Securitization and House Price Growth

Genevieve Nelson*

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Abstract

From 2000-2006 US house prices and mortgage credit grew while the relative cost of mortgage credit fell – particularly for privately securitized mortgages – suggesting a credit supply expansion. This paper explores two (credit supply) shocks: an increased inflow of global savings into the US, and innovations in the securitization of mortgage credit. I model the interaction of financially constrained commercial banks and mortgage securitizers, generating a novel *balance sheet effect*: changes in the distribution of aggregate mortgage credit quantity are linked to changes in mortgage spreads. Only innovation in securitization (direct relaxation of the securitizers' financial constraint) matches mortgage market dynamics.

Keywords: Securitization, Mortgage Credit, House Prices, Non-Banks.
JEL Codes: G21, G23, E21, E44.

*Research Department, Danmarks Nationalbank, Langelinie All 47, 2100 Copenhagen, Denmark, gne@nationalbanken.dk. The views expressed in this paper are solely my own, and not those of Danmarks Nationalbank, as are any remaining errors.This paper is a revised version of the 2nd chapter of my PhD dissertation. I am very grateful to my advisor Andrea Ferrero for his guidance and support, as well as the members of the Oxford Macroeconomics group, in particular Michael McMahon and Francesco Zanetti. I also thank Matteo Iacoviello for insightful comments in the examination of my dissertation. This paper benefited greatly from time spent, presentations and many conversations with economists at the Bank of Canada, the Bank of England, the Federal Reserve Bank of Chicago and Federal Reserve Bank of New York. In particular Andrea Tambalotti, Jeffrey Campbell and Jose Dorich. I thank Andrea Tambalotti and co-authors for kindly sharing their conditional mortgage spread series. I thank James Vickery for helpful conversations and facilitating my access to data.

1 Introduction

The Great Recession was preceded by a boom in US real house prices from 2000 to 2006. During this time US mortgages were increasingly being held not by regulated commercial banks or the implicitly government backed Fannie Mae and Freddie Mac but by the shadow banking sector[1]. The vehicle for this shift was private mortgage backed securitization[2]. The issuance of private mortgage backed securities grew from 126 Billion USD in 2000 to 1,145 Billion USD in 2006. This period was a culmination of a series of "innovations" in private securitization, including increased use of tranching[3] and other credit enhancements, which drove investor willingness to treat private sector issued mortgage backed securities as nearly substitutable to US Treasuries.

In addition to the increase in house prices the quantity of mortgage credit taken out by American households increased during this period (Figure 1a). Simultaneously the relative cost of mortgages, measured by the mortgage spread, fell (Figure 1b). This suggests a credit supply expansion. The contribution of this paper is to disentangle different potential drivers of that credit supply expansion. One, a securitization driven credit supply shock ("innovation in securitization"). And two, a shock to the risk free rate ("exogenous savings" shock) which is meant to capture the view articulated by Bernanke (2005) that an increase in the global supply of savings during this period drove equilibrium interest rates down and increased the influx of foreign savings into the U.S.

I find that innovation in the securitization of mortgage credit is the only credit supply

[1] Appendix B summarizes the relevant institutions in the shadow banking sector given the housing and mortgage market focus of this paper.

[2] Securitization is the process of a financial entity buying a group of mortgages and issuing an asset, the mortgage backed security (MBS), that pays out based on the underlying income stream from those mortgages as borrowers repay.

[3] When you buy a mortgage backed security you can buy the right to be paid off first (senior tranche) or last (equity tranche). Tranches are essentially your position in line to be paid back as borrowers repay their mortgages.

shock that can match the mortgage market dynamics during this period. Furthermore I also find that the exogenous savings shock has counterfactual implications: though it matches the increase house prices and mortgage credit it counter-factually predicts an increase in the mortgage spread.

In this paper I explicitly model the private securitization of mortgage credit. By doing so I get a new *balance sheet effect*, which drives the key results. In my model financial intermediaries face constraints on the size and composition of their balance sheets. Shadow banks (the issuers of private[4] mortgage backed securities) face a constraint, imposed by the market, which limits the total quantity of mortgage credit they can hold, relative to the profits (i.e. spread) they make. They cannot exceed this limit because their liabilities (mortgage backed securities) would go from being perceived as riskless to being perceived as too risky to hold. Commercial banks face a constraint that mimics the effect of regulation during the 2000-2006 period: it is more costly (in terms of regulatory capital) for commercial banks to retain the mortgages they issue than to hold MBS. This constraint drives commercial banks to diversify their assets by selling the (idiosyncratically risky) mortgages they issue and buying mortgage backed securities (which only have aggregate risk). The constraint on shadow banks is the ultimate constraint on aggregate mortgage credit that the financial sector can absorb at a given mortgage spread. Because of the balance sheet effect a relaxation of the constraint faced by shadow banks is needed to explain the decline in mortgage spreads and increase in total mortgage credit in the 2000 - 2006 U.S. data. This is "innovation in securitization".

Capturing the balance sheet effect is key to distinguishing between different potential drivers of the expansion in credit supply. The exogenous savings credit supply shift, driven

[4] I.e. Private Label Mortgage Backed Securities (PLMBS) as opposed to the MBS issued by Government Sponsored Enterprises (GSE). The real stock of PLMBS grew by 395% from 2000Q4 - 2006Q4, in contrast the real stock of GSE MBS only grew 34%.

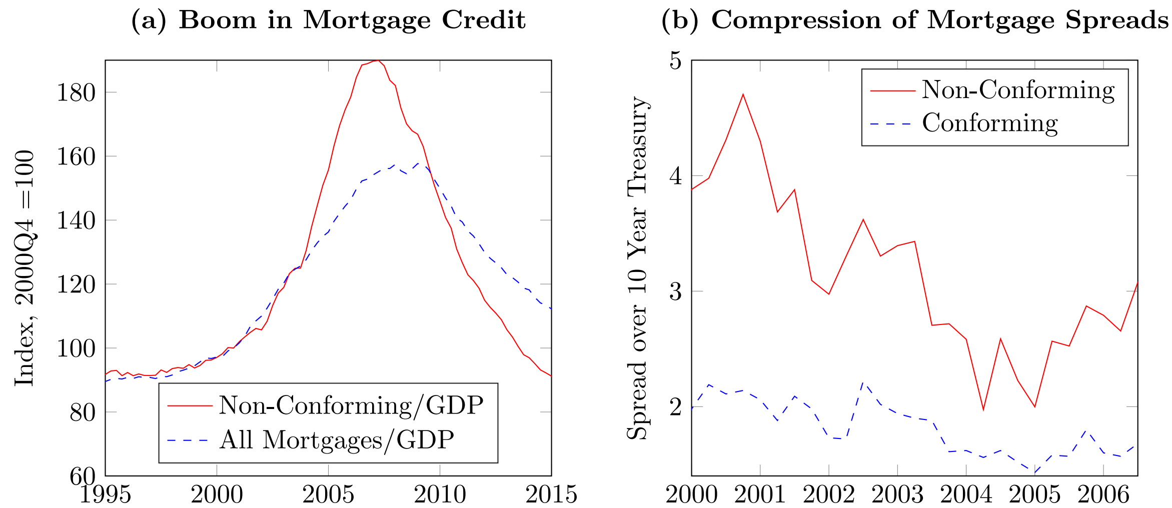

Figure 1: Credit Supply View - Key Stylized Facts

Note: (a) All Mortgages/GDP: The total outstanding stock of mortgage credit relative to GDP, indexed to 2000Q4 levels. Non-Conforming/GDP: Estimated as "All Mortgages" minus those mortgages held by Government Sponsored Enterprises (GSEs) and GSE & Agency backed pools, relative to GDP, indexed to 2000Q4 levels. Source: Board of Governors of the Federal Reserve System (US), Z1 Financial Accounts of the United States, retrieved from DDP; www.federalreserve.gov/datadownload/, August 15, 2019.
(b) Conforming: Board of Governors of the Federal Reserve System (US), 30-Year Conventional Mortgage Rate (DISCONTINUED) [MORTG], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/MORTG, September 1, 2019. Non-Conforming: average mortgage rate at origination for the near-universe of privately securitized mortgages, source: Justiniano, Primiceri, & Tambalotti (2017).

by an increase in savers' patience which pushes the risk-free rate down, drives commercial banks to increase the size of their balance sheet. Commercial banks issue more mortgage credit but also demand more mortgage backed securities. This is because the financial constraint faced by commercial banks penalizes them for holding their own originated mortgages. They choose to sell a portion of these mortgages and hold mortgage backed securities instead. In this way the exogenous savings credit *supply* shock translates into an increase in *demand* for mortgage backed securities - driving mortgage spreads up because of the balance sheet effect.

Not only is the the innovation in securitization channel necessary to explain mortgage spread dynamics in the 2000 - 2006 data, it could have set the stage to amplify other potential factors driving credit dynamics during this period. I show that, in a world where mortgage securitizing shadow banks face looser financial constraints, shifts in the demand for mortgage backed securities increase house prices and the quantity of credit more with a smaller increase in the mortgage spread. That is, the boom driven by innovation in securitization could have amplified the mortgage credit and house price response to other credit supply or credit demand shifts during this period. The conclusion here is not that innovation in securitization was *the only* driver of mortgage credit market dynamics during this period, rather that innovation in securitization was necessary to set the stage for these other shocks.

There are a number of recent papers that consider shadow banking in a general equilibrium setting. These papers focus on a general credit market setting without a focus on mortgage credit finance or house price dynamics. Gertler, Kiyotaki and Prestipino (2016) extends the framework in Gertler and Kiyotaki (2010) to include "wholesale" banks (i.e. highly leveraged shadow banks that lend to each other). They show that growth in this sector generates a boom and then collapse. Similarly Meeks, Nelson and Alessandri (2017) incorporate Gertler and Kiyotaki (2010) style frictions into a model with commercial banks and shadow banks. They find that a liquidity crisis generated by shadow banks matches the correlation between output, commercial, and shadow bank credit. Ferrante (2018) builds a model with costly screening effort, and loans of varying quality into a model with traditional banks and shadow banks that face bank runs. Ferrante (2018) links asset quality deterioration to increased securitization. This work clearly tells us that shadow banking and securitization mattered to the boom. The contribution of this paper is to examine the transmission of a securitization driven credit supply shock to housing and mortgage markets.

The empirical literature is divided on the degree to which ex-ante borrower quality deteriorated during the 2000-2006 boom. Mian and Sufi (2009) find that mortgage defaults in 2007 were higher in U.S. ZIP codes that had a larger share of subprime borrowers (measured in 1996). In contrast Adelino, Schoar and Severino (2016) find that prime borrowers' share of mortgage defaults increased during this period. Ferreira and Gyourko (2015) find that from 2006-2012 twice as many prime borrowers foreclosed on their homes than subprime borrowers. They also find across all borrower types negative equity accumulation is strongly correlated with the probability of default. Clearly the ex-post mortgage quality deteriorated in the lead up to the 2007 crisis. However ex-ante mortgage borrower quality dynamics are less clear. Given this my paper takes a step back and examines how financial innovation in the securitization sector drives mortgage credit and house price dynamics when borrower quality is held constant. This does not preclude that the credit quality shifts explored by Ferrante (2018) also mattered. Layering his asset quality deterioration effect on top of the innovation in securitization channel I build in this paper, would further amplify the buildup in leverage in the shadow banking sector (consistent with the data).

In this paper I build on the aforementioned literature on shadow banking in general-equilibrium, but with a focus on the residential mortgage market and house price dynamics during the pre-2007 boom. Mian and Sufi (2017) and Justiniano, Primiceri and Tambalotti (2019) point to the large increase in the quantity of mortgage credit along with a decrease in the relative cost of mortgage credit, suggesting that the boom was driven by a positive shift in credit supply (Figure 1). Justiniano, Primiceri and Tambalotti (2017) find that the mortgage spread compressed particularly in 2003 and the effect is robust to adjusting for fluctuations in borrower characteristics during this period. Justiniano, Primiceri and Tambalotti (2019) show that in a simple model with an inelastic limit on total lending, an expansionary shift in this limit can match the increase in mortgage quantity and decrease in mortgage cost seen in the data. They hypothesize that one explanation of this shift is mortgage securitization but their model is too parsimonious to distinguish this from other changes in the financial sector. The contribution of this paper is that by modeling the securitization process I am able to show that only a relaxation of the constraints faced by securitizers can match the mortgage market dynamics during this period, in particular the shift of mortgages off commercial banks balance sheets onto the balance sheets of asset backed securities issues (shadow banks).

Favilukis, Ludvigson and Nieuwerburgh (2017) also explore an exogenous savings shock, they find that the combination of looser loan-to-value constraints and influx of foreign savings match the mortgage market dynamics during the 2000s period. However their model lacks the feedback effects generated by a constrained financial sector. In contrast, I find that the exogenous savings shock pushes the mortgage spread up (in the opposite direction of the data), due to the balance sheet effect. Landvoigt (2016) also develops a model with mortgage credit intermediation including securitization. In contrast to this paper where innovations in the securitization process alone can drive a decline in the mortgage spread, his model requires underestimation of credit risk to do so.

The focus of this paper is on the credit supply side. However there is also an active area of the literature that examines potential credit demand drivers on boom in US house prices and mortgage debt between 2000 and 2006. This research suggest that some non-financial factors, for example: optimism about future house prices (Kaplan, Mitman and Violante, 2017), or a speculative bubble (Shiller, 2007) drove an increase in house prices which in turn, drove an increase in the demand for credit – to finance the purchase of more expensive housing. Again, because of the *balance sheet effect* I find that a credit demand shock alone cannot explain the mortgage market dynamics in the data as it generates a counterfactual increase in the mortgage spread.

I build a model in which idiosyncratic mortgage default risk generates the existence of the mortgage backed securitization market. I embed this model into the housing in DSGE framework originated in Iacoviello and Neri (2010). The mortgage securitizing financial sector is comprised of mortgage issuing commercial banks and mortgage securitizing shadow banks. Shadow banks in this context are the Special Purpose Vehicles - the off-balance sheet entities owned by commercial or investment banks who bought and packaged non-conforming[5] mortgages into private mortgage backed securities. By providing an outlet for commercial banks to move their own lending off their balance sheet shadow banks enabled commercial banks to circumvent the regulatory constraints that would limit a credit supply boom.

The model captures the geographic dispersion of the US mortgage and housing markets and idiosyncratic mortgage default risk by incorporating an island structure. There is a continuum of islands, and each island has a borrower, saver, and commercial bank. Households can only interact with their island's commercial bank. In each period a proportion of islands receive a default shock which means borrowers on these "bad" islands do not pay back a proportion of debt. Commercial banks can choose to either hold the mortgages they issue or mortgage backed securities. Shadow banks sit off-islands, so can buy mortgages across islands and sell to commercial banks an asset (the mortgage backed security) that pays the average mortgage return across islands. By holding mortgage backed securities commercial banks can reassures savers that the deposits they issue will be paid back even on "bad" islands. This allows commercial banks to intermediate more funds and expand total mortgage credit provision on island - and thus overall mortgage credit supply. In contrast to the island setup in Ferrante (2018), here islands are ex-ante identical and all agents have common knowledge over the potential on-island outcomes.

The paper proceeds as follows. Section 2 presents the model. Section 3 presents the

[5]Those mortgages that fell outside the standards required for securitization by the Government Sponsored Enterprises (Fannie Mae & Freddie Mac).

calibration and simulation method. Section 4 explains the innovation in securitization mechanism. Section 5 presents and discusses the simulation results. And section 6 concludes.

2 The Model

2.1 Overview

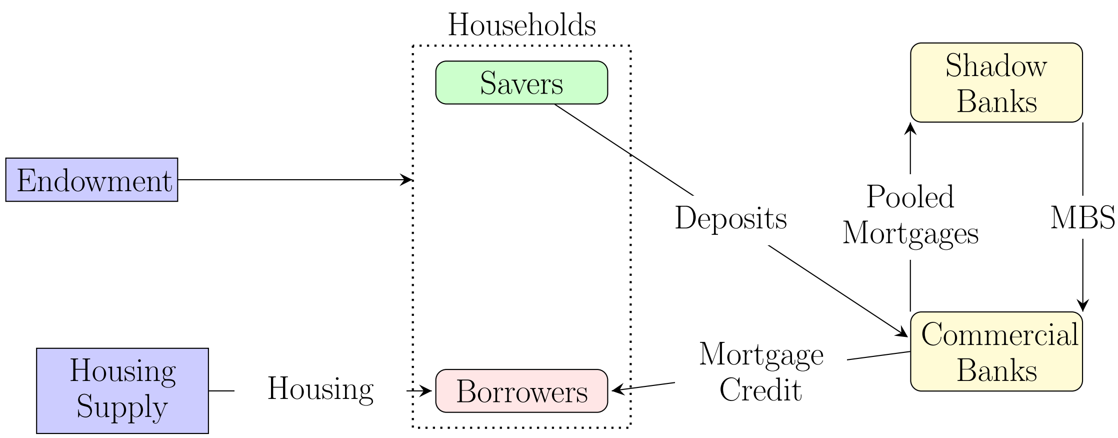

Figure 2: The Model

I build a model in which idiosyncratic mortgage default risk micro-founds the existence of mortgage backed securitization, and embed this model into a simplified version of the housing in DSGE framework originated in Iacoviello and Neri (2010). The key innovation is the addition of a two-layered mortgage securitizing financial sector comprised of mortgage issuing commercial banks and mortgage securitizing shadow banks. Borrowers, savers, and commercial banks exist in geographically disperse locations (islands). A commercial bank can only take deposits from savers on their island and can only lend to borrowers on their island. Each period a proportion of islands receive a default shock. On these "bad" islands borrowers do not pay back a proportion (ν) of what they owe on their mortgage debt ($R_{M,t}b_t$).

The model overlays an island structure onto a RBC model. Each island contains a borrower household, a saver household, and a commercial bank. Saver households operate the technology that produces new housing. Households can only interact with their local (on island) commercial bank.

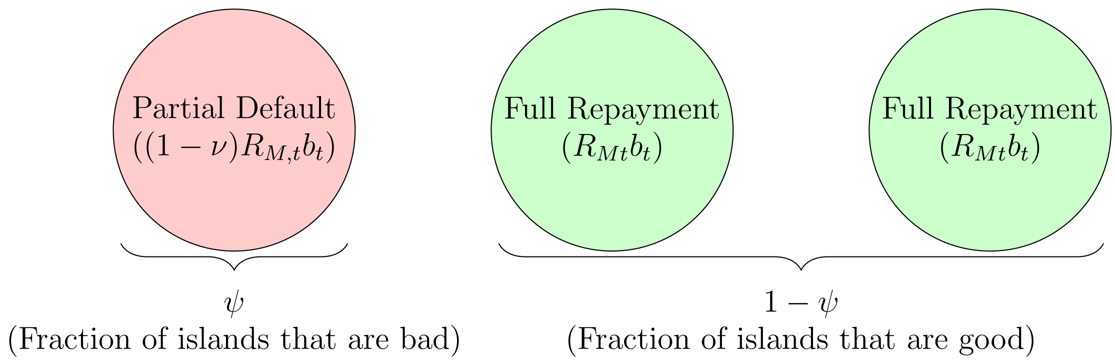

Figure 3: Risky Mortgage Lending

Note: Each period a fraction of islands (ψ) realize a default shock. On these islands borrowers do not repay a fraction (ν) of what they owe on their mortgages. So each period a fraction $\nu\psi$ of total mortgages are defaulted on.

Figure 3 illustrates the island structure of the default process. The commercial banking sector on each island may only lend to households on their island. Every period a random fraction ψ of islands are hit by a default shock, similar to Gertler and Kiyotaki (2010)'s island-specific investment opportunity shock. On "bad" islands (those receiving a default shock) the borrower only repays a fraction $1-\nu$ of what they owe on their mortgage debt[6], where $R_{M,t}$ is the mortgage rate and b_t is the quantity of mortgage debt taken out by an borrower.

The timing is as follows (see Figure 4): prior to the start of the period mortgages are

[6]This paper focuses on idiosyncratic risk. This framework could be extended to address aggregate mortgage market uncertainty by making ψ time-varying.

originated, commercial banks choose how to construct their balance sheet (between holding their own mortgages and holding mortgage backed securities). And shadow banks choose the quantity of pooled mortgages to buy and the quantity of mortgage backed securities to issue. These decisions jointly determine the mortgage spread. At the start of a new period the islands realize their default status. On a good island the borrowers repay in full, on a bad island the borrowers default proportionally. Commercial banks across all islands repay deposits, then commercial banks travel across islands to equalize credit conditions on islands going into the next period.

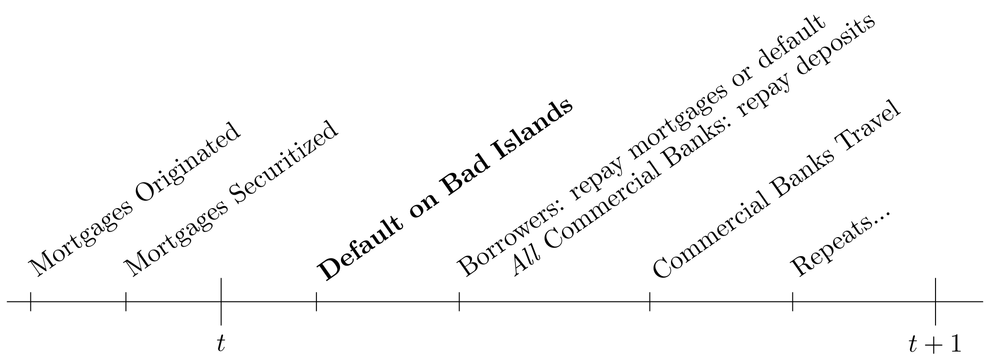

Figure 4: Timing of Default

Note: On "Travel": After deposits are repaid commercial banks move across islands to equalize credit conditions on all islands going into the next period. Essentially commercial banks are acting as a representative commercial banking sector but commercial banks across islands cannot insure each other against island specific shocks until *after* deposits are repaid.

Commercial banks can choose to retain the mortgages they issue on balance sheet (as "portfolio loans"), or to sell them to the off-island securitizing shadow bank. The shadow banking sector purchases mortgages from across all islands and packages them into "pass-thru" mortgage backed securities (with payoffs based on the aggregate mortgage market return, averaged across islands). Shadow banks are able to divert funds, a la Gertler and Kiyotaki (2010) and Meeks, Nelson and Alessandri (2017), and therefore are subject to an incentive compatibility constraint.

2.2 Households

There are two types of households. Savers are the ultimate source of funding for mortgage debt. Borrowers are relatively impatient individuals who value housing and face a collateral constraint when obtaining mortgage credit. Each household type, each of mass 1, risk shares in a large family across islands, an abstraction that focuses the idiosyncratic risk from island specific default shocks entirely onto the financial sector in this model.

2.2.1 Savers' Problem

Savers have an unmodeled rigid demand for housing. As a result borrowers are the marginal buyers of housing. This reflects Geanakoplos (2010)'s idea that the asset is priced by the most levered individuals (the borrowers), and is consistent with the empirical evidence. Landvoigt, Piazzesi and Schneider (2015) find that poorer households' access to cheaper credit was a major driver of house prices. Mian, Rao and Sufi (2013) find that the poorer and more leveraged households had a higher marginal propensity to consume out of housing wealth, which is also consistent with a segmentation of the housing market. Justiniano, Primiceri and Tambalotti (2019), Ferrante (2019), and Greenwald (2018) all make similar assumptions about segmentation.

Savers are relatively patient (their discount factor $\tilde{\beta}$ is larger than the borrowers' discount factor). They hold deposits, consume, and operate the technology that produces new housing. Their problem is:

$$\max_{\{\tilde{c}_t, d_t, I_t^h\}} \quad E_0 \sum_{t=0}^{\infty} (\tilde{\beta})^t \tilde{u}(\tilde{c}_t), \tag{1}$$

subject to their budget constraint:

$$\tilde{c}_t + d_t + I_t^h \leq p_{h,t} IH_t + R_{t-1} d_{t-1} + \tilde{y}_t + div_t, \tag{2}$$

and the Cobb-Douglas production technology for new housing:

$$IH_t = A_h (I_t^h)^{1-\mu_l} l^{\mu_l}, \tag{3}$$

where IH_t is newly produced housing, $p_{h,t}$ is the price of housing. I_t^h is materials, which are 1-for-1 convertible from consumption goods, and l is land (which is in fixed supply). Saver specific notation is denoted with tildes: $\tilde{c}_t$ denotes the savers' consumption of non-durable goods, $\tilde{y}_t$ is their period t endowment, and d_t deposits (which pay the risk-free rate R_t). Finally div_t denotes the dividend received from commercial and shadow banks by an individual saver (savers are the ultimate owners of financial institutions).

2.2.2 Borrowers' Problem

Borrowers are relatively impatient (discount factor: $\hat{\beta} < \tilde{\beta}$). They receive loans from commercial banks, consume, work, and purchase housing using a combination of current income and mortgage loans. Their problem is:

$$\max_{\{\hat{c}_t, \hat{h}_t, b_t\}} \quad E_0 \sum_{t=0}^{\infty} (\hat{\beta})^t \left[\hat{u}(\hat{c}_t) + j_t \ln \hat{h}_t \right], \tag{4}$$

subject to their budget constraint:

$$\hat{c}_t + p_{h,t} \hat{h}_t + (1 - \nu\psi) R_{M,t-1} b_{t-1} = b_t + (1 - \nu\psi)(1 - \delta_h) p_{h,t} \hat{h}_{t-1} + \hat{y}_t, \tag{5}$$

and a collateral constraint:

$$b_t \leq \bar{m} p_{h,t} \hat{h}_t, \tag{6}$$

where $\bar{m}$ is the exogenous collateral value of housing, and $p_{h,t}$ is the price of housing. Borrower specific notation is denoted with hats: $\hat{c}_t$ denotes the borrowers' consumption of non-durable goods, $\hat{h}_t$ is the quantity of housing they own, $\hat{y}_t$ their period t endowment, and b_t mortgage debt ($R_{M,t}$ is the mortgage rate). j_t is the borrowers' housing preference - shocks to j_t capture factors unrelated to financing conditions that move house prices.

Credit demand can be shifted in two ways. One, via housing demand shocks (positive shocks to the housing preference parameter j_t) which drive house prices up and therefore push borrowers to demand larger mortgage balances to finance the purchase of more expensive housing (via a collateral cycle effect this is possible). And two, an increase in the collateral value of housing ($\bar{m}$) which directly expands the borrowers' ability to borrow via loosening of their collateral constraint.

Borrowers risk-share in large families that are perfectly diversified across all islands[7]. Therefore the risk-sharing borrower family loses a fraction of housing (after depreciation) equal to the fraction of borrowers who default in aggregate: $\nu\psi$. Housing depreciates at the rate δ_h. So the borrower family enters the period with a fraction $(1 - \nu\psi)(1 - \delta_h)$ of their housing wealth from last period.

2.3 Financial Sector

The model's island structure motivates the existence of mortgage backed securities. Shadow banks sit off-islands and so can buy mortgages from across all islands. Shadow banks sell[8]

[7] This means the model abstracts from potentially interesting heterogeneity between borrowers with different histories of default. This assumption is required for tractability outside of a heterogeneous agent model of borrowers. However, this treatment still allows commercial banks to face idiosyncratic risk from retaining their own lending, the focus of this paper.

[8] Only to commercial banks.

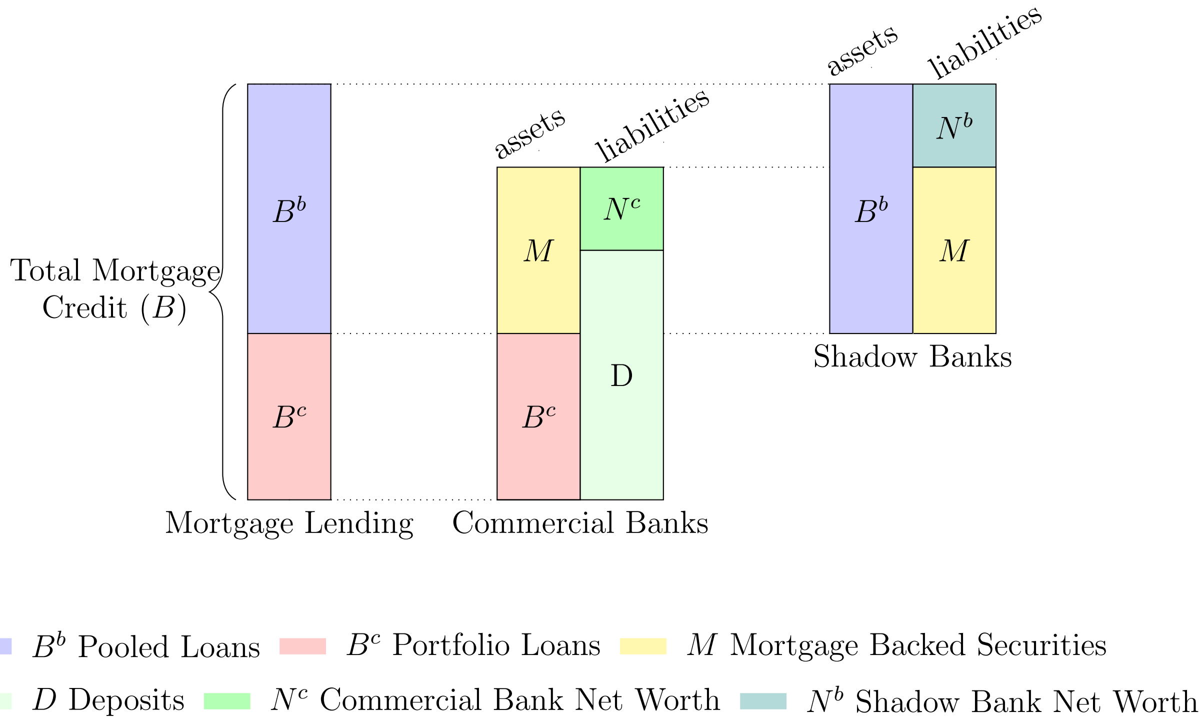

Figure 5: Financial Sector Balance Sheet

Note: Portfolio Loans (B^c) are the loans originated and then retained by an individual commercial bank. These loans are subject to island specific default risk. In contrast the Pooled Loans (B^b) are the loans purchased by shadow banks from across all islands. These loans are diversified, so only have aggregate risk not island specific risk.

an asset that pays the average mortgage return across islands (the mortgage backed security, MBS) . Commercial banks demand MBS because holding MBS reassures savers deposits will be paid back allowing them to intermediate more funds and expand total mortgage credit provision on island.

Figure (5) provides an overview of the balance sheets of financial intermediaries. Capital letters indicate aggregate quantities of the following: mortgage lending (B), mortgages retained by commercial banks ("portfolio loans", B^c), shadow bank held loans ("pooled loans", B^b), commercial bank net worth (N^c), shadow bank net worth (N^b), deposits (D), and total MBS (M). Note: MBS issued by shadow banks (M^b) are held entirely within the financial sector by commercial banks (M^c), so that $M = M^c = M^b$.

2.3.1 Commercial Banking Sector

Commercial banks are constrained by the savers' willingness to make deposits. Savers will only make an additional deposit in their local commercial bank if they expect to be repaid in full even in the event of being on a "bad" (default hit) island. This "solvency constraint" requirement limits the ratio of portfolio loans to MBS the commercial bank can hold. Commercial banks can relax the solvency constraint via the securitization process selling mortgages off their balance sheet and buying MBS which is diversified of their island specific risk.

There exists a continuum of commercial banks indexed by $c \in \left[0, 1\right]$. Each period commercial banks choose a specific island on which to locate for the purposes of mortgage lending and deposit taking, meaning that ex-ante islands have identical mortgage credit markets. In the following period the island's default status is realized. Commercial banks on all islands receive the same rate of return on MBS held, and must pay back deposits. Commercial banks on bad (default hit) islands are not fully repaid what is owed on mortgage debt. Commercial banks on good (non-defaulter) islands receive the full amount owed on mortgage debt and repay depositors. After repaying, commercial banks come together to redistribute net worth and travel across islands to equalize credit conditions. The solvency constraint is important because commercial banks can only risk share *after* deposits on island are repaid. Commercial banks continue with probability σ_c and exit with probability $(1 - \sigma_c)$. Upon exit their net worth goes to saver households (the ultimate owners of all financial institutions). New commercial banks enter with transfers made by saver households. The entry and exit assumption is standard (e.g Gertler and Kiyotaki (2010)) and ensures that net worth is not accumulated to the point that the solvency constraint is slack.

The commercial bank's problem is to choose deposit volumes (d_t), on balance sheet loans (b_t^c), and MBS holdings (m_t^c) to maximize their continuation value (V_t^c):

$$\max_{d_t, b_t^c, m_t^c} \; V_t^c = E_t \tilde{\Lambda}_{t,t+1} \left\{ (1-\sigma_c) \left[(1-\psi) n_{t+1}^{c,good} + \psi n_{t+1}^{c,bad} \right] + \sigma_c V_{t+1}^c \right\}, \tag{7}$$

subject to their balance sheet identity:

$$b_t^c + m_t^c = n_t^c + d_t, \tag{8}$$

and the solvency constraint:

$$(1-\nu) R_{M,t} b_t^c + \bar{R}_{m,t} m_t^c \geq R_t d_t, \tag{9}$$

where $\tilde{\Lambda}_{t,t+1}$ is the saver households' stochastic discount factor. Individual commercial bank net worth is denoted by n_t^c. $R_{M,t}$, $\bar{R}_{m,t}$ and R_t, are the mortgage rate, the mortgage backed security rate, and the deposit rate respectively. Net worth is realized as follows on good and bad islands:

$$n_{t+1}^c = \begin{cases} n_t^{c,good} \equiv R_{M,t} b_t^c + \bar{R}_{m,t} m_t^c - R_t d_t, & \text{if on a good island,} \\ n_t^{c,bad} \equiv (1-\nu) R_{M,t} b_t^c + \bar{R}_{m,t} m_t^c - R_t d_t, & \text{if on a bad island.} \end{cases} \tag{10}$$

The solvency constraint is the requirement that, when the commercial bank's island is hit with the default shock, its revenue on mortgage lending and MBS holdings must exceed or be equal to its obligation to depositors. The solvency constraint can be motivated as reflecting, in a consolidated way, deposit insurance plus bank regulation. The solvency constraint mimics the effect of risk-weighted equity requirements faced by regulated intermediaries during the period. The key point is that during this period the risk weight on MBS was lower than the risk weight on whole mortgages[9], so that the total equity the intermediary was required to hold could be lowered by moving assets from mortgages to MBS.

Gennaioli, Shleifer and Vishny (2013) use a similar constraint, motivated by extreme risk-aversion among depositors. In Ferrante (2018) a related financial constraint on traditional banks arises from asymmetric information between banks and creditors.

Aggregate commercial banking sector net worth evolves according to:

$$N_t^c = (\sigma_c + \xi_c)\Big((1-\nu\psi)R_{M,t-1}B_{t-1}^c + \bar{R}_{m,t-1}M_{t-1}\Big) - \sigma_c R_{t-1}D_{t-1}, \tag{11}$$

where ξ_c is the proportional transfer saver households make to new entering commercial banks.

2.3.2 Shadow Banking Sector

Shadow banks are constrained by the market's willingness to hold their assets, the mortgage backed security (MBS). This constraint is the Gertler and Kiyotaki (2010) running away constraint. If this constraint exogenously loosens they are able to securitize more mortgage credit, which allows commercial banks to provide more mortgage credit. This is the innovation in securitization credit supply shock.

Shadow Banks exist off-island. Each period they buy a perfectly diversified set of mortgages from every island and issue MBS which pay the average return on mortgage

[9]Under Basel I regulation mortgages with $>$ 80% LTV had a risk weight of 100%, and private label MBS had a risk weight of 50%, (Hayre, 2001). Under Basel II which came into effect in 2004 the regulatory system had a greater reliance on market discipline, including credit ratings (The Bank for International Settlements, 2014).

credit across islands. They exit with probability $(1-\sigma_b)$ and continue with probability σ_b. They face an agency problem that follows that in Meeks, Nelson and Alessandri (2017) and Gertler and Kiyotaki (2010).

The shadow bank's problem is to purchase diversified (pooled) mortgage debt (b_t^b) and issue MBS (m_t^b) to maximize their continuation value (V_t^b):

$$\max_{\{b_t^b, m_t^b\}} \quad V_t^b = E_t \tilde{\Lambda}_{t,t+1} \Bigg[(1-\sigma_b) n_{t+1}^b + \sigma_b V_{t+1}^b \Bigg], \tag{12}$$

subject to their balance sheet identity:

$$b_t^b = m_t^b + n_t^b, \tag{13}$$

and the incentive compatibility constraint:

$$V_t^b \geq \theta_{b,t} b_t^b. \tag{14}$$

An individual shadow bank's net worth evolves according to:

$$n_{t+1}^b = \underbrace{(1-\psi\nu) R_{M,t} b_t^b}_{\text{return on the diversified mortgage pool}} - \bar{R}_{m,t} m_t^b. \tag{15}$$

The shadow bank's incentive compatibility constraint (14) captures the agency problem between a shadow bank and the commercial banks that hold the MBS the shadow bank issues. The literal interpretation of $\theta_{b,t}$ is as follows: each period the shadow bank is able to choose to close down and run away with a fraction $\theta_{b,t}$ of the pooled loans the shadow bank owns. If the shadow bank chooses this they will never be trusted again. They close down and forfeit their continuation value V_t^b. This constraint (14) limits the quantity of MBS shadow banks can issue, so that they always prefer their continuation value. Essentially $\theta_{b,t}$ indexes the trust that MBS holders place in shadow banks. A fall in $\theta_{b,t}$ captures financial innovation of the sort experienced prior to the financial crisis.

Financial innovation in this context relates directly to "credit enhancements"[10]– the implicit or explicit agreements such as tranching that were used to reassure investors that MBS were nearly risk-free assets. An "innovation in securitization" shock (exogenous drop in $\theta_{b,t}$) captures in reduced form either: a) actual technological improvements in credit enhancements, or b) an increase in investor's perception about the ability of credit enhancements to minimize MBS credit risk. With innovation in securitization shadow banks can hold mortgage credit in greater quantities with a lower spread, meaning that the general equilibrium effect is lower mortgage spreads[11].

Aggregate shadow banking sector net worth evolves according to:

$$N_t^b = (\sigma_b + \xi_b)(1 - \nu\psi)R_{M,t-1}B_{t-1}^b - \sigma_b \bar{R}_{m,t-1}M_{t-1}, \tag{16}$$

where ξ_b is the proportional transfer saver households make to new entering shadow banks.

[10]See Gorton and Souleles (2007) for a discussion of credit enhancements.

[11]The primary focus of this paper is the spread between the mortgage rate and the MBS rate, which is driven by the tightness of the shadow banks' incentive compatibility constraint. In contrast the optimality conditions of the commercial bank (see appendix D) imply that the spread between the MBS rate and the risk free rate is always zero. This is a simplification: Merrill, Nadauld and Strahan (2019) and Chernenko, Hanson and Sunderam (2014) both show that the spread between Non-Agency Asset Backed Securities (including MBS) and comparably rated corporate bonds was positive during the early 2000s period. This drove regulatory arbitrage activity by investors such as insurance companies– in that both asset types required similar levels of regulatory capital. Adding these institutional investors and the MBS rate over the risk free rate spread is outside of the scope of this paper but would most likely amplify the quantitative impacts of innovation in securitization.

2.3.3 Dividends to Savers

The dividend payment to savers in aggregate is:

$$Div_t \equiv \underbrace{(1-\nu\psi)R_{M,t-1}B_{t-1} - R_{t-1}D_{t-1}}_{\text{Consolidated Financial Sector Profits}} \quad - \quad \underbrace{(N_t^c + N_t^b)}_{\text{Profits retained by the Financial Sector}}$$
$$+ \underbrace{\nu\psi(1-\delta_h)p_{h,t}\hat{h}_{t-1}}_{\text{Value of defaulted housing}} \tag{17}$$

The dividend payment is made to the savers at the start of period. When borrowers default on their mortgage debt they lose a proportional amount of their housing. This is possessed by the commercial banks and passed fully onto savers. Savers then sell the non-depreciated housing, $\nu\psi(1-\delta_h)\hat{h}_{t-1}$, back into the market at the market price.

2.4 Equilibrium

Endowment:

$$\hat{y}_t = (1-\alpha)Y, \tag{18}$$

$$\tilde{y}_t = \alpha Y, \tag{19}$$

where Y, the aggregate endowment size, is normalized to 1.

Goods Market equilibrium:

$$Y = \tilde{c}_t + \hat{c}_t + I_t^h. \tag{20}$$

Total supply of housing evolves according to:

$$H_t - (1-\delta_h)H_{t-1} = IH_t \tag{21}$$

Housing market clearing:

$$\hat{h}_t = H_t. \tag{22}$$

Mortgage market clearing:

$$B_t = B_t^c + B_t^b. \tag{23}$$

MBS market clearing:

$$M_t^c = M_t^b. \tag{24}$$

Land is in fixed supply and normalized to 1:

$$l = 1. \tag{25}$$

2.5 Functional Forms and House Pricing Equation

For simplicity I assume that both borrower and saver households have linear utility in non-durable consumption. This simplifying assumption does not qualitatively change the results (see appendix F for robustness). This means the house pricing equation (from the borrower's choice of housing, equation 41) can be written as:

$$p_{h,t} = \frac{1}{1 - \hat{\mu}_t \bar{m}_t} \left[\frac{j_t}{\hat{h}_t} + \hat{\beta}(1 - \nu\psi)(1 - \delta_h) E_t p_{h,t+1} \right]. \tag{26}$$

Iterate the pricing equation forward to see that today's house price is the expected discounted value of the sum of the borrower's marginal utility for housing, divided by a term that is a function of the Lagrange multiplier on the collateral constraint:

$$p_{h,t} = E_t \left\{ \sum_{i=0}^{\infty} \frac{\Psi^i \frac{j_{t+i}}{\hat{h}_{t+i}}}{\Pi_{k=0}^{i}(1 - \bar{m}\hat{\mu}_{t+k})} \right\}. \tag{27}$$

If the collateral constraint never binds ($\hat{\mu}_t = 0 \forall t$), then the house pricing equation (27) indicates that today's house price is simply the present discounted value of the sum of the borrower's marginal utility for housing, where the discounting term, $\Psi \equiv (1-\nu\psi)(1-\delta_h)$, includes both default and depreciation.

Using the borrowers' optimality condition for credit (42) to substitute out $\hat{\mu}_t$, the house pricing equation (27) becomes:

$$p_{h,t} = E_t \left\{ \sum_{i=0}^{\infty} \frac{\Psi^i \frac{j_{t+i}}{\hat{h}_{t+i}}}{\Pi_{k=0}^{i} \Phi(R_{M,t+k})} \right\}, \tag{28}$$

where $\Phi(R_{M,t+k}) \equiv (1-\bar{m}) + \bar{m}(1-\nu\psi)R_{M,t+k}$. As long as the collateral constraint is binding[12] any shock that lowers the expected path of mortgage rates will push up house prices, as is clear in (28). The innovation in securitization shocks have the effect of lowering the equilibrium level of the mortgage rate, and so drive house prices up.

3 Calibration & Simulation

3.1 Calibration

3.1.1 Macroeconomic Parameters

This set of parameters either match well established calibrations in the literature, or target an average of the 1990s data. $\tilde{\beta}$ is set to target the average real Fed Funds rate in the 1990s data (of 2.28% annualized[13]). $\hat{\beta}$ is set to match the calibration in Iacoviello and Neri (2010). The relative impatience has a minimal effect on the co-movement of house prices and mortgage credit. The calibration of the labor income share going to savers (α) comes

[12] When the collateral constraint is slack ($\hat{\mu}_t = 0$) $R_{M,t} = \frac{1}{\tilde{\beta}(1-\nu\psi)}$.

[13] The average nominal Fed Funds rate (FEDFUNDS) in this period is 5.14% and the average growth in the Consumer Price Index (CPIAUSCSL) is 2.86%

Table 1: Calibrated Parameters

Parameter	Value	Description
Macroeconomic Parameters		
$\tilde{\beta}$	0.9943	Saver's discount factor
$\hat{\beta}$	0.97	Borrower's discount factor
α	0.64	Labor income share of savers
Y	1	Aggregate endowment
Housing and Financial Parameters		
μ_l	1	Land Share in housing production
δ_h	0.003	Depreciation of housing
A_h	0.003	Housing sector productivity
σ_c, σ_b	0.95	Financial institution survival probability
$\bar{m}$	0.9	Housing collateral value
j	0.03	Borrower housing preference parameter
ψ	0.92%	Quarterly mortgage delinquency rate
ν	34.8%	On island default
θ_b	0.6	Fraction of pooled loans that are divertible
ξ_c	0.0074	Fraction of assets transferred to new commercial banks
ξ_b	0.0042	Fraction of assets transferred to new shadow banks

from Justiniano, Primiceri and Tambalotti (2015) who identify borrowers as households whose liquid assets are less than two months of their total income - using the 1992, 1995 and 1998 Survey of Consumer Finances (SCF).

3.1.2 Housing and Financial Parameters

In the main results presented below (section 5.1) the land share in production of new houses (μ_l) is set to 1, so that new housing production is constant. The quarterly depreciation of houses, δ_h, is calibrated using the National Income and Product Accounts (NIPA) Fixed Asset Tables, as in Justiniano, Primiceri and Tambalotti (2019). A_h, the productivity of the housing sector, is set equal to the depreciation of housing so that when $\mu_l = 1$ total housing supply is constant[14]. σ_c and σ_b target an expected survival horizon for commercial

[14]This results in the steady state level of total housing supply equaling the land supply l.

and shadow banks of 5 years, consistent with the literature (eg Gertler and Kiyotaki, 2015). The collateral value of housing ($\bar{m}$) sets the borrower's loan-to-value (LTV) ratio at 90%[15]. The borrower's housing preference parameter (j) targets a mortgage-to-income ratio of 0.8, matching the mortgage-to-income ratio Justiniano, Primiceri and Tambalotti (2019) find when looking at households whose liquid assets are less than two months of their total income - using the 1992, 1995 and 1998 Survey of Consumer Finances (SCF). Their measure of mortgages comes from the Flow of Funds, home mortgages on the balance sheet of households and nonprofit organizations.

3.1.3 Simulation Initialization Targets

The remaining parameters: $\nu, \theta_b, \xi_c, \xi_b$, and ψ which pertain most directly to the financial sector, jointly target the moments in the 2000 Q1 - 2000 Q4 data in table 2. This narrower target period better reflects the condition of the private securitization market, because the early 1990s were characterized by only a handful of private securitization deals. The first four parameters target the spread and balance sheet moments in table 2 and then ψ is set so that the product of ψ (the fraction of islands that are bad islands) and ν (the proportional default on bad islands) jointly target the fraction of mortgage dollars entering serious (90+ day) delinquency[16] in the FRBNY's Quarterly Report on Household Debt and Credit (0.32%).

The data series on the mortgage spread used here is the conditional mortgage spread series constructed by Justiniano, Primiceri and Tambalotti (2017). The series measures

[15]This is a compromise between the higher documented LTV ratios in the non-conforming mortgage pool, and maintaining consistency with similar targets eg Justiniano, Primiceri and Tambalotti (2015) in the literature.

[16]This is calculated as the mortgage dollars entering serious delinquency ("Mortgage" from the "New Seriously Delinquent Balance by Loan Type" table) divided by total mortgage dollars ("Mortgage" from the "Total Debt Balance and its Composition" table). Source: Federal Reserve Bank of New York's Center for Microeconomic Data, retrieved from: https://www.newyorkfed.org/microeconomics/hhdc.html, August 19, 2019.

Table 2: Simulation Initialization Targets

Target	Value
Mortgage Spread ($R_M - R$)	4.4%
Commercial bank asset composition ($\frac{M^c}{Bc}$)	0.05
MBS to Mortgages Ratio	0.04
Adjusted commercial bank leverage	3
% of Mortgage dollars entering serious delinquency	0.32%

the average mortgage rate in the Private Label Securities Database (PLSD)[17], where each mortgage rate is adjusted for loan and borrower characteristics, taken as a spread over the 10 year US Treasury yield[18]. The commercial bank asset composition is the ratio of the value of private label MBS (PLMBS) held by commercial banks[19] to the value of mortgages retained by commercial banks (i.e. "Portfolio Loans"[20]). Because the focus here is on MBS held by commercial banks MBS the MBS-to-Mortgages Ratio (M/B) is calibrated as follows. (M) is measured by the total value of private label MBS held by U.S. Chartered Depository Institutions[21]. Total mortgages (B) is measured as the sum of portfolio loans[22] and loans held in the shadow banking sector[23], weighted by the fraction of MBS held by commercial banks[24]. The "adjusted commercial bank leverage" is average

[17]This is the near universe of mortgages in non-agency securitization pools.

[18] Here I use their conditional mortgage spread series based only on purchases, however during the target period (2000Q1-Q4) the purchases & refinancing series produces essentially the same target (4.29%).

[19]This is the sum of Private Residential Mortgage Pass-Through Securities (LM763063673.Q) and Private Residential CMOs and Other Structured MBS (LM763063663.Q) on Table L.111 (holdings of U.S. Chartered Depository Institutions) in the Flow of Funds Z1 release data. Source: Board of Governors of the Federal Reserve System (US), Z1 Financial Accounts of the United States, retrieved from DDP; www.federalreserve.gov/datadownload/, August 15, 2019.

[20]Portfolio Loans are those loans retained by commercial banks: "U.S.-chartered depository institutions; one-to-four-family residential mortgages, including farm houses" (FL763065105.Q) on Table L.218 in the Flow of Funds data.

[21]See footnote 19.

[22]See footnote 20.

[23]This includes residential mortgages held by ABS issuers: "Issuers of asset-backed securities; one-to-four-family residential mortgages; asset (FL673065105.Q), and residential mortgages held by mortgage companies: "Finance companies; one-to-four-family residential mortgages; asset" (FL613065105.Q) also on Table L.218 in the Flow of Funds data.

[24]In 2000 this was 18.9-20.5%, measured by the MBS held by commercial banks (see footnote 19) relative

commercial bank leverage[25] during the calibration period normalized by the percentage of assets on commercial banks' balance sheets that are either portfolio loans or private mortgage backed securities (as measured by the Flow of Funds data[26]).

3.2 Simulation Method

The following simulations involve large shocks (moving the model far away from the initial steady state) and multiple occasionally binding constraints. Therefore, I use a deterministic simulation method with the fully non-linear model. This preserves the integrity of the simulation even as it moves far away from the initial steady state. The non-linearity also allows for all relevant constraints to be occasionally binding. The approach to the deterministic simulation is the extended path approach of Fair and Taylor (1983), which is applied (and explained in more detail) in Christiano, Eichenbaum and Trabandt (2015). Let z_t denote the $Nx1$ vector of endogenous variables determined at time t, and $\epsilon_t = \{\theta_{b,t}, j_t, \tilde{\beta}_t\}$ the vector of exogenous deterministic variables realized at time t. Each period the agents realize an unexpected shock (to either $\theta_{b,t}$, j_t, or $\tilde{\beta}_t$) and expect the economy to transition to a new steady state consistent with the realization of that shock. In t=1 the starting point of the deterministic simulation is the initial steady state, in $t \geq 2$ the starting point is the vector of endogenous variables in $t-1$.

to the total outstanding stock of Non-Agency MBS (*source:* Inside Mortgage Finance (2013) Mortgage Market Statistical Annual. Volume I and II. Bethesda, MD.).

[25] Commercial bank leverage is measured using aggregate data in the Federal Deposit Insurance Corporation's Quarterly Bank Report. It is specifically the ratio of Total Assets to Total Equity Capital.

[26] Total Commercial Bank assets are measured by "U.S.-chartered depository institutions, including IBFs; total financial assets" (FL764090005.Q) on Table L.111 of the Flow of Funds

4 Which Credit Supply Shock?

This section uses a simplified two-period version of the model (see appendix D). First I show how the combination of binding financial constraints on commercial and shadow banks drives the equilibrium in the MBS market, which in turn generates an upward sloping credit supply curve. The collateral constraint on borrowers drives a downward sloping credit demand curve.

Second I show the transmission channels of the two credit supply shocks – the exogenous savings shock and the innovation in securitization shock – operate through supply and demand shifts in both the MBS and mortgage credit markets.

4.1 Mortgage Credit Supply

Total credit supply (B^{supply}) is the sum of financial intermediary equity and deposits:

$$B^{\text{supply}} = N^c + N^b + D \tag{29}$$

Both commercial bank equity(N^c) and shadow bank equity (N^b) are fixed so the credit supply schedule is driven by deposits (D). The representative saver (with linear utility) has the following inverse demand schedule for deposits:

$$R(D) = \begin{cases} \frac{1}{\tilde{\beta}}, & \text{if } D < \tilde{y}_1 \\ \frac{1+\Xi_1}{\tilde{\beta}}, & \text{otherwise} \end{cases} \tag{30}$$

where Ξ_1 is the multiplier on the non-negativity constraint for period 1 consumption, $\tilde{y}_1$ is the saver's period 1 endowment, and R is the rate on deposits. The focus in the following will be on $B^{\text{supply}} < N^c + N^b + \tilde{y}_1$ so that $R = 1/\tilde{\beta}$.

Define S to be the mortgage spread adjusted for default[27]:

$$S \equiv (1 - \nu\psi)R_M - R, \tag{31}$$

where $\nu\psi$ is the fraction of borrowers who default, and R_M is the mortgage rate. Rearranging this expression one can express the mortgage rate adjusted for default relative to the risk free rate as:

$$\frac{(1 - \nu\psi)R_M}{R} = 1 + \frac{S}{R}, \tag{32}$$

The normalized spread ($\bar{S} \equiv S/R$) is determined by the equilibrium in the MBS market. Appendix E.2 shows that when the financial sector is constrained, the shadow banking sector and commercial banking sector have the following inverse MBS supply ($\bar{S}^{\mathrm{S}}$) and MBS demand ($\bar{S}^{\mathrm{D}}$)curves (figure 6a):

$$\bar{S}^{\mathrm{S}}(M; B, \theta_b) = \max\Big(0, \Big[\theta_b - \frac{N^b}{N^b + M}\Big]\Big), \tag{33}$$

$$\bar{S}^{\mathrm{D}}(M; B) = \max\Big(0, \Big[\frac{\nu(1-\psi)}{1-\nu} + \frac{1-\nu\psi}{1-\nu}\frac{N^c}{N^b + M - B}\Big]\Big), \tag{34}$$

where M is the total value of MBS, and θ_b is the divertibility parameter that indexes the extent of innovation in securitization (high θ_b corresponds to low innovation). When total credit supply (B) increases the MBS demand curve shifts out ($a \to b$ in left panel of figure 6). This generates an upward sloping credit supply curve (right panel of figure 6).

[27]Using the fact that the MBS rate equals the risk free rate $R_m = R$, as shown in appendix D.

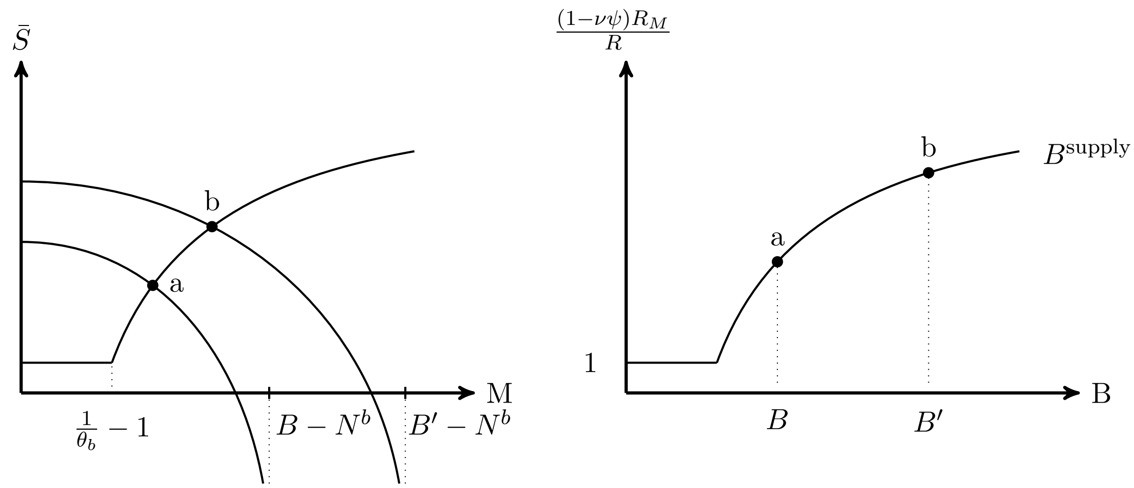

Figure 6: MBS Market Equilibrium Generates an Upward Sloping Credit Supply Curve

4.2 Mortgage Credit Demand

Section 2.5 derived the borrower's house pricing equation (26). Here in the two period model the house pricing equation is:

$$p_{h,1} = \frac{1}{1 - \hat{\mu}\bar{m}} \left[\frac{j}{\hat{h}_1} + \hat{\beta}(1 - \nu\psi) \underbrace{\frac{j}{\hat{h}_2}}_{=p_{h,2}} \right], \tag{35}$$

where $\hat{\mu}$ is the multiplier on the collateral constraint, $\bar{m}$ is the fraction of the housing value that can serve as collateral, j is the borrower's housing preference parameter, and $\hat{\beta}$ is the borrower's discount factor. When the collateral constraint binds it determines the borrowers' demand for credit:

$$B^{\text{demand}} = \bar{m} p_{h,1} \hat{h}_1 \tag{36}$$

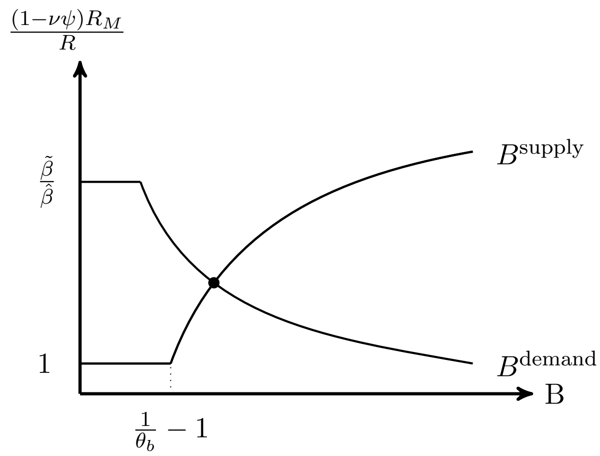

Figure 7: Credit Market Equilibrium

Using this the borrower's inverse demand function for credit (see appendix E.3) can be written as:

$$\frac{(1-\nu\psi)R_M}{R} = \begin{cases} \frac{\tilde{\beta}}{\hat{\beta}}\left[1-\frac{1}{\bar{m}}+j\left[1+\hat{\beta}(1-\nu\psi)\right]\frac{1}{B^{\text{demand}}}\right], & \text{if } \hat{\mu}>0, \\ \\ \frac{\tilde{\beta}}{\hat{\beta}}, & \text{if } \hat{\mu}=0. \end{cases} \tag{37}$$

The borrower has the downward sloping inverse credit demand curve pictured in figure 7. The equilibrium in the mortgage credit market is determined by the intersection of the inverse credit supply and inverse credit demand curves.

4.3 Global Savings Glut Channel

In his 2005 speech Bernanke characterized the "Global Savings Glut" view: the substantial increase in the supply of foreign savings flowing into the U.S. could in part explain the increase in the U.S. current account deficit and the low level of long-term real interest rates. More recently Favilukis, Ludvigson and Nieuwerburgh (2017) find that a shock that drives the risk-free interest rate down in combination with an LTV shock can replicate the mortgage market dynamics during the 2000-2006 period. In this section I illustrate why, because of the *balance sheet effect*, this "exogenous savings" credit supply shock actually has counter-factual implications for the mortgage market.

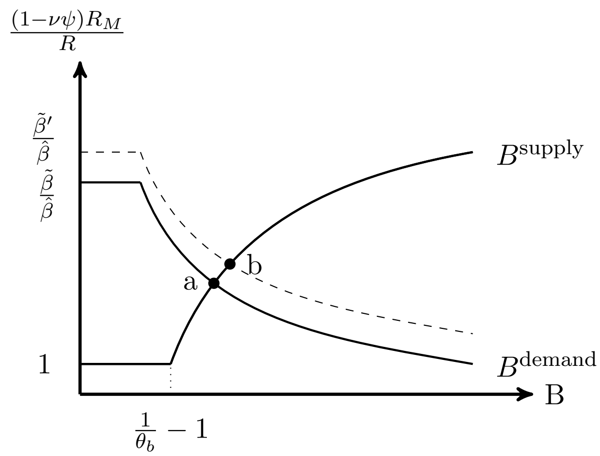

Figure 8: Credit Market Equilibrium: ES Shock

The exogenous savings shock is an increase in the savers' discount factor, $\tilde{\beta}$. As is clear from the MBS supply and demand curves (33, 34), the exogenous savings shock does not directly shift either curve. However it does shift the borrower's inverse credit demand curve (37) – figure 8. This is intuitive as a lower risk free rate lowers the level of the mortgage rate, stimulating borrower demand[28].

This shift drives up the equilibrium level of total mortgage credit. An increase in total mortgage credit puts upward pressure on the size of the commercial banks' balance sheets, as commercial banks must absorb more deposits to fund additional mortgages. Because of the solvency constraint the commercial banks are limited in the ratio of mortgage loans they can retain relative to the quantity of mortgage backed securities they must hold. What

[28] The demand curve shifts because it is expressed in terms of the relative mortgage rate $(1 - \nu\psi)R_M/R$.

starts as a credit supply shock (the lowering of the risk-free rate) transmits to the MBS market as a MBS demand shock. This shifts the MBS demand curve out (see figure 9). Because the shadow bank's financial constraint generates an upward sloping MBS supply curve, the new equilibrium in the MBS market is at a higher normalized spread. This is the *balance sheet effect*.

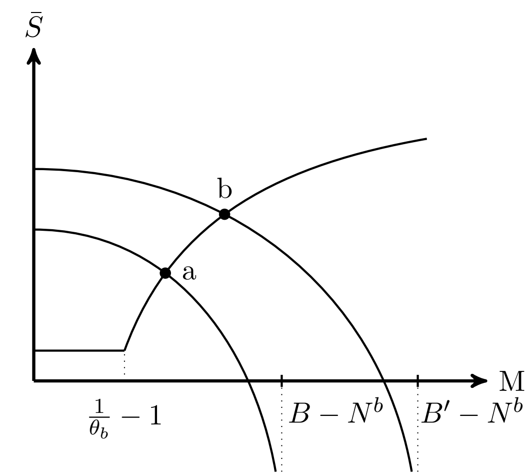

Figure 9: Mortgage Backed Securities Market - MBS Demand Shock

4.4 The Innovation in Securitization Channel

In contrast the innovation in securitization shock (an exogenous decrease in θ_b) directly shifts the MBS supply curve (10, left panel). In turn this shifts the credit supply curve out (figure 10, right panel). It operates as follows: the decrease in θ_b makes the pooled mortgages (B^b) less divertible. This lowers the continuation value required for shadow banks to meet their incentive compatibility constraint (78), and means that shadow banks can respond by increasing the quantity of MBS they issue even while the mortgage spread in equilibrium falls.

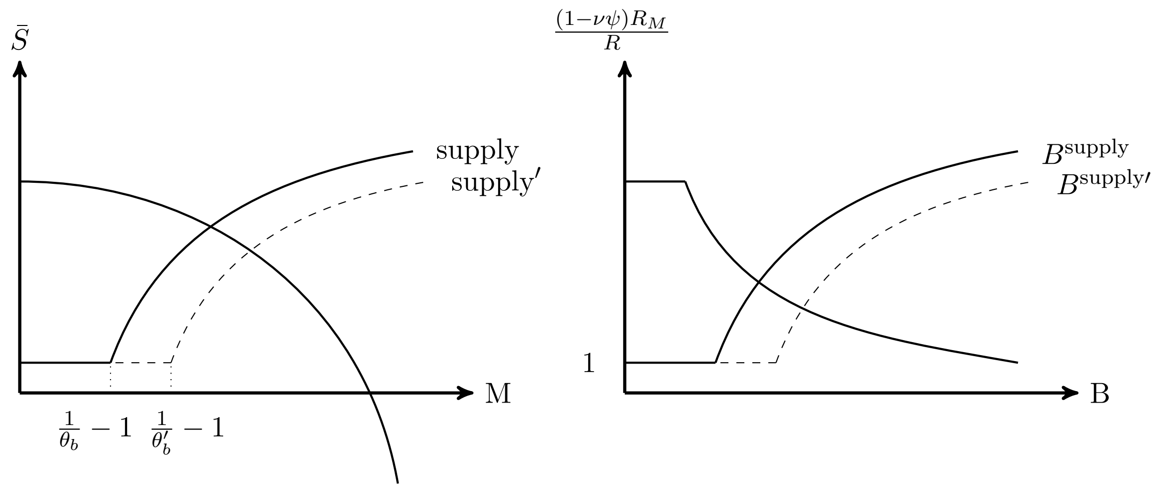

Figure 10: Credit Market Equilibrium: IIS shock

4.4.1 Innovation in Securitization as an Amplifier

Figure 11 explores the effect of a one-off permanent exogenous savings shock that decreases the risk-free rate 38 basis points (calibrated to generate a peak 1% point increase in mortgage credit in the Pre-Boom version of the model). The picture is clear – the more innovation in securitization has taken place (lower θ_b) the more the exogenous savings shock drives credit quantity and house prices up, and the smaller its effect is on the mortgage spread. This suggests that the innovation in securitization channel could have played a key role in amplifying the impact the global savings influx might have had on the U.S. mortgage and housing market during this period.

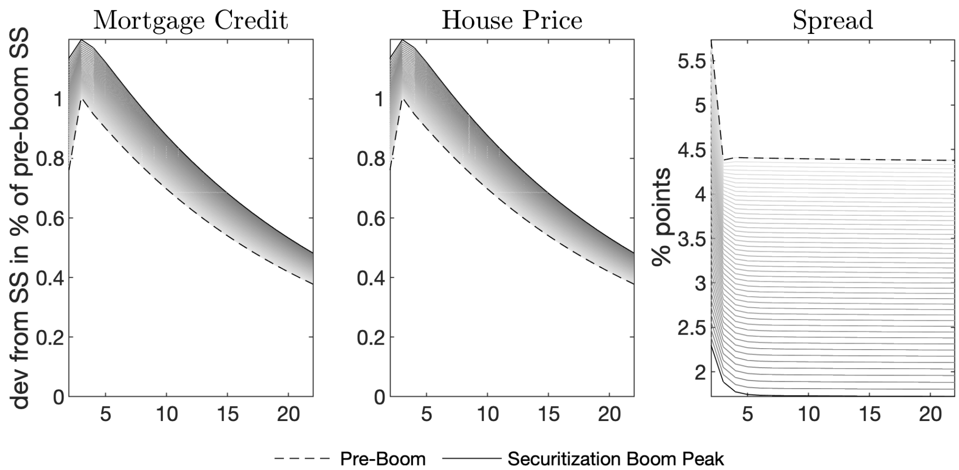

Figure 11: Transmission of an Exogenous Savings Shock

Note: The "exogenous savings shock" is an increase in savers' discount factor $\tilde{\beta}$.

4.5 Comparison to a Generalized Lending Constraint Relaxation

Justiniano, Primiceri and Tambalotti (2019) explore the effects of a shift in an inelastic limit on total lending (figure 12). They find that an increase in the total supply of lending available is necessary to explain the mortgage market dynamics during the 2000-2006 period in the United States. They motivate the lending limit as capturing a number of constraints that limit the channeling of funds towards the mortgage market. They motive the inelastic lending limit as coming from a combination of leverage limit on the financial sector in aggregate and infinite costs to raising equity[29]. So in their model an increase in the aggregate leverage limit drives the expansionary shift to the total lending limit.

While Justiniano, Primiceri and Tambalotti (2019) include liberalization of the private label MBS markets as a potential driver of the lending limit, they cannot distinguish the effect of a relaxation of the constraints faced by MBS securitizers from a relaxation of

[29]This assumption does not impact the overall result. If the cost of raising equity is finite their lending supply curve is upward sloping, instead of inelastic. This case is explored in Justiniano, Primiceri and Tambalotti (2019)'s web appendix.

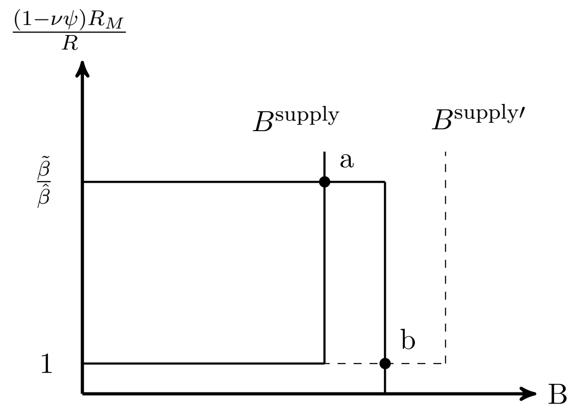

Figure 12: General Lending Constraint Relaxation

constraints on other financial intermediaries in their model. By modeling the securitization process explicitly I am able to show that shifts in the constraint faced by commercial banks and shifts in the constraint faced by shadow banks (the innovation in securitization shocks) have starkly different predictions for the distribution of mortgages across financial intermediary balance sheets.

To see this consider the commercial bank's solvency constraint, modified to include a "stress" term:

$$(1-\nu-\epsilon^{\nu})R_M + \bar{R}_m M - RD \geq 0, \tag{38}$$

when $\epsilon^{\nu} > 0$, the discounting of on balance sheet mortgages, is greater than the true on-island default experienced on "bad" (default hit) islands. This captures simply a tighter regulatory environment faced by commercial banks. This modifies the commercial banks' MBS demand curve:

$$\bar{S}^D = \max\Big(0, \Big[\frac{(\nu+\epsilon^{\nu})(1-\psi)}{1-(\nu+\epsilon^{\nu})} + \frac{1-(\nu+\epsilon^{\nu})\psi}{1-(\nu+\epsilon^{\nu})}\frac{N^c}{N^b+M-B}\Big]\Big). \tag{39}$$

When the regulatory environment relaxes (ϵ^{ν} decreases), the MBS demand curve (39) shifts inward, because $\partial \bar{S}^D / \partial \epsilon^\nu > 0$. Intuitively this is because when regulation is less tight commercial banks have a smaller incentive to use MBS to evade regulation. Figure (13) shows that this shifts the lending supply curve down (at each level of total credit the financial sector demands a smaller normalized spread).

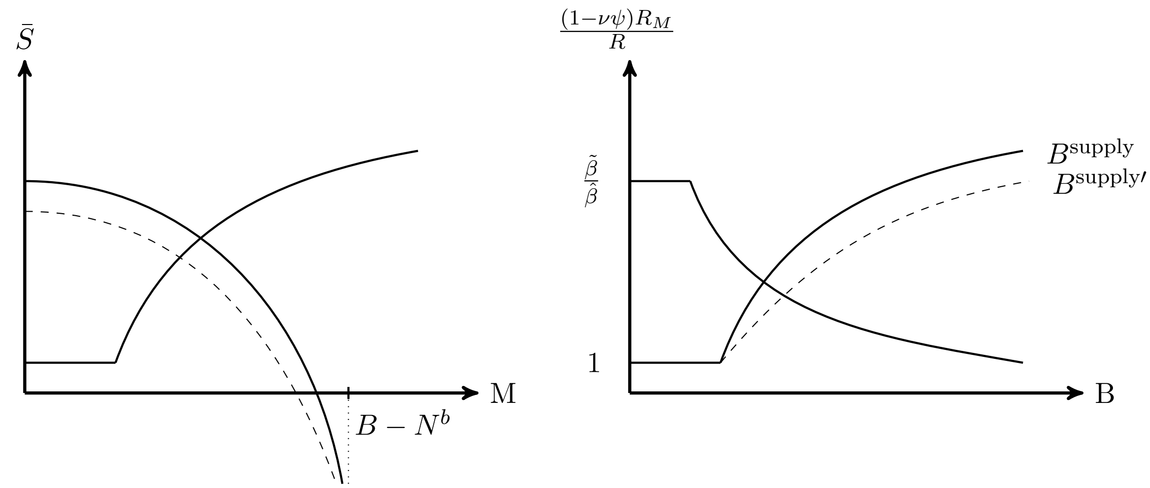

Figure 13: Liberalization of Commercial Banking Regulation

The dynamics of the mortgage credit quantity and the spread in response to a liberalization in the commercial banking sector are observationally indistinguishable from the innovation in securitization shock. However the two shocks have opposite predictions for the distribution of mortgages across financial intermediary balance sheets. The innovation in securitization shock predicts that (given a specific level of total lending) the equilibrium quantity of MBS increases. This means that more mortgages are held by the securitizers of MBS (shadow banks) and fewer mortgages are held by commercial banks. The liberalization of commercial banking regulation predicts the opposite. Figure 14 shows that during the 2000-2006 time period mortgages were increasingly being held by the shadow banking sector and not the commercial banking sector. The only shock that can match the dynamics in these data is the innovation in securitization shock.

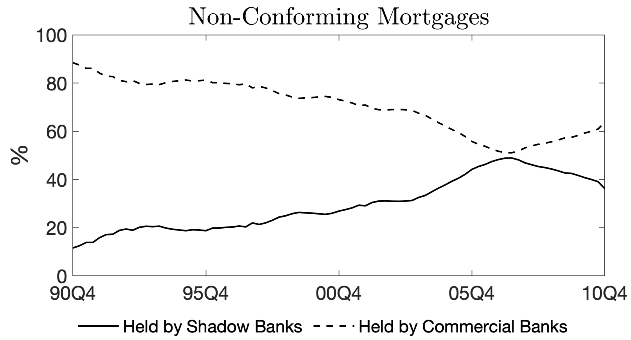

Figure 14: Mortgages Shifted from the Regulated to the Unregulated Sector

Note: Source: Board of Governors of the Federal Reserve System (US), Z1 Financial Accounts of the United States, retrieved from DDP; www.federalreserve.gov/datadownload/, August 15, 2019. Mortgages held by shadow banks are the sum of residential mortgages held by ABS issuers: "Issuers of asset-backed securities; one-to-four-family residential mortgages; asset (FL673065105.Q), and residential mortgages held by mortgage companies: "Finance companies; one-to-four-family residential mortgages; asset" (FL613065105.Q) also on Table L.218 in the Flow of Funds data. Mortgages held by commercial banks are "U.S.-chartered depository institutions; one-to-four-family residential mortgages, including farm houses" (FL763065105.Q) on Table L.218 in the Flow of Funds data. The series are expressed as a pecentage of the total sum of mortgages held by commercial banks and shadow banks (the non-conforming mortgages in figure 1).

5 Boom-Bust Simulation Results and Discussion

Two exercises are presented below. The first exercise is a horse-race between the following three candidate explanations of the boom. One, the "Securitization Boom": driven by negative shocks to $\theta_{b,t}$ (the "innovation in securitization" shock). Two, the "Housing Demand Boom": driven by positive shocks to borrower housing preference, j_t. And three, the "Exogenous Savings Boom": driven by positive shocks to saver time preference, $\tilde{\beta}_t$. This is an alternative credit supply shock unrelated to shifts in the securitization sector. It is a way of capturing the Global Savings Glut argument put forward by Bernanke (2005).

The second exercise is a quantitative assessment of the extent to which innovation in securitization drove house prices and mortgage debt.

The key finding here is that only innovation in securitization can explain the simultaneous increase in mortgage debt and decrease in the mortgage spread. Quantitatively I find that innovation in securitization drove between 46 - 73% of the appreciation in house prices, 19 - 27% of the increase in non-conforming mortgage debt, and 66 - 73% of the drop in the mortgage spread during the boom period.

5.1 Horse-Race to Match House Price Growth

In each of the three competing simulations each shock series is calibrated to target the peak in real house prices during the boom (35% in 2006 Q4 according to the Federal Housing Finance Agency's All-Transaction House Price Index deflated by CPI). Figure 15 shows the target series and corresponding shock processes for each simulation in the horse-race. The goal here is to match the boom in house prices, and then ask how much of the bust can be matched by reversing the shock that drove the boom.

Only the innovation in securitization shocks can match (the direction & magnitude) of the spread between the mortgage rate and the risk free rate (figure 16). Unsurprisingly the housing demand driven boom (a demand for credit shock) puts upward pressure on the mortgage spread. More interestingly the exogenous savings expansion (a credit supply shock), which in this closed economy model stands in for an influx of foreign credit, also generates upward pressure on the mortgage spread. This is because the exogenous increase in savings drives deposits up, expanding the commercial banking sector's aggregate balance sheet. To expand their balance sheets commercial banks must hold more MBS to continue to meet the solvency constraint - this increases the *demand* for MBS. Because shadow banks are financially constrained they require an increase in the spread in order to increase quantity of MBS supplied (the balance sheet effect). While the generalized credit supply expansion – "exogenous savings boom" – is *a credit supply shock*, the counter-factual im-

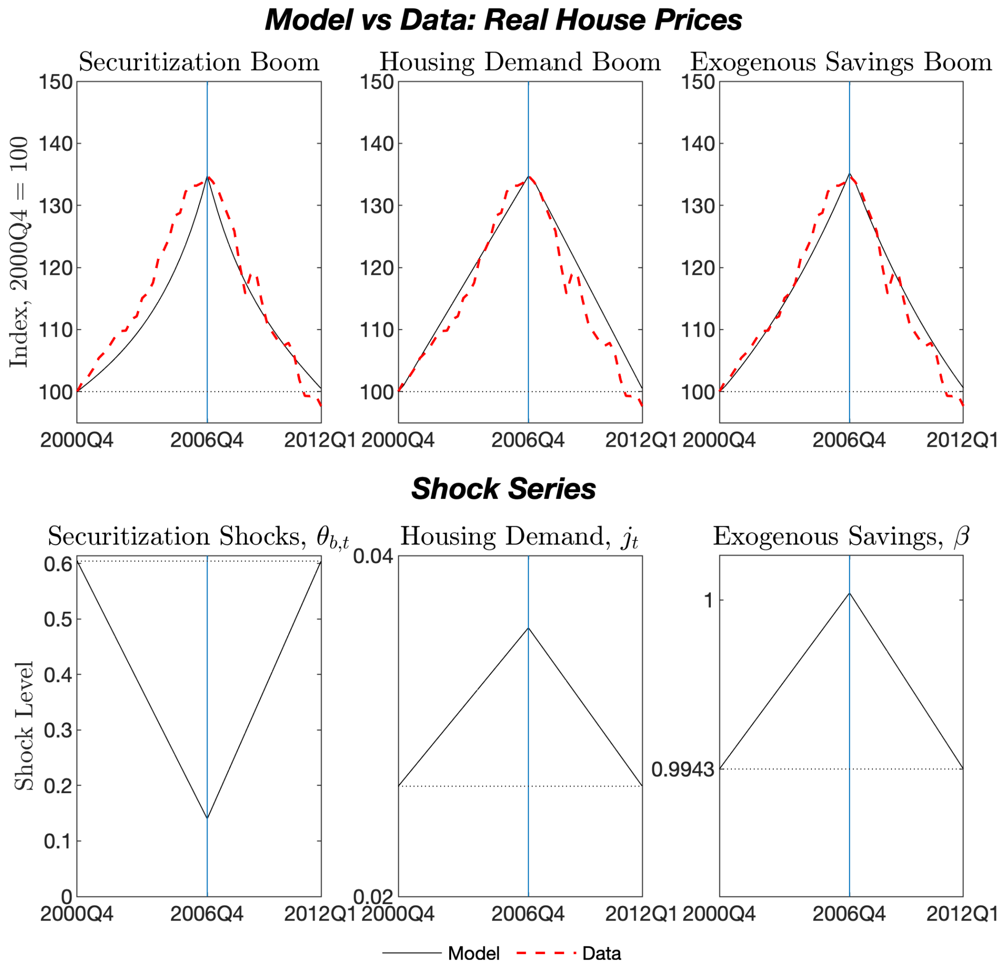

Figure 15: Matching Real House Price Growth

Note: In this figure each column is a different simulation in the horse-race. The data is the FHFA house price index divided by CPI, indexed to 2000Q4. The vertical blue line is 2006Q4 (the peak period for real house prices according to this real house price index). FHFA index: U.S. Federal Housing Finance Agency, All-Transactions House Price Index for the United States [USSTHPI], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/USSTHPI, February 1, 2021. CPI: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL, February 1, 2021.

plications suggest that it is likely not *the credit supply shock* that drove the US housing and mortgage market during the 2000s.

The mortgage spread increases less under the exogenous savings boom than the housing demand driven boom. This is because under the exogenous savings boom Gertler and Kiyotaki (2010)'s accelerator effect does put downward pressure on the mortgage spread. However the balance sheet effect wins out – meaning that ultimately the spread goes up. The accelerator effect operates as follows: an exogenous savings shock is an increase in the saver's discount rate ($\tilde{\beta}$) which decreases the risk free rate relative to what it otherwise would be. Because there is a zero spread between the risk free rate and the MBS rate (see appendix D.2.1) this shock also decreases the shadow banks' cost of funding, boosting their net worth (see figure 24, in appendix C). Because the shock is permanent this effect holds for both current and future shadow bank net worth, meaning that the shadow bank's franchise value (V_t^b) increases. This loosens the incentive compatibility constraint faced by shadow banks.

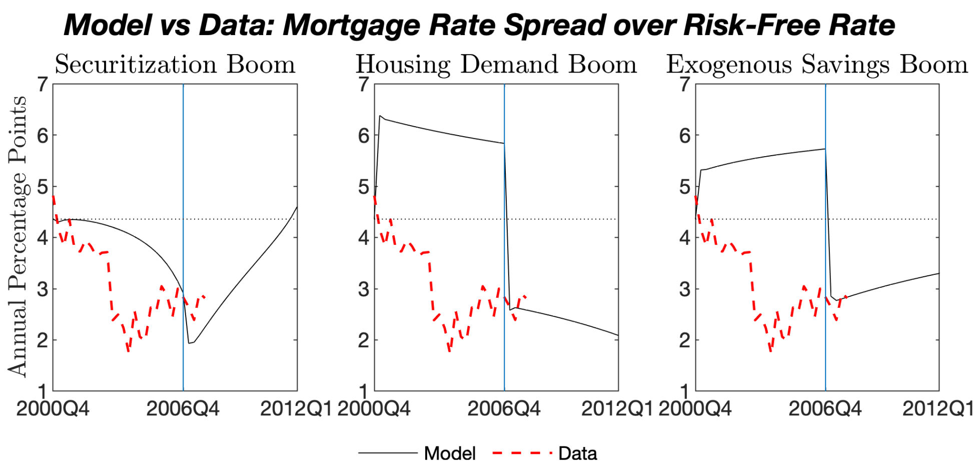

Figure 16: Only the Securitization Boom Explains Mortgage Spreads

Note: In this figure each column is a different simulation in the horse-race. The data series is the conditional mortgage spread (based on purchases) in Justiniano, Primiceri and Tambalotti (2017).

5.2 Measuring the Contribution of Innovation in Securitization

The proceeding section shows that only innovation in securitization shocks can match the mortgage market dynamics and MBS market dynamics observed during 2000-2006. This section quantifies how much the innovation in securitization channel drove housing and mortgage market dynamics during this period. I do this by matching the growth in issuance of private label mortgage backed securities in the data (from 2000Q4 to 2006Q4 – the peak period for house prices), using 3 different versions of the model: (i) inelastic housing production ($\mu_L = 0.99$), (ii) medium elasticity of housing production ($\mu_L = 0.5$), and (iii) high elasticity of housing production ($\mu_L = 0.2$). This is because adjustment to the value of housing in response to fluctuations in house market conditions can either come through a) the house price or b) the quantity of housing available. In these simulations innovation in securitization drives house prices to a peak that is between 46 - 73% of the peak in real house prices in the data, and mortgage credit to a peak that is between 19 - 27% of the peak in mortgage credit in the data. Furthermore innovation in securitization explains 66 - 73% of the compression in the mortgage spread during this period.

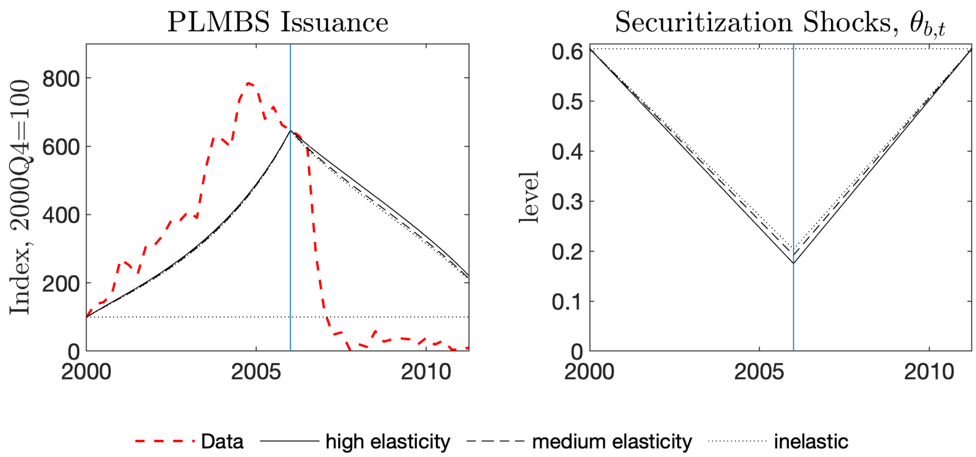

Figure 17: Matching Growth of PLMBS Issuance

Note: The data series is the real Non-Agency MBS Issuance indexed to 2000Q4. That is the new Non-Agency Mortgage Backed Security issuance each quarter (*source:* Inside Mortgage Finance (2016) Inside MBS & ABS. Bethesda, MD.) divided by CPI: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL, February 1, 2021.

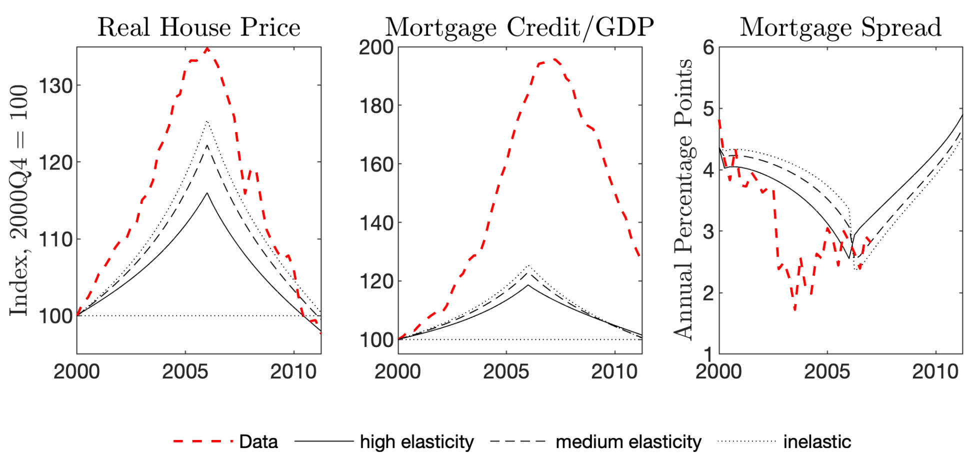

Figure 18: The Effect of Innovation in Securitization

Note: The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index). The Real House Price Index series is the real FHFA house price index (see figure 15 notes for construction details). The Mortgage Credit/GDP data series is the Non-Conforming/GDP series is a estimated measure of the real growth in mortgages that were not eligible for securitization by U.S. government sponsored enterprises (see figure 1 notes for construction details). And the mortgage spread series is again the conditional mortgage spread (based on purchases) in Justiniano, Primiceri and Tambalotti (2017).

6 Conclusion

In this paper I build a model in which the interaction of regulated commercial banks and the unregulated shadow banking sector is crucial. In the model the existence of mortgage backed securitization is driven by idiosyncratic mortgage default risk. Shadow banks face a financial constraint on their balance sheet which relaxes over the boom period (2000 - 2006). This is "Innovation in Securitization". This innovation captures a number of factors including: the increased sophistication and use of tranching during this period, and increased market familiarity with private mortgage backed securitization (relative to the much older government associated securitization[30]). I find that this innovation was a primary driver of the increase in house prices and mortgage debt in the US between 2000 and 2006. The Innovation in Securitization shocks account for 46 - 73% of the increase in house prices, 19 - 27% of the increase in non-conforming mortgage debt, and 66 - 73% of the drop in the mortgage spread observed during the 2000-2006 period.

I show that other candidate explanations (a housing demand driven boom or an exogenous savings driven boom – the Global Savings Glut view) cannot on their own match the mortgage spread dynamics. For the housing demand driven boom the balance sheet effect amplifies the upward pressure on the mortgage spread. For the exogenous savings boom the balance sheet effect quantitatively reverses the initial negative impact on the mortgage spread. Because of the feedback driven by the balance sheet effect, capturing it shows that these two alternative explanations of the 2000 - 2006 US boom generate counter-factual implications for the mortgage spread.

I find that in a more liberalized[31] shadow banking sector the impact of exogenous savings shocks on mortgage credit growth and house price growth are amplified relative to

[30]Mortgage backed securitization done by Fannie Mae, Freddie Mac, and Ginnie Mae.
[31]The model after a series of positive innovation in securitization shocks.

the pre-boom version of the model, and the response of the mortgage spread is moderated. This suggests securitization played an important role in amplifying the impact of inflows of foreign savings into the U.S. during this period.

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A Model Equations

Marginal utility of consumption:

$$\tilde{\lambda}_t = 1.$$

$$\hat{\lambda}_t = 1.$$

$$\tilde{\Lambda}_{t,t+1} = \tilde{\beta}\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t}.$$

Endowment:

$$\tilde{y}_t = \alpha Y.$$

$$\hat{y}_t = (1-\alpha)Y.$$

Land supply:

$$l = 1.$$

Shadow bank leverage:

$$\phi_t^b \equiv \frac{B_t^b}{N_t^b}.$$

Financial Intermediary discounting terms:

$$\Omega_{t+1}^c := \sigma_c\Big(\gamma_{t+1}^c R_{t+1} + v_{t+1}^c\Big) + (1-\sigma_c).$$

$$\Omega_{t+1}^b := (1-\sigma_b) + \sigma_b(\mu_{M,t+1}^b \phi_{t+1}^b + \bar{v}_{m,t+1}^b).$$

MBS market clearing:

$$M_t^c = M_t^b.$$

Saver FOCs:

$$\tilde{\lambda}_t = \tilde{\beta} E_t \tilde{\lambda}_{t+1} R_t, \tag{40}$$

Borrower FOCs:

$$\frac{j_t}{\hat{h}_t} - \hat{\lambda}_t p_{h,t} + \hat{\beta} E_t\Big[\hat{\lambda}_{t+1}(1-\psi\nu)(1-\delta_h)p_{h,t+1}\Big] + \hat{\mu}_t \bar{m}_t p_{h,t} = 0. \tag{41}$$

$$\hat{\lambda}_t - \hat{\beta} E_t\Big[\hat{\lambda}_{t+1}(1-\psi\nu)R_{M,t}\Big] - \hat{\mu}_t = 0. \tag{42}$$

$$\hat{c}_t + p_{h,t}\hat{h}_t + (1-\psi\nu)R_{M,t-1}B_{t-1} = B_t + (1-\psi\nu)(1-\delta_h)p_{h,t}, \hat{h}_{t-1} + \hat{y}_t. \tag{43}$$

$$B_t \leq \bar{m}_t p_{h,t} \hat{h}_t. \tag{44}$$

Commercial Bank:

Solvency constraint (binding if $\gamma_t^c \geq 0$):

$$(1-\nu)R_{M,t}B_t^c + \bar{R}_{m,t}M_t^c - R_tD_t \geq 0. \tag{45}$$

FOC wrt on balance sheet loans:

$$(v_{M,t}^c - v_t^c) + \gamma_t^c\Big((1-\nu)R_{M,t} - R_t\Big) = 0. \tag{46}$$

FOC wrt MBS:

$$(\bar{v}_{m,t}^c - v_t^c) + \gamma_t^c\Big(\bar{R}_{m,t} - R_t\Big) = 0. \tag{47}$$

Marginal value of on-balance sheet loans:

$$v_{Mt}^c = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^c(1-\psi\nu)R_{M,t}. \tag{48}$$

Marginal value of MBS:

$$\bar{v}_{m,t}^c = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^c\bar{R}_{m,t}. \tag{49}$$

Marginal value of deposits:

$$v_t^c = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^cR_t. \tag{50}$$

Aggregate net worth:

$$N_t^c = (\sigma_c+\xi_c)\Big((1-\psi\nu)R_{M,t-1}B_{t-1}^c + \bar{R}_{m,t-1}M_{t-1}\Big) - \sigma_cR_{t-1}D_{t-1}. \tag{51}$$

Balance sheet:

$$D_t + N_t^c = B_t^c + M_t^c. \tag{52}$$

Shadow Bank:
FOC wrt loans:

$$\mu_{M,t}^b = \frac{\lambda_t^b\theta_{b,t}}{1+\lambda_t^b}. \tag{53}$$

Incentive compatibility constraint (binding if $\lambda_t^b \geq 0$):

$$\phi_t^b \leq \frac{\bar{v}_{mt}^b}{\theta_{b,t} - \mu_{M,t}^b}. \tag{54}$$

Marginal value of loans (Note: $\mu_{M,t}^b := v_{Mt}^b - \bar{v}_{mt}^b$):

$$\mu_{M,t}^b = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^b\Big[(1-\psi\nu)R_{Mt} - \bar{R}_{m,t}\Big]. \tag{55}$$

Marginal value of MBS:

$$\bar{v}_{mt}^b = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^b\bar{R}_{mt}. \tag{56}$$

Balance sheet identity:

$$B_t^b = N_t^b + M_t^b. \tag{57}$$

Aggregate shadow bank net worth:

$$N_t^b = (\sigma_b + \xi_b)(1 - \psi\nu)R_{M,t-1}B_{t-1}^b - \sigma_b \bar{R}_{m,t-1}M_{t-1}^b. \tag{58}$$

Housing Production:
Housing production technology:

$$IH_t = A_h (I_t^h)^{1-\mu_l} l_t^{\mu_l}. \tag{59}$$

Housing supply:

$$H_t - (1 - \delta_h)H_{t-1} = IH_t. \tag{60}$$

Saver's choice of materials:

$$I_t^h = \Big(A_h p_{h,t}(1 - \mu_l)\Big)^{\frac{1}{\mu_l}} l_t. \tag{61}$$

Market Clearing:
Housing market clearing:

$$H_t = \hat{h}_t. \tag{62}$$

Resource constraint:

$$Y = \tilde{c}_t + \hat{c}_t + I_t^h. \tag{63}$$

Mortgage market clearing:

$$B_t = B_t^c + B_t^b. \tag{64}$$

B Institutional Details

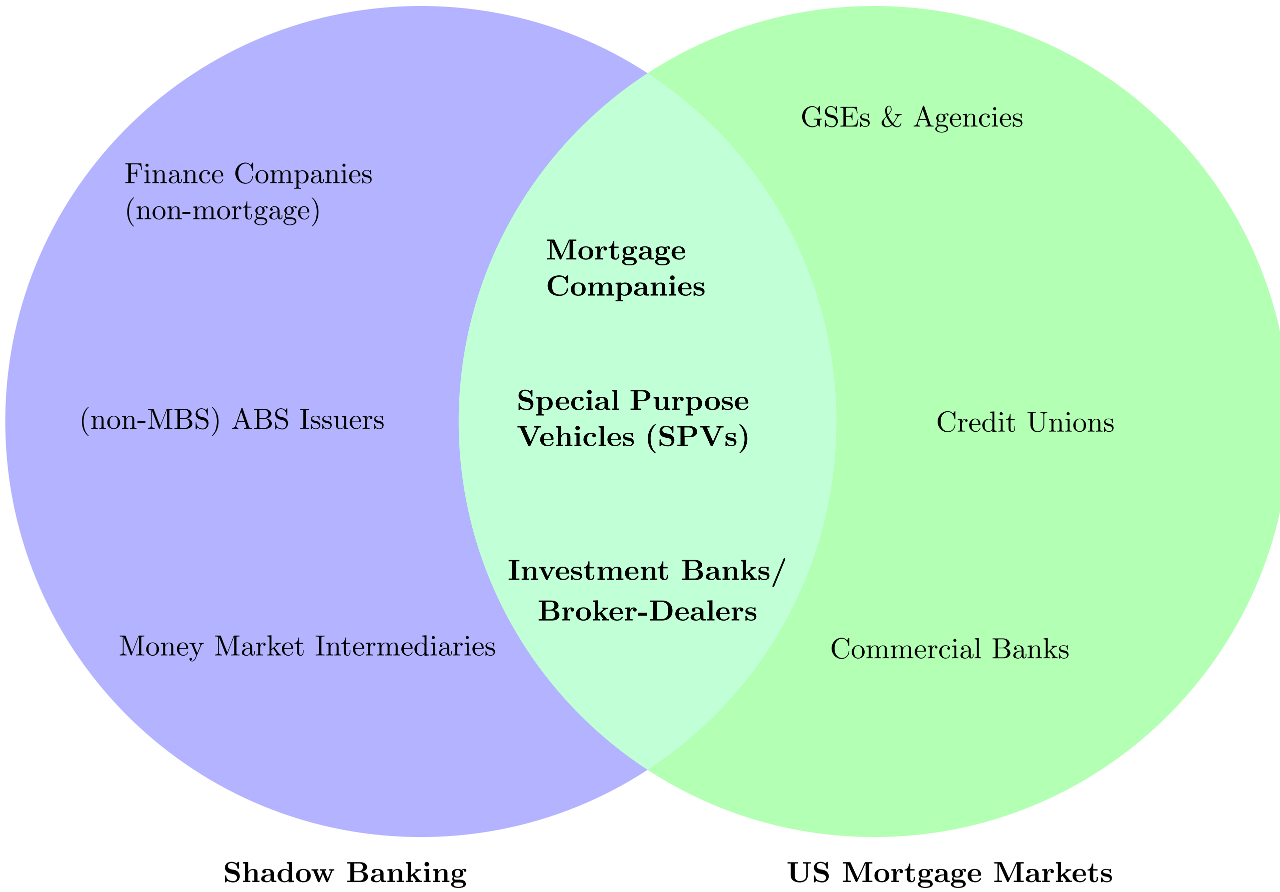
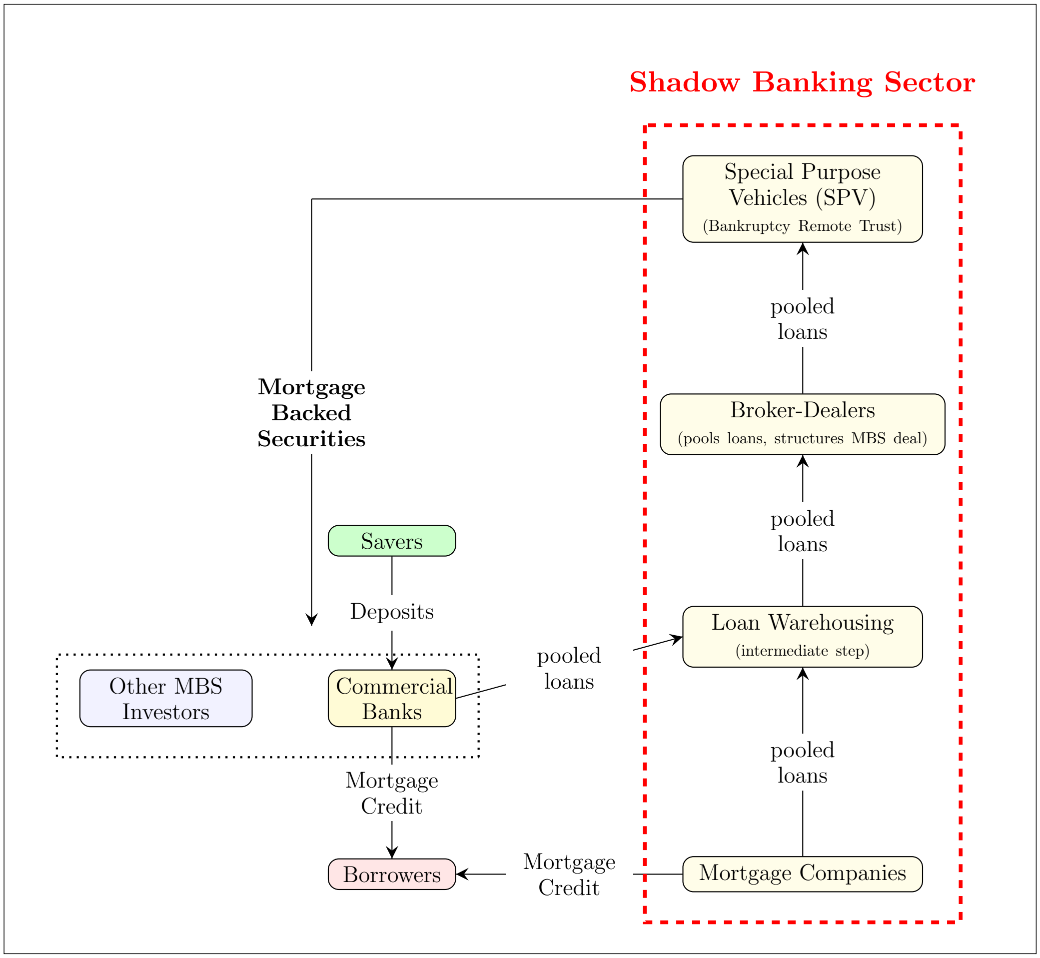


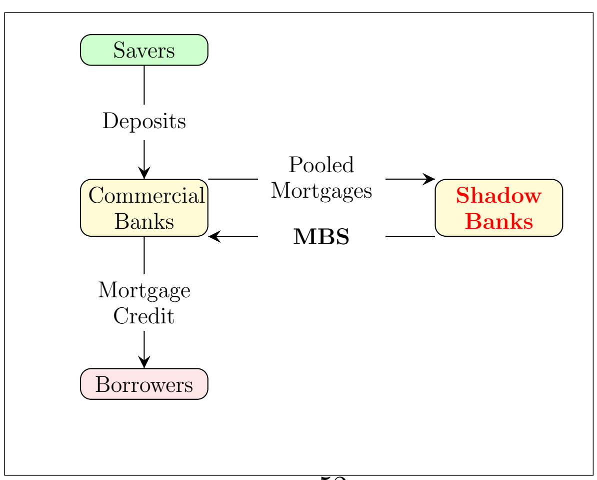
Figure 19: Overlap Between Shadow Banking and US Mortgage Markets

Note: this is a simplified characterization of the summary of the shadow banking sector presented by Pozsar et al. (2012).



(a) Shadow Banking Sector in Reality

This based on the detailed description of the securitization process in Ashcraft and Schuermann (2008)



(b) Model Simplification

Figure 20: Mortgage Securitization Process in Reality vs Model Simplification

C Boom-Bust Simulation Additional Results

This appendix presents some additional results. The three candidate booms are indistinguishable in the response of mortgage debt (figure 21). The Securitization boom generates the most volatility in borrower and saver consumption (figure 22) and is the largest shift of mortgages off regulated intermediaries balance sheets (figure 23).

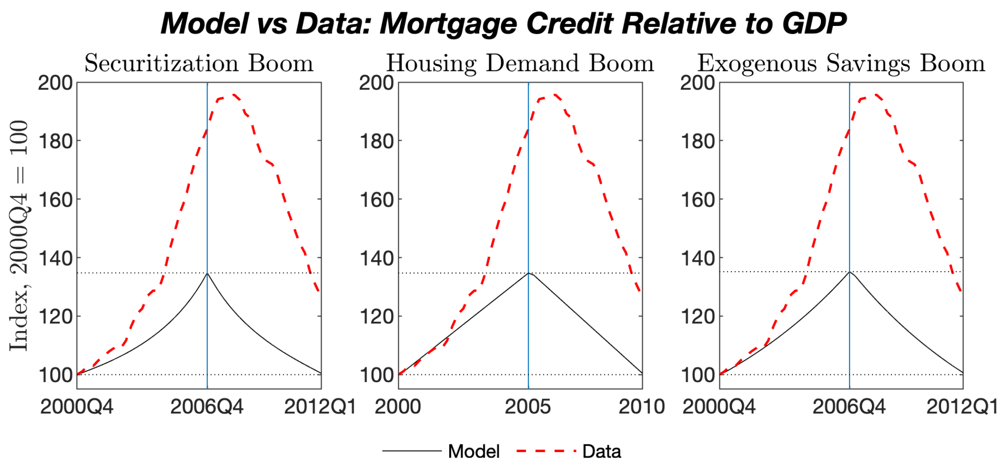


Figure 21: Candidate Booms are Indistinguishable on Credit Growth

Note: The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index). The Mortgage Credit/GDP data series is the Non-Conforming/GDP series is a estimated measure of the real growth in mortgages that were not eligible for securitization by U.S. government sponsored enterprises (see figure 1 notes for construction details).

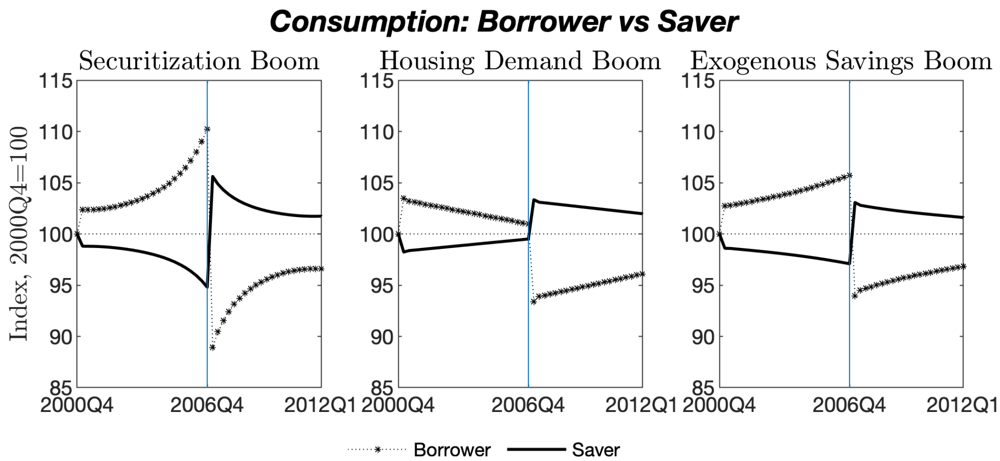


Figure 22: Consumption is Most Volatile in the Securitization Boom

Note: The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index).

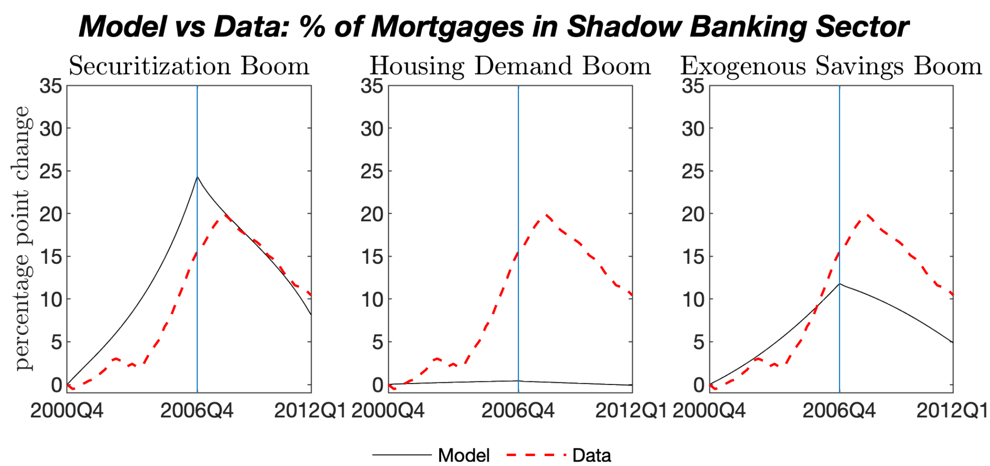


Figure 23: Only the Securitization Boom Generates the Largest Shift of Mortgages Off Commercial Banks' Balance Sheets

Note: The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index). The data series here is the value of residential mortgages held by the shadow banking sector divided by total residential mortgages outstanding. Mortgages held by the shadow banking sector are measured by: residential mortgages held by ABS issuers: Issuers of asset-backed securities; one-to-four-family residential mortgages; asset (FL673065105.Q), and residential mortgages held by mortgage companies: Finance companies; one-to-four-family residential mortgages; asset (FL613065105.Q) also on Table L.218 in the Flow of Funds data. Total residential mortgages is measured as the sum of residential mortgages held by the shadow banking sector plus U.S.-chartered depository institutions; one-to four-family residential mortgages, including farm houses (FL763065105.Q) on Table L.218 in the Flow of Funds data. Source: Board of Governors of the Federal Reserve System (US), Z1 Financial Accounts of the United States, retrieved from DDP; www.federalreserve.gov/datadownload/, August 15, 2019.

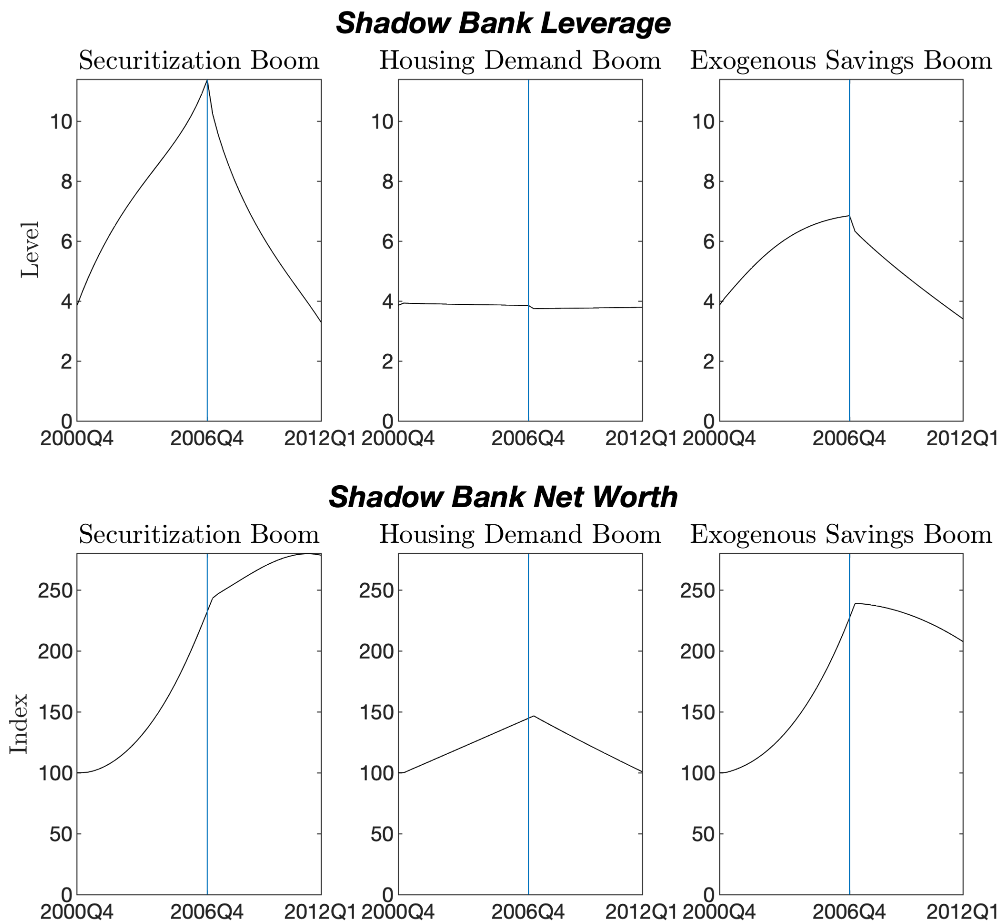


Figure 24: Shadow Bank Leverage and Net Worth

Note: The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index).

D Two Period Model

This is a two-period simplified version of the baseline model (without housing depreciation or production of new houses) presented in section 2. There are two periods: $t = 1, 2$. At $t = 1$ mortgages are originated (B), MBS is issued (M), the fraction of liabilities that the shadow bank can divert (θ_b) is known. For simplicity consider the perfect foresight case. Both savers and borrowers have linear utility in nondurable consumption (the results hold when savers have log utility as long as their stochastic discount factor is increasing in $\tilde{\beta}$: $\partial\tilde{\Lambda}_{1,2}/\partial\tilde{\beta} > 0$)For simplicity of notation the time subscript is left off period 1 variables, with a few exceptions to ensure clarity.

D.1 Household

D.1.1 Savers ($\tilde{\beta} \geq \hat{\beta}$)

An individual savers' problem is:

$$\max_{\{\tilde{c}_1, \tilde{c}_2, d\}} \tilde{c}_1 + \tilde{\beta}\tilde{c}_2,$$

subject to their budget constraints:

$$\tilde{c}_1 + d \leq \tilde{y}_1,$$
$$\tilde{c}_2 \leq \tilde{y}_2 + Rd + \pi_2,$$

where π_2 is the transfer saver's receive from the financial intermediaries they own. And to a non-negativity constraint on period 1 consumption:

$$\tilde{c}_1 \geq 0, \qquad (\Xi_1 \geq 0). \tag{65}$$

Saver's first order condition wrt deposits:

$$1 + \Xi_1 = \tilde{\beta} R. \tag{66}$$

Under linear utility the savers' stochastic discount factor is $\tilde{\Lambda}_{1,2} \equiv \tilde{\beta}\frac{\tilde{\lambda}_2}{\tilde{\lambda}_1} = \tilde{\beta}$.

D.1.2 Borrowers

An individual borrowers' problem is:

$$\max_{\{\hat{c}_1, \hat{c}_2, \hat{h}_1, \hat{h}_2, b\}} \left[\hat{c}_1 + j \log \hat{h}_1\right] + \hat{\beta}\left[\hat{c}_2 + j \log \hat{h}_2\right],$$

subject to their budget constraints;

$$\hat{c}_1 + p_{h,1}\hat{h}_1 \leq \hat{y}_1 + B + p_{h,1}\hat{h}_0, \tag{67}$$

$$\hat{c}_2 + p_{h,2}\hat{h}_2 + (1 - \psi\nu)R_M B \leq \hat{y}_2 + (1 - \psi\nu)p_{h,2}\hat{h}_1, \tag{68}$$

and the housing collateral constraint:

$$B \leq \bar{m}_1 p_{h,1}\hat{h}_1, \qquad (\hat{\mu} \geq 0). \tag{69}$$

Borrower's first order conditions:

$$\frac{j_1}{\hat{h}_1} - p_{h,1} + \hat{\beta}\left[(1 - \psi\nu)p_{h,2}\right] + \hat{\mu}\bar{m}p_{h,1} = 0, \tag{70}$$

$$1 - \hat{\beta}\left[(1 - \psi\nu)R_M\right] - \hat{\mu} = 0, \tag{71}$$

$$\frac{j_2}{\hat{h}_2} - p_{h,2} = 0. \tag{72}$$

D.2 Financial Sector

Individual shadow and commercial banks are endowed with starting net worth, n^b and n^c respectively, in $t = 1$.

D.2.1 Commercial Banking Sector

Net worth in period 2:

$$n_2^c = \begin{cases} R_M b^c + \bar{R}_m m^c - Rd, & \text{if "good" (non-defaulter) island,} \\ (1-\nu) R_M b^c + \bar{R}_m m^c - Rd, & \text{if "bad" (defaulter) island.} \end{cases}$$

An individual commercial bank's problem is:

$$\max_{\{b^c, d, m^c\}} V^c = \tilde{\beta} \Big\{ (1-\psi) n_2^{c,good} + \psi n_2^{c,bad} \Big\},$$

subject to their balance sheet identity:

$$b^c + m^c = n^c + d, \tag{73}$$

and the solvency constraint:

$$(1-\nu) R_M b^c + \bar{R}_m m^c \geq Rd, \qquad (\gamma^c \geq 0). \tag{74}$$

$$\mathcal{L} = \Big\{ V^c + \gamma^c \Big[((1-\nu) R_M - R) b^c + (\bar{R}_m - R) m^c + Rn^c \Big] \Big\}.$$

Commercial bank's optimality conditions:

$$\frac{\partial \mathcal{L}}{\partial b^c} = \left\{ \tilde{\beta}\big[(1-\psi\nu)R_M - R\big] + \gamma^c((1-\nu)R_{M,1} - R_1) \right\} = 0, \tag{75}$$

$$\frac{\partial \mathcal{L}}{\partial m_1^c} = \left\{ \tilde{\beta}\big[\bar{R}_m - R\big] + \gamma^c\big[\bar{R}_m - R\big] \right\} = 0, \tag{76}$$

$$\frac{\partial \mathcal{L}}{\partial \gamma^c} = \left\{ \Big[((1-\nu)R_M - R)b^c + (\bar{R}_m - R)m^c + Rn^c\Big] \right\} = 0. \tag{77}$$

(76) holds when either $\bar{R}_m - R = 0$ or $\gamma^c = -\tilde{\beta}$, which violates the non-negativity of the shadow value $\gamma^c \geq 0$, so $\bar{R}_m = R$. This holds in the infinite horizon model as well.

D.2.2 Shadow Banking Sector

An individual shadow bank's problem is:

$$\max_{b^b} \; V^b = \tilde{\beta}\Big[\underbrace{(1-\nu\psi)R_M b^b - \bar{R}_m m^b}_{=n_2^b}\Big]$$

subject to the ICC:

$$V^b \geq \theta_b b^b, \qquad\qquad (\lambda^b \geq 0), \tag{78}$$

and their balance sheet identity:

$$b^b = n^b + m^b. \tag{79}$$

$$\mathcal{L} = \left\{ V^b + \lambda^b\Big[V^b - \theta_b b^b\Big] \right\}.$$

Shadow bank's optimality conditions:

$$\frac{\partial \mathcal{L}}{\partial b^b} = \left\{ \tilde{\beta} \Big[(1-\nu\psi) R_M - \bar{R}_m \Big] (1+\lambda^b) - \theta_b \lambda^b \right\} = 0, \tag{80}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_1^b} = \left\{ V^b - \theta_b b^b \right\}. \tag{81}$$

D.3 Aggregation

Aggregate commercial banking sector net worth:

$$N_2^c = (1-\nu\psi) R_M B^c + \bar{R}_m M^c - RD. \tag{82}$$

Aggregate shadow banking sector net worth:

$$N_2^b = (1-\nu\psi) R_M B^b - \bar{R}_m M^b. \tag{83}$$

Aggregate transfer from the financial sector to savers:

$$\Pi_2 \equiv N_2^c + N_2^b + \psi\nu p_{h,2} \hat{h}_1. \tag{84}$$

The equilibrium is symmetric so:

$$b = B, d = D, b^c = B^c, b^b = B^b, m^c = M^c, m^b = M^b, n^c = N^c, n^b = N^b \tag{85}$$

D.4 Resource Constraints

$$\tilde{c}_1 + \hat{c}_1 = \tilde{y}_1 + \hat{y}_1 + N^c + N^b + p_{h,1}(\hat{h}_0 - \hat{h}_1), \tag{86}$$

$$\tilde{c}_2 + \hat{c}_2 = \tilde{y}_2 + \hat{y}_2. \tag{87}$$

Housing is in fixed supply:

$$\hat{h}_0 = \bar{H}, \tag{88}$$

$$\hat{h}_1 = \bar{H}, \tag{89}$$

$$\hat{h}_2 = \bar{H}. \tag{90}$$

MBS market clearing:

$$M^c = M^b. \tag{91}$$

Mortgage market clearing:

$$B = B^c + B^b. \tag{92}$$

E The Mortgage Market and MBS Market

E.1 Constrained Financial Sector

The commercial banks' pricing of the MBS means that the spread of the MBS rate over the risk-free rate is zero ($\bar{R}_m = R$). Therefore the spread faced by the shadow bank is the spread of the mortgage rate (adjusted for default) over the risk-free rate:

$$S \equiv (1 - \nu\psi)R_M - R. \tag{93}$$

The shadow bank's optimality condition for pooled loans (80) can be rearranged to express the spread in terms of the multiplier on the shadow bank's financial constraint:

$$S = \frac{1}{\tilde{\beta}} \frac{\theta_b \lambda^b}{1 + \lambda^b}. \tag{94}$$

It is clear to see that when the shadow bank's constraint binds, $\lambda^b > 0$, the default adjusted mortgage spread (S) is greater than zero. The commercial bank's optimality condition for portfolio loans (75) can be rearranged as follows:

$$\gamma^c = \frac{\tilde{\beta} S}{R - (1 - \nu)R_M}. \tag{95}$$

Clearly when $S > 0$, as long as $R - (1 - \nu)R_M > 0$, the multiplier on the commercial bank's financial constraint (γ^c) is also greater than zero and the commercial bank's financial constraint binds. I will refer to the case where both constraints bind as the "constrained financial sector", the following focuses on equilibria characterized by a constrained financial sector.

Note that the shadow banks' incentive compatibility constraint the commercial bank's solvency constraint can be rewritten into "leverage" limits as follows:

$$\frac{B^b}{N^b} = \frac{1}{\theta_b - \tilde{\beta} S} =: \chi^b, \qquad \frac{B^c}{N^c} = \frac{1 - \nu\psi}{\nu(1 - \psi) - (1 - \nu)\tilde{\beta} S} =: \chi^c. \tag{96}$$

Note that for the commercial bank the solvency constraint does not limit their overall leverage ($(B^c + M^c)/N^c$), rather it places a limit on the ratio of portfolio loans (B^c) to equity (N^c). Its instructive to think of these limits when the constraints are not binding (i.e. when $S = 0$):

$$\chi^b(S=0) = \frac{1}{\theta_b}, \qquad \chi^c(S=0) = \frac{1-\nu\psi}{\nu(1-\psi)}. \tag{97}$$

E.2 MBS Supply and Demand Curves

The spread S is determined by the equilibrium in the MBS market. Note that for a given level of total credit (B) the leverage limits (96) can be used to write MBS supply and demand schedules:

$$S^{\mathrm{S}}(M) = \max\Big(0, R\Big[\theta_b - \frac{N^b}{N^b+M}\Big]\Big), \tag{98}$$

$$S^{\mathrm{D}}(M) = \max\Big(0, R\Big[\frac{\nu(1-\psi)}{1-\nu} + \frac{1-\nu\psi}{1-\nu}\frac{N^c}{N^b+M-B}\Big]\Big). \tag{99}$$

Written in terms of the normalized mortgage spread these become:

$$\bar{S}^{\mathrm{S}}(M) = \max\Big(0, \Big[\theta_b - \frac{N^b}{N^b+M}\Big]\Big), \tag{100}$$

$$\bar{S}^{\mathrm{D}}(M) = \max\Big(0, \Big[\frac{\nu(1-\psi)}{1-\nu} + \frac{1-\nu\psi}{1-\nu}\frac{N^c}{N^b+M-B}\Big]\Big). \tag{101}$$

At each level of total credit (B) the equilibrium in the MBS market, given by the intersection of MBS supply and demand, give the normalized mortgage spread. It is interesting to note how the equilibrium normalized spread changes given the following: i) changes in B, ii) changes in θ_b (i.e. innovation in securitization shocks), changes in $\tilde{\beta}$ (exogenous savings shocks).

Increases in total credit B shift the MBS demand curve out. This generates a new equilibrium with a higher normalized spread. Equilibria in the MBS market at each level of B trace out the credit supply curve (see figure 6).

An innovation in securitization (IIS) shock, a decrease in θ_b, shifts the MBS supply curve out. Now at each level of B the spread is lower, so the IIS shock results in an outward shift in the mortgage credit supply curve (figure 10).

Lastly, the level of $\tilde{\beta}$ does not directly shift the MBS supply or demand curves. It does have an effect on the level of the mortgage rate which shifts the mortgage credit demand curve (described in the following section), this drives the total level of credit (B) up and shifts out the MBS demand curve (figure 9).

E.3 Credit Demand Curve

The borrower's first order conditions for housing (70) and mortgage credit (71) combine to give a pricing equation for housing[32], which under linear borrower utility is:

$$p_{h,1} = \begin{cases} \frac{1}{1-\bar{m}+\bar{m}\hat{\beta}(1-\nu\psi)R_M} \frac{j}{H} \Big[1+\hat{\beta}(1-\nu\psi)\Big], & \text{if } \hat{\mu} > 0, \\ \\ \frac{j}{H} \Big[1+\hat{\beta}(1-\nu\psi)\Big], & \text{if } \hat{\mu} = 0, \end{cases} \tag{102}$$

where $\hat{\mu}$ is the multiplier on the collateral constraint when it binds borrowers' demand for credit (B^{demand}) is determined by the collateral value for housing:

$$B^{\text{demand}} = p_{h,1}\bar{m}H = \frac{\bar{m}j}{1-\bar{m}+\bar{m}\hat{\beta}(1-\nu\psi)R_M} \Big[1+\hat{\beta}(1-\nu\psi)\Big]. \tag{103}$$

Lastly this can be written in terms of the normalized mortgage rate $\frac{(1-\nu\psi)R_M}{R}$:

[32]Using $j_1 = j_2 = j$, and $\hat{h}_1 = \hat{h}_2 = H$.

$$B^{\text{demand}} = \frac{\bar{m}j}{1 - \bar{m} + \bar{m}\hat{\beta}\frac{(1-\nu\psi)R_M}{R}R}\Big[1 + \hat{\beta}(1-\nu\psi)\Big], \qquad \text{if } \hat{\mu} > 0. \tag{104}$$

Rearranging and using $R = 1/\tilde{\beta}$, the inverse credit demand curve is:

$$\frac{(1-\nu\psi)R_M}{R} = \begin{cases} \frac{\tilde{\beta}}{\hat{\beta}}\left[1 - \frac{1}{\bar{m}} + j\big[1 + \hat{\beta}(1-\nu\psi)\big]\frac{1}{B^{\text{D}}}\right], & \text{if } \hat{\mu} > 0, \\ \\ \frac{\tilde{\beta}}{\hat{\beta}}, & \text{if } \hat{\mu} = 0. \end{cases} \tag{105}$$

Where the $\hat{\mu} = 0$ case comes from the borrower's optimality condition for mortgage credit (71).

F Robustness: Log Saver Utility

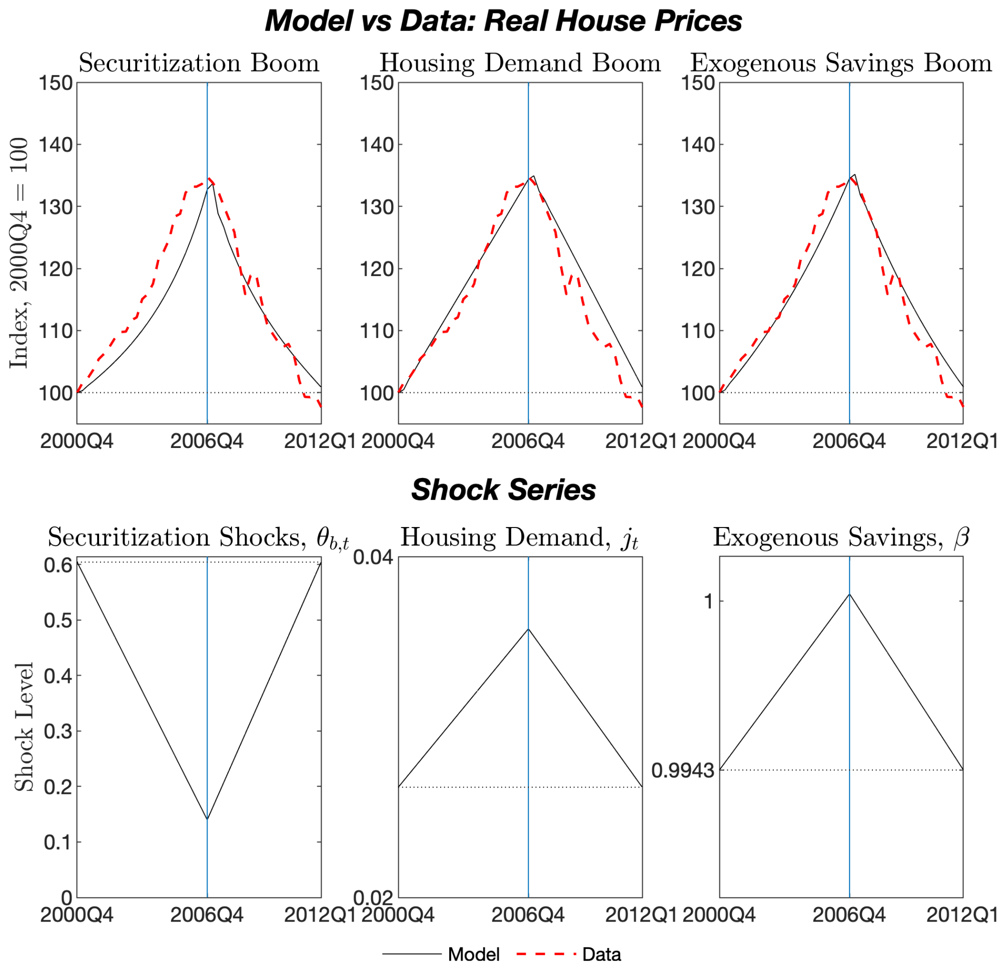


Figure 25: Matching Real House Price Growth - Robustness

Note: In this figure each column is a different simulation in the horse-race. The data is the FHFA house price index divided by CPI, indexed to 2000Q4. The vertical blue line is 2006Q4 (the peak period for real house prices according to this real house price index. FHFA index: U.S. Federal Housing Finance Agency, All-Transactions House Price Index for the United States [USSTHPI], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/USSTHPI, February 1, 2021. CPI: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL, February 1, 2021.

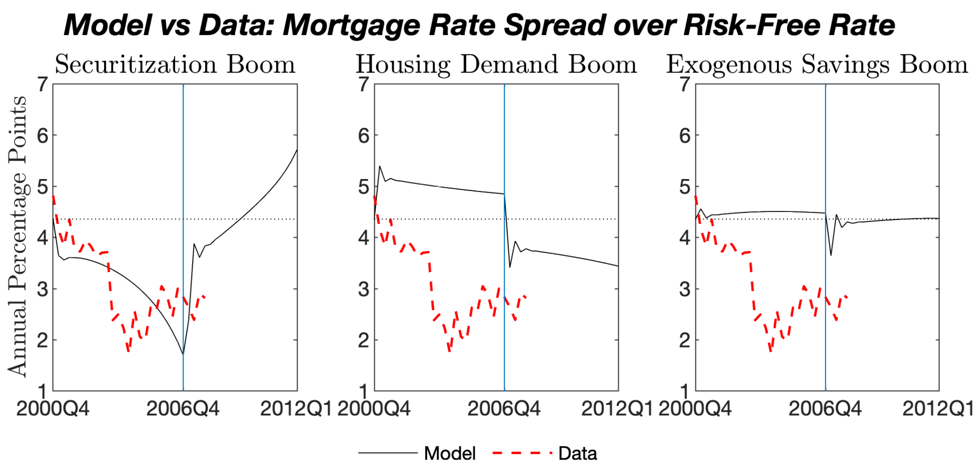


Figure 26: Only the Securitization Boom Explains Mortgage Spreads - Robustness

Note: In this figure each column is a different simulation in the horse-race. The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index). The data series is the conditional mortgage spread (based on purchases) in Justiniano, Primiceri and Tambalotti (2017).

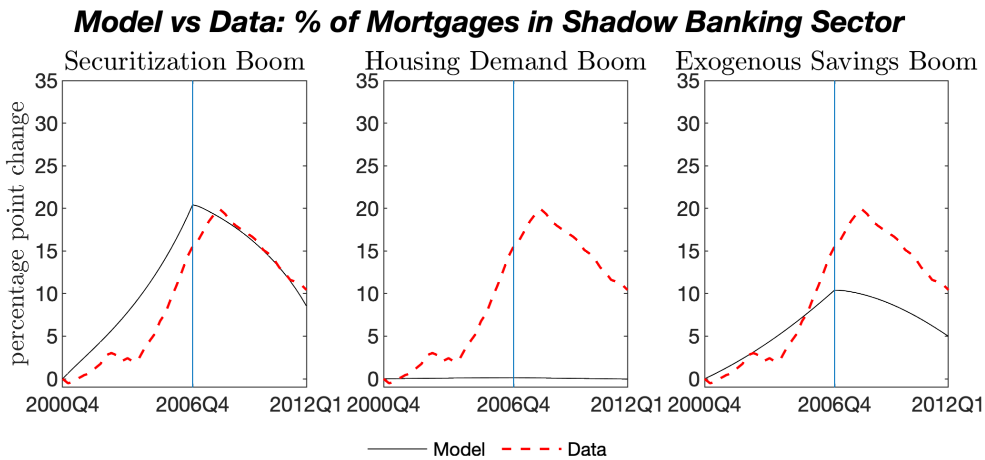


Figure 27: Only the Securitization Boom Generates the Largest Shift of Mortgages Off Commercial Banks' Balance Sheets - Robustness

Note: The vertical blue line is 2006Q4 (the peak period for real house prices according to the FHFA Index). The data series here is the value of residential mortgages held by the shadow banking sector divided by total residential mortgages outstanding. Mortgages held by the shadow banking sector are measured by: residential mortgages held by ABS issuers: Issuers of asset-backed securities; one-to-four-family residential mortgages; asset (FL673065105.Q), and residential mortgages held by mortgage companies: Finance companies; one-to-four-family residential mortgages; asset (FL613065105.Q) also on Table L.218 in the Flow of Funds data. Total residential mortgages is measured as the sum of residential mortgages held by the shadow banking sector plus U.S.-chartered depository institutions; one-to four-family residential mortgages, including farm houses (FL763065105.Q) on Table L.218 in the Flow of Funds data. Source: Board of Governors of the Federal Reserve System (US), Z1 Financial Accounts of the United States, retrieved from DDP; www.federalreserve.gov/datadownload/, August 15, 2019.