Securitization and House Price Growth[1]

Genevieve Nelson[2]
University of Oxford

December 5, 2019

Job Market Paper
Please click here for latest version

Abstract

From 2000-2006 US house prices and mortgage credit grew substantially. Simultaneously, the relative cost of mortgage credit fell – particularly for privately securitized mortgages – suggesting the importance of credit supply factors. This paper explores two candidate (credit supply) shocks: an increase in the inflow of global savings into the US, and innovations in the securitization of mortgage credit. I model a two-layered mortgage market. This generates a novel *balance sheet effect*: changes in aggregate mortgage credit quantity are linked to changes in mortgage spreads via the interaction of financially constrained commercial banks and mortgage securitizers. Innovation in securitization matches mortgage credit market dynamics by directly relaxing the securitizers' financial constraint. Conversely, the inflow of global savings leads to a counter-factual increase of mortgage spreads through the balance sheet effect.

Keywords: Securitization, Mortgage Credit, House Prices, Non-Banks.
JEL Codes: G01, G21, G23, E21, E44

[2]University of Oxford, Manor Road Building, Manor Road, Oxford OX1 3UQ, genevieve.nelson@economics.ox.ac.uk

1　Introduction

The Great Recession was preceded by an unprecedented 48% boom in US real house prices from 2000 to 2006. In contrast during the "Baby Boom" period from 1946 - 1964 real house price growth peaked at 33%. 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. The vehicle for this shift was private mortgage backed securitization[3]. 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[4] and other credit enhancements, which drove investor willingness to treat private sector issued mortgage backed securities as nearly substitutable to US Treasuries. My paper explores the role of a securitization driven credit supply expansion during this period. My key finding is that innovation in securitization drove at least 71% of the house price appreciation and 34 - 45% of the increase in non-conforming mortgage credit during this period.

The contribution of this paper is to explicitly model the private securitization of mortgage credit. By doing so I get a new *balance sheet effect* missed by standard models. In my model financial intermediaries face constraints on the size and composition of their balance sheets. Shadow banks (the issuers of mortgage backed securities) face a constraint 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 risk-less to being perceived as too risky to hold. Commercial banks face a solvency constraint. This constraint forces them to diversify their assets by selling the (idiosyncratically risky) mortgages they issue and buying mortgage backed securities (which only have aggregate risk). The aggregate 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

---

[3]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.

[4]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.

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".

The U.S. experience of the Financial Crisis opened up a debate as to whether positive shifts in credit demand or credit supply drove the boom in US house prices and mortgage debt between 2000 and 2006. On credit demand, researchers 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. The credit supply view, advanced by Mian and Sufi (2017) and Justiniano, Primiceri and Tambalotti (2019), points 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).

Figure 1: Credit Supply View - Key Stylized Facts

(a) Boom in Mortgage Credit   **(b) Compression of Mortgage Spreads**
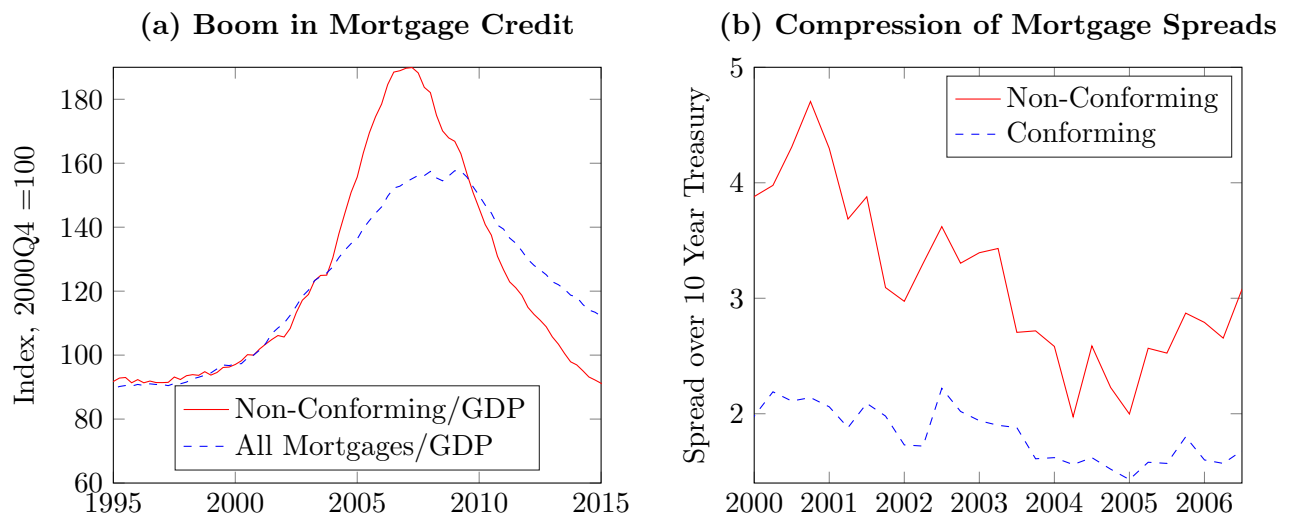
(a) All Mortgages/GDP: The total outstanding stock of mortgage credit relative to GDP, indexed to 2000Q4 levels. Non-Conforming/GDP: Estimated as "All Mortgages" minus those mortgages held by Government Sponsored Enterprises (GSEs) and GSE & Agency backed pools, relative to GDP, indexed to 2000Q4 levels. 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).

Capturing the balance sheet effect is key to distinguishing between different potential

drivers of the expansion in credit supply. A generic credit supply shift, driven by an increase in savers' demand for deposits, 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 generic credit *supply* shock translates into an increase in *demand* for mortgage backed securities - driving mortgage spreads up because of the balance sheet effect. Furthermore the balance sheet effect magnifies the positive impact on the mortgage spread that a credit demand shift ("Housing Demand" shock) would have.

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 securitizers face looser financial constraints, shifts in the demand for mortgage backed securities increase the quantity of credit more with a smaller increase in the mortgage spread. That is, the innovation in securitization driven boom could have amplified the mortgage credit response to other credit supply or credit demand shifts during this period. This suggests that the innovation in securitization driven boom story is complimentary to other candidate credit supply and demand explanations explored by the literature - as innovation in securitization amplifies the impact of these other shocks. 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.

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 key innovation is the addition of a two-layered mortgage securitizing financial sector 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. This captures the institutional reality of this period, missed by standard models, that by providing an outlet for commercial banks to move their own lending off their balance sheet shadow banks enabled commercial banks to loosen the regulatory constraints that would limit a credit supply boom. Models that do not account for securitization as an outlet for commercial banks will falsely reject the credit supply boom story.

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 "hit" 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. Because of the idiosyncratic risk involved in retaining individual mortgages commercial banks hold mortgage backed securities as insurance. Without this idiosyncratic risk commercial banks would prefer to hold the mortgages they originate (earning a greater return in expectation). Holding mortgage backed securities reassures savers that the deposits issued by commercial banks will be paid back even on the default "hit" islands. This allows commercial banks to intermediate more funds and expand total mortgage credit provision on island - and thus overall mortgage credit supply.

The paper proceeds as follows. Section 2 presents the model. Section 3 presents the calibration and simulation method. Section 4 explains the innovation in securitization mechanism. Section 5 presents and discusses the simulation results. And section 6 concludes.

---

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

2 The Model

2.1 Overview

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 (δ) of what they owe on their mortgage debt $(R_{M,t}b_t)$.

Figure 2: The Model
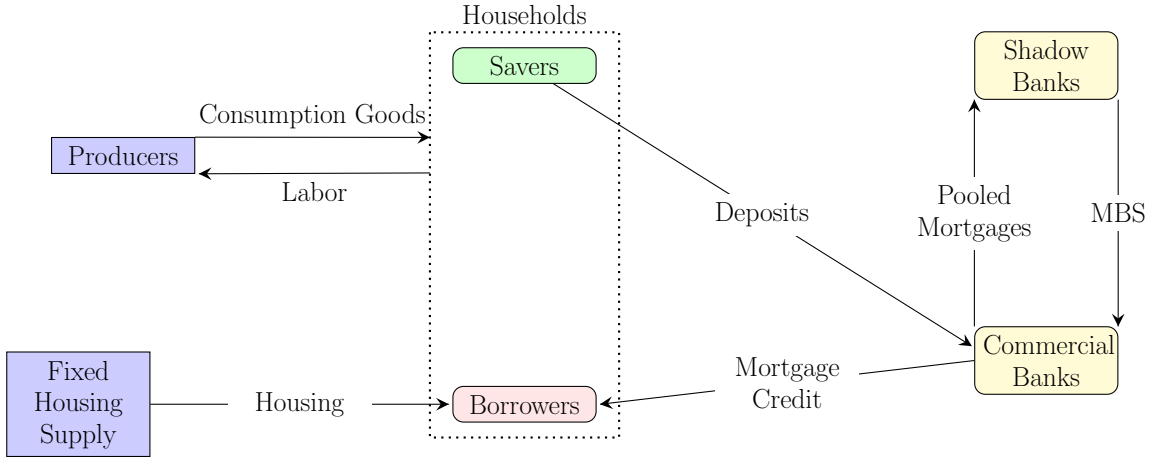
The model overlays an island structure onto a RBC model. Each island contains a borrower household, a saver household, a commercial bank, and a producer who uses on island labor to produce output that is 1-for-1 convertible into the consumption good. Households can only interact with their local (on island) commercial bank.

Figure 3 illustrates the island structure of default. 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-

Figure 3: Risky Mortgage Lending
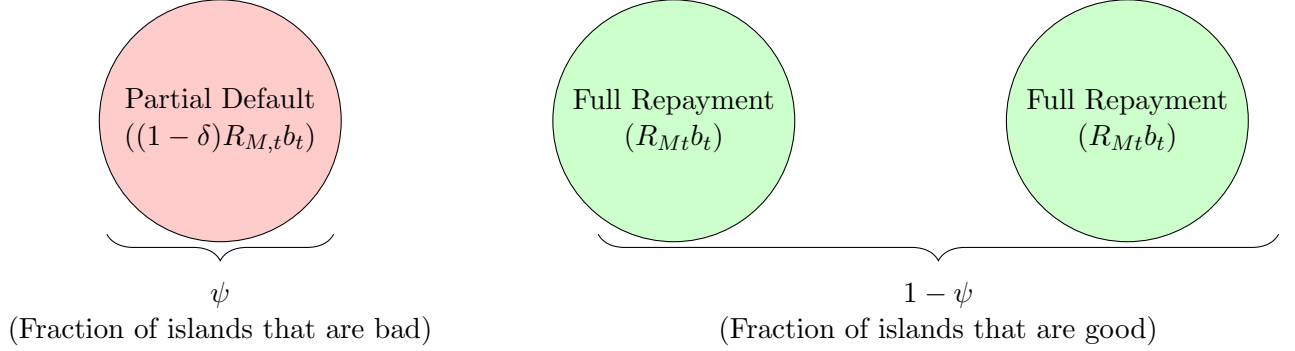
specific investment opportunity shock. On "bad" islands (those receiving a default shock) the borrower only repays a fraction $1 - \delta$ of what they owe on their mortgage debt[6]. Where $R_{M,t}$ is the mortgage rate and b_t is the quantity of mortgage debt taken out by an individual borrower.

The timing is as follows (see Figure 4): prior to the start of the period mortgages are 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 borrower repays in full, on a bad island the borrower defaults 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[7].

---

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

[7]Essentially there is a representative commercial banking sector but commercial banks across islands cannot insure each other until *after* deposits on island are repaid.

Figure 4: Default Timing
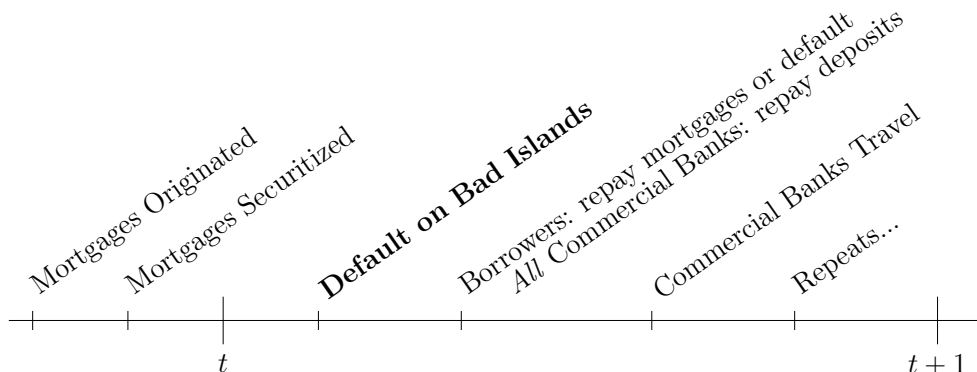
Note on "Travel": After deposits are repaid commercial banks move across islands to equalize credit conditions on all islands going into the next period. Essentially commercial banks are acting as a representative commercial banking sector but they cannot insure each other against adverse island shocks 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 (which payoff 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 et al. (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 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. Both household types have log preferences in consumption, and borrowers have additively separable log preferences in housing.

7

2.2.1 Savers' Problem

Savers are the previously wealthy individuals who have already bought a house and so do not price housing. They exist in the model to be the ultimate source of funding. Savers' are relatively patient (their discount factor $\tilde{\beta}$ is larger than the borrower's discount factor), they hold deposits, consume, and work.

$$E_0 \sum_{t=0}^{\infty} (\tilde{\beta})^t \left[\ln \tilde{c}_t - \frac{(\tilde{n}_t)^{1+\eta}}{1+\eta} \right] \tag{2.1}$$

Subject to their budget constraint:

$$\tilde{c}_t + d_t \leq R_{t-1} d_{t-1} + \tilde{w}_t \tilde{n}_t + Div_t \tag{2.2}$$

Saver specific notation is denoted with tildes: $\tilde{c}_t$ denotes consumption of non-durable goods, $\tilde{n}_t$ labor hours, $\tilde{w}_t$ the wage rate, and d_t deposits (which pay the risk-free rate R_t). Finally Div_t denotes dividends received from commercial and shadow banks, as 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.

$$\max_{\{\hat{c}_t, \hat{h}_t, \hat{n}_t, b_t\}} E_0 \sum_{t=0}^{\infty} (\hat{\beta})^t \left[\ln \hat{c} + j_t \ln \hat{h}_t - \frac{(\hat{n}_t)^{1+\eta}}{1+\eta} \right] \tag{2.3}$$

Subject to their budget constraint:

$$\hat{c}_t + p_{h,t} \hat{h}_t + (1 - \psi\delta) R_{M,t-1} b_{t-1} = b_t + (1 - \psi\delta) p_{h,t} \hat{h}_{t-1} + \hat{w}_t \hat{n}_t \tag{2.4}$$

And a collateral constraint:

$$R_{Mt} b_t \leq \bar{m}_t E_t p_{h,t+1} \hat{h}_t \tag{2.5}$$

8

Where $\bar{m}_t$ 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 consumption of non-durable goods, $\hat{n}_t$ labor hours, $\hat{w}_t$ the wage rate, and b_t mortgage debt ($R_{M,t}$ is the mortgage rate). j_t is the borrower's housing preference - shocks to j_t are any factor unrelated to financing conditions that move house prices.

Borrowers in this model risk share: the aggregate (across island) value of non-defaulted housing and non-defaulted debt enters the borrower budget constraint (2.4). 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.

Positive mortgage debt demand shocks are captured 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, housing collateral shocks (positive shocks to the collateral value of housing $\bar{m}_t$) which directly expand the borrowers ability to borrower via increasing the collateral value of their house.

2.3 Financial Sector

The models island structure motivates the existence of mortgage backed securities. Shadow banks sit off-islands so can buy mortgages from across all islands and sell (to commercial banks only) an asset (the mortgage backed security, MBS) that pays the average mortgage return across islands. 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 (B^b), commercial bank net worth (N^c), shadow bank net worth (N^b), deposits (D), and total issuance of MBS (M). Note: MBS issued by shadow banks (M^b) is held entirely within the financial sector

Figure 5: Financial Sector Balance Sheet
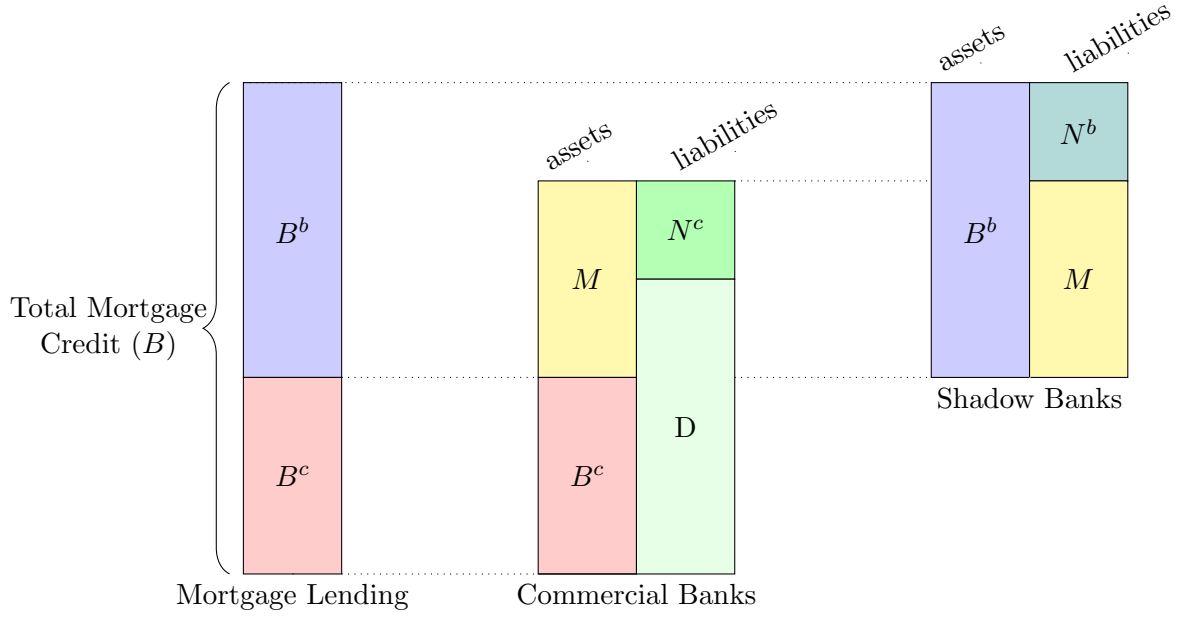
Note: Portfolio Loans (B^c) are the loans originated and then retained by an individual commercial bank, these loans are subject to island specific default risk. In contrast the Pooled Loans (B^b) are the loans purchased by shadow banks from across all islands, these loans are diversified so only have aggregate risk not island specific risk.

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 mortgages to MBS the commercial bank can hold. Commercial banks can 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 $c \in [0, 1]$. Each period commercial banks choose a specific island on which to locate for the purposes of mortgage lending

and deposit taking, so 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 which 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 die with probability $(1 - \sigma_c)$. Upon death 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 the standard assumption to ensure net worth is not accumulated so much such 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) subject to their balance sheet identity & to the solvency constraint.

$$\max_{b_t^c, d_t, m_t^c} V_t^c = E_t \tilde{\Lambda}_{t,t+1} \left\{ (1 - \sigma_c) \left[(1 - \psi) n_{t+1}^{c,good} + \psi n_{t+1}^{c,bad} \right] + \sigma_c V_{t+1}^c \right\} \tag{2.6}$$

subject to:

Their balance sheet identity:

$$b_t^c + m_t^c = n_t^c + d_t \tag{2.7}$$

The Solvency Constraint:

$$(1 - \delta) R_{M,t} b_t^c + \bar{R}_{m,t} m_t^c \geq R_t d_t \tag{2.8}$$

Where $\tilde{\Lambda}_{t,t+1}$ is the patient 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.

$$n_{t+1}^c = \begin{cases} R_{M,t}b_t^c + \bar{R}_{m,t}m_t^c - R_t d_t, & \text{if on a good island} \\ (1-\delta)R_{M,t}b_t^c + \bar{R}_{m,t}m_t^c - R_t d_t, & \text{if on a bad island} \end{cases} \tag{2.9}$$

The solvency constraint is the requirement that, when the banks 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. Essentially the solvency constraint plays the role of a value-at-risk (VaR) constraint[8], where the probability of defaulting on deposits is 0.

Aggregate commercial banking sector net worth evolves according to:

$$N_t^c = (\sigma_c + \xi_c)\Big((1 - \delta\psi)R_{M,t-1}B_{t-1}^c + \bar{R}_{m,t-1}M_{t-1}\Big) - \sigma_c R_{t-1}D_{t-1} \tag{2.10}$$

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 credit across islands. They die with probability $(1-\sigma_b)$ and survive with probability σ_b. They face an agency problem that follows that in Meeks et al. (2017) and Gertler and Kiyotaki (2010).

The shadow bank's problem is to purchased diversified (pooled) mortgage debt (b_t^b) and issue MBS (m_t^b) to maximize their continuation value (V_t^b) subject to their balance sheet identity and incentive compatibility constraint:

---

[8]Eg that in Adrian and Shin (2014).

$$\max_{\{b_t^b, m_t^b\}} V_t^b = E_t \tilde{\Lambda}_{t,t+1} \left[(1 - \sigma_b) n_{t+1}^b + \sigma_b V_{t+1}^b \right] \tag{2.11}$$

subject to:

Their balance sheet identity:

$$b_t^b = m_t^b + n_t^b \tag{2.12}$$

The incentive compatibility constraint:

$$V_t^b \geq \theta_{b,t} b_t^b \tag{2.13}$$

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

$$n_{t+1}^b = \underbrace{(1 - \psi\delta) R_{M,t} b_t^b}_{\text{return on the diversified mortgage pool}} - \bar{R}_{m,t} m_t^b \tag{2.14}$$

The shadow bank's incentive compatibility constraint (2.13) captures the agency problem between a shadow bank and the commercial banks that holds 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 take away a fraction $\theta_{b,t}$ of the amount repaid on the mortgage debt 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 (2.13) limits the quantity of MBS shadow banks can issue. 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 experience prior to the financial crisis. As the sophistication of securitization grew, the view that mortgage backed securities as an asset would default fell, and this in turn lowered the costly credit enhancements [9] issuers of mortgage backed securities had to provide to investors in mortgage backed securities. Meaning that mortgage backed securities could be issued in greater quantities with a lower spread charged by the issuers of mortgage backed securities (they were able to provide mortgages at lower cost).

---

[9]See Gorton and Souleles (2007) for a discussion of these Credit Enhancements.

Aggregate shadow banking sector net worth evolves according to:

$$N_t^b = (\sigma_b + \xi_b)(1 - \delta\psi)R_{M,t-1}B_{t-1}^b - \sigma_b\bar{R}_{m,t-1}M_{t-1} \tag{2.15}$$

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

2.4   Production

Production is based on labor and labor is differentiated across borrower and saver types. This is a simplification of the Iacoviello and Neri (2010) framework.

Each island contains a goods producer who chooses saver $(\tilde{n}_t)$ and borrower $(\hat{n}_t\})$ labor to maximize their profit (2.16) subject to their production function (2.17). Household members can travel costlessly across islands to work and consume, so that wages and prices equalize across islands (alternatively this can be considered as one aggregate producer), the producer problem is:

$$\max_{\tilde{n}_t,\hat{n}_t} Y_t - \left[\tilde{w}_t\tilde{n}_t + \hat{w}_t\hat{n}_t\right] \tag{2.16}$$

subject to:

$$Y_t = A_t\tilde{n}_t^\alpha\hat{n}_t^{1-\alpha} \tag{2.17}$$

2.5   Market Clearing

Goods Market equilibrium

$$Y_t - p_{h,t}\left[\hat{h}_t - (1 - \delta\psi)\hat{h}_{t-1}\right] = \tilde{c}_t + \hat{c}_t \tag{2.18}$$

Total Housing:

$$\bar{H} = \hat{h}_t \tag{2.19}$$

Total lending:

$$B_t = B_t^c + B_t^b \tag{2.20}$$

MBS market:

$$M_t^c = M_t^b \tag{2.21}$$

3 Calibration & Simulation

3.1 Calibration

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
A	1	Steady state level of TFP
α	0.64	Labor income share of savers
η	1	Inverse of the Frisch elasticity of labor supply
Housing and Financial Parameters		
$\bar{H}$	1	Total inelastic supply of housing
σ_c, σ_b	0.95	Financial institution survival probability
$\bar{m}$	0.92	Housing collateral value
j	0.067	Borrower housing preference parameter
ψ	1.3%	Quarterly mortgage delinquency rate
δ	23.8%	On island default
θ_b	0.60	Fraction of pooled loans that are divertible
ξ_c	0.0028	Fraction of assets transfered to new commercial banks
ξ_b	0.0042	Fraction of assets transfered to new shadow banks

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[10]). $\hat{\beta}$ 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 but does not effect the overall results appreciably.The level of TFP in steady state is normalized to 1. The calibration of the labor income share going to savers

---

[10]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%

(α) comes from Justiniano et al. (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). The labor dis-utility parameter is normalized to 1 (it only has a scale effect on the size of the economy). Following Justiniano et al. (2015) the Frisch elasticity of labor supply $\left(\frac{1}{\eta}\right)$ is set to 1.

3.1.2 Housing and Financial Parameters:

The supply of housing $\bar{H}$ is normalized to 1. σ_c and σ_b target an expected survival horizon for commercial and shadow banks of 5 years, consistent with the literature (eg Gertler and Kiyotaki, 2015). The collateral value of housing ($\bar{m}$) and the borrower's housing preference parameter (j) jointly target a mortgage to borrower income ratio of 0.8[11], and a calculated loan-to-value (LTV) ratio of 90%[12].

3.1.3 Simulation Initialization Targets:

The remaining parameters: $\delta, \theta_b, \xi_c, \xi_b$, 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 δ (the proportional default on bad islands) jointly target the fraction of mortgage dollars entering serious (90+ day) delinquency in the Quarterly Report on Household Debt and Credit (0.3180%).

The data series on the mortgage spread is the spread of the average mortgage rate in the PLSD over the 10 year US Treasury yield, using the adjusted for borrower quality series in Justiniano et al. (2017). The commercial bank asset composition is that of depository institutions (commercial banks and thrifts) in the US[13] In the MBS to Mortgages Ratio

---

[11]This follows the target in Justiniano et al. (2019): they identify borrowers as households whose liquid assets are less than two months of their total income - using the 1992, 1995 and 1998 SCF.

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

[13]These data come from the Flow of Funds Z1 release on U.S. Chartered Depository Institutions (Table L.111)

Table 2: Simulation Initialization Targets

Target	Value
Mortgage Spread ($R_M - R$)	4.36%
Commercial bank asset composition ($\frac{M^c}{Bc}$)	0.05
MBS to Mortgages Ratio	0.04
Adjusted commercial bank leverage	4.6
% of Mortgage dollars entering serious delinquency	0.32%

Note: These targets are intended to match an average of 2000 Q1 - Q4 in the data, this is the starting point for the subsequent simulation.

($\frac{M}{B}$) total mortgages (B) is measures as the sum of portfolio loans and loans held in the shadow banking sector (by ABS issuers & mortgage companies - in the Flow of Funds data). The quantity of loans held in the shadow banking sector is adjusted by percentage of MBS held in the commercial banking sector[14]The "adjusted commercial bank leverage" is average commercial bank leverage during the calibration period (measure by the aggregate data in the Federal Deposit Insurance Corporation's Quarterly Bank Report) 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[15]).

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 et al. (2015). Let z_t denote the $Nx1$ vector of endogenous variables determined at time t, and $\epsilon_t = \{\theta_{b,t}, j_t, \tilde{\beta}_t, \bar{m}_t\}$ 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, $\tilde{\beta}_t$ or $\bar{m}_t$) and expect the economy to transition to a new steady state

---

[14]This makes the ratio of pooled loans to MBS consistent with the aggregate ratio

[15]Flow of Funds Z1 release on U.S. Chartered Depository Institutions (Table L.111)

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 $t - 1$.

4   The Innovation in Securitization Channel

Considering a simplified two-period version of the model with linear saver utility (see appendix C.2) the shadow banks incentive compatibility constraint (2.13) can be expressed as follows (for simplicity I drop the timing subscript here, all variables refer to the same period):

$$\tilde{\beta} \left\{ \underbrace{\left[(1 - \delta\psi)R_M - \bar{R}_m \right]}_{\text{Mortgage Spread}} B^b + \bar{R}_m N_1^b \right\} \geq \theta_b B^b \tag{4.1}$$

The left hand side of (4.1) is the value shadow banks derive from choosing to honor the their liabilities from the mortgage backed securities they issued. And the right hand side of (4.1) is the value shadow banks get from choosing to divert (i.e. run away) with the pooled mortgages (B^b) on their balance sheet. θ_b is the fraction of pooled mortgages that are divertible. θ_b indexes the state of financial liberalization in the private mortgage backed securitization market (the lower θ_b is the more liberalized the securitization market is). An exogenous decrease in the divertible fraction (θ_b) is a "innovation in securitization" shock.

From the above it is clear to see that 1 unit increase in pooled mortgages held by the shadow bank (driven by a 1 unit increase in mortgage backed securities issued) will increase the quantity of divertible loans by θ_b and continuation value for shadow banks (LHS) by:

$$\tilde{\beta} \times \text{(old) Spread} + \tilde{\beta} \frac{\partial \text{ Spread}}{\partial B^b} \tag{4.2}$$

As long as the divertible fraction (θ_b) is sufficiently greater than zero the mortgage spread must *increase* in response to any increase in the quantity of mortgage backed securities demanded (see figure 6).

Mortgage backed security demand shocks include both shifts in housing demand (driven by positive shocks to the borrower's housing preference parameter, j_t) and exogenous shifts

Figure 6: Mortgage Backed Securities Market - Partial Equilibrium Effect of an MBS Demand Shock
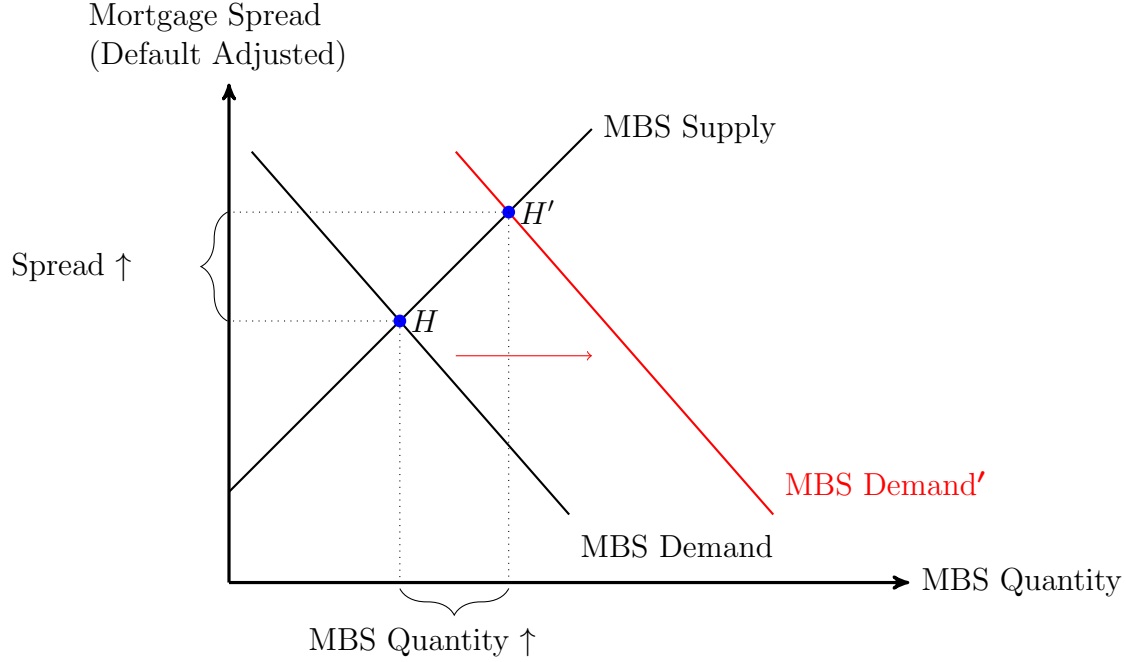
in savings (driven by positive shocks to the saver's discount factor, $\tilde{\beta}_t$). This exogenous shift in savings demand should be thought of as the way to capture Bernanke (2005)'s the Global Savings Glut Both put upward pressure on the size of the commercial banks' balance sheets (in the housing demand case because borrowers demand more mortgages, and in the exogenous savings shock case because savers demand more deposits). Because of the solvency constraint the commercial banks are limited in the ratio of mortgage loans they can retain to quantity of mortgage backed securities they must hold. Therefore both credit demand *and* the credit supply shocks that originate outside of the shadow banking sector operate as *MBS demand* shocks from the shadow banks perspective and generate a counter-factual *increase* in the mortgage spread.

In contrast the innovation in securitization shock (an exogenous decrease in θ_b) directly decreases the quantity of divertible loans, because it makes the pooled mortgages (B^b) less divertible. This directly lowers the continuation value required for shadow banks to meet their incentive compatibility constraint (4.1), and means that shadow banks can respond by increasing the quantity of MBS they issue even while the mortgage spread in equilibrium

Figure 7: Mortgage Backed Securities Market - Partial Equilibrium Effect of an Innovation in Securitization Shock
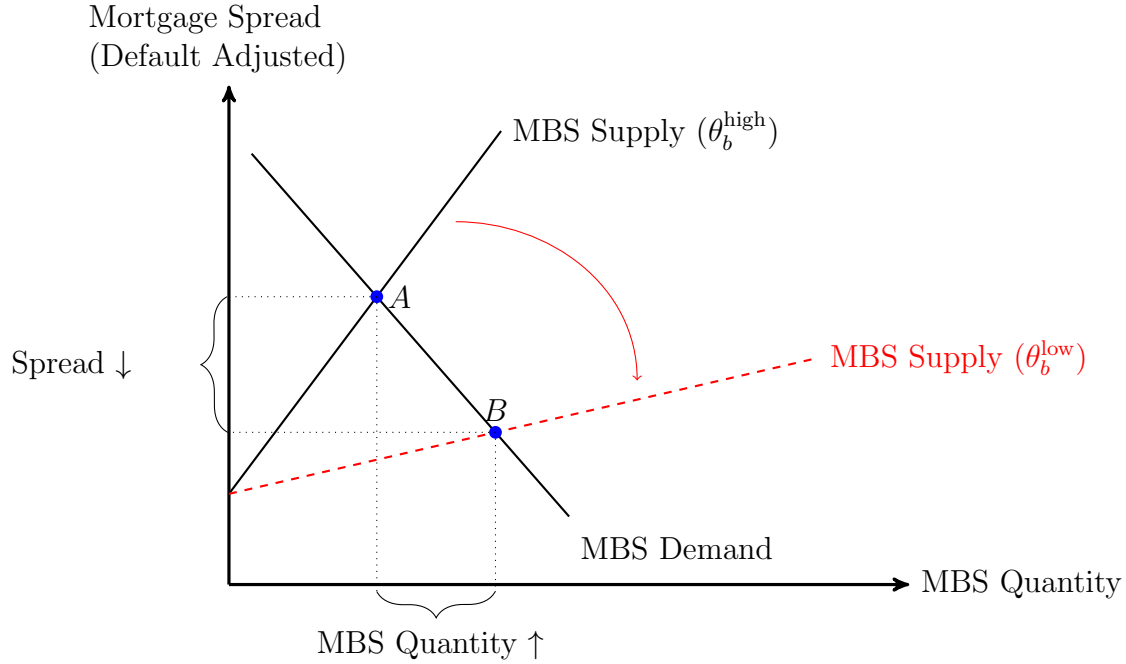
falls (see figure 7). Finally - the pooled mortgage divertibility parameter (θ_b) indexes the liberalization of the shadow banking sector. For higher values of θ_b the shadow banking sector amplifies other shocks less, and for lower values of θ_b the shadow banking sector amplifies shocks more (see figure 8). This underlines the importance of correctly identifying the role of innovation in securitization as a potential driver of the boom in US house prices and mortgage debt. It also indicates that the innovation in securitization channel if present could have amplified the housing demand and alternative credit supply explanations that others have pointed to, to explain the US experience.

Figure 8: Mortgage Backed Securities Market - A More Liberalized Shadow Banking Sector Magnifies Other Shocks
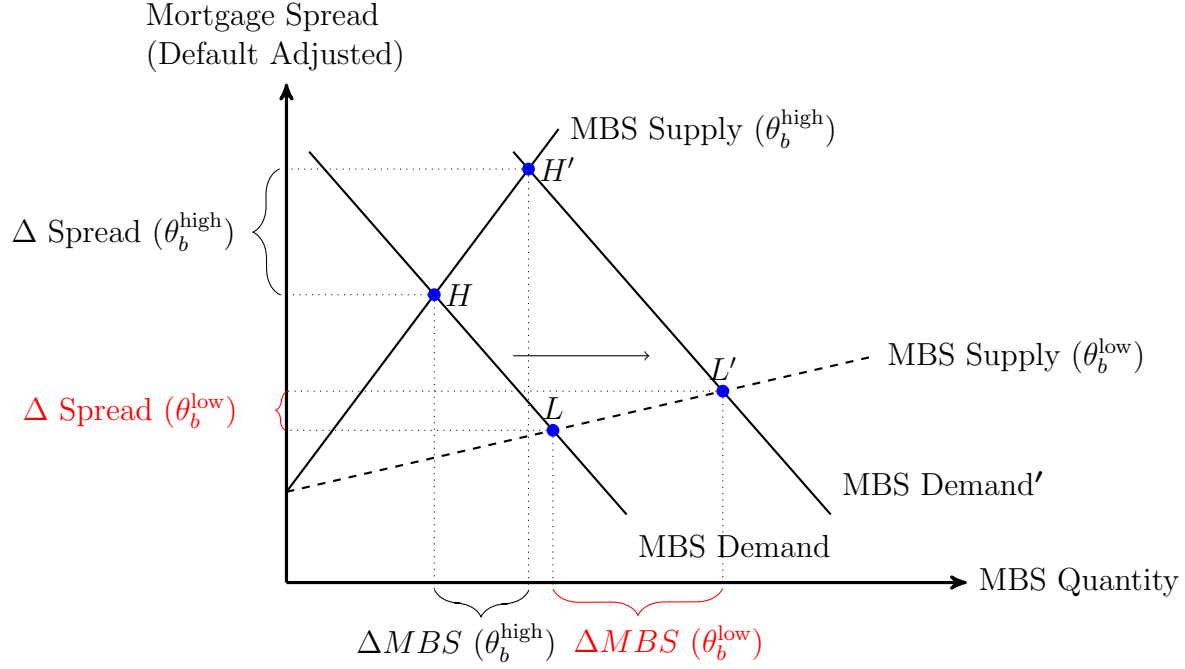

Figures 9, 10, and 11 make the qualitative amplification point in figure 8 quantitatively. In each figure respectively I calibrate a 1-off permanent shock to housing preference, housing collateral, and saver patience to generate a 1% increase in total outstanding mortgage credit in the pre-boom (year 2000) version of the model. I then run the same shock at the Securitization Peak, Housing Demand Peak, and Exogenous Savings Peak (that is the model version consistent with the various 2006 Q4 versions of the model in the following horse-race). The qualitative point in figure 8 - for all three 1-off shocks the Securitization Peak amplifies the impact of the shock on house prices and mortgage credit the most relative to the other peaks. And in all three cases the response of the mortgage spread is least under the Securitization Peak.

Figure 9: Transmission of a Housing Demand Shock

Note the housing demand shock is an exogenous increase in the borrowers' preference for housing parameter (j_t), in their utility function - equation (2.3). The mortgage spread is plotted in basis points deviation from steady state.

Figure 10: Transmission of a Housing Collateral Shock
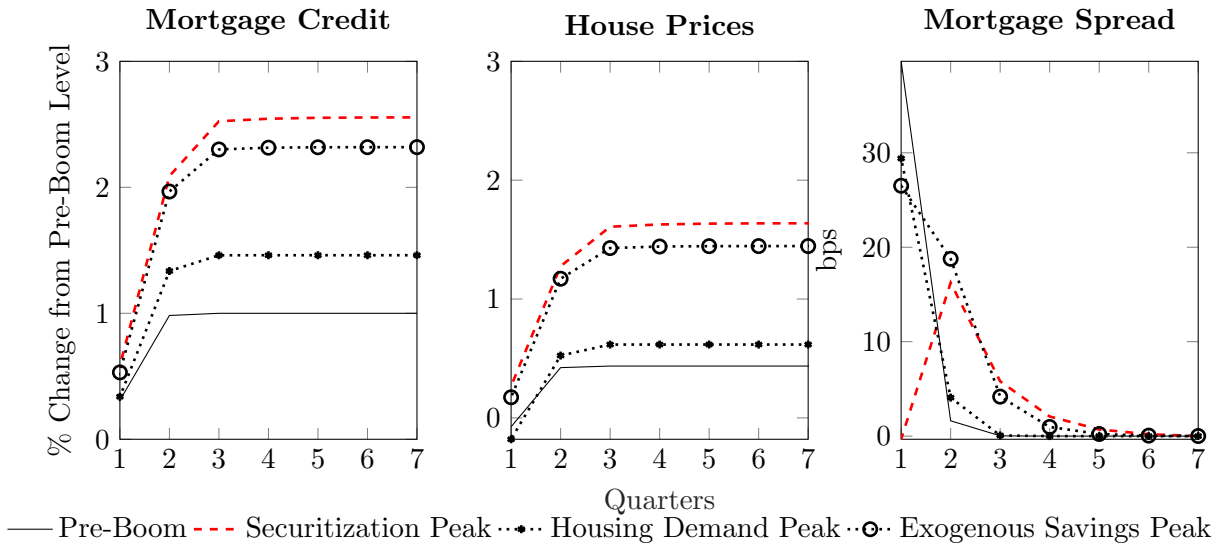
Note: The housing collateral shock is an exogenous increase in $\bar{m}_t$, the housing collateral value in the borrowers' collateral constraint - equation (2.5).

Figure 11: Transmission of a Savings Shock

Note: The "savings shock" is an exogenous increase in saver time preference $\tilde{\beta}_t$.

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" shocks). 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 results here are 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 71 - 100% of the appreciation in house prices and 34 - 45% of the increase in non-conforming mortgage debt during the boom period.

5.1   Horse-Race to Match House Price Growth

In each of the three competing simulations the individual shock series is calibrated to target the peak in house prices during the boom (47% in 2006 Q4 according to the Case-Shiller Real House Price Index). Figure 12 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.

Figure 12: Matching Real House Price Growth
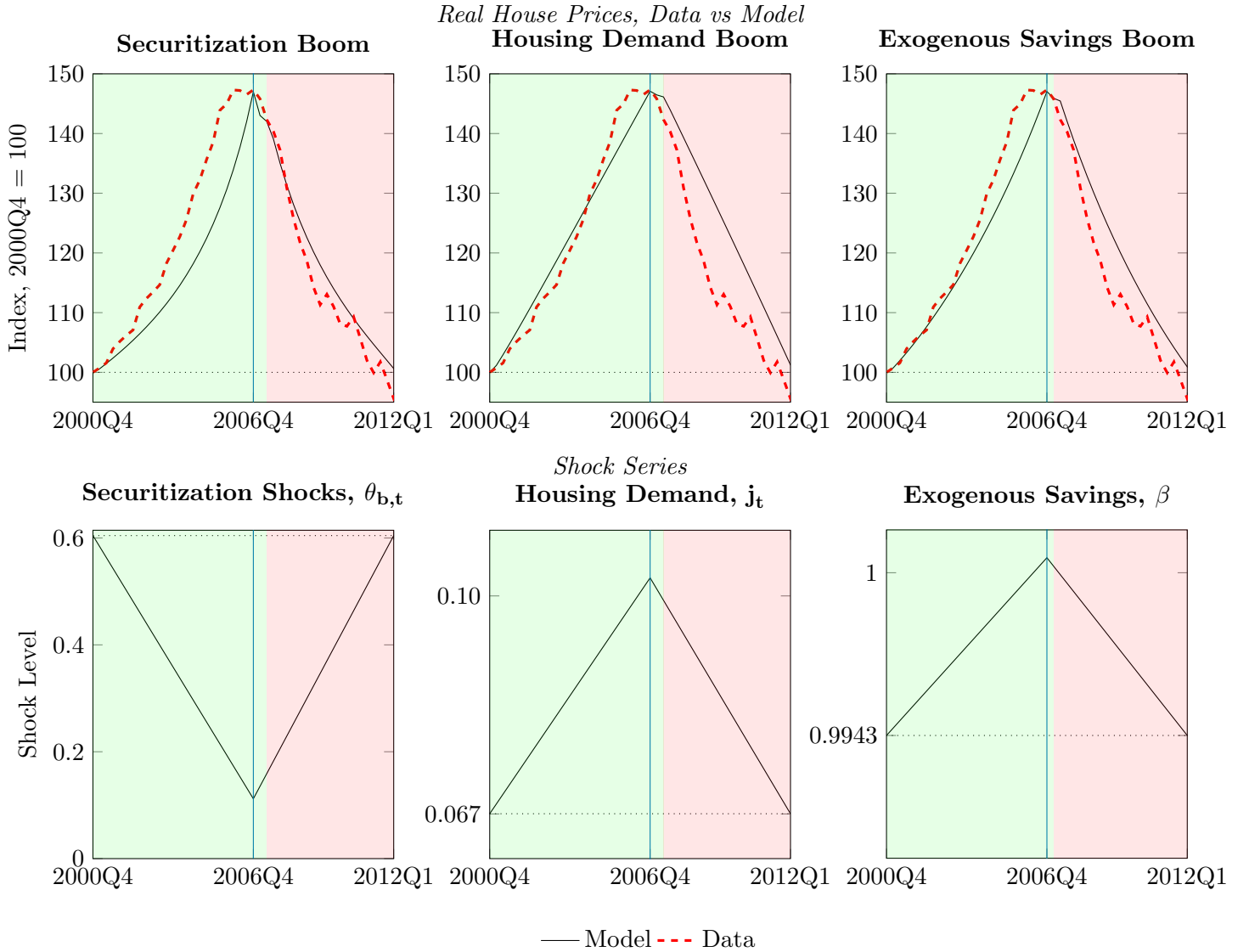
In this figure each column is a The green shaded area indicates the housing collateral constraint is slack, the red shaded area indicates the housing collateral constraint binds. The vertical blue line is 2006Q4 (the peak period for real house prices according to the Case-Shiller Index).

24

Figure 13: Only the Securitization Boom Explains Mortgage Spreads

*Model vs Data: Mortgage Rate Spread over Risk-Free Rate*
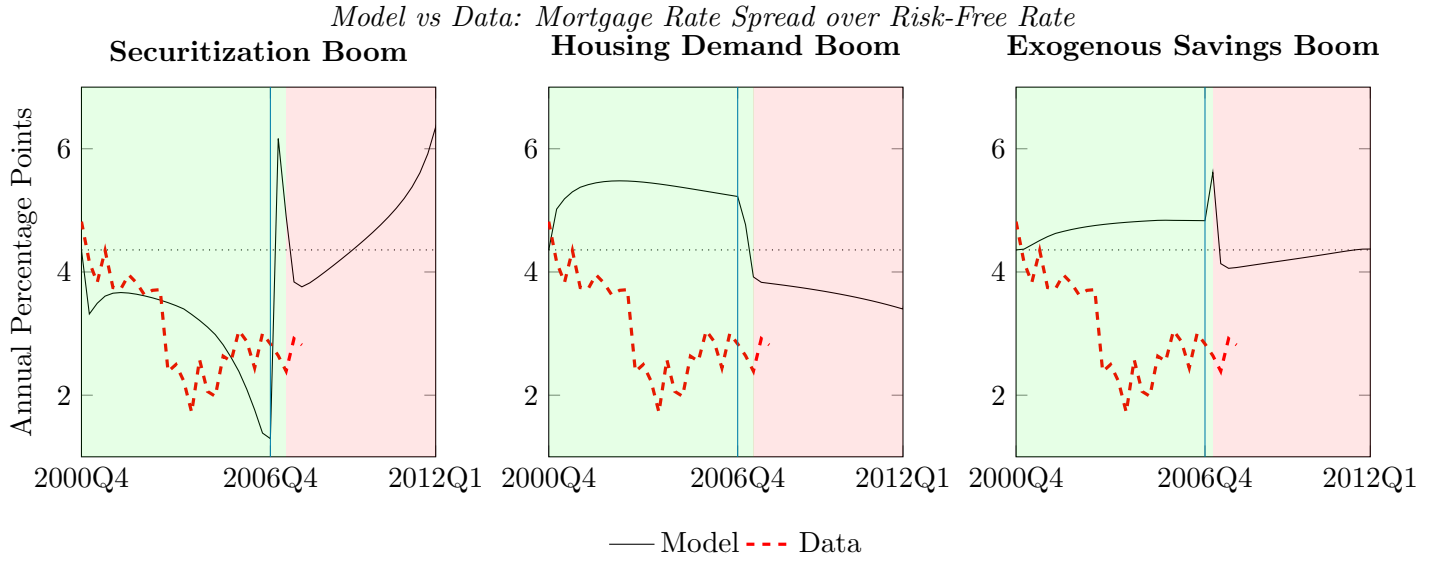
The key result, captured in figure 13 in this simulation is that only the innovation in securitization shocks can match (direction & magnitude) of the spread between the mortgage rate and the risk free rate. Unsurprisingly the housing demand driven boom (a demand for credit shock) puts upward pressure on the mortgage spread. More interestingly the exogenous savings expansion, which operates like the inelastic credit supply shock in Justiniano et al. (2019) and in this closed economy model stand 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* shadow banks face for MBS, and because of the incentive compatibility constraint faced by shadow banks to increase quantity of MBS they issue they require an increased spread. This result underlines the necessity of modeling the securitization process, while the generalized credit supply expansion – "exogenous savings boom" – is *a credit supply shock*, the counter-factual implications suggest that it is likely not *the credit supply shock* that drove the US housing and mortgage market during the 2000s.

Additionally the Securitization boom generates the most volatility in borrower and saver consumption (figure 14) and is the only channel which generates a quantitatively reasonable response of several moments in the private securitization market (see Figure 18 in Appendix

B). Lastly the three candidate booms are indistinguishable in the response of mortgage debt
and the borrower debt-to-annual income ratio (see Figure 17 in Appendix B).

Figure 14: Consumption is Most Volatile Under in the Securitization Boom
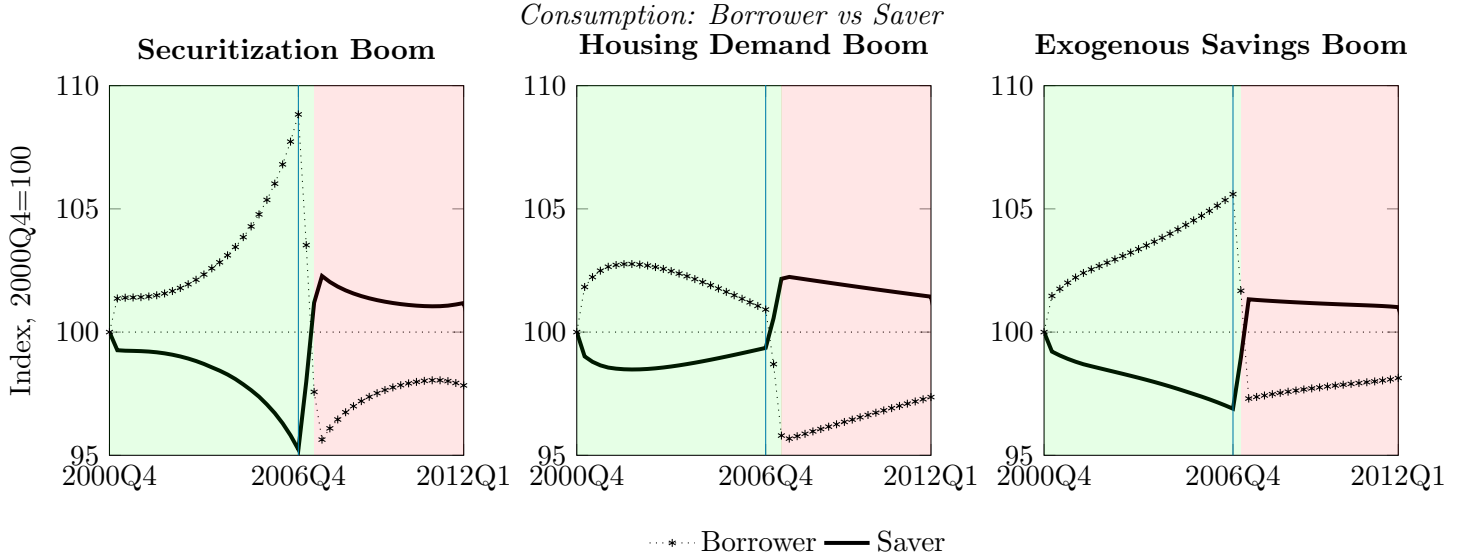

Consumption: Borrower vs Saver

The green shaded area indicates the housing collateral constraint is slack, the red shaded area indicates the
housing collateral constraint binds. The vertical blue line is 2006Q4 (the peak period for real house prices
according to the Case-Shiller Index).

5.2 Measuring the Contribution of Innovation in Securitization

In this section I put upper and lower bounds on the model's prediction as to the extent to
which innovation in securitization could have driven house price growth. The data series
most closely related to the innovation in securitization shocks are: private mortgage backed
security issuance and the Securitization Rate. Issuance is the flow of private mortgage backed
securities produced by the shadow banking sector each quarter. This grew by over 790%
between 2000 Q4 and its peak in 2005 Q3 (See the leftmost subplot in Figure 15), matching
this data series gives a lower bound as to the magnitude of the innovation in securitization
channel (see sold black line in Figure 15). In contrast matching the Securitization Rate gives
an upper bound as to the magnitude of the innovation in securitization channel (see dotted
black line in Figure 15). The securitization rate is the ratio of private mortgage backed
security issuance to non-conforming mortgages originated in any given quarter. It is another

flow series that is closely related to the constraints faced by the shadow banking sector when issuing private mortgage backed securities.

Figure 15: Matching Moments - Upper and Lower Bounds
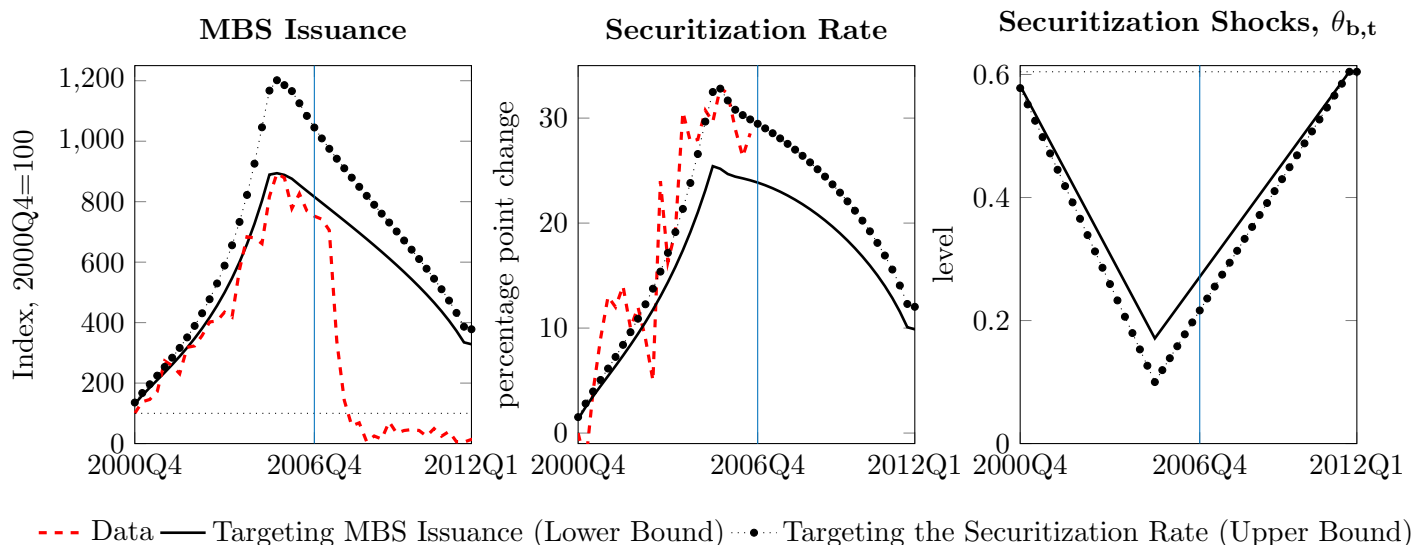
--- Data —— Targeting MBS Issuance (Lower Bound) ···•··· Targeting the Securitization Rate (Upper Bound)

Here the upper estimate of the securitization shock series (targeted to match the securitization rate - the ratio of MBS issued to mortgage debt originated) is the dashed black line. The lower estimate of the securitization shock series is the solid black line (targeted to match the growth in private mortgage backed security issuance). The dashed red line is the data.

Figure 16 shows the upper and lower bounds the securitization rate target simulation and the MBS issuance target simulation put on the extent to which innovation in securitization drove the boom in house prices, mortgage credit, the mortgage spread, and the percentage of the stock of (non-conforming) mortgages held by the shadow banking sector. The results of the two simulations suggest that the innovation in securitization can explain between 72% and over 100% of the increase in real house prices seen in the data[16]. innovation in securitization drives between 34.3% to 45.8% of the increase in mortgage credit relative to GDP[17]. innovation in securitization explains at least 235 basis points of the 273 basis point drop in the mortgage spread found in the data (86% of the data)[18].

---

[16]The securitization rate target simulation overshoots the real house price peak by 3%.

[17]The multiplier between house price growth and mortgage credit growth does not match the data. This could be in part because the model's supply of housing is fixed, adding housing investment may bring the multiplier more in line with the data. This would not change the qualitative point made in the proceeding section.

[18]The securitization rate target simulation overshoots the data by 33 bps.

Figure 16: Quantifying the Innovation in Securitization Channel - Upper and Lower Bounds
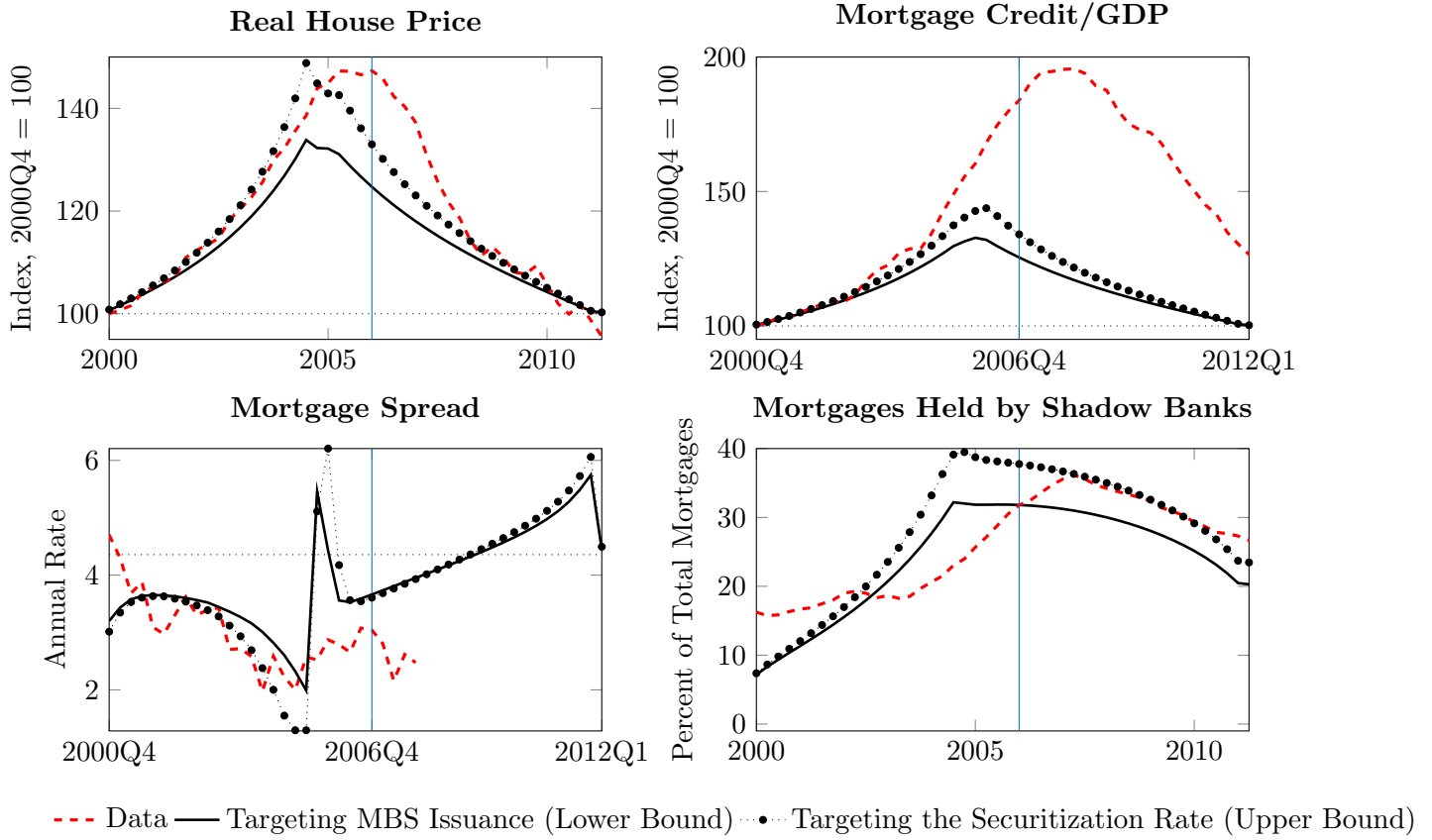
Here the upper estimate of the securitization shock series (targeted to match the securitization rate - the ratio of MBS issued to mortgage debt originated) is the dashed black line. The lower estimate of the securitization shock series is the solid black line (targeted to match the growth in private mortgage backed security issuance). The dashed red line is the data. On the mortgage spread subplot, the dotted red and blue lines are the adjusted for borrower quality mortgage spread series in Justiniano et al. (2019). Total mortgages refers to estimated total non-conforming mortgages outstanding.

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 based on 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[19]). 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 71 - 100% of the increase in house prices and 34 - 45% of the increase in non-conforming mortgage debt observed in the data.

Additionally I show that other candidate explanations (a housing demand driven boom or a 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. This is not to say that the model rules out housing demand and exogenous savings shocks as *amplifiers* of the securitization driven boom. I find that in a more liberalized[20] shadow banking sector the impact of housing demand and savings shocks on mortgage credit growth and house price growth are amplified relative to the pre-boom version of the model, and the response of the mortgage spread is moderated. The amplification effect is particularly strong for the transmission of savings shocks - suggesting securitization played an important role in amplifying the impact of inflows of foreign savings into the U.S. during this period.

In ongoing work I am exploring the impact of macro-prudential regulation of commercial banks in this model, particularly the potential leakages and interactions with the shadow banking sector.

---

[19]Mortgage backed securitization done by Fannie Mae, Freddie Mac, and Ginnie Mae.

[20]The model after a series of positive innovation in securitization shocks.

References

Adrian, Tobias and Hyun Song Shin, "Procyclical leverage and value-at-risk," *Review of Financial Studies*, 2014, *27* (2), 373–403. (Not cited.)

Ashcraft, Adam B and Til Schuermann, "Federal Reserve Bank of New York Staff Reports Understanding the Securitization of Subprime Mortgage Credit," *New York*, 2008, *2* (318), 1779–1808. (Not cited.)

Bernanke, Ben S., "The global saving glut and the U.S. current account deficit," Technical Report 2005. (Not cited.)

Christiano, Lawrence J., Martin S. Eichenbaum, and Mathias Trabandt, "Understanding the Great Recession," *American Economic Journal: Macroeconomics*, January 2015, *7* (1), 110–167. (Not cited.)

Fair, Ray C and John B Taylor, "Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectations Models," *Econometrica*, July 1983, *51* (4), 1169–1185. (Not cited.)

Gertler, Mark and Nobuhiro Kiyotaki, *Financial intermediation and credit policy in business cycle analysis*, Vol. 3, Elsevier Ltd, 2010. (Not cited.)

_ **and** _ , "Banking, Liquidity, and Bank Runs in an Infinite Horizon Economy," *American Economic Review*, July 2015, *105* (7), 2011–2043. (Not cited.)

Gorton, Gary B. and Nicholas S. Souleles, "Special Purpose Vehicles and Securitization," in "The Risks of Financial Institutions" NBER Chapters, National Bureau of Economic Research, Inc, May 2007, pp. 549–602. (Not cited.)

Iacoviello, Matteo and Stefano Neri, "Housing Market Spillovers: Evidence from an Estimated DSGE Model," *American Economic Journal: Macroeconomics*, April 2010, *2* (2), 125–164. (Not cited.)

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, "Household leveraging and deleveraging," *Review of Economic Dynamics*, January 2015, *18* (1), 3–20. (Not cited.)

_ , _ , **and** _ , "The Mortgage Rate Conundrum," Working Paper Series WP-2017-23, Federal Reserve Bank of Chicago August 2017. (Not cited.)

_ , _ , **and** _ , "Credit Supply and the Housing Boom," *Journal of Political Economy*, 2019, *127* (3), 1317–1350. (Not cited.)

Kaplan, Greg, Kurt Mitman, and Giovanni L. Violante, "The Housing Boom and Bust: Model Meets Evidence," NBER Working Papers 23694, National Bureau of Economic Research, Inc August 2017. (Not cited.)

Meeks, Roland, Benjamin Nelson, and Piergiorgio Alessandri, "Shadow Banks and Macroeconomic Instability," *Journal of Money, Credit and Banking*, 2017, *49* (7), 1483–1516. (Not cited.)

Mian, Atif and Amir Sufi, *Household Debt and Defaults from 2000 to 2010: The Credit Supply View*, Cambridge University Press, (Not cited.)

Pozsar, Zoltan, Tobias Adrian, Adam B. Ashcraft, and Hayley Boesky, "Federal Reserve Bank of New York Staff Reports," Technical Report 458, Federal Reserve Bank of New York Staff Reports 2012. (Not cited.)

Shiller, Robert J., "Understanding recent trends in house prices and homeownership," *Proceedings - Economic Policy Symposium - Jackson Hole*, 2007, pp. 89–123. (Not cited.)

A   Model Equations

Auxiliary Expressions:

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

Aux 2:
$$\Omega_{t+1}^c := \sigma_c\left(\gamma_{t+1}^c + v_{t+1}^c\right) + (1 - \sigma_c)$$

Aux 3:
$$\Omega_{t+1}^b := (1 - \sigma_b) + \sigma_b(\mu_{M,t+1}^b\phi_{t+1}^b + \bar{v}_{m,t+1}^b)$$

Saver FOCs

$$\tilde{\lambda}_t = \frac{1}{\tilde{c}_t} \tag{A.1}$$

$$\tilde{\lambda}_t = \tilde{\beta}E_t\tilde{\lambda}_{t+1}R_t \tag{A.2}$$

$$\phi\tilde{n}_t^{\eta} = \tilde{\lambda}_t\tilde{w}_t \tag{A.3}$$

Borrower FOCs

$$\hat{\lambda}_t = \left[\hat{c}_t - \frac{\hat{n}^{1+\hat{\omega}}}{1 + \hat{\omega}}\right]^{-\hat{\sigma}} \tag{A.4}$$

$$\frac{j_t}{\hat{h}_t} - \hat{\lambda}_t p_{h,t} + \hat{\beta}E_t\left[\hat{\lambda}_{t+1}(1 - \psi\delta)p_{h,t+1}\right] + \mu_t\frac{\bar{m}_tE_tp_{h,t+1}}{R_{M,t}} = 0 \tag{A.5}$$

$$\hat{\lambda}_t - \hat{\beta}E_t\left[\hat{\lambda}_{t+1}(1 - \psi\delta)R_{M,t}\right] - \hat{\mu}_t = 0 \tag{A.6}$$

$$\phi\hat{n}_t^{\eta} = \hat{\lambda}_t\hat{w}_t \tag{A.7}$$

$$\hat{c}_t + p_{h,t}\hat{h}_t + (1 - \psi\delta)R_{M,t-1}B_{t-1} = B_t + (1 - \psi\delta)p_{h,t}\hat{h}_{t-1} + \hat{w}_t\hat{n}_t \tag{A.8}$$

$$R_{Mt}B_t \le m_tE_tp_{h,t+1}\hat{h}_t \tag{A.9}$$

Production

$$Y_t = A_t\tilde{n}_t^{\alpha}(\hat{n}_t)^{1-\alpha} \tag{A.10}$$

$$\tilde{w}_t = \frac{\alpha Y_t}{\tilde{n}_t} \tag{A.11}$$

$$\hat{w}_t = \frac{(1-\alpha)Y_t}{\hat{n}_t} \tag{A.12}$$

Commercial Bank

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

$$(1-\delta)R_{M,t}B_t^c + \bar{R}_{m,t}M_t^c - R_tD_t \geq 0 \tag{A.13}$$

FOC wrt on balance sheet loans

$$(v_{M,t}^c - v_t^c) + \gamma_t^c\Big((1-\delta)R_{M,t} - R_t\Big) = 0 \tag{A.14}$$

FOC wrt MBS

$$(\bar{v}_{m,t}^c - v_t^c) + \gamma_t^c\Big(\bar{R}_{m,t} - R_t\Big) = 0 \tag{A.15}$$

Marginal Value on on-balance sheet loans:

$$v_{Mt}^c = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^c(1-\psi\delta)R_{M,t} \tag{A.16}$$

Marginal value on MBS:

$$\bar{v}_{m,t}^c = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^c\bar{R}_{m,t} \tag{A.17}$$

Marginal Value of Deposits:

$$v_t^c = E_t\tilde{\Lambda}_{t,t+1}\Omega_{t+1}^c R_t \tag{A.18}$$

Aggregate net worth:

$$N_t^c = (\sigma_c + \xi_c)\Big((1-\psi\delta)R_{M,t-1}B_{t-1}^c + \bar{R}_{m,t-1}M_{t-1}\Big) - \sigma_c R_{t-1}D_{t-1} \tag{A.19}$$

Balance sheet:

$$D_t + N_t^c = B_t^c + M_t^c \tag{A.20}$$

Shadow Bank:

FOC wrt loans:

$$\mu^b_{M,t} = \frac{\lambda^b_t \theta_{b,t}}{1 + \lambda^b_t} \tag{A.21}$$

Incentive compatibility constraint (binding if $\lambda^b_t \geq 0$):

$$\phi^b_t \leq \frac{\bar{v}^b_{mt}}{\theta_{b,t} - \mu^b_{M,t}} \tag{A.22}$$

Marginal Value of Loans (Note: $\mu^b_{M,t} := v^b_{Mt} - \bar{v}^b_{mt}$):

$$\mu^b_{M,t} = E_t \tilde{\Lambda}_{t,t+1} \Omega^b_{t+1} \Big[(1 - \psi\delta) R_{Mt} - \bar{R}_{m,t} \Big] \tag{A.23}$$

Marginal Value of MBS:

$$\bar{v}^b_{mt} = E_t \tilde{\Lambda}_{t,t+1} \Omega^b_{t+1} \bar{R}_{mt} \tag{A.24}$$

Balance Sheet Identity:

$$B^b_t = N^b_t + M^b_t \tag{A.25}$$

Aggregate Shadow Bank Net Worth:

$$N^b_t = (\sigma_b + \xi_b)(1 - \psi\delta) R_{M,t-1} B^b_{t-1} - \sigma_b \bar{R}_{m,t-1} M^b_{t-1} \tag{A.26}$$

Shadow Bank leverage:

$$\phi^b_t = \frac{B^b_t}{N^b_t} \tag{A.27}$$

Market Clearing:

$$\bar{H} = \hat{h}_t \tag{A.28}$$

$$\tilde{c}_t + \hat{c}_t = Y_t - p_{h,t} \Big[\hat{h}_t - (1 - \delta\psi_t)\hat{h}_{t-1} \Big] \tag{A.29}$$

$$M^c_t = M^b_t \tag{A.30}$$

$$B_t = B^c_t + B^b_t \tag{A.31}$$

B Boom-Bust Simulation Additional Results

Figure 17: Candidate Booms are Indistinguishable on Credit Growth and Change in Borrower Indebtedness
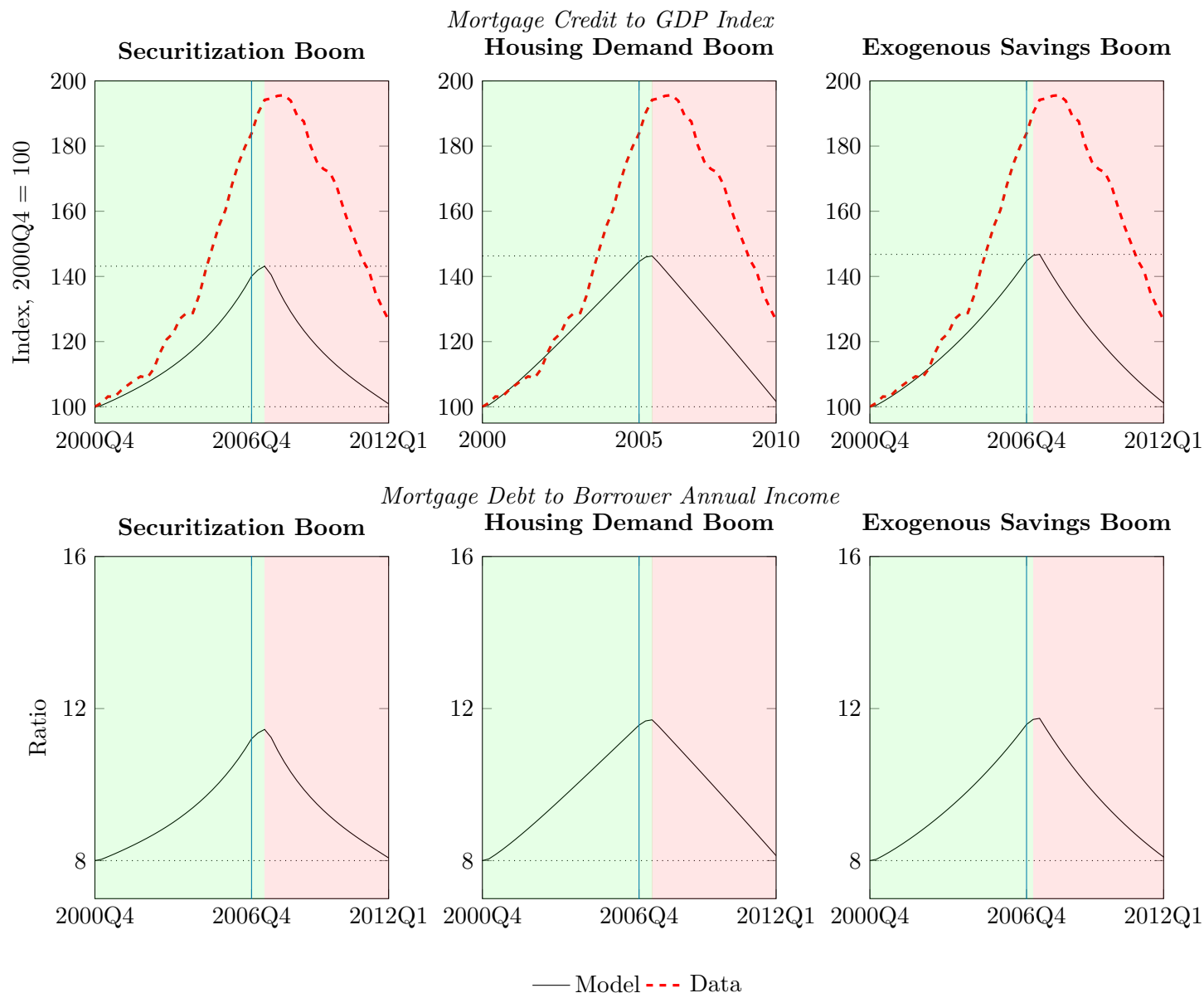
Mortgage Credit to GDP Index

Mortgage Debt to Borrower Annual Income

The green shaded area indicates the housing collateral constraint is slack, the red shaded area indicates the housing collateral constraint binds. The vertical blue line is 2006Q4 (the peak period for real house prices according to the Case-Shiller Index).

Figure 18: Horse-Race: Only the Securitization Boom can Match Secondary Market Moments
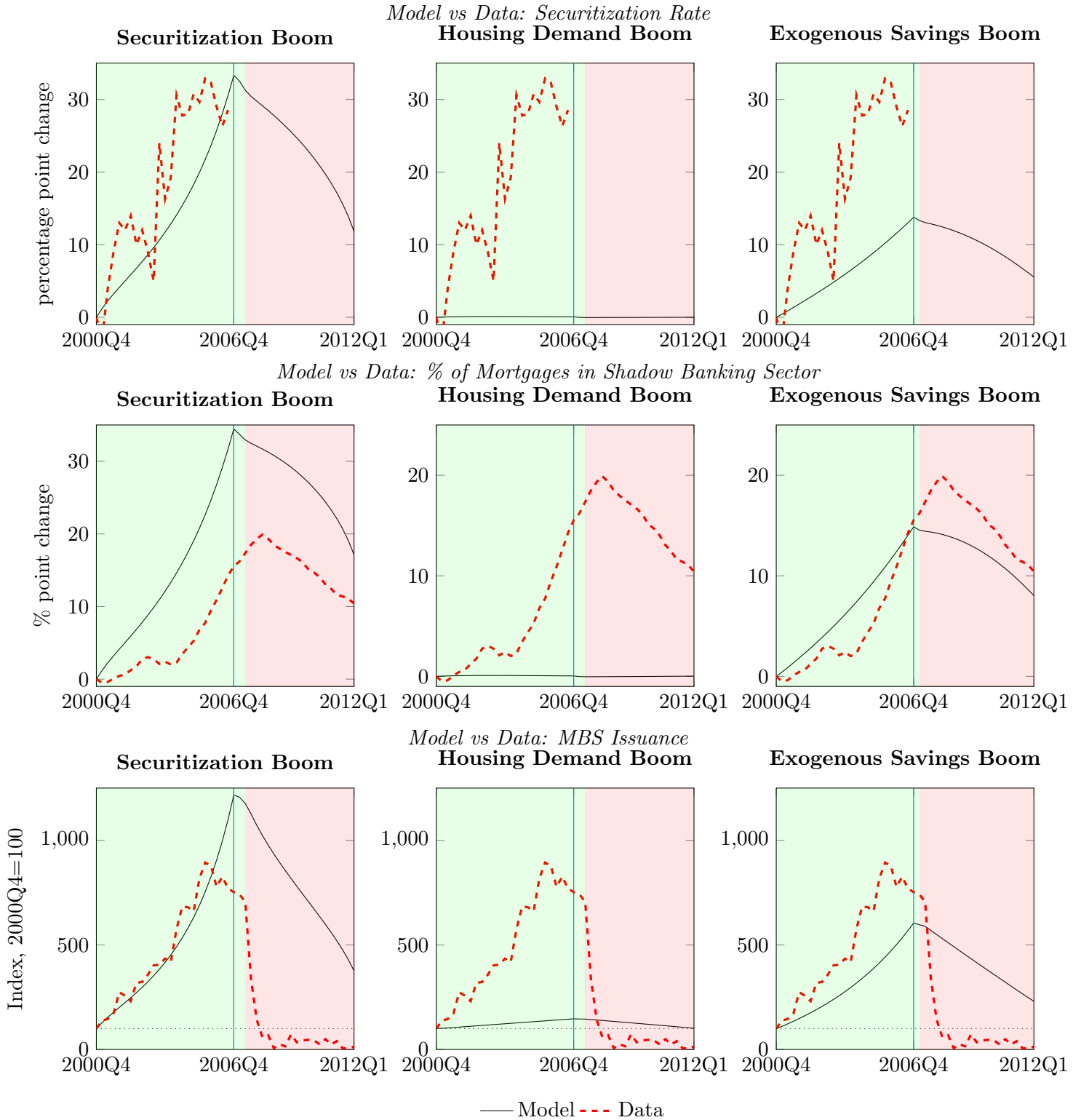
Model vs Data: Securitization Rate

Securitization Boom   **Housing Demand Boom**   **Exogenous Savings Boom**

Model vs Data: % of Mortgages in Shadow Banking Sector

Securitization Boom   **Housing Demand Boom**   **Exogenous Savings Boom**

Model vs Data: MBS Issuance

Securitization Boom   **Housing Demand Boom**   **Exogenous Savings Boom**

—— Model   - - - Data

The green shaded area indicates the housing collateral constraint is slack, the red shaded area indicates the housing collateral constraint binds. The vertical blue line is 2006Q4 (the peak period for real house prices according to the Case-Shiller Index). The securitization rate is the ratio of mortgage backed securities issued to mortgage debt originated in a given quarter, it is a flow measure of the extent to which mortgages were being originated and then quickly sold.

36

C   Two Period Model

Date 1: Mortgages are originated (B_1), MBS is issued (M_1), $\theta_{b,1}$ is known.

- States: The individual and aggregate shadow bank net worth (n_1^b, N_1^b), individual and aggregate commercial bank net worth (n_1^c, N_1^c), the borrowers endowment $(\hat{\omega}_1)$, and the saver's endowment $(\tilde{\omega}_1)$.

- Controls: Saver consumption $(\tilde{c}_1)$, borrower consumption $(\hat{c}_1)$, borrower housing consumption $(\hat{h}_1)$, borrower mortgage debt (b_1), individual and aggregate commercial banks mortgage holdings (b_1^c, B_1^c), individual and aggregate shadow banks pooled mortgage holdings (b_1^b, B_1^b), individual and aggregate commercial banks MBS holdings (m_1^c, M_1^c), individual and aggregate shadow banks MBS holdings (m_1^b, M_1^b).

- Prices: Deposit rate (R_1), mortgage rate (R_M), return on MBS $\bar{R}_m$, house price $(p_{h,1})$. Multipliers: on the housing collateral constraint $(\hat{mu}_1)$, on the solvency constraint (γ_1^c), on the divertibility constraint (λ_1^b), on the savers budge constraint $(\tilde{\lambda}_1)$, and on the borrowers budget constraint $(\hat{\lambda}_1)$.

Date 2: Mortgages paid back or defaulted on, mortgage backed securities are paid back.

- Variables: Saver consumption $(\tilde{c}_2)$, borrower consumption $(\hat{c}_2)$, borrower housing consumption $(\hat{h}_2)$, house price $(p_{h,2})$, the multiplier on the savers budge constraint $(\tilde{\lambda}_2)$, and on the borrowers budget constraint $(\hat{\lambda}_2)$.

Symmetric equilibrium:

- $\forall$ borrowers: $b_t = B_t, \hat{h}_t = \hat{H}_t = \bar{H}, \hat{c}_t = \hat{C}_t$.

- $\forall$ savers: $d_t = D_t, \tilde{c}_t = \tilde{C}_t$

- $\forall$ CBanks: $b_t^c = B_t^c, m_t^c = M_t^c = M_t, n_t^c = N_t^c$

- $\forall$ SBanks: $b_t^b = B_t^b, m_t^b = M_t^b = M_t, n_t^b = N_t^b$

C.1 Household

C.1.1 Borrowers

$$\hat{U} \equiv \left[u(\hat{c}_1) + j\log\hat{h}_1\right] + \hat{\beta}\left[u(\hat{c}_2) + j\log\hat{h}_2\right]$$

Borrower Budget Constraints:

$$\hat{c}_1 + p_{h,1}\hat{h}_1 \leq \hat{y}_1 + \hat{\omega}_1 + B_1$$

$$\hat{c}_2 + p_{h,2}\hat{h}_2 + (1 - \psi\delta)R_{M,1}B_1 \leq \hat{y}_2 + (1 - \psi\delta)p_{h,2}\hat{h}_1$$

Housing Collateral Constraint:

$$R_{M,1}B_1 \leq \bar{m}_1 E_1 p_{h,2}\hat{h}_1 \qquad\qquad \text{(multiplier:}\hat{\mu}_1) \qquad\qquad\qquad \text{(A.1)}$$

FOCs:

1.

$$\frac{\partial\mathcal{L}_1}{\partial\hat{c}_1} = \hat{u}_{c,1} - \hat{\lambda}_1 = 0 \qquad\qquad\qquad\qquad \text{(A.2)}$$

2.

$$\frac{\partial\mathcal{L}_1}{\partial\hat{h}_1} = \frac{j_1}{\hat{h}_1} - \hat{\lambda}_1 p_{h,1} + \hat{\beta}E_1\left[\hat{\lambda}_2(1 - \psi\delta)p_{h,2}\right] + \hat{\mu}_1\bar{m}_1 E_1 p_{h,2} = 0 \qquad \text{(A.3)}$$

3.

$$\frac{\partial\mathcal{L}_1}{\partial B_1} = \hat{\lambda}_1 - \hat{\beta}E_1\left[\hat{\lambda}_2(1 - \psi\delta)R_{M,1}\right] - \hat{\mu}_1 R_{M,1} = 0 \qquad\qquad \text{(A.4)}$$

4.

$$\frac{\partial\mathcal{L}_2}{\partial\hat{c}_2} = \hat{u}_{c,2} - \hat{\lambda}_2 = 0 \qquad\qquad\qquad\qquad \text{(A.5)}$$

5.

$$\frac{\partial\mathcal{L}_2}{\partial\hat{h}_2} = \frac{j_2}{\hat{h}_2} - \hat{\lambda}_2 p_{h,2} = 0 \qquad\qquad\qquad\qquad \text{(A.6)}$$

C.1.2 Savers ($\tilde{\beta} \geq \hat{\beta}$)

$$\tilde{U} \equiv u(\tilde{c}_1) + \tilde{\beta}^2 u(\tilde{c}_2)$$

Saver Budget Constraints:

$$\tilde{c}_1 + D_1 \leq \tilde{y}_1 + \tilde{\omega}_1$$

$$\tilde{c}_2 \leq \tilde{y}_2 + R_1 D_1 + \Pi_2$$

$\Pi \equiv N_2^c + N_2^b.$

FOCs:

1.
$$\frac{\partial \mathcal{L}_1}{\partial \tilde{c}_1} = \tilde{u}_{c,1} - \tilde{\lambda}_1 = 0 \qquad (A.7)$$

2.
$$\frac{\partial \mathcal{L}_1}{\partial D_1} = -\tilde{\lambda}_1 + \tilde{\beta} E_1 \left[\tilde{\lambda}_2 R_1 \right] = 0 \qquad (A.8)$$

3.
$$\frac{\partial \mathcal{L}_2}{\partial \tilde{c}_2} = \tilde{u}_{c,2} - \tilde{\lambda}_2 = 0 \qquad (A.9)$$

Linear saver utility implies:
$$R_1 = \frac{1}{\tilde{\beta}} \qquad (A.10)$$

And their stochastic discount factor is:
$$\tilde{\Lambda}_{1,2} \equiv \tilde{\beta} \frac{\tilde{\lambda}_2}{\tilde{\lambda}_1} = \tilde{\beta} \qquad (A.11)$$

C.2   Shadow Banks

Net worth:

$$n_1^b \equiv \text{given}$$

$$n_2^b \equiv (1 - \delta\psi) R_{M,1} b_1^b - \bar{R}_{m,1} m_1^b$$

$$(A.12)$$

Period 1 Problem:

$$V_1^b = E_1 \tilde{\Lambda}_{1,2} n_2^b$$
$$= E_1 \tilde{\beta} \left[(1 - \delta\psi) R_{M,1} b_1^b - \bar{R}_{m,1} m_1^b \right]$$
$$= E_1 \tilde{\beta} \left[\left((1 - \delta\psi) R_{M,1} - \bar{R}_{m,1} \right) b_1^b + \bar{R}_{m,1} n_1^b \right] \tag{A.13}$$

The problem is to max V_1^b subject to the ICC:

$$V_1^b \geq \theta_{b,1} b_1^b \tag{A.14}$$

$$\mathcal{L}_1 = E_1 \left\{ V_1^b + \lambda_1^b \left[V_1^b - \theta_{b,1} b_1^b \right] \right\}$$

FOCs:

$$\frac{\partial \mathcal{L}_1}{\partial b_1^b} = E_1 \left\{ \tilde{\beta} \left[(1 - \delta\psi) R_{M,1} - \bar{R}_{m,1} \right] (1 + \lambda_1^b) - \theta_{b,1} \lambda_1^b \right\} = 0 \tag{A.15}$$

$$\frac{\partial \mathcal{L}_1}{\partial \lambda_1^b} = E_1 \left\{ V_1^b - \theta_{b,1} b_1^b \right\} \tag{A.16}$$

Aggregate Net Worth:

$$N_2^b = (1 - \delta\psi) R_{M,1} B_1^b - \bar{R}_{m,1} M_1^b \tag{A.17}$$

Note: plugging in the value function guess (A.13) into the divertibility constraint (A.14) implies at the symmetric equilibrium:

$$\tilde{\beta} \left[\left((1 - \delta\psi) R_{M,1} - \bar{R}_{m,1} \right) b_1^b + \bar{R}_{m,1} n_1^b \right] \geq \theta_{b,1} B_1^b \tag{A.18}$$

C.3 Commercial Banks

$$
n_2^c = \begin{cases} R_{M,1}b_1^c + \bar{R}_{m,1}m_1^c - R_1 d_1, & \text{if ``good'' (non-defaulter) island} \\[2mm] (1-\delta)R_{M,1}b_1^c + \bar{R}_{m,1}m_1^c - R_1 d_1, & \text{if ``bad'' (defaulter) island} \end{cases} \tag{A.19}
$$

Aggregate Net Worth:

$$
N_2^c = (1-\delta\psi)R_{M,1}B_1^c + \bar{R}_{m,1}M_1^c - R_1 D_1 \tag{A.20}
$$

Period 1 Problem:

$$
\max_{b_1^c, d_1, m_1^c} V_1^c = E_1 \tilde{\Lambda}_{1,2}\left\{ (1-\psi)n_2^{c,good} + \psi n_2^{c,bad} \right\} \tag{A.21}
$$

$$
= E_1 \tilde{\beta}\left\{ (1-\psi)n_2^{c,good} + \psi n_2^{c,bad} \right\} \tag{A.22}
$$

subject to:

Their balance sheet identity:

$$
b_1^c + m_1^c = n_1^c + d_1 \tag{A.23}
$$

The Solvency Constraint:

$$
(1-\delta)R_{M,1}b_1^c + \bar{R}_{m,1}m_1^c \geq R_1 d_1 \qquad (\gamma_1^c \geq 0) \tag{A.24}
$$

$$
\mathcal{L}_1 = E_1\left\{ V_1^c + \gamma_1^c\left[((1-\delta)R_{M,1} - R_1)b_1^c + (\bar{R}_{m,1} - R_1)m_1^c + R_1 n_1^c \right] \right\}
$$

FOCs:

$$\frac{\partial \mathcal{L}_1}{\partial b_1^c} = E_1 \left\{ \tilde{\beta} \left[(1 - \psi\delta)R_{M,1} - R_1 \right] + \gamma_1^c ((1 - \delta)R_{M,1} - R_1) \right\} = 0 \tag{A.25}$$

$$\frac{\partial \mathcal{L}_1}{\partial m_1^c} = E_1 \left\{ \tilde{\beta} \left[\bar{R}_{m,1} - R_1 \right] + \gamma_1^c \left[\bar{R}_{m,1} - R_1 \right] \right\} = 0 \tag{A.26}$$

$$\frac{\partial \mathcal{L}_0}{\partial \gamma_0^c} = E_1 \left\{ \left[((1 - \delta)R_{M,1} - R_1)b_1^c + (\bar{R}_{m,1} - R_1)m_1^c + R_1 n_1^c \right] \right\} = 0 \tag{A.27}$$

C.4 Resource Constraints

$$\tilde{c}_1 + \hat{c}_1 = \tilde{y}_1 + \hat{y}_1 + \tilde{\omega}_1 + \hat{\omega}_1 + N_1^c + N_1^b - p_{h,1}\hat{h}_1$$

$$\tilde{c}_2 + \hat{c}_2 = \tilde{y}_2 + \hat{y}_2 - p_{h,2} \left[\hat{h}_2 - (1 - \psi\delta)\hat{h}_1 \right]$$

Housing Supply:

$$\hat{h}_0 = \bar{H} \tag{A.28}$$

$$\hat{h}_1 = \bar{H} \tag{A.29}$$

$$\hat{h}_2 = \bar{H} \tag{A.30}$$

$$\tag{A.31}$$
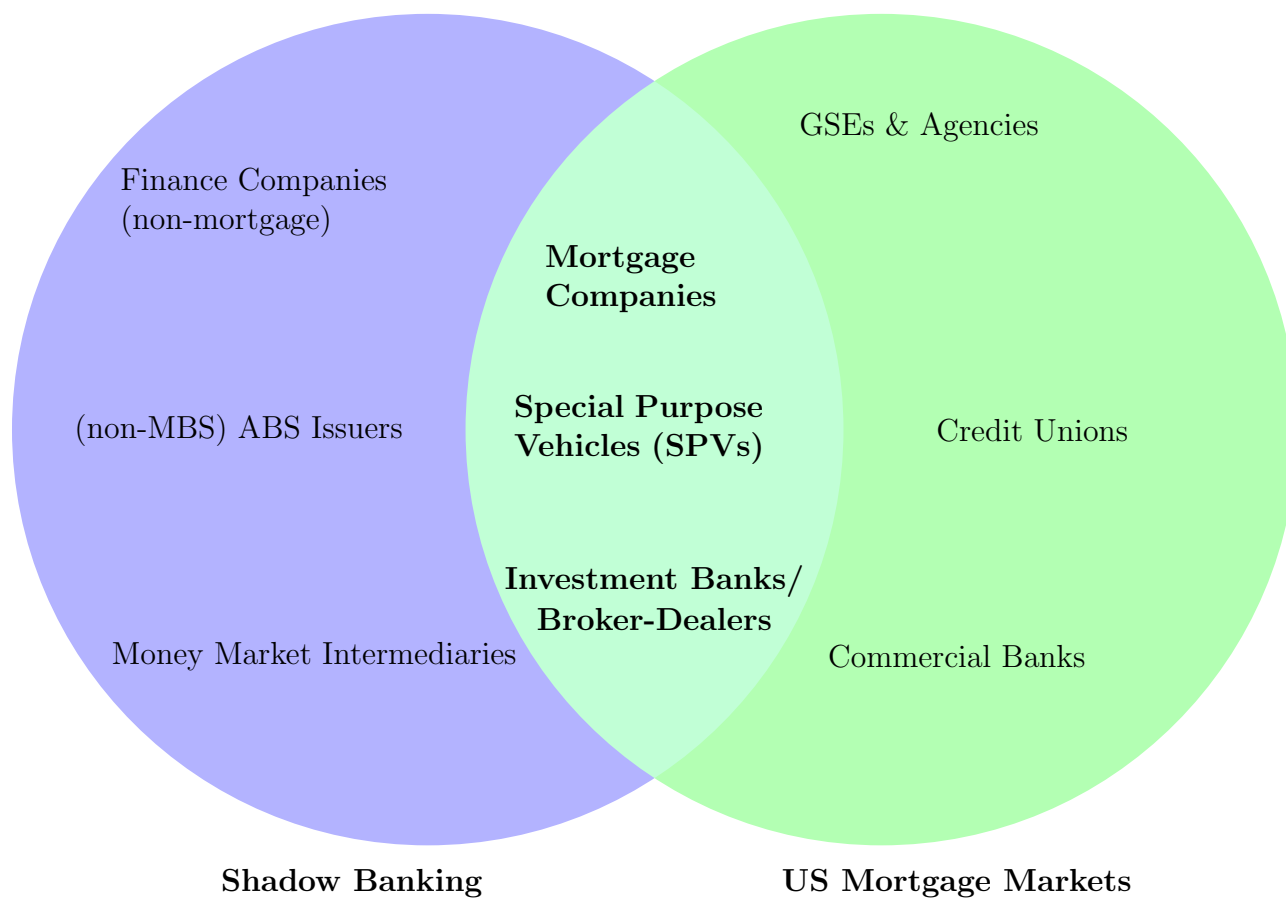
Debt Market:

$$B_1 = B_1^c + B_1^b \tag{A.32}$$

$$\tag{A.33}$$

D   Institutional Details Appendix

Figure 19: Overlap Between Shadow Banking and US Mortgage Markets

Finance Companies
(non-mortgage)

GSEs & Agencies

**Mortgage
Companies**

(non-MBS) ABS Issuers

**Special Purpose
Vehicles (SPVs)**

Credit Unions

**Investment Banks/
Broker-Dealers**

Money Market Intermediaries

Commercial Banks

Shadow Banking

US Mortgage Markets

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

Figure 20: Mortgage Securitization Process in Reality vs Model Simplification
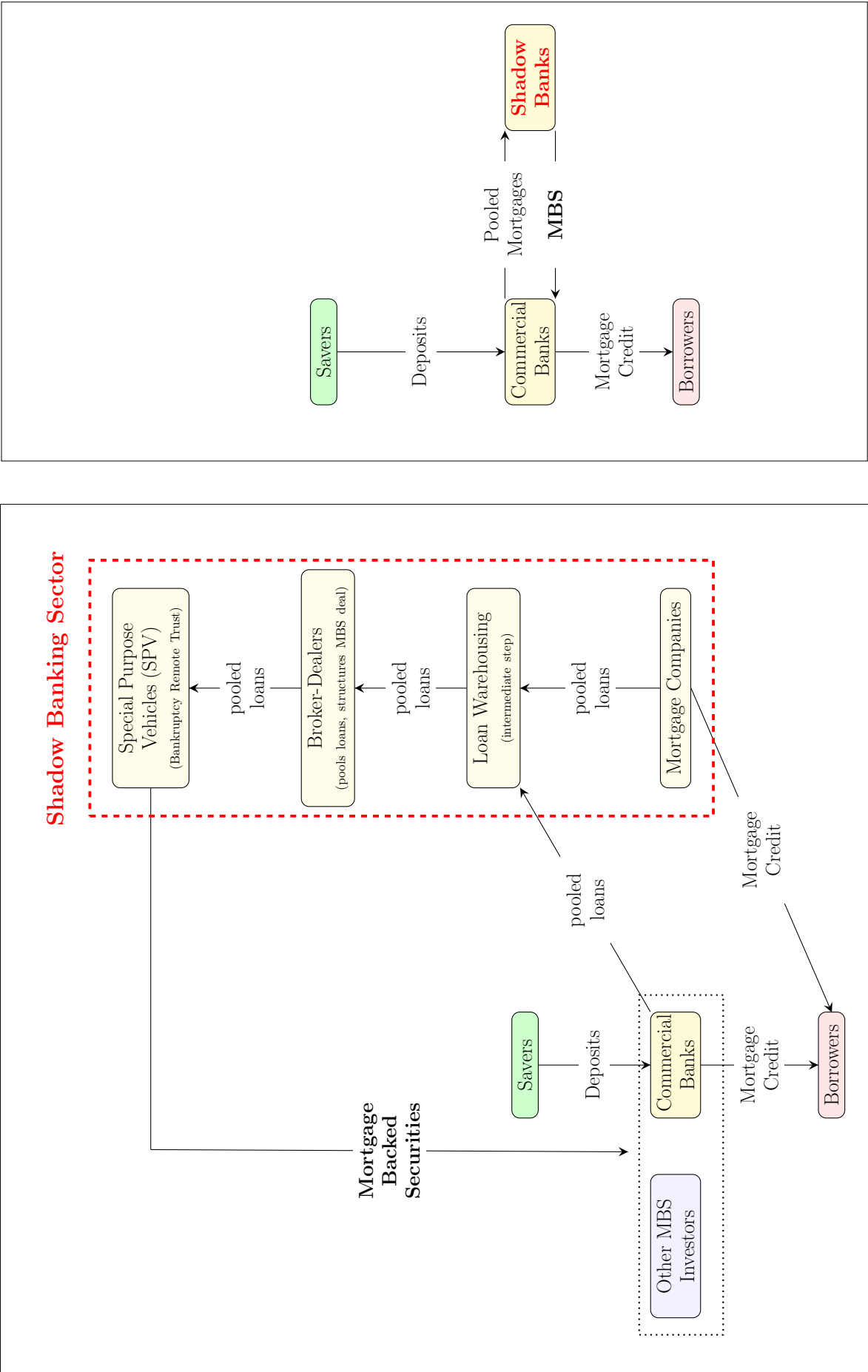
(a) Shadow Banking Sector in Reality

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

(b) Model Simplification