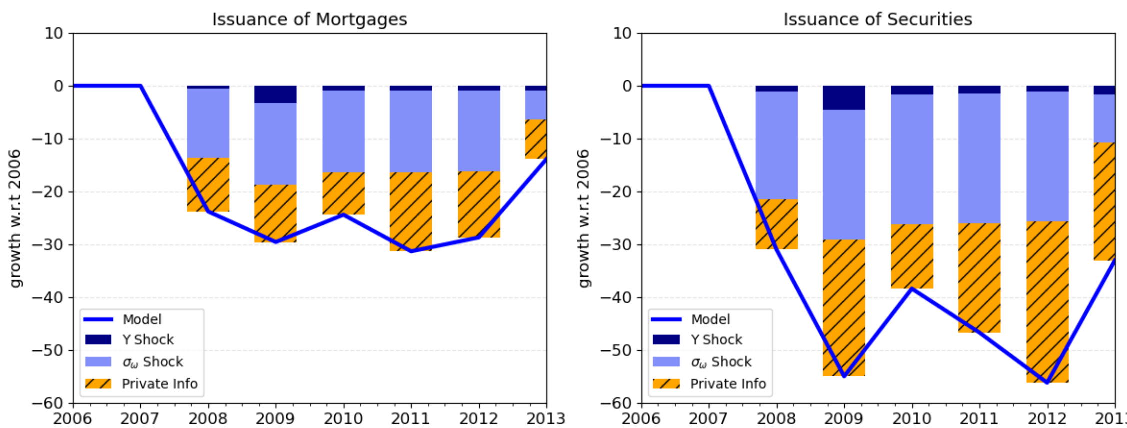


Figure 6 shows the shock decomposition for the both aggregates in the credit and securitization market. The bars quantifying the contribution of private information correspond to the difference between the benchmark economy and an economy with complete information, both with the same sequence of household's income and housing valuation shocks. The quantification of the effect of exogenous shocks is obtained by turning-off one shock at time in an economy under complete information.

Panel (a) in Figure 6 shows that on average forty percent of the model's predicted decline in mortgage lending arises from information frictions. Put differently, information frictions amplify the dry up of liquidity in the securitization market by almost double. Panel (b) shows that trading of securities would have remained at the levels observed previous to the Great Recession up until 2011.

Table 6: Average contribution of forces during 2008-2013

Contribution (pp)	priv. info	σ_ω^2	Y
Credit Market	43	52	5
Securitization Market	46	50	4

Given that the model replicates two-thirds of the dynamics of mortgage credit, and given that information frictions account for forty percent of the model predicted contraction, in the aggregate, the decomposition shows that about thirty percent of the credit contraction observed in the Great Recession can be attributed to the collapse of the securitization market.

5.5 Evaluation of Policies

After the Great Recession, two main changes took place in the securitization mortgage market. The first was the collapse of the private segment of the RMBS market in 2008, which effectively left in place only the agency segment. This change can be interpreted as an expansion of the coverage α^G of the subsidy in the market, going from 69 percent to 100. The second change was the increase in the guarantee fee charged by GSEs to mortgage originators for insuring RMBS investors against default risk. After 2012, this fee went up from 20 basis points to 60 basis points. Table 7 reports unconditional means and standard deviations for the main outcomes in the primary and securitization markets, and for government variables obtained from simulating the economy for 10,000 periods under each scenario. The first two columns correspond to moments obtained from simulations for the benchmark economy and simulations for an economy with both changes. The two decomposition columns report moments obtained by simulating economies with one change at a time.

Table 7: Policy changes after the Great Recession

Description	Benchmark	$\Delta^+\tau$	$\Delta^+\gamma$	$\Delta^+\gamma$ & $\Delta^+\tau$
Primary Market				
Mortgage spread (bps)	329	261	356	290
Mortgage spread, std (pp)	6.3	4.8	6.1	4.7
Default rate (pp)	2.7	3.2	2.6	3.0
Securitization Market				
Fraction of loans traded (pp)	85.1	100	85.7	100
Price of securities, std (pp)	11.3	9.2	11.3	9.2
Prob. of market collapse (pp)	6.3	0.0	6.1	0.0
Government Policy				
Costs of policy (pp), $\tau = \alpha^G \mu$	6.8	11.8	6.5	11.2
Borrower's share of tax (pp)	29	39	0	15

*Moments obtained from simulating the model for a long time series (10,000 periods).

The model predicts that the policy changes introduced after the Great Recession are effective in stabilizing the mortgage market by reducing the volatility of quantities and prices in both primary and securitization markets compared with the benchmark economy. In the primary market, the volatility of the interest rate falls from 6.3 to 4.7 percentage points, reflecting higher stability in the mortgage rates faced by households. This magnitude of change is consistent with the observed decline in the volatility of the mortgage spread in the data, which fell by about 60 percent between periods 1990-2006 and 2013-2018, as shown in Table 13 in Appendix B.

In the securitization market, the volatility of the price of securities also falls substantially, declining from 11.3 in the benchmark economy to 9.2 percentages in the economy after both policy changes. The decomposition columns in Table 7 show that the reduction in the volatility of the mortgage rate spread and in the price of securities comes from increasing the subsidy. By completely compensating buyers for losses from default risk and adverse selection, the economy achieves its maximum level of trade at every realization of the aggregate states. This implies that all lenders classify as either sellers or buyers, and no lenders are left holding on to their portfolio of good-outstanding loans. Fluctuations in the default rate affect the supply of and demand for securities in the securitization market through the general equilibrium effect from borrowers' demand for new lending.

Overall, the model predicts that the mortgage spread settles slightly below the level of the benchmark economy. The increase in the subsidy implies a reduction in the interest rates by 70 basis points; this reduction comes from a more efficient reallocation of assets between lenders in the securitization market. Increasing the fee on originators pushes the mortgage spread up, and mortgage originators pass on part of the tax in the form of higher interest rates to households in the primary market.

A more stable mortgage market comes at the cost of higher taxes to both borrowers and lenders. The cost of expanding the government subsidy in the securitization market increases substantially from 6.8 cents on the dollar to 11.8 cents on the dollar. Raising taxes (fee) on originators reduces the tax burden on borrowers. Furthermore, it implies a lump-sum transfer to borrowers from lenders.

Table 8: Welfare effects: policy changes after Great Recession

Description	$\Delta^{+}\gamma$ & $\Delta^{+}\tau$	Decomposition	
		$\Delta^{+}\tau$	$\Delta^{+}\gamma$
Δ% Borrower welfare	0.06	-0.16	0.18
Δ% Non-durable cons.	-0.15	-0.69	0.47
Δ% Housing good cons.	0.55	2.63	-1.89
Δ% Lenders' welfare	1.3	3.01	-1.53

*Moments obtained from simulating the model for a long time series (10,000 periods).

Changes in welfare are in consumption-equivalent units.

A welfare analysis of the policy changes introduced after the Great Recession shows positive but unequal welfare gains among borrowers and lenders. Table 8 shows that the policy changes introduced after the Great Recession imply small welfare gains for borrowers and larger welfare gains for lenders. The decomposition shows that borrowers benefit from the lower interest rates and lower volatility. However, the increase in taxes subdues these welfare gains. For lenders, the gains from stabilization in the securitization market are higher because the subsidy policy has an additional benefit of improving lending efficiency, which reduces their lending costs and allows them to consume more. Here, it is important to keep in mind that I have modeled the government as having access to a limited set of policy tools. In particular, government expenditure is financed using non-distortionary taxes on borrowers, whereas the subsidy policy affects borrowers through changes in the interest rate (i.e., an intertemporal margin). It would be interesting to expand the set of government tools to taxes that affect other margins on households' decisions. Additionally, the capacity of the government to issue debt could smooth tax payments in aggregate states in which government expenditures are high because of higher default risk. Thus, having access to debt could increase the welfare gains from policy interventions in the securitization market.

6 Conclusion

This paper develops a framework that connects dynamics in the lending and securitization mortgage markets in a dynamic general equilibrium model. The calibrated model matches the main features of the U.S. mortgage market from 1990 to 2006. I find that liquidity and information frictions in the securitization market accounted for about one third of the total mortgage credit contraction during the Great Recession. The model's success in generating large fluctuations in both markets rests on two important forces: (i) the severity of information frictions, and (ii) the concentration among loan originators in the U.S. mortgage market. A welfare analysis of the policy changes introduced in the securitization market after the Great Recession shows positive but unequal welfare gains among borrowers and lenders.

On the policy analysis, a substantial amount of research has focused on the moral hazard cost of expanding GSEs and finds little scope or no role at all for policy interventions. My analysis focuses on liquidity frictions arising from information problems—adverse selection—and shows that in the presence of this type of frictions, expanding government policy can have an important stabilization role in the mortgage market. In particular, this paper contributes by highlighting two aspects of the benefits of expanded government policy: the increase in liquidity to mortgage originators who actively participate in the securitization mortgage market, and the reduction in lending costs from better reallocation of resources in the economy.

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A Data Sources

Home Mortgage Disclosure Act - HMDA

Here I describe the details about the data set and the construction of variables used in the analysis of Section 2. HMDA requires mortgage originators, banks and non-bank institutions, to collect and publicly disclose information about their mortgage lending activity. The information includes characteristics of the mortgage loan an institution originate or purchase during a calendar year. HMDA is estimated to represent the near universe of home lending in the United States, see Neil et al. (2017). I construct a panel of mortgage originator-institutions for the period 1990-2016. First, I use the Loan Application Registries(LAR) to compute aggregate volumes, in dollar amount and loan counts, of mortgages originated and mortgages sold in the secondary market every year for every reporter institution. As is standard in the literature, I restrict the sample to conventional, one-to-four family, owner-occupied dwellings, and include both home purchases and refinanced mortgage loans. Second, I use the HMDA Reporter Panel which contain the records of originator-institutions (reporter). Variables of interest are the type of institution (Bank Holding Company, Independent Mortgage Company, Affiliate Mortgage Company), the institution supervisory government agency, and assets. Finally, I merge the collapsed LARs dataset with the Panel of Reporters using the unique reporter ID. From 1990 to 2016 the HMDA panel covers 8,127 mortgage reporters every year on average.

RMBS Issuance. Data on Residential Mortgage Backed Security issuance is taken from the Securities Industry and Financial Markets Association (SIFMA). Source: `https://www.sifma.org/resources/`. The volume of issuance for Agency are obtained by adding up the dollar amount of RMBS issuance of Freddie Mac, Fannie Mae and Ginnie Mae. The volume of RMBS issuance for non-agency corresponds to private institutions other than Government Sponsored Entities.

Households Income. I compute the cyclical component, Hodrick-Prescott filter, of Households Disposable Personal Income from the Flow of Funds account divided by GDP deflator (2015 base). Source: Table F.101 Households and Nonprofit Organizations.

Default rates. Corresponds to the national delinquency rate for mortgage loans that are 90 or more days delinquent or went into foreclosure. Source: National Mortgage Database (NMDB).

Mortgage Interest rates. I use the average 30 year fixed mortgage rate from Freddie Mac Primary Mortgage Market Survey 2018.

Table 9: Description of HMDA LAR and Reporter Panel files

Period	File type	Observations
1990-2003	.dat	Source: https://catalog.archives.gov. See document 233.1-24ADL.pdf for a description of data-file length of fields. Starting 2004 length of fields was changed.
2004-2013	.dat	Source: https://catalog.archives.gov. For 2010 numbers coincide with tables from National Aggregates reported on FFIEC
2014-2017	.csv	Source: Consumer of Finance Protection Bureau. https://www.consumerfinance.gov/data-research/hmda/

Guarantee Fees. Taken from Fannie Mae and Freddie Mac Single-Family Guarantee Fees Reports provided by the Federal Housing and Finance Administration (FHFA). Source: https://www.fhfa.gov/AboutUs/Reports.

B Additional Figures and Tables

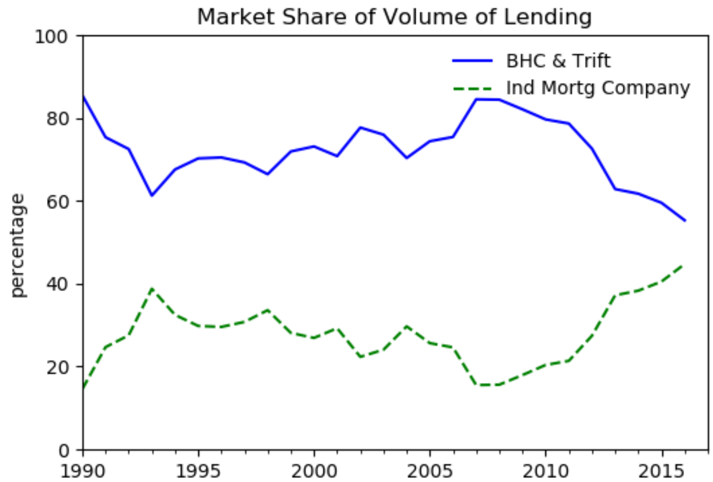
B.1 Cross-sectional characteristics of the mortgage market

Table 10: Moments of the distribution of mortgage lending

Moments	**90-06**	**90-16**
Market share top 1%	0.62	0.64
Market share top 10%	0.89	0.90
Market share top 25%	0.96	0.96
Lending top 10% to bottom 90%	9.22	9.30
Mean/median	18.5	18.9
Average number of institutions	8,596	8,206

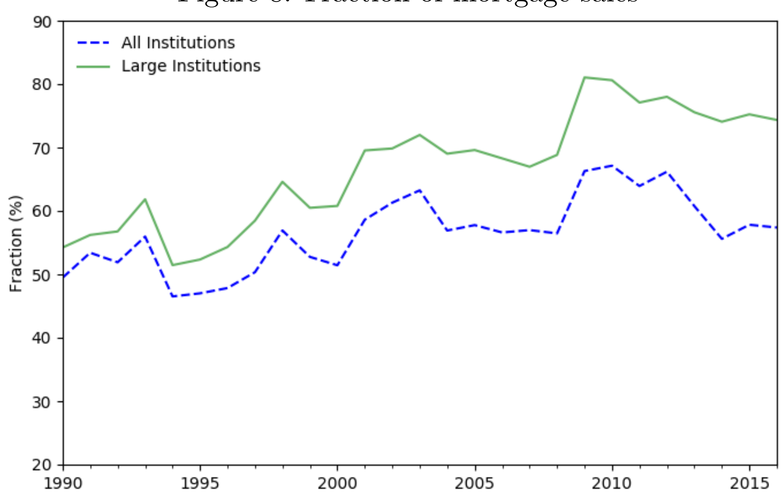
Source: HMDA LARs and Reporter Panel 1990-2017

Figure 7: Primary mortgage market, market share of the volume of lending



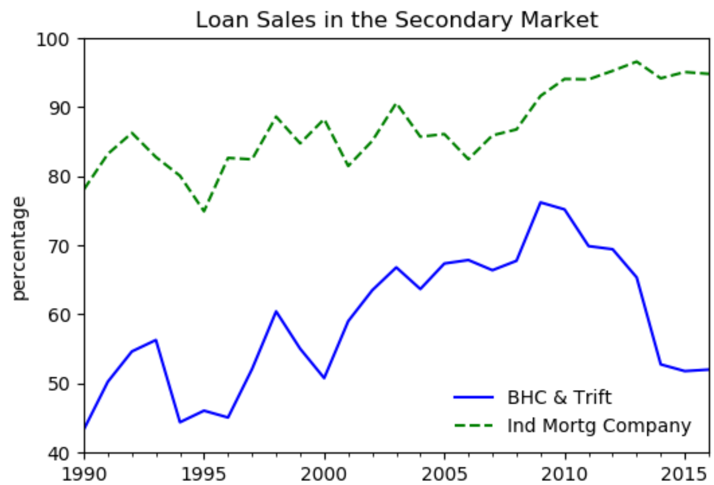
Source: HMDA LARs and Reporter Panel 1990-2017.
BHC & Thrifts refers to Bank Holding Companies and Thrifts Holding Companies including their affiliates. This category also includes savings institutions like Credit Unions.

Figure 8: Fraction of mortgage sales



Source: HMDA. The fraction of sales corresponds to the cross-sectional average aggregate dollar amount of mortgage sales divided by the aggregate dollar amount of lending for a mortgage reporter institution, for loans originated within the year that are reported. Large reporters are institutions reporting more than 1,000 new mortgage loans every year.

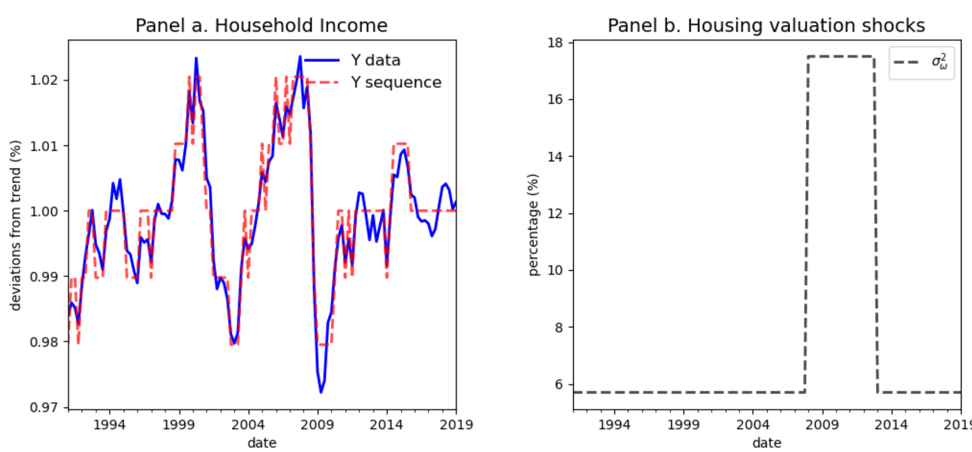
Figure 9: Sales by type of Institution



Source: HMDA LARs and Reporter Panel 1990-2017.
BHC & Thrifts refers to Bank Holding Companies and Thrifts Holding Companies including their affiliates. This category also includes savings institutions like Credit Unions.

Income and Default Rates

Figure 10: Income and default processes



Panel a. Household Income corresponds to the cyclical component of Disposable Personal Income from NIPA.
Panel b. Sequence of housing valuation shocks needed to match the moments of the default rate (percentage of delinquent mortgage loans 90 days or more, or in foreclousure). Source: National Mortgage Database, FHFA.

Estimation of Exogenous Processes

Households' income state space and transition matrix is obtained from the cyclical component of the Disposable Personal Income from the Flow of Funds account. First, I estimate an auto-regressive model of first order, AR(1), for the period of analysis 1990-2006, and discretize the AR processes into a Markov chain of first order. Then, I combine this process with a first order Markov chain for the housing volatility shock with two states.

Table 11: Joint Markov Process for income and default rates

State	s_1	s_2	s_3	s_4	s_5	s_6	s_7	s_8	s_9	s_{10}
Y	0.980	0.980	0.990	0.990	1.000	1.000	1.010	1.010	1.020	1.020
σ^2_ω	0.078	0.203	0.078	0.203	0.078	0.203	0.078	0.203	0.078	0.203
Stationary Prob										
Prob	0.035	0.028	0.176	0.074	0.340	0.035	0.244	0.006	0.062	0.000

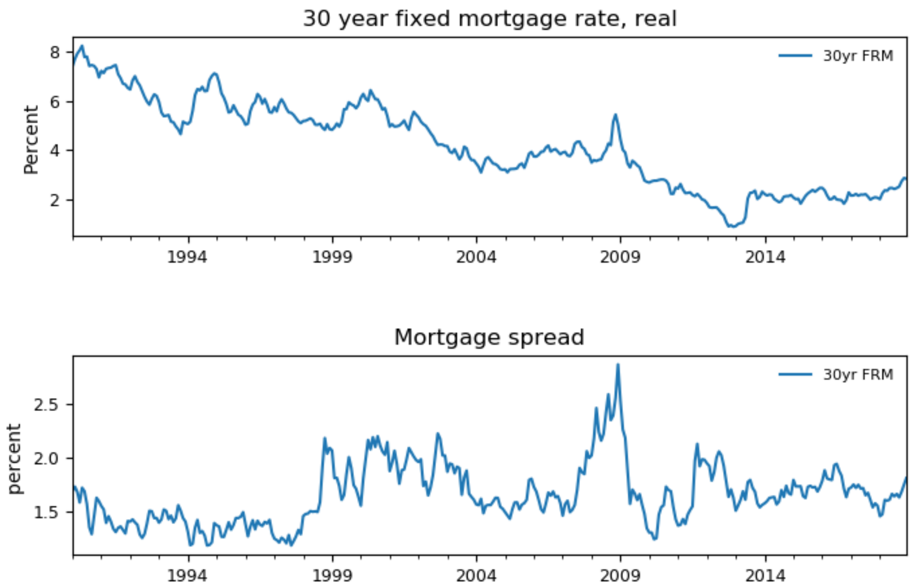
The Markov process fits well the unconditional means and standard deviations for income, and default rate, and the negative correlation between income and delinquency rates. Table 12 shows the moments obtained from a simulated time series of 100,00 periods versus the data moments

Table 12: Fitted moments for time series

	mc simulation	data, 90-06
Y mean	1.0	1.0
Y std	0.010	0.010
ρ_Y std	0.69	0.69
corr(Y,σ^2_ω)	-0.35	

Mortgage Interest Rates

Figure 11: Historic mortgage interest rates



Source: Freddie Mac Primary Mortgage Market Survey 2018.
Mortgage spread is the different between the 30 year fixed mortgage rates and a 10 year treasury bill rate. Mortgage rate correspond to the real rate obtained from subtracting 10 year expected inflation to the nominal 30 year fixed mortgage rate.

Table 13: Historic average mortgage rates

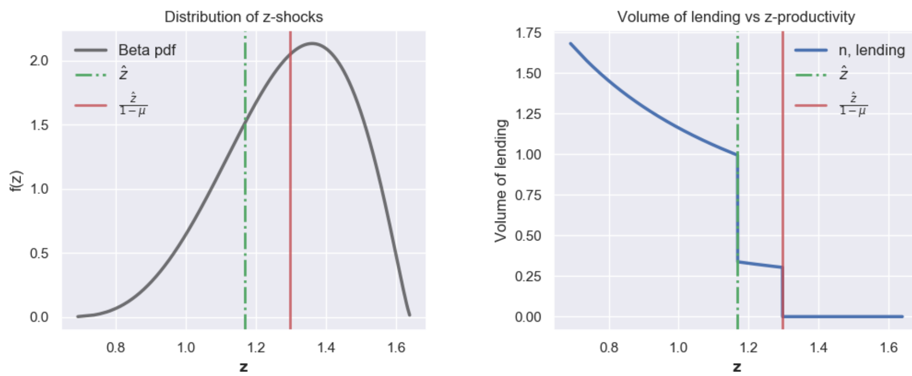
Period	90-06	13-18
spread	1.60	1.68
std	0.27	0.10
rate	5.34	2.10
std	1.23	0.36

Source: Freddie Mac Primary Mortgage Market Survey 2018.
Mortgage spread is the difference between the 30 year fixed mortgage rate and a 10 year treasury bill rate. Mortgage rate correspond to the real rate obtained from subtracting the 10 year expected inflation to the nominal 30 year fixed mortgage rate.

C Model Simulations

C.1 Quantitative Mechanism

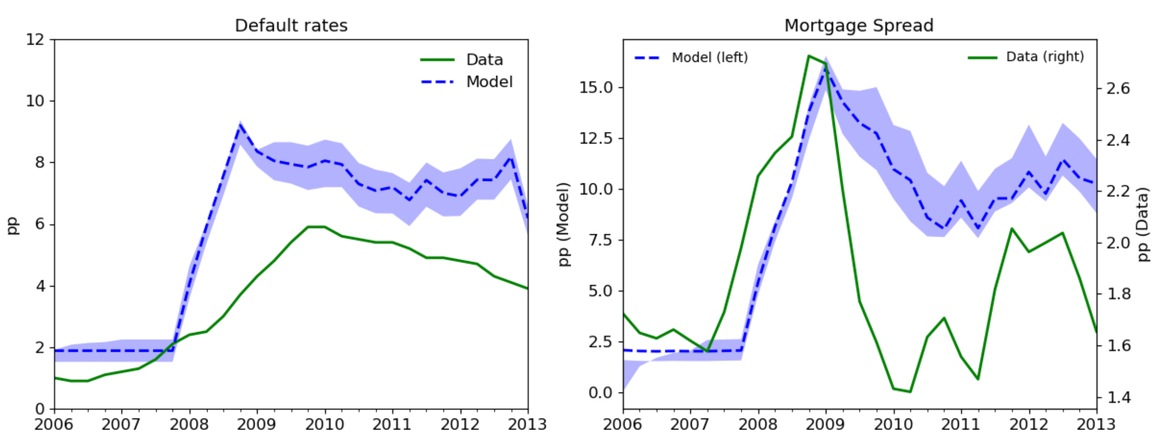
Figure 12: Distribution of lending cost and lending volumes across lenders



The left panel shows the implied density for $F(z)$ on the benchmark calibration. The right panel plots the volume of loan origination to households (y-axis) against the support of lending costs (x-axis).

C.2 The Great Recession

Figure 13: Household aggregates during the Great Recession



Panel a: Data corresponds to the percentage of delinquent mortgage loans 90 days or more, or in foreclousure. Source: National Mortgage Database, FHFA.

Panel b: Data is the flow of residential real estate investment in 2015 prices from the flow of funds. All series are shown as the percentage change with respect to 2006.

Dynamic Panel Estimations

I perform a dynamic panel data estimation following the methodology in Arellano and Bond (1991) to document that the volumes of mortgage lending at the level of the originating institution are negatively associated with aggregate measures of households default on their mortgage obligations, and households aggregate disposable personal income. Table 14 shows this, I control by asset size and funding costs which have the predicted sign.

Table 14: Arellano-Bond dynamic panel data estimation

Dependent var: log(lending)	
lending vol USD, first lag	0.143***
default rate	-0.037***
10yr TB rate	-0.364***
DPI growth rate	-0.011***
log (assets USD)	0.112***
Number of obs	22,356
Period	1990-2016

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Source: HMDA LARs and Reporter Panel 1990-2016.
Dependent variable is the logarithm of the aggregate volume of lending in USD of 2015 at the level of the mortgage originator. Default rate corresponds to the fraction of single family mortgage loans that are delinquent 90 days or more, or in foreclosure. DPI stands for disposable personal income from NIPA.

Table 15 shows the estimate for the volume of sales at the level of originator against the same measure of aggregate households' default and income, using the same set of controls. HMDA reports the type of purchases of loans in the secondary market, so it is possible to differentiate between sales of loans to the agency segment, Freddie Mac and Fannie Mae, and to other private institutions.

Also, the magnitude and signs of correlations of the volume of sales with respect to all variables are of similar magnitude as those observed for the volume of lending when breaking down the market by segments.

Table 15: Fixed effects, panel regression

Dependent var: log(sales)	Priv segment	Agency segment
default rate	-0.060*	-0.040**
10yr TB rate	-0.436***	-0.405***
DPI growth rate	0.015	-0.052***
log (assets)	0.121***	0.277***
R-sq	0.0717	0.0310
Number of obs	5,163	17,443
Period	1990-2016	1990-2016

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Source: HMDA LARs and Reporter Panel 1990-2016
Dependent variable is the logarithm of the aggregate volume of loan sales in USD of 2015 at the level of the mortgage originator. Default rate corresponds to the fraction of single family mortgage loans that are delinquent 90 days or more, or in foreclosure. DPI stands for disposable personal income from NIPA.

D Computational Algorithm

D.1 Solving the General Equilibrium Model

I solve the model in a discrete state space for endogenous and exogenous state variables. Exogenous states are characterize by a joint state space $(\sigma_\omega, Y) \in \mathcal{L}\times\mathcal{Y}$, and an associated transition Π_s matrix. The aggregate endogenous states for debt and housing holdings are given by the space $\mathcal{B}\times\mathcal{H}$. The space of all aggregate state is given by $\mathcal{X} \equiv \mathcal{L}\times\mathcal{Y}\times\mathcal{B}\times\mathcal{H}$. Because the problem is computationally demanding, I set a grid of 40 points for $\mathcal{B}$, 40 points for $\mathcal{H}$, and 10 points for the joint state space (σ_ω, Y).
Solving the model consists on finding:

- policy, and value functions for borrower's problem;
- schedule of prices $\{q(X), p(X)\}$ for all realizations of the aggregate state vector $X \in \mathcal{X}$.

I solve the model by global solution methods performing value function iteration to solve and obtain borrowers policy functions, and use the closed form characterization of lender's decision rules to solve for the system of market clearing conditions within the space of aggregate states.

$$N^D(q;X) = N^S(p,q;X)$$
$$D(X) = S(X)$$

D.2 Welfare evaluation

This section explain the approach we follow for the welfare evaluation. We compute two metrics, one based in the consumption equivalent units of the non-durable consumption good, and another taking into account changes in the services from the housing good.

Define $\tilde{V}(\tilde{c}, \tilde{h})$ as the lifetime utility under the benchmark economy and $V(c, h)$ the utility under an alternative economy subject to the same aggregate exogenous states S_t. We evaluate welfare as the fraction of non-durable consumption allocation, in the benchmark economy, a household will be willing to forego in order to be indifferent to live under the alternative specification. Hence, the permanent consumption loss κ is such that:

$$
\begin{aligned}
\mathbb{E}_{t|t_0} V(c_t, h_t; S_t) &= \mathbb{E}_{t|t_0} V((1-\kappa)\tilde{c}_t, \tilde{h}_t; S_t) \\
&= \sum_{t=0}^{\infty} \beta^t \left((1-\theta)\log((1-\kappa)\tilde{c}_t) + \theta \log \tilde{h}_t \right) \\
&= \frac{(1-\theta)\log(1-\kappa)}{1-\beta} + \sum_{t=0}^{\infty} \beta^t ((1-\theta)\log \tilde{c}_t + \theta \log \tilde{h}_t) \\
\log(1-\kappa) &= \frac{1-\beta}{1-\theta} \left[\mathbb{E}_{t|t_0} V(c_t, h_t; S_t) - \mathbb{E}_{t|t_0} V(\tilde{c}_t, \tilde{h}_t; S_t \right] \\
\kappa &= 1 - \exp\left[\frac{1-\beta}{1-\theta} \mathbb{E}_{t|t_0}(V - \tilde{V}) \right]
\end{aligned}
$$

$\kappa > 0$ indicates welfare losses associated to transitionning from the benchmark economy to the alternative economy, as the households is willing to sacrifice a positive amount of her benchmark consumption allocation in order to be indifferent with the alternative economy.

The second metric, we evaluate consumption equivalent change for both goods:

$$
\begin{aligned}
\mathbb{E}_{t|t_0} V(c_t, h_t; S_t) &= \mathbb{E}_{t|t_0} V((1-\kappa)\tilde{c}_t, \tilde{h}_t; S_t) \\
&= \sum_{t=0}^{\infty} \beta^t \left((1-\theta)\log((1-\kappa)\tilde{c}_t) + \theta \log((1-\kappa)\tilde{h}_t) \right) \\
&= \frac{\log(1-\kappa)}{1-\beta} + \sum_{t=0}^{\infty} \beta^t ((1-\theta)\log \tilde{c}_t + \theta \log \tilde{h}_t) \\
\log(1-\kappa) &= (1-\beta) \left[\mathbb{E}_{t|t_0} V(c_t, h_t; S_t) - \mathbb{E}_{t|t_0} V(\tilde{c}_t, \tilde{h}_t; S_t \right] \\
\kappa &= 1 - \exp\left[(1-\beta) \mathbb{E}_{t|t_0}(V - \tilde{V}) \right]
\end{aligned}
$$

E Proofs to Lemmas and Propositions

E.1 Derivation of default threshold $\bar{\omega}$

The recursive representation of the representative borrower household problem

$$
\begin{aligned}
V(B_t, H_t; X_t) &= \max_{\{C_t, N_t, H_{t+1}, \bar{\omega}\}} u(C_t, H_t) + \beta^B \mathbb{E}_{X'|X} V(B_{t+1}, H_{t+1}; X_{t+1}) \\
s.t. & \\
C_t + p_{h,t} H_{t+1} &= Y_t + T_t^B + (1 - \lambda(\bar{\omega}_t))(\mu_\omega(\bar{\omega}_t) p_{h,t} H_t - \phi B_t) + q_t N_t \\
B_{t+1} &= (1 - \phi)(1 - \lambda(\bar{\omega}_t)) B_t + N_t \\
B_{t+1} &\leq \pi p_{h,t} H_{t+1} \\
& N_t \geq 0, \;\; H_{t+1} \geq 0 \quad \text{given } \{B_0, H_0\}.
\end{aligned}
$$

where

$$
\begin{aligned}
\lambda(\bar{\omega}_t) &= \int_0^\infty \iota(\omega) g_\omega(\omega) d\omega \\
&= Pr[\omega_t^i \leq \bar{\omega}_t] \\
&= \int_0^{\bar{\omega}_t} g_\omega d\omega \\
&= G_\omega(\bar{\omega}_t; \chi_1, \chi_2)
\end{aligned}
$$

and

$$
\begin{aligned}
\mu_\omega(\bar{\omega}_t) &= \mathbb{E}[\omega_{i,t} | \omega_{i,t} \geq \bar{\omega}; \chi] \\
&= \mu_\omega \frac{1 - G_\omega(\bar{\omega}_t; 1 + \chi_1, \chi_2)}{1 - G_\omega(\bar{\omega}_t; \chi_1, \chi_2)}
\end{aligned}
$$

$$
(1 - \lambda(\bar{\omega}_t)) \mu_\omega(\bar{\omega}_t) = \mu_\omega [1 - G_\omega(\bar{\omega}_t; 1 + \chi_1, \chi_2)]
$$

the optimal default threshold $\bar{\omega}_t$ can be derived by taking First Order Conditions of the above problem w.r.t $\{N_t, H_{t+1}, \bar{\omega}_t\}$:

$$
\begin{aligned}
N_t &: \quad U_{c,t}(q_t - \tilde{\xi}_t) = -\beta^B \mathbb{E}[V_{B_{t+1}}] \\
H_{t+1} &: \quad U_{c,t} p_{h,t}(1 - \pi \tilde{\xi}_t) = \beta^B \mathbb{E}[V_{H_{t+1}}]
\end{aligned}
$$

where $V_{B_{t+1}} = \partial V / \partial B_{t+1}$ and $\mathbb{E}[V_{H_{t+1}}] = \partial V / \partial H_{t+1}$, and ξ_t is the Lagrange multiplier associated to the borrowing constraint, and $\tilde{\xi} = \xi_t / U_{c,t}$.

The Envelope Theorem in this case

$$V_{B_t} = -U_{c,t}(1-\lambda(\bar{\omega}_t))(q_t(1-\phi)+\phi)$$
$$V_{H_t} = U_{c,t}(1-\lambda(\bar{\omega}_t))\mu_\omega(\bar{\omega}_t)p_{h,t} + U_{H,t}$$

Combining equations from the Envelope theorem and the F.O.C. yields

$$q_t = \tilde{\xi}_t + \beta^B \mathbb{E}\left[\frac{U_{c_{t+1}}}{U_{c_t}}(1-\lambda(\bar{\omega}_{t+1}))(q_{t+1}(1-\phi)+\phi)\right] \tag{26}$$
$$p_{h,t}(1-\pi\tilde{\xi}_t) = \beta^B \mathbb{E}\left[\frac{U_{c_{t+1}}}{U_{c_t}}\left((1-\lambda(\bar{\omega}_t))\mu_\omega(\bar{\omega}_{t+1})p_{h,t+1} + \frac{U_{H,t+1}}{U_{C,t+1}}\right)\right] \tag{27}$$

The derivative of $\lambda(\bar{\omega}_t)$ and $\mu_\omega(\bar{\omega}_t)$ functions are

$$\begin{aligned}
\frac{\partial\lambda(\bar{\omega}_t)}{\partial\omega_t} &= \frac{\partial}{\partial\bar{\omega}_t}\int_0^{\bar{\omega}_t} g_\omega(\omega)d\omega \\
&= g_\omega(\bar{\omega}_t) \\
\frac{\partial[(1-\lambda(\bar{\omega}_t))\mu_\omega(\bar{\omega}_t)]}{\partial\omega_t} &= \frac{\partial}{\partial\bar{\omega}_t}\int_{\bar{\omega}_t}^{\infty} \omega g_\omega(\omega)d\omega \\
&= -\bar{\omega}_t g_\omega(\bar{\omega}_t)
\end{aligned}$$

Taking the F.O.C. of the value function w.r.t. $\bar{\omega}_t$ yields:

$$\begin{aligned}
U_{c,t}(-\bar{\omega}_t g_\omega(\bar{\omega}_t)p_{h,t}H_t + g_\omega(\bar{\omega}_t)\phi B_t) + \mu_t(1-\phi)g_{\omega_t}(\bar{\omega}_t)B_t &= -\beta^B\mathbb{E}\left[\frac{\partial V}{\partial B_{t+1}}\frac{\partial B_{t+1}}{\partial\bar{\omega}_t}\right] \\
U_{c,t}g_\omega(\bar{\omega}_t)(-\bar{\omega}_t p_{h,t}H_t + \phi B_t) + U_{c,t}\tilde{\xi}_t(1-\phi)g_{\omega_t}(\bar{\omega}_t)B_t &= \beta^B\mathbb{E}\left[\frac{\partial V}{\partial B_{t+1}}(1-\phi)g_\omega(\bar{\omega}_t)B_t\right] \\
U_{c,t}g_\omega(\bar{\omega}_t)(-\bar{\omega}_t p_{ht}H_t + \phi B_t + \tilde{\xi}_t(1-\phi)B_t) &= (1-\phi)g_\omega(\bar{\omega}_t)B_t\left[\beta^B\mathbb{E}[V_{B_{t+1}}]\right] \\
U_{c,t}g_\omega(\bar{\omega}_t)(-\bar{\omega}_t p_{h,t}H_t + \phi B_t + \tilde{\xi}_t(1-\phi)B_t) &= -(1-\phi)g_\omega(\bar{\omega}_{h,t})B_t U_{c,t}(q_t - \tilde{\xi}_t) \\
-\bar{\omega}_t p_{h,t}H_t + \phi B_t &= -(1-\phi)B_t q_t \\
\bar{\omega}_t &= \frac{B_t}{p_{h,t}H_t}[\phi + (1-\phi)q_t] \qquad (28)
\end{aligned}$$

E.2 Proof of Lemma 1

1. Assumptions: i) lender holds one asset: budget set is linear in b. ii) homothetic preferences, $u(c) = \log(c)$, imply:

   (a) policy functions are linear in b: $c(z,b,X), b'(z,b,X), s_G(z,b,X), s_B(z,b,X), d(z,b,X)$

2. By assumption $z \sim$ iid: z^j is independent of b^j, also $\Gamma(z,b) = F(z)G(b)$.

3. For given $\{p, \mu\}$: aggregates S_G, S_B, D do not depend on the distribution of b. See additional derivations E.13.

4. Therefore, neither do market clearing values $p(X),\ q(X),\ \mu(X)$. See additional derivations E.13.

5. Thus, it is not necessary to know the distribution Γ to compute aggregate quantities and prices. B is a sufficient statistic.

E.3 Proof of Lemma 2

From the analysis in section 4.1 it follows that if there is a price $p > 0$ in the secondary market, then:

- Seller. For a lender j that such that $z^j \in [z_a, p/q)$, trading decisions are: $\{d^j = 0,\ s^j_G = (1-\lambda)(1-\phi)b^j,\ s^j_B = \lambda(1-\phi)b\}$. By replacing these policy functions in the law of motion of debt holdings, equation (6), it follows that the origination decision for a seller is $n^j = b'^j$.

- Buyer. For a lender j such that $z^j \in (\frac{p}{q}\frac{1}{1-\mu}, z_b]$, trading decisions are $\{d^j > 0,\ s^j_G = 0,\ s^j_B = \lambda(1-\phi)b^j\}$. Notice that n^j and d^j are alternative ways of saving resources. Originating one loan today costs $z^j q$ and pays off one unit tomorrow, while purchasing one loan in the secondary market today costs p and pays off $(1-\mu)$ units tomorrow. Hence, the return on saving by originating loans is $\frac{1}{z^j q}$, while the return for purchasing a loan is $\frac{1-\mu}{p}$. Given that $z^j > \frac{p}{q}\frac{1}{1-\mu}$, the optimal decision is to set $n^j = 0$, and accumulate loans by purchasing existing loans in the secondary market. Replacing these decisions in the law of motion of debt holdings, equation (6), yields the policy function for purchases $d^j = \frac{b'^j - (1-\phi)(1-\lambda)b^j}{1-\mu}$.

- Holder. For a lender j such that $z^j \in [\frac{p}{q},\ \frac{p}{q}\frac{1}{1-\mu}]$, trading decisions are $\{d^j = 0,\ s^j_G = 0,\ s^j_B = \lambda(1-\phi)b^j\}$. Replacing these decisions in the law of motion of debt holdings, equation (6), obtains $n^j = b'^j - (1-\lambda)(1-\phi)b^j$.

In the case in which there is no positive price that clears the secondary market, the secondary market will not be active. Trading decisions for all lenders are trivial: $\{d^j = 0,\ s^j_G = 0,\ s^j_B = 0\}$. Replacing these decisions in the law of motion of debt holdings, equation (6), obtains the origination decision: $n^j = b'^j - (1-\lambda)(1-\phi)b^j$.

E.4 Proof of Lemma 3

We will derive $\{c, b'\}$ policy functions by guess and verify.

1. Taking First Order Conditions w.r.t to b' to program (18) obtains:

$$\begin{aligned} u_c q \min\{z, \frac{p/q}{1-\mu}\} &= \beta^L \mathbb{E}_{X'|X}\left[V_{b'}(b', z'; X')\right] \\ &= \beta^L \mathbb{E}_{X'|X}\left[u_{c'} W_{b'}(b', z'; X')\right] \end{aligned}$$

where the second equation holds because of the Envelope theorem, and $W_b = \frac{\partial W(b,z,X)}{\partial b}$ is the marginal change in a lender's virtual wealth, equation (17), of increasing debt claims in one unit. Given that preferences are assumed to be logarithm:

$$\frac{1}{c} q \min\{z, \frac{p/q}{1-\mu}\} = \beta^L \mathbb{E}_{X'|X}\left[\frac{1}{c'} W_{b'}(b', z'; X')\right]$$

2. Guess that the policy function for consumption has the form: $c = \alpha W(b, z; X)$, where $\alpha \in \mathbb{R}$. Then, from budget constraint in (18) it implies:

$$b' = \frac{(1-\alpha)W(b, z; X)}{q \min\{z, \frac{p/q}{1-\mu}\}}$$

and

$$\begin{aligned} c' &= \alpha W(b', z'; X') \\ &= \alpha W_{b'}(b', z'; X') b' \\ &= \alpha W_{b'}(b', z'; X') \left[\frac{(1-\alpha)W(b, z; X)}{q \min\{z, \frac{p/q}{1-\mu}\}}\right] \end{aligned}$$

3. Replacing expression for c' in the Euler equation obtains:

$$\begin{aligned} \frac{1}{c} q \min\{z, \frac{p/q}{1-\mu}\} &= \beta^L \mathbb{E}_{X'|X}\left[\frac{q \min\{z, \frac{p/q}{1-\mu}\} W_{b'}(b', z'; X')}{\alpha W_{b'}(b', z'; X')\left[(1-\alpha)W(b, z; X)\right]}\right] \\ \frac{1}{\alpha W(b, z; X)} &= \beta^L \mathbb{E}_{X'|X}\left[\frac{1}{\alpha(1-\alpha)W(b, z; X)}\right] \\ \alpha &= 1 - \beta^L \end{aligned}$$

which yields:

$$\begin{aligned} c &= (1-\beta^L) W(b, z; X) \\ b' &= \frac{\beta^L}{q \min\{z, \frac{p/q}{1-\mu}\}} W(b, z; X) \end{aligned}$$

E.5 Proof of Lemma 4

Suppose there is a lender for whom the solutions of each program differ. Such lenders must be a buyer or a holder, since both programs are identical for sellers. Then, at least one buyer or holder chooses $b' < (1-\lambda)(1-\phi)b$ but given the non-negativity constraint on purchases, it must be that such buyer purchases $d = 0$. By revealed preferences, if every buyer chooses to buy zero then aggregate demand $D = 0$.

E.6 Proof of Lemma 5

If there is a $p > 0$ that clears the secondary market, by Lemma 2 the policy function of lenders with origination costs below the second equilibrium cut-off imply a strictly positive amount of new loan issuance, see Lemma 2. Hence, the last marginal lender to issue new loans is such that $z^j \leq \frac{p/q}{1-\mu(p/q)}$ and the right hand side determines the cut-off $\bar{z}$.

Instead, whenever the price that clears the secondary market is given by $p = 0$, the virtual wealth function of the lender reduces to $W = b\left[(1-\lambda)\phi + (1-\lambda)(1-\phi)zq\right]$. Using the optimal saving policy function in Lemma 3 the policy function of new loan issuance for lenders becomes $n = \frac{\beta^L}{zq}b(1-\lambda)\phi - (1-\beta^L)(1-\lambda)(1-\phi)b$. Then, we can derive the upper bound for a lender's origination cost z so that a lenders issues a strictly positive amount of new loans

$$n > 0$$
$$\frac{\beta^L \phi}{(1-\beta^L)(1-\phi)}\frac{1}{q} > z$$

the left hand side determines the cut-off $\bar{z}$ when the price of securities in the secondary market is zero. Lastly, this upper bound is relevant as long as it is within the support of the origination costs drawn by lenders, the min function incorporates that.

E.7 Proof of Lemma 6

First, given that G'_ω is a mean preserving spread of G_ω by definition it satisfies: $G_\omega(\omega) \leq G'_\omega(\omega)\ \forall\ \omega$ in the support. Second, in steady state, borrowers default is function given by $\lambda(\bar{\omega}) = G_\omega(\bar{\omega})$ where $\bar{\omega} = \frac{B_{ss}}{pH_{ss}}(\phi + (1-\phi)q_{ss})$. Then, ceteris paribus, given that the increase in housing volatility is by a mean preserving spread it follows that: $\lambda(\bar{\omega}) \leq \lambda'(\bar{\omega})$.

E.8 Proof of Lemma 7

Lemma 7 establishes that the adverse selection discount μ is increasing in borrowers default rate λ and decreasing in the securitization market cut-off $\hat{z}$.

By definition

$$\begin{aligned}
\mu(\lambda,\hat{z}) &= \frac{S_B(\hat{z})}{S(\hat{z})} \\
&= \frac{\int_{z_a}^{z_b}\lambda(\bar{\omega})(1-\phi)b\; d\Gamma(z,b)}{S_B(\hat{z})+S_G(\hat{z})} \\
&= \frac{\lambda(\bar{\omega})(1-\phi)B}{\lambda(\bar{\omega})(1-\phi)B+\int_{z_a}^{\hat{z}} s_G dF} \\
&= \frac{\lambda(\bar{\omega})}{\lambda(\bar{\omega})+(1-\lambda(\bar{\omega}))F(\hat{z})}
\end{aligned}$$

where the last equality using: $s_G = (1-\lambda(\bar{\omega}))(1-\phi)b$. F is the CDF of z. First, for a given cut-off $\hat{z}$, consider an increase in the default rate arising from higher housing volatility. In Lemma 6 we established that $\lambda(\bar{\omega}) \leq \lambda'(\bar{\omega})$. Then, using the definition we want to show that:

$$\begin{aligned}
\mu(\lambda',\hat{z}) &\geq \mu(\lambda,\hat{z}) \\
\frac{\lambda'(\bar{\omega})}{\lambda'(\bar{\omega})+(1-\lambda'(\bar{\omega}))F(\hat{z})} &\geq \frac{\lambda(\bar{\omega})}{\lambda(\bar{\omega})+(1-\lambda(\bar{\omega}))F(\hat{z})} \\
\lambda'(\bar{\omega})[\lambda(\bar{\omega})+(1-\lambda(\bar{\omega}))F(\hat{z})] &\geq \lambda(\bar{\omega})[\lambda'(\bar{\omega})+(1-\lambda'(\bar{\omega}))F(\hat{z})] \\
\frac{\lambda'(\bar{\omega})}{\lambda(\bar{\omega})}\frac{(1-\lambda(\bar{\omega}))}{(1-\lambda'(\bar{\omega}))} &\geq 1
\end{aligned}$$

which is satisfied. Second, keeping the default rate fixed, consider $\hat{z}' > \hat{z}$, then given that the CDF is a strictly increasing function $F(\hat{z}') > F(\hat{z})$. Then, following the same as strategy as before, it is straightforward to see that $\mu(\lambda,\hat{z}') \leq \mu(\lambda,\hat{z})$.

E.9 Proof of Lemma 8

Conjecture that exist a market cut-off $\hat{z}$ that satisfies $A1$, then we want the ratio $\frac{\hat{z}}{1-\mu(\hat{z})}$ to be decreasing in $\hat{z}$, i.e. for $\frac{\partial \cdot}{\partial \hat{z}} < 0$ to hold it must be that:

$$\frac{1}{\hat{z}}\left(1+\frac{1-\lambda}{\lambda}F(\hat{z})\right) < m(\hat{z})$$

where $m(\hat{z}) = \frac{f(\hat{z})}{F(\hat{z})}$ is the inverse mills ratio of $\hat{z}$. Which is exactly the condition assumed in Assumption $A1$.

E.10 Proof of Proposition 1

The proof consists in showing that the implied discount price of new mortgage debt satisfied the relation presented in Proposition 1. First, I derive the analytical expression for each discounted price and then verify the inequality.

In steady state the demand for new loans in primary market is given by

$$N_{ss}^{D} = B_{ss}(1-(1-\phi)(1-\lambda(\bar{\omega}_{ss})))$$

Under complete information non-performing loans are not traded since all lenders can easily identify them and their payoff is zero. If lenders have access to a securitization market, their consumption, saving and trading decisions can be derived in similar fashion to Lemma 2. In this case, there is only one cutoff $\bar{z}$. All lenders self-classify into two groups: sellers and buyers. In the aggregate, the total supply of new loans is given by integrating the supply of new loans from sellers:

$$\begin{aligned}
N_{ss}^{S} &= \int_{z_a}^{\bar{z}} n^{CI}(b,z;X)d\Gamma(b,z) \\
&= B_{ss}\frac{\beta^L}{q^{CI}}(1-\lambda(\bar{\omega}_{ss}))(\phi+p(1-\phi))\int_{z_a}^{\bar{z}}\frac{1}{z}dFz \\
&= B_{ss}\frac{1}{q^{CI}}(1-\lambda(\bar{\omega}_{ss}))\phi\int_{z_a}^{\bar{z}}\frac{1}{z}dFz + B_{ss}\beta^L(1-\lambda(\bar{\omega}_{ss}))\bar{z}(1-\phi)\int_{z_a}^{\bar{z}}\frac{1}{z}dFz
\end{aligned}$$

Notice that aggregate supply is a function of the discounted price of debt. Then, using market clearing condition for the primary market $N_{ss}^{D} = N_{ss}^{S}$ we can derive an expression for the discounted price of new mortgage debt in steady state:

$$q_{ss}^{CI} = \frac{\beta^L(1-\lambda(\bar{\omega}_{ss})\phi)\int_{z_a}^{\bar{z}}\frac{1}{z}dFz}{1-(1-\phi)(1-\lambda(\bar{\omega}_{ss}))-\beta^L(1-\lambda(\bar{\omega}_{ss}))\bar{z}(1-\phi)\int_{z_a}^{\bar{z}}\frac{1}{z}dFz} \tag{29}$$

If lenders do not have access to a securitization market their decisions can be derived directly from Lemma 2. In steady state the aggregate credit supply is given by:

$$\begin{aligned}
N_{ss}^{NSM} &= \int_{z_a}^{z_b} n^{NSM}(b,z;X)d\Gamma(b,z) \\
&= \frac{1}{q^NSM}\beta^L(1-\lambda(\bar{\omega}_{ss}))B_{ss}\phi\int_{z_a}^{z_b}\frac{1}{z}dFz - (1-\beta^L)(1-\phi)(1-\lambda(\bar{\omega}_{ss}))B_{ss}
\end{aligned}$$

Then, using market clearing condition for the primary market we can derive an expression for the discounted price of new mortgage debt in steady state:

$$q_{ss}^{NSM} = \frac{\beta^L(1-\lambda(\bar{\omega}_{ss}))\phi\int_{z_a}^{z_b}\frac{1}{z}dFz}{1-\beta^L(1-\lambda(\bar{\omega}_{ss}))(1-\phi)} \tag{30}$$

The last step consist in comparing equations (29) and (30). Notice that the numerator must satisfy

$$\int_{z_a}^{\bar{z}}\frac{1}{z}dFz > \int_{z_a}^{z_b}\frac{1}{z}dFz \quad \forall \bar{z} < z_b$$

which is the case for the calibration of the support of the origination costs. For the denominator the condition boils down to:

$$\frac{1}{\beta^L} + \bar{z} \int_{z_a}^{\bar{z}} \frac{1}{z} dFz > 1$$

which is always the case given that $\beta^L < 1$ and $\bar{z} \int_{z_a}^{\bar{z}} \frac{1}{z} dFz > 0$.

E.11 Proof of Proposition 2

First, in Lemma 6 we established that exogenous increase in the volatility of housing valuation shocks that preserve the mean of the distribution will lead an increase in borrowers default rate. Then, if Lemma 4 is satisfied, item 1 follows from Lemma 7. Second, by Lemma 8 the second cutoff will increase when the adverse selection discount increases. Which by the definition of the aggregate demand of securities, equation (21), implies that the mass of buyers will decrease. Consequently, the quantities of securities demanded will also decrease because lenders who still buy securities have limited resources (cash in hand) and cannot borrow from external sources. Third, lower demand and supply forces the market price of securities downward, which necessarily settles a lower price than before in order for supply and demand to clear.

E.12 Proof of Proposition 3

The condition for a market crash can be derived from the expression for demand of securities, see Subsection E.13, which can be expressed as:

$$\begin{aligned}
D(X) &= \int d(b,z;X)\ d\Gamma(b,z) \\
&= \frac{1 - F\left(\hat{z}\frac{(1-\tau)}{(1-\mu)}\right)}{1-\mu} B \left[\frac{\beta^L}{z^m}[(1-\lambda)(\phi + (1-\phi)z^m) + \lambda(1-\phi)p] - (1-\lambda)(1-\phi)\right] \\
&= \frac{1 - F\left(\hat{z}\frac{(1-\tau)}{(1-\mu)}\right)}{p(1-\tau)} B \left[\beta^L(1-\lambda(\bar{\omega}))\phi - \frac{p(1-\tau)}{(1-\mu)}(1-\beta^L)(1-\lambda(\bar{\omega}))(1-\phi)\right] \\
&\quad + \frac{\beta^L}{p(1-\tau)} \underbrace{p\lambda(\bar{\omega})(1-\phi)B\left[1 - F\left(\hat{z}\frac{(1-\tau)}{(1-\mu)}\right)\right]}_{S_B^{\text{buyers}}}
\end{aligned}$$

where S_B^{buyers} denotes the supply of non-performing loans from buyers of securities. Notice that if $D(X) < S_B^{\text{buyers}}$ then there cannot be a positive price clearing the securities market. Rearranging the expression in the large bracket of the first term in the last equation above, yields a sufficient condition for the securities market not to be active:

$$\min_p \left\{ \frac{p(1-\tau)}{(1-\mu)} \right\} > \frac{\beta^L \phi}{(1-\beta^L)(1-\phi)}$$

Item 1 in Proposition 3 follows directly from the condition derived above and from the characterization of lenders policy functions for the case in which the securities market is not active, i.e. when Lemma 4 is not satisfied. For Item 2, notice that we established in Lemma 2 that under private information, if there is a positive equilibrium price in the securitization market, the second cutoff satisfies: $\hat{z} < \hat{z}\frac{1-\tau}{1-\mu}$, i.e. in any equilibrium outcome under private information there is a positive wedge given by the distance between both cutoffs. This implies that any equilibrium price of debt under private information, q^*, must satisfy: $q^* < q^{CI}$. Also, notice that an economy without securitization market features zero reallocation of resources among lenders and hence the highest possible intermediation cost, which implies: $q^{NSM} < q^*$.

E.13 Additional derivations

For Proof of Lemma 1

1. Given that we assume $z \sim i.i.d.$, and the linearity of policy functions on b, the aggregate supply and demand of debt claims in the secondary market $\{S, D\}$ do not depend on the distribution of b, this can be shown by working out the expressions for supply and demand in the secondary market from the definitions.

   (a) Supply, $S(X)$

$$\begin{aligned}
S(X) &= S_B(X) + S_G(X) \\
&= \int s_B(b,z,X)\ d\Gamma(b,z) + \int s_G(b,z,X)\ d\Gamma(b,z) \\
&= \int_z \int_b s_B(b,z,X)\ dG(b)dF(z) + \int_z \int_b s_B(b,z,X)\ dG(b)dF(z) \\
&= \int_z \int_b \lambda(\bar{\omega})(1-\phi)b\ dG(b)dF(z) + \int_z \int_b (1-\lambda(\bar{\omega}))(1-\phi)b\ dG(b)dF(z) \\
&= \lambda(\bar{\omega})(1-\phi) \int_{z_a}^{z_b} \left[\int_b bdG(b) \right] dF(z) + (1-\lambda(\bar{\omega}))(1-\phi) \int_{z_a}^{p/q} \left[\int_b bdG(b) \right] dF(z) \\
&= \lambda(\bar{\omega})(1-\phi) \int_{z_a}^{z_b} BdF(z) + (1-\lambda(\bar{\omega}))(1-\phi) \int_{z_a}^{p/q} BdF(z) \\
&= B(1-\phi) \left[\lambda(\bar{\omega}) \int_{z_a}^{z_b} dF(z) + (1-\lambda(\bar{\omega})) \int_{z_a}^{p/q} dF(z) \right] \\
&= B(1-\phi) \left[\lambda(\bar{\omega}) + (1-\lambda(\bar{\omega}))F(p/q) \right]
\end{aligned}$$

(b) Demand, $D(X)$

$$\begin{aligned}
D(X) &= \int d(b,z;X)\ d\Gamma(b,z) \\
&= \int_z \int_b d(b,z;X)\ dG(b)dF(z) \\
&= \int_{z^m/q}^{z_b} \int_b \frac{b' - (1-\lambda(\bar{\omega}))(1-\phi)b}{1-\mu}\ dG(b)dF(z) \\
&= \frac{1}{1-\mu}\left[\int_{z^m/q}^{z_b}\int_b b'\ dG(b)dF(z) - (1-\lambda(\bar{\omega}))(1-\phi)\int_{z^m/q}^{z_b}\int_b b\ dG(b)dF(z)\right] \\
&= \frac{1}{1-\mu}\left[\int_{z^m/q}^{z_b} \frac{\beta}{z^m}\left((1-\lambda(\bar{\omega}))\phi + \lambda(\bar{\omega})(1-\phi)p + (1-\lambda(\bar{\omega}))(1-\phi)z^m\right) BdF(z)\right] \\
&\quad - \frac{1}{1-\mu}(1-\lambda(\bar{\omega}))(1-\phi)B\int_{z^m/q}^{z_b} dF(z) \\
&= \frac{1-F(z^m/q)}{1-\mu} B\left[\frac{\beta}{z^m}[(1-\lambda(\bar{\omega}))(\phi+(1-\phi)z^m) + \lambda(\bar{\omega})(1-\phi)p] - (1-\lambda(\bar{\omega}))(1-\phi)\right]
\end{aligned}$$

where $z^m = \frac{p(1-\tau)}{1-\mu(p,q)}$. It follows that the market clearing values of $\{p, \mu\}$ do not depend on the distribution of b either.

2. The price of debt q does not depend on the distribution of debt holdings across lenders because the market clearing condition in the credit market is a function only of the aggregate level of debt B.

   (a) Demand of credit from borrowers depends only on aggregates states $\{B, H, \lambda(\bar{\omega}), Y\}$ through the policy function of $B'(B, H; X)$. Hence, the distribution of debt claims is irrelevant from the stand point of the borrower:

   $$N^B = B'^B - (1-\lambda(\bar{\omega}))(1-\phi)B^B$$

   (b) Supply of credit from lenders correspond to the integral across the individual originations n^j. Given that lending policy functions are linear in b, the aggregate supply of lending is linear in the aggregate amount of debt claims in the economy B. This can be seen from the aggregation of the origination decisions.

   $$N^L = \int n(b,z;X)d\Gamma(b,z)$$

   There are two possible expressions for the aggregate supply of credit. The first case when the secondary market is active meaning $p > 0$,

$$
\begin{aligned}
N^{\text{seller}} &= \int n(b,z;X)d\Gamma(b,z) \\
&= \int_{z_a}^{p/q}\int_b b'(b,z;X)\ dG(b)dF(z) \\
&= \int_{z_a}^{p/q}\frac{\beta}{zq}\left[(1-\lambda(\bar{\omega}))\phi+(1-\phi)p\right]\left[\int_b b\ dG(b)\right]dFz \\
&= B\frac{\beta}{q}\left[(1-\lambda(\bar{\omega}))\phi+(1-\phi)p\right]\int_{z_a}^{p/q}\frac{1}{z}dFz \\
N^{\text{holder}} &= \int n(b,z;X)d\Gamma(b,z) \\
&= \int_p^{z^m/q}\int_b \left[b'(b,z;X)-(1-\lambda(\bar{\omega}))(1-\phi)b\right]\ dG(b)dF(z) \\
&= \int_p^{z^m/q}\frac{\beta}{zq}\left[(1-\lambda(\bar{\omega}))\phi+\lambda(\bar{\omega})(1-\phi)p+(1-\lambda(\bar{\omega}))(1-\phi)zq\right]\left[\int_b b\ dG(b)\right]dFz \\
&\quad -\int_p^{z^m/q}(1-\lambda(\bar{\omega}))(1-\phi)\left[\int_b b\ dG(b)\right]dFz \\
&= B\frac{\beta}{q}\left[(1-\lambda(\bar{\omega}))\phi+\lambda(\bar{\omega})(1-\phi)p\right]\int_p^{z^m/q}\frac{1}{z}dFz+\beta(1-\lambda(\bar{\omega}))(1-\phi)B\int_p^{z^m/q}dFz \\
&\quad -(1-\lambda(\bar{\omega}))(1-\phi)B\int_p^{z^m/q}dFz \\
&= B\frac{\beta}{q}\left[(1-\lambda(\bar{\omega}))\phi+\lambda(\bar{\omega})(1-\phi)p\right]\log(z)f(z)|_p^{z^m/q} \\
&\quad -B(1-\beta)(1-\lambda(\bar{\omega}))(1-\phi)\left(F(z^m/q)-F(p/q)\right) \\
N^L &= N^{\text{seller}}+N^{\text{holder}}
\end{aligned}
$$

The case when there is no trade in secondary markets (or alternatively all assets trade at $p=0$) and each lender originates loans using its own technology.

$$
\begin{aligned}
N^L &= \int n(b,z;X)d\Gamma(b,z) \\
&= \int_{z_a}^{z_b}\int_b \left[b'(b,z;X)-(1-\lambda(\bar{\omega}))(1-\phi)b\right]\ dG(b)dF(z) \\
&= \int_{z_a}^{z_b}\frac{\beta}{zq}\left[(1-\lambda(\bar{\omega}))\phi+(1-\lambda(\bar{\omega}))(1-\phi)zq\right]\left[\int_b b\ dG(b)\right]dF(z) \\
&\quad -\int_{z_a}^{z_b}(1-\lambda(\bar{\omega}))(1-\phi)\left[\int_b b\ dG(b)\right]dFz \\
&= B(1-\lambda(\bar{\omega}))\left[\frac{\beta}{q}\phi\int_{z_a}^{z_b}\frac{1}{z}dF(z)-(1-\beta^L)(1-\phi)\right]
\end{aligned}
$$

Budget sets by type of lender

Replacing the optimal origination and trading decisions of Lemma 2 in the budget constraint and in the law of motion of lenders, problem (10), obtains:

- Buyers:

$$c + p(1-\tau)\left[\frac{b' - (1-\lambda(\bar{\omega}))(1-\phi)b}{1-\mu}\right] = (1-\lambda(\bar{\omega}))\phi b + \lambda(\bar{\omega})(1-\phi)pb$$
$$c + z^m b' = \left[(1-\lambda(\bar{\omega}))\phi + \lambda(\bar{\omega})(1-\phi)p + (1-\lambda(\bar{\omega}))(1-\phi)z^m\right] b$$

  where $z^m = p(1-\tau)/(1-\mu)$.

- Sellers:

$$c + zq\left[b'\right] = (1-\lambda(\bar{\omega}))\phi b + \lambda(\bar{\omega})(1-\phi)pb + (1-\lambda(\bar{\omega}))(1-\phi)pb$$
$$c + zqb' = \left[(1-\lambda(\bar{\omega}))\phi + (1-\phi)p\right] b$$

- Holder:

$$c + zq[b' - (1-\lambda(\bar{\omega}))(1-\phi)b] = (1-\lambda(\bar{\omega}))\phi b + \lambda(\bar{\omega})(1-\phi)pb$$
$$c + zqb' = \left[(1-\lambda(\bar{\omega}))\phi + \lambda(\bar{\omega})(1-\phi)p + (1-\lambda(\bar{\omega}))(1-\phi)zq\right] b$$