Structural Models of Housing and Mortgages

Dan Greenwald, NYU Stern

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Introduction

- Today's lecture: structural models of housing and mortgages.
  - Why? Dominant asset for typical household, while mortgage is the dominant liability.
  - What determines house prices at equilibrium?
  - What role does credit play?

- Road map:
  1. Basic setup.
  2. Credit standards: LTV vs. PTI limits.
  3. How segmented are housing markets?
  4. Some final thoughts about the research process.

Why use models?

- Why bother writing down structural models? Motivating example from history.
- In the 1990s, GSEs switched to automated underwriting (Johnson and Tsur-Ilan, 2025).
  - Automated underwriting $\approx$ use fitted values from a default regression, accept if low enough.
- Cross-sectionally, payment-to-income (a.k.a. "DTI") ratio is not a good predictor of default (De Fusco, Johnson, Mondragon, 2020).
  - More important whether you lose your job than what your income was while employed.
  - As a result, new automated underwriting rules basically ignored this variable.
- But this cross-sectional regression failed to take into account **general equilibrium effects** of having largest underwriters remove this constraint on house prices.
  - Led to large boom and bust that left many households underwater, causing defaults.
- Models we cover today designed to capture GE effects and counterfactual policies.

Basic Setup

Household's Problem

- Let's consider the basic problem of a household who optimizes

$$V_t(h_{t-1}, y_t) = u(c_t, h_{t-1}) + \beta E_t \Big[V_{t+1}(h_t, y_{t+1}) \Big]$$

where h is housing, c is nondurable consumption, y is income, subject to

$$c_t \leq y_t - \underbrace{p_t \big(h_t - (1 - \delta) h_{t-1} \big)}_{\text{net housing purchased}} .$$

- Lagrangian:

$$\mathcal{L} = u(c_t, h_{t-1}) + \beta E_t \Big[V_{t+1}(h_t, y_{t+1}) \Big] + \lambda_t \left(y_t - p_t \big(h_t - (1 - \delta) h_{t-1} \big) - c_t \right)$$

- First-order conditions (where e.g., $u_{c,t} = \partial u(c_t, h_{t-1}) / \partial c_t$):

$$(c_t) : u_{c,t} = \lambda_t$$

$$(h_t) : \lambda_t p_t = \beta E_t \Big[V_{h,t+1}(h_t, y_{t+1}) \Big]$$

Household's Problem

- Envelope theorem:

$$V_{h,t+1}(h_t, y_{t+1}) = u_{h,t+1} + (1-\delta)\lambda_{t+1}p_{t+1} = \lambda_{t+1}\left(\frac{u_{h,t+1}}{\lambda_{t+1}} + (1-\delta)p_{t+1}\right)$$

- Putting it all together:

$$p_t = E_t\left\{\beta\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{u_{h,t+1}}{\lambda_{t+1}} + (1-\delta)p_{t+1}\right)\right\} = E_t\left\{\beta\left(\frac{u_{c,t+1}}{u_{c,t}}\right)\left(\frac{u_{h,t+1}}{u_{c,t+1}} + (1-\delta)p_{t+1}\right)\right\}$$
$$= E_t\Big[\Lambda_{t+1}\big(\rho_{t+1} + (1-\delta)p_{t+1}\big)\Big]$$

where the implied rent ρ_{t+1} and stochastic discount factor Λ_{t+1} are defined by

$$\rho_{t+1} = \frac{u_{h,t+1}}{u_{c,t+1}} \qquad \Lambda_{t+1} = \beta\frac{u_{c,t+1}}{u_{c,t}}.$$

Adding Credit

- Now let's add in mortgage credit following e.g., Iacoviello (2005).
- Assume household can borrow at rate R_m subject to a loan-to-value (LTV) limit.
- Budget constraint becomes (π_t is inflation):

$$c_t \leq y_t - \underbrace{p_t \big(h_t - (1 - \delta) h_{t-1}\big)}_{\text{net housing purchased}} + \underbrace{m_t - \pi_t^{-1} R_{m,t-1} m_{t-1}}_{\text{net new credit}}$$

- We add a **loan-to-value constraint**:

$$m_t \leq \theta p_t h_t$$

where θ is the maximum LTV ratio.

Adding Credit

- New Lagrangian:

$$\mathcal{L} = u(c_t, h_{t-1}) + \beta E_t \Big[V_{t+1}(h_t, m_t, y_{t+1}) \Big]$$
$$\lambda_t \Big\{ \big(y_t - p_t \big(h_t - (1-\delta) h_{t-1}\big) - c_t + m_t - \pi_t^{-1} R_{m,t-1} m_{t-1}\big) + \mu_t \big(\theta p_t h_t - m_t\big) \Big\}$$

- New optimality conditions

$$(h_t) : \lambda_t p_t = \beta E_t \Big[V_{h,t+1}(h_t, y_{t+1}) \Big] + \lambda_t \mu_t \theta p_t$$
$$(m_t) : \lambda_t \mu_t = \lambda_t + \beta E_t \Big[V_{m,t+1}(h_t, m_t, y_{t+1}) \Big]$$

- Rearranging using envelope condition $V_{m,t+1} = -\lambda_{t+1} \pi_{t+1}^{-1} R_{m,t}$:

$$(h_t) : p_t = \frac{E_t \Big[\Lambda_{b,t+1} \Big(\rho_{t+1} + (1-\delta) p_{t+1} \Big) \Big]}{1 - \mu_t \theta}$$
$$(m_t) : \mu_t = 1 - R_{m,t} E_t \Big[\pi_{t+1}^{-1} \Lambda_{b,t+1} \Big]$$

Adding Credit

- Incorporating credit and an LTV limit added a new term to the house price:

$$p_t = \frac{E_t\left[\Lambda_{b,t+1}\left(\rho_{t+1} + (1-\delta)p_{t+1}\right)\right]}{1 - \mu_t\theta}$$

- Denominator < 1, so prices are higher than without credit.
- New term $\mu_t\theta$ reflects the **collateral value** of housing.
  - θ: the extra amount you can borrow for each \$1 of housing purchased.
  - μ_t: the shadow value of an extra \$1 of credit.
  - Marginal collateral benefit is the product of the two.

Adding Credit

- Recall that μ_t can be pinned down by the optimality condition ($\Lambda_{b,t+1}$ is borrower SDF):

$$\mu_t = 1 - R_{m,t} E_t \Big[\underbrace{\pi_{t+1}^{-1} \Lambda_{b,t+1}}_{\text{nominal SDF}} \Big]$$

- If we define $R_{b,t}$ to be the nominal rate at which the borrower would willingly save, we have

$$1 = R_{b,t} E_t \left[\pi_{t+1}^{-1} \Lambda_{b,t+1} \right].$$

- Substituting, we obtain

$$\mu_t = 1 - \frac{R_{m,t}}{R_{b,t}} = \frac{R_{b,t} - R_{m,t}}{R_{b,t}}.$$

- In steady state (where β_s is the saver discount factor):

$$\mu = \frac{\beta_s - \beta_b}{\beta_s}.$$

House Prices and Credit Constraints

Justiniano, Primiceri, Tambalotti (2019)

- In simple LTV-only model, increasing θ increases prices.
- Now consider extension with two constraints, no heterogeneity:

$$m_t \leq \theta p_t^h h_t$$
$$m_t \leq \bar{M}_t.$$

- Optimality conditions:

$$p_t^h = \frac{E_t\left[\Lambda_{b,t+1}\left(\rho_{t+1} + p_{t+1}^h\right)\right]}{1 - \theta\mu_{1,t}}$$
$$\mu_t \equiv \mu_{1,t} + \mu_{2,t} = 1 - R_t E_t\left[\Lambda_{b,t+1}\right]$$

- Surprising result: region of state space with positive measure where both constraints bind.

Justiniano, Primiceri, Tambalotti (2019)

- Proof by contradiction.
- If only collateral constraint binds, $\mu_{1,t} = \mu_t$ and price is

$$\bar{p}_t^h = \frac{E_t \left[\Lambda_{b,t+1} \left(\rho_{t+1} + p_{t+1}^h\right)\right]}{1 - \theta\mu_t}$$

- If only alternative constraint binds, $\mu_{1,t} = 0$ and price is

$$\underline{p}_t^h = E_t \left[\Lambda_{b,t+1} \left(\rho_{t+1} + p_{t+1}^h\right)\right] < \bar{p}_t^h$$

- For $\theta \underline{p}_t^h h_t \leq \bar{M}_t \leq \theta \bar{p}_t^h h_t$, must have both constraints binding (only way to get $0 < \mu_{1,t} < \mu_t$).
- In this region, we have $p_t^h = \bar{M}_t / \theta h_t$.
  - Price moves one-for-one with $\bar{M}_t$, while price falls with θ.

Justiniano, Primiceri, Tambalotti (2019)

- JPT further claim that second constraint $\bar{M}$ needs to be on lender side.
- Demand-driven credit booms have counterfactual prediction that interest rates should rise:

$$R_t = \frac{1 - \mu_t}{\beta E_t \left[\Lambda_{b,t+1} \right]}$$

since $\mu_t \to 0$ as constraints loosen.

- Instead, can use lending supply constraint:

$$R_t = \frac{1 + \tilde{\mu}_t}{\beta E_t \left[\Lambda_{s,t+1} \right]}$$

where $\bar{\mu}$ is lender multiplier.

- Now rates fall as $\bar{\mu} \to 0$, matching boom experience.

Justiniano, Primiceri, Tambalotti (2019)

- What's behind these results?
- Rate borrowers are willing to pay higher than rate lenders willing to accept.
- When only borrowers are constrained, effectively have all bargaining power, lenders forced to compete for them.
  - Equilibrium rate is lender reservation rate.
- When only lenders are constrained, situation is reversed, rate is borrower reservation rate.
- At the end of the day, comes down to assumptions on who has bargaining power. Can support many prices when credit is rationed.
  - Possible area for future research!

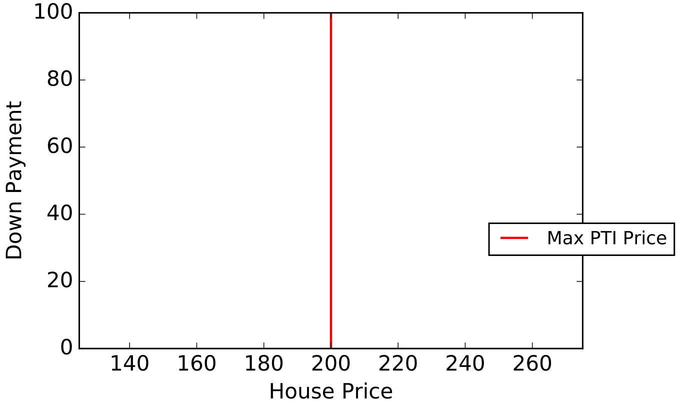
LTV vs. PTI Limits

Greenwald (2018)

- **“The Mortgage Credit Channel of Macroeconomic Transmission”**
- **Approach**: General equilibrium framework with two novel features.
  1. Size of new loans limited by **payment-to-income** (PTI) constraint, alongside loan-to-value (LTV) constraint.
  2. Borrowers hold long-term, fixed-rate loans and can choose to prepay existing loans and replace with new ones (**see paper**).
- **Main Finding**: PTI liberalization appears essential to boom-bust.
  - Changes in LTV standards alone insufficient. PTI liberalization compelling theoretically and empirically.
  - Quantitative impact: 35% of observed rise in price-rent ratios, 42% of the rise in debt-household income from PTI relaxation alone.

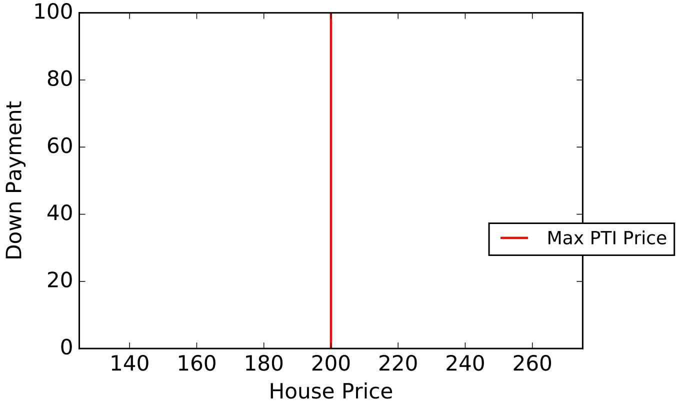
Simple Example

- Consider homebuyer who wants large house, minimal down payment. Faces PTI limit of 28%, LTV limit of 80%.



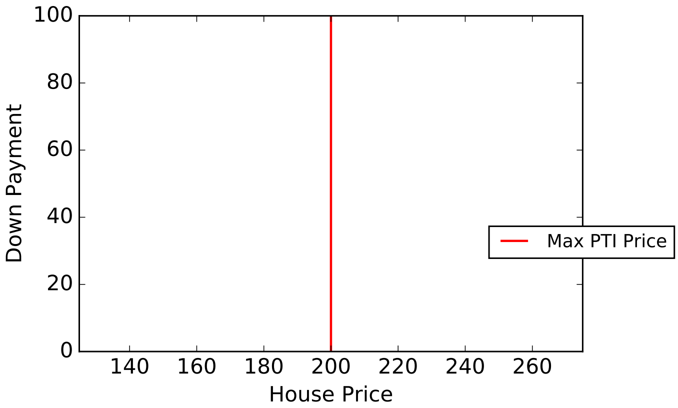
Simple Example

- At income of \$50k per year, 28% PTI limit $\implies$ max monthly payment of $\sim$ \$1,200.



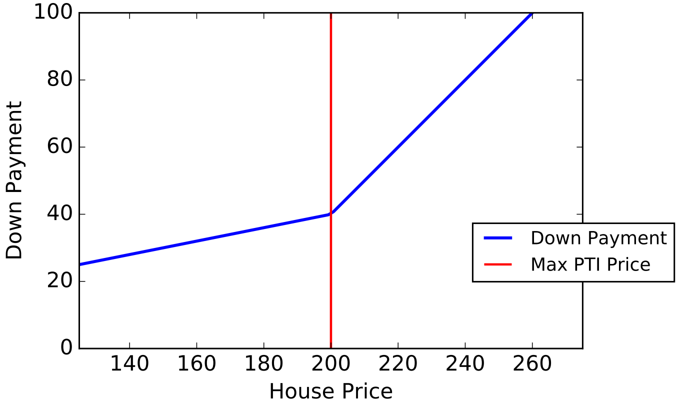
Simple Example

- At 6% interest rate, \$1,200 payment $\implies$ maximum PTI loan size \$160k. Plus 20% down payment $\implies$ house price of \$200k.



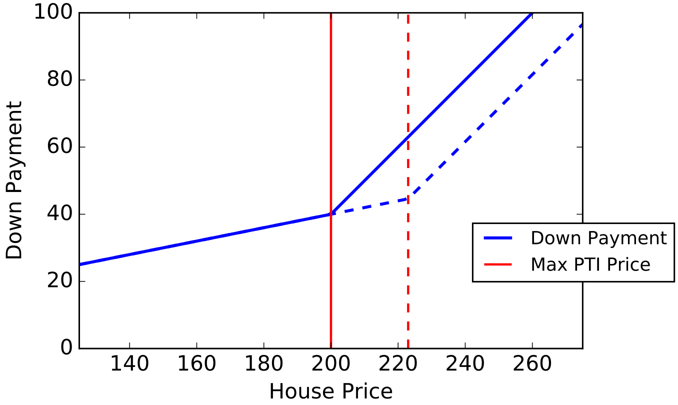
Simple Example

- Kink in down payment at price $200k. Below this point size of loan limited by LTV, above by PTI. Kink likely optimum for homebuyers.



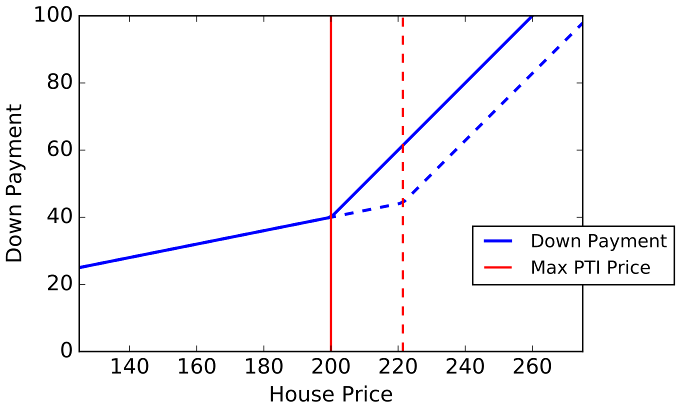
Simple Example

- Interest rates fall from 6% to 5%. Borrower's max PTI now limits loan to $178k (rise of 11%). Kink price now $223k, housing demand increases.



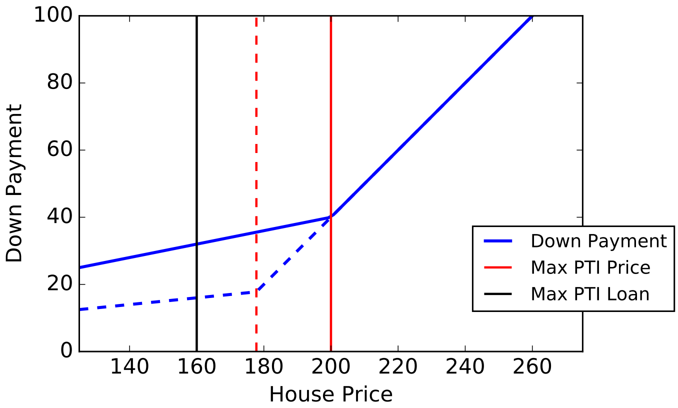
Simple Example

- Increasing the maximum PTI ratio from 28% to 31% has a similar effect to fall in rates, increases max loan size and corresponding price.



Simple Example

- In contrast, increasing maximum LTV ratio from 80% to 90% means that $160k loan associated with only $178k house. Housing demand **falls**.



Model Overview

- Borrowing $\Longrightarrow$ impatient borrowers/patient savers.
  - Permanent types with fixed measure χ_j for $j \in \{b, s\}$.
  - Preferences:

$$V_{j,t} = \log(c_{j,t}/\chi_j) + \xi \log(h_{j,t}/\chi_j) - \eta \frac{(n_{j,t}/\chi_j)^{1+\varphi}}{1+\varphi} + \beta_j E_t V_{j,t+1}$$

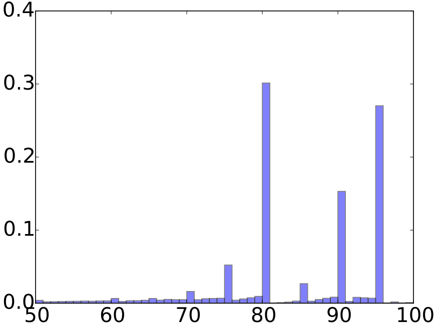
- Mortgage debt $\Longrightarrow$ durable housing.
  - Divisible, cannot change stock without prepaying mortgage.
  - Fixed housing stock, saver housing demand.
- Realistic mortgage contracts $\Longrightarrow$ long-term fixed-rate bonds
  - Endogenous fraction ρ_t prepay each period, update balance and interest rate.
- Movements in long rates $\Longrightarrow$ shock to inflation target (nominal), term premia (real).
- Effects on real economy $\Longrightarrow$ labor supply, sticky prices, TFP shocks.

Credit Limits

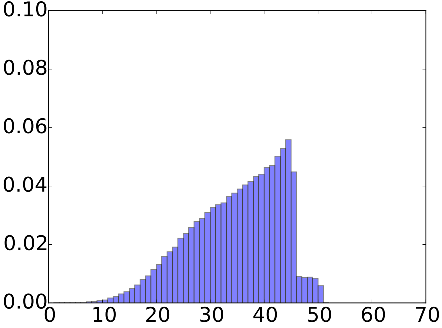
- Borrowers face two credit limits **at origination only**.
- **Loan-to-value** constraint: $m^*_{i,t} \leq \theta^{ltv} p^h_t h^*_{i,t}$.
  - Widely studied in the literature.
  - Key property: moves with house prices.
  - $\bar{m}^{ltv}_{i,t} \equiv \theta^{ltv} p^h_t h^*_{i,t}$.
- **Payment-to-income** constraint: $(r^*_t + \alpha) m^*_{i,t} \leq (\theta^{pti} - \omega) \cdot \text{income}_{i,t}$.
  - Real constraint affecting all US borrowers, but largely unstudied in macro.
  - Key property: moves with interest rates (elasticity $\simeq 8$).
  - $\bar{m}^{pti}_{i,t} \equiv (\theta^{pti} - \omega) \cdot \text{income}_{i,t} / (r^*_t + \alpha)$.
- Overall limit: $m^*_{i,t} \leq \min\left(\bar{m}^{ltv}_{i,t}, \bar{m}^{pti}_{i,t}\right)$.

LTV and PTI in the Data

- LTV limits show up as large single-bin spikes at various institutional limits.



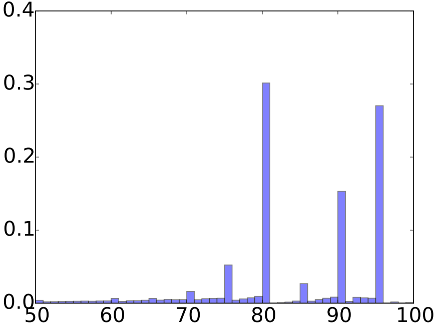
(a) CLTV Histogram: 2014 Q3



(b) PTI Histogram: 2014 Q3

LTV and PTI in the Data

- PTI ratios instead look like truncated distribution. Are borrowers constrained?



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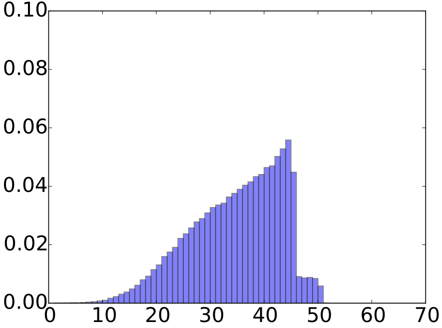
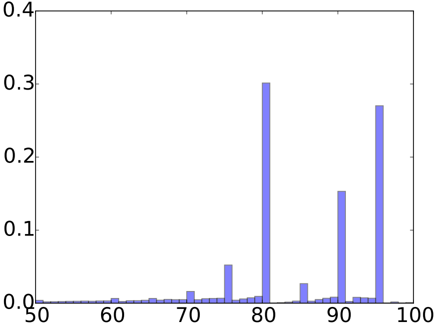


(b) PTI Histogram: 2014 Q3

LTV and PTI in the Data

- Interpretation: some borrowers search for a house that exactly satisfies both limits, but may end up with one a little smaller. Then max out LTV.



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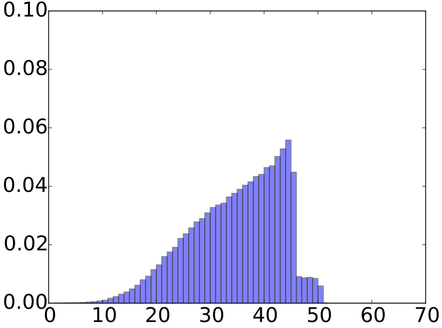
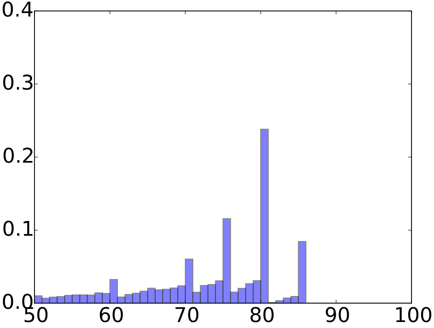


(b) PTI Histogram: 2014 Q3

LTV and PTI in the Data

- Support for theory: PTI bunching larger in cash-out refinances, where no housing search occurs (even though LTVs lower).



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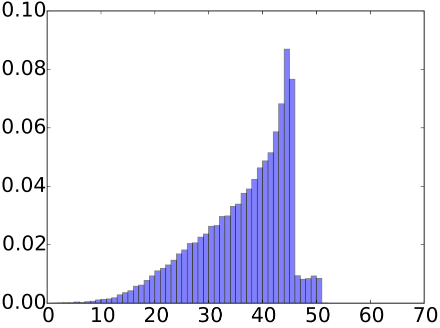

(b) PTI Histogram: 2014 Q3

Representative Borrower's Housing Decision

- Housing optimality condition (unconstrained or no LTV):

$$p_t^h = \frac{u_{b,t}^h / u_{b,t}^c + E_t \left\{ \Lambda_{b,t+1} p_{t+1}^h \left[1 - \delta \qquad \right] \right\}}{1}$$

- $\Lambda_{b,t+1}$ is borrower stochastic discount factor, μ_t is multiplier on credit constraint.

- $\mathcal{C}_t$ ("collateral value") is marginal value of relaxing constraint via extra \$1 of house value:

$$\mathcal{C}_t = \mu_t F_t^{ltv} \theta^{ltv}$$

where F_t^{ltv} is fraction constrained by LTV.

- Note: p_t^h is the price of housing that can be used to collateralize a new loan.

Representative Borrower's Housing Decision

- Housing optimality condition ($\rho_{t+1} = 1$, LTV only):

$$p_t^h = \frac{u_{b,t}^h / u_{b,t}^c + E_t \left\{ \Lambda_{b,t+1} p_{t+1}^h \left[1 - \delta \qquad \right] \right\}}{1 - \mu_t \theta^{ltv}}$$

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Representative Borrower's Housing Decision

- Housing optimality condition ($\rho_{t+1} = 1$, LTV and PTI):

$$p_t^h = \frac{u_{b,t}^h / u_{b,t}^c + E_t \left\{ \Lambda_{b,t+1} p_{t+1}^h \left[1 - \delta \qquad\qquad\qquad \right] \right\}}{1 - \mathcal{C}_t}$$

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- Note: p_t^h is the price of housing that can be used to collateralize a new loan.

Representative Borrower's Housing Decision

- Housing optimality condition (Benchmark model):

$$p_t^h = \frac{u_{b,t}^h / u_{b,t}^c + E_t \left\{ \Lambda_{b,t+1} p_{t+1}^h \left[1 - \delta - (1 - \rho_{t+1}) \mathcal{C}_{t+1} \right] \right\}}{1 - \mathcal{C}_t}$$

- $\Lambda_{b,t+1}$ is borrower stochastic discount factor, μ_t is multiplier on credit constraint.

- $\mathcal{C}_t$ ("collateral value") is marginal value of relaxing constraint via extra $1 of house value:

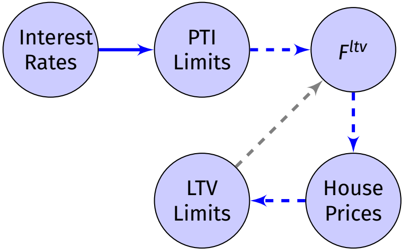
$$\mathcal{C}_t \equiv \mu_t F_t^{ltv} \theta^{ltv}$$

  where F_t^{ltv} is fraction constrained by LTV.

- Note: p_t^h is the price of housing that can be used to collateralize a new loan.

Constraint Switching Effect

- When rates fall, PTI limits loosen.
- Borrowers switch from PTI-constrained to LTV-constrained, increasing F_t^{ltv}.
- House prices rise, also loosening LTV limits.

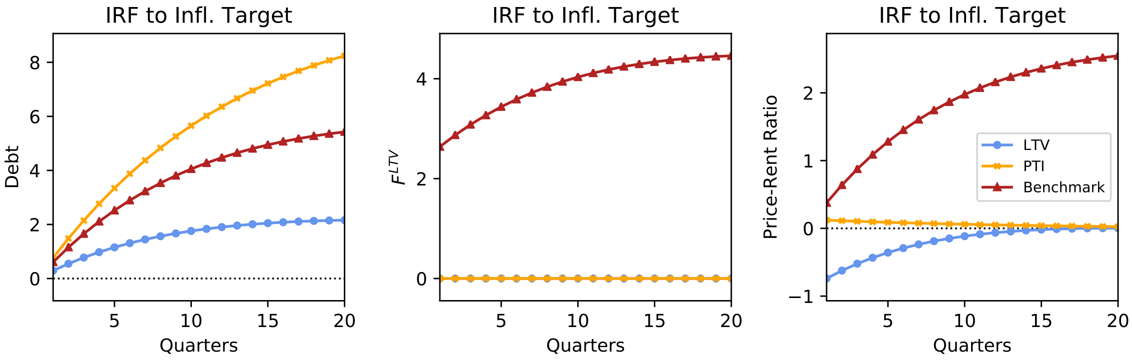


Comparison of Models

- **Main Result #1:** Strong transmission from interest rates into debt, house prices, output.
- **Experiment:** consider economies that differ by credit limit and compare propagation of shocks:
  1. **LTV Economy**: LTV constraint only.
  2. **PTI Economy**: PTI constraint only.
  3. **Benchmark Economy**: Both constraints, applied borrower by borrower.
- **Computation:** Linearize model to obtain impulse responses.

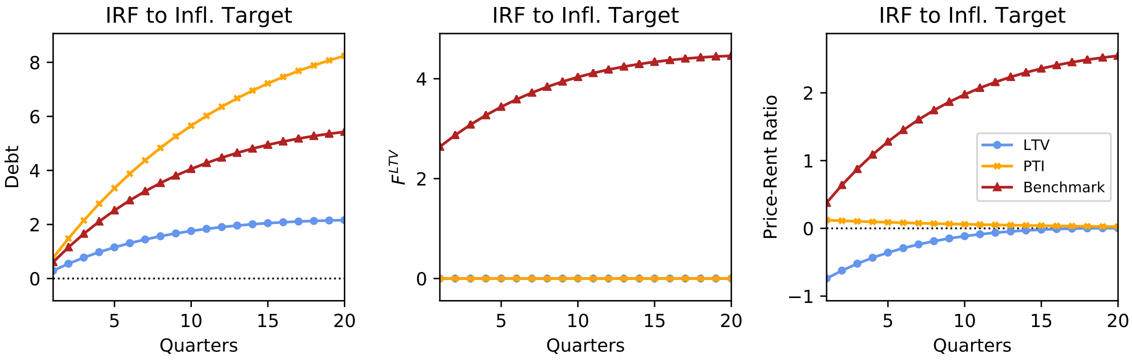
Constraint Switching Effect (Monetary Policy Shock)

- Important feature of PTI limits: endogenously shifted by interest rates.
- IRF to near-permanent -1% (annualized) fall in nominal rates (trend inflation).



Constraint Switching Effect (Monetary Policy Shock)

- Debt response of Benchmark Economy closer to PTI Economy even though most borrowers constrained by LTV (75% in steady state).

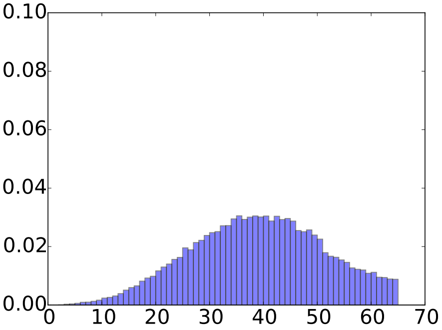


Credit Standards and the Boom-Bust

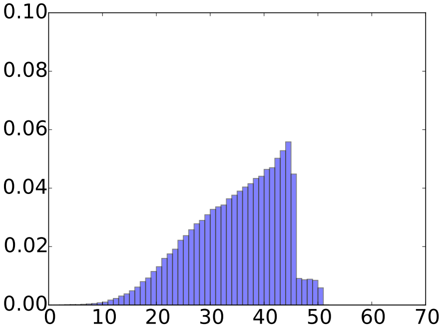
- **Main Finding:** PTI liberalization essential to the boom-bust.
  - So far, have been treating maximum ratios $\theta^{ltv}, \theta^{pti}$ as fixed, but credit standards can change.
  - Fannie/Freddie origination data: substantial increase in PTI ratios in boom.

Credit Standards and the Boom-Bust

- Fannie Mae data: PTI constraints appear to bind after bust but not during boom.



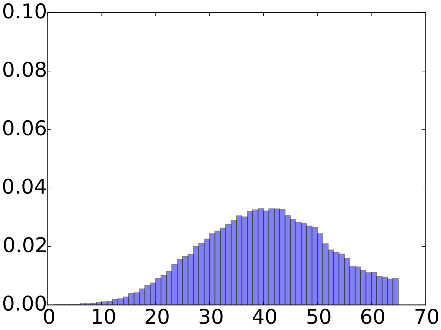
(a) PTI Histogram: 2006 Q1



(b) PTI Histogram: 2014 Q3

Credit Standards and the Boom-Bust

- Cash-out refi plots even more striking.



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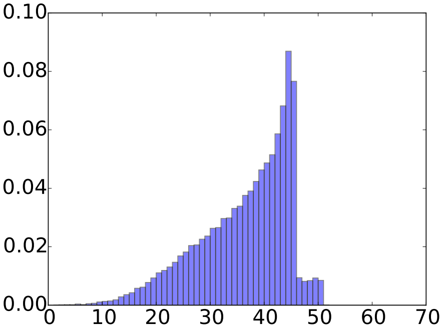

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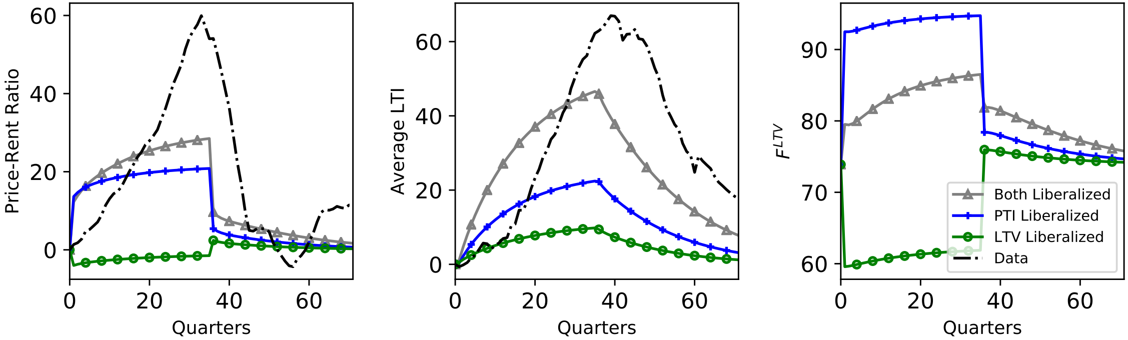
Credit Standards and the Boom-Bust

- **Main Finding:** PTI liberalization essential to the boom-bust.
  - So far, have been treating maximum ratios $\theta^{ltv}, \theta^{pti}$ as fixed, but credit standards can change.
  - Fannie/Freddie origination data: substantial increase in PTI ratios in boom.
- **Experiment**: unexpectedly change parameters, unexpectedly return to baseline 32Q later.
  1. **PTI Liberalization**: θ^{pti} from 0.36 $\to$ 0.54.
  2. **LTV Liberalization**: θ^{ltv} from 0.85 $\to$ 0.99.
- Computation: nonlinear transition paths.
  - Reference: Juillard, Laxton, McAdam, Pioro (1998).

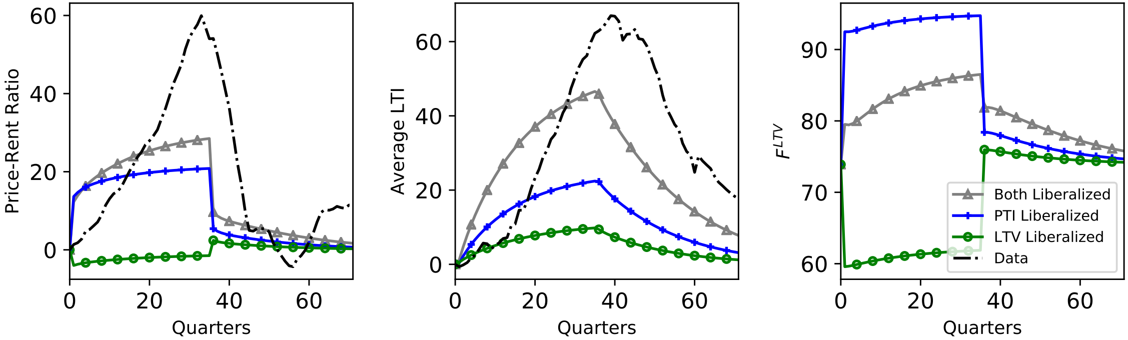
Credit Liberalization Experiment

- LTV liberalization generates small rise in debt-to-household income (15%). House prices, price-rent ratios **fall** (-2%).



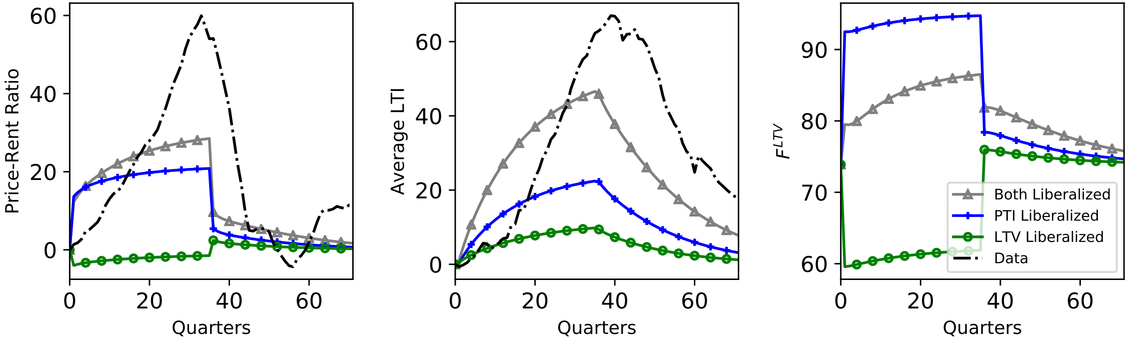
Credit Liberalization Experiment

- PTI liberalization generates large boom in house prices, price-rent ratios (35%), debt-household income (33%).



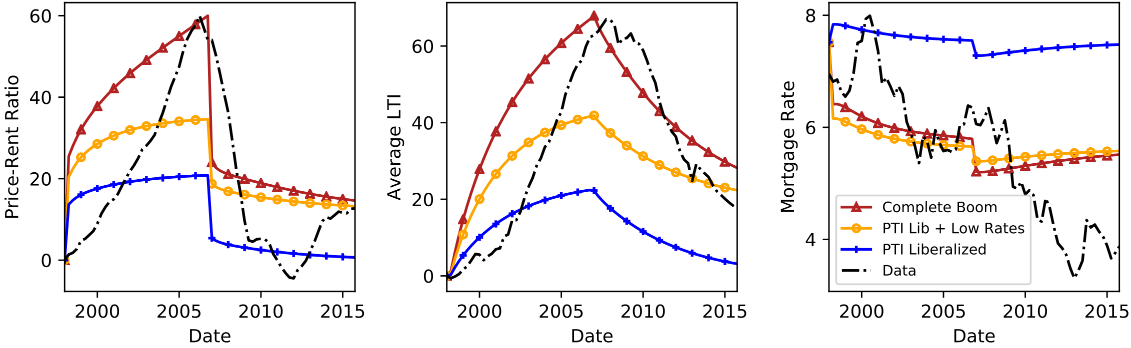
Credit Liberalization Experiment

- Liberalized PTI amplifies contribution of other factors (e.g., LTV liberalization) to boom.



Explaining the Boom

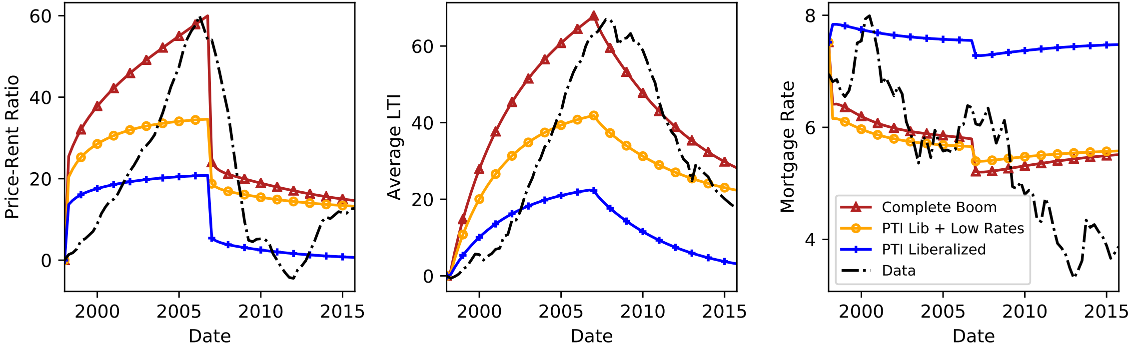
- Add observed drop in mortgage rates: 0.82% fall in expected inflation, 1.08% fall in real rates. Captures 58% of price-rent, 62% of LTI increases.



▸ More Series

Explaining the Boom

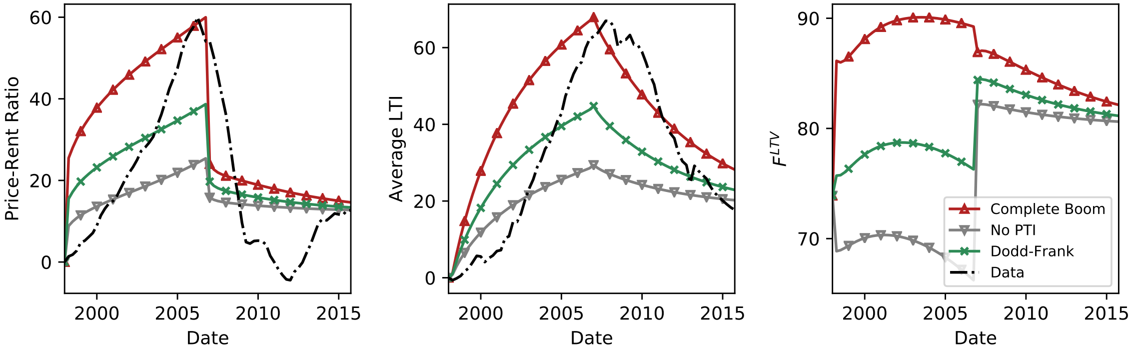
- Overoptimistic HP beliefs (anticipated 24% increase in utility) small increase in LTV limit (85% $\rightarrow$ 88%) can explain remaining share.



More Series

Macroprudential Policy

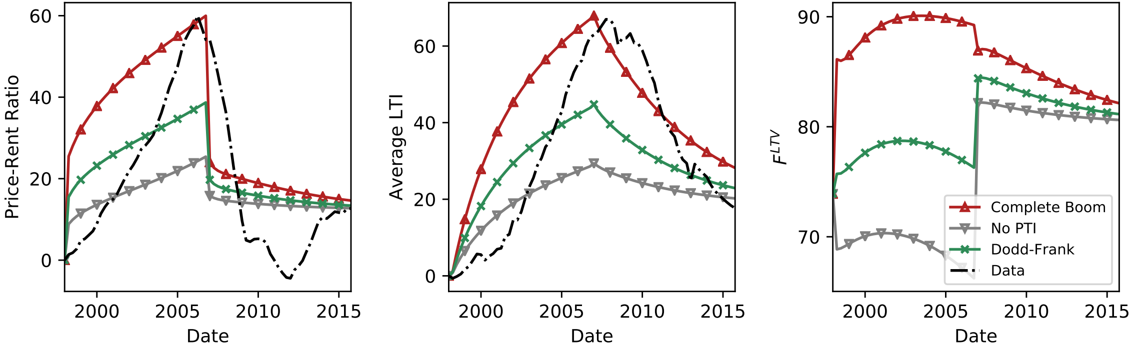
- But without PTI liberalization, other forces severely diminished, explain only 42% of price-rent, 43% of debt-income $\implies$ necessary condition.



More Series

Macroprudential Policy

- Liberalizing PTI only to Dodd-Frank limit of (36% $\rightarrow$ 43%) would have made a big difference (down to 65% of price-rent, debt-income).



▸ More Series

Summary: Credit Standards

- Two key constraints in US mortgage market: LTV and PTI.
- Interaction $\implies$ constraint switching effect:
  - Shifts in PTI limits lead to large movements in house prices.
- Loosening PTI limits key to 2000s housing boom.
  - Largest change in credit standards from microdata.
  - Model: observed PTI relaxation alone can explain $\sim 1/3$ of boom.
  - Removing PTI would kill $\sim 60\%$ of boom due to interaction with expectations.
- Note: PTI limits has loosened again (to a smaller but significant degree).

How segmented are housing markets?

Greenwald and Guren (2025)

- **Do Credit Conditions Move House Prices?**
- Previous paper considers which constraint was most relevant for housing boom.
- Broader debate in the literature: did credit matter at all?
  - Fundamental question for macroprudential policy.
- Two prominent (and opposing) examples:
  - Faviliukis-Ludvigson-Van Nieuwerburgh: Credit explains most (60%) of movement in prices.
  - Kaplan-Mitman-Violante: Credit had virtually no effect on prices.

Favilukis, Ludvigson, Van Nieuwerburgh (2017 JPE)

- Large scale heterogeneous agent life-cycle model with idio + aggregate shocks.
- Financial market liberalization (modeled as increase in LTV ratio) explains housing boom.
- Two separate contributions of LTV relaxation:
  - Increase in collateral value.
  - Fall in risk premia due to improved risk sharing.
- Risk sharing result likely depends on how mortgage contract is modeled.
  - Hurst and Stafford (2004) show this is an important margin.
  - FLVN use one-period debt, ideal for consumption smoothing in normal times/boom.
  - With realistic debt that is long-term, costly to refinance, risk-sharing impact may be smaller.

Kaplan, Mitman, Violante (2020 JPE)

- Large scale heterogeneous agent life-cycle model with idio + aggregate shocks.
- Financial market liberalization (modeled as increase in LTV + PTI ratios) **cannot** explain housing boom.
  - Relaxation of credit leads households to buy from their landlords.
  - Increases the homeownership rate, but not the price-rent ratio.
- Instead, shocks to **expectations** of future rental growth explain the rise in price-rent ratio.

Greenwald and Guren (2025)

- **Do Credit Conditions Move House Prices?**
- Previous paper considers which constraint was most relevant for housing boom.
- Broader debate in the literature: did credit matter at all?
  - Fundamental question for macroprudential policy.
- Two prominent (and opposing) examples:
  - Faviliukis-Ludvigson-Van Nieuwerburgh: Credit explains most (60%) of movement in prices.
  - Kaplan-Mitman-Violante: Credit had virtually no effect on prices.
- Key difference: Extent to which **credit insensitive** agents absorb credit-driven demand.
  - Depends on degree of **segmentation** in housing markets.

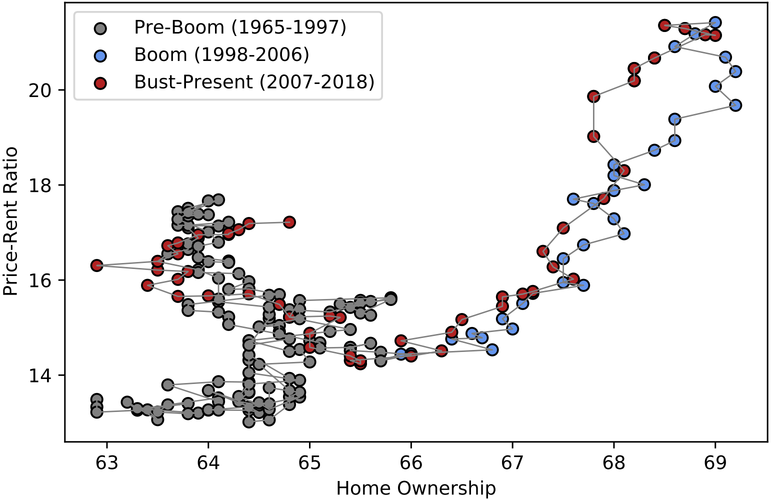
Greenwald and Guren (2025)

- Clearest in **rental market**, where two polar assumptions are often used:
- **Perfectly segmented**: Fixed homeownership rate.
  - Credit $\rightarrow$ demand $\rightarrow$ prices (e.g., FLVN).
- **Perfectly frictionless**: Deep-pocketed landlords who do not use credit.
  - When credit loosens, renters buy from landlord, prices pinned down by PV of rents (e.g., KMV).
- **Unconstrained savers** can play similar role unless their housing is segmented.

Greenwald and Guren (2025)

- **Main Question:** How sensitive are house prices to credit standards and interest rates?
- **Approach:** Tractable macro-housing framework + novel empirical estimates.
  - **Introduce model** with arbitrary degree of segmentation through heterogeneity, nesting polar cases.
  - **New empirical moment for calibration**: Relative causal elasticity of price-rent and homeownership to credit supply shock is sufficient statistic for degree of segmentation.
  - **Calibrate model** to match empirical findings, then decompose boom-bust.
- **Main Findings:**
  - Price-rent ratio responds at least **3**$\times$ more to identified credit shock than homeownership.
  - Change in credit standards as in 2000s explains **32% and 53%** of price-rent rise.
  - Close to full segmentation model, much stronger than no segmentation model.

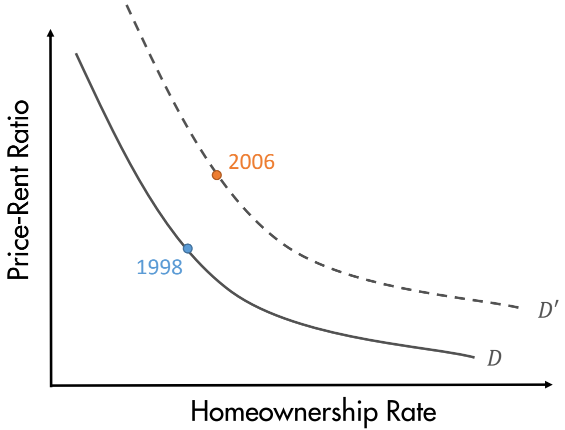
Time Series: Price-Rent Ratio vs. Home Ownership Rate



National data. Price/Rent: Flow of Funds. Homeownership: Census.

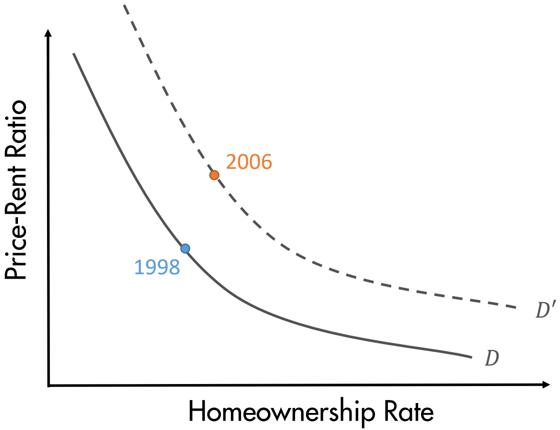
Intuition: Modified Supply and Demand

- Plot demand for owner-occupied housing. Price-rent ratio and homeownership rate robust to changes in housing stock.



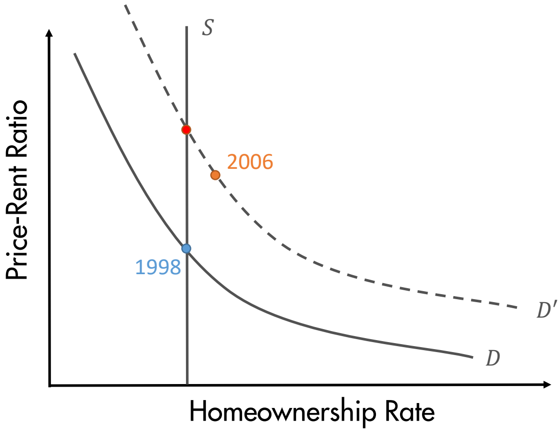
Intuition: Modified Supply and Demand

- Credit expansion: Demand for owner-occupied housing shifts right.



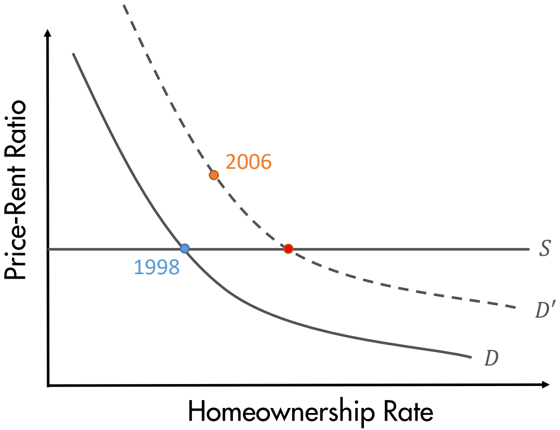
Intuition: Modified Supply and Demand

- Fixed "supply" (homeownership rate) $\implies$ all adjustment through price-rent ratio.



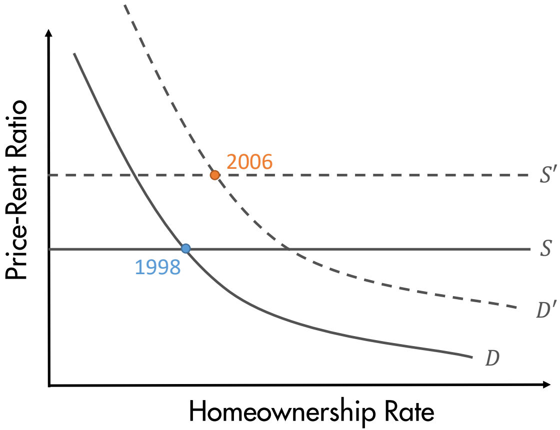
Intuition: Modified Supply and Demand

- Perfect rental market $\implies$ all adjustment through homeownership rate.



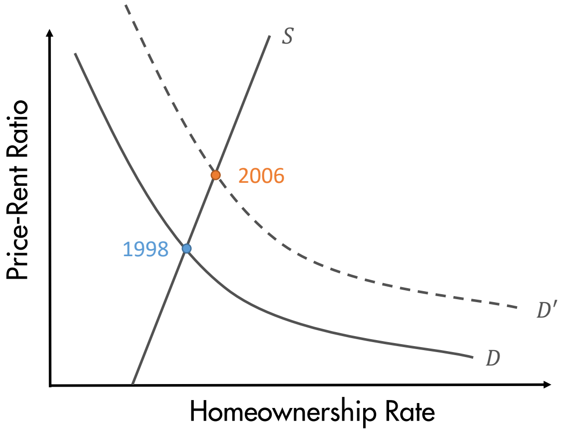
Intuition: Modified Supply and Demand

- In this world, increase in price-rent requires **separate** shock to supply.
  - E.g., Change in expectations about future rents.



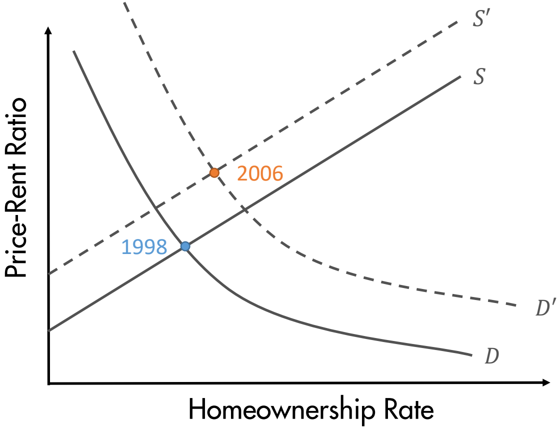
Intuition: Modified Supply and Demand

- Alternative view: credit expansion + **upward sloping supply** (imperfect rental market).



Intuition: Modified Supply and Demand

- Any intermediate combination of upward sloping supply and supply shift also possible.
  - To separate role of credit from other shocks, need a way to **identify slope** of supply curve.



Empirical Overview

- Use three off-the-shelf empirical approaches to estimate causal effect of credit supply on price-rent ratio and homeownership rate.
    1. **Loutskina and Strahan (2015)**: Exploit differential city-level exposure to national changes in conforming loan limits.
    2. **Di Maggio and Kermani (2017)**: Exploit federal preemption of national banks from local anti-predatory-lending laws in 2004.
    3. **Mian and Sufi (2019)**: Exploit differential city-level exposure to private-label securitization expansion.
- Robustness to alternative methodologies assuages concerns for any one approach.
    - Each instrument has different identification assumptions.
    - Operate on prime (#1) vs. riskier (#2, #3) segments of the market.

Data

- CBSA-Level Panel 1990-2017
- Prices: CoreLogic Repeat Sale HPI
- Rents: CBRE Economic Advisors Torto-Wheaton Index (CBSA)
  - High-quality repeat rent index for multi-family (single family index behaves similarly).
  - Measures rent commanded by newly rented unit.
- Homeownership Rate: Census Housing and Vacancy Survey
  - CBSA definitions change over time. Drop periods where definitions change.
  - Use state data with fixed definitions as robustness check.

Empirical Approach 1: Conforming Loan Limit Exposure

- Credit shock: Loutskina and Strahan (2015)
  - CLL: Max loan size eligible for GSE subsidy, for most part changes nation-wide.
  - Idea: Change in conforming loan limit has more bite in cities with more loans near CLL.
  - Instruments: Frac. originations within 5% of CLL at $t-1 \times$ % change in CLL, interaction of this with Saiz instrument (effect of share-shift estimated for supply elasticity that maximizes power)
- Identifying assumption: No non-credit shock that varies with CLL in time series and affects more exposed cities in cross section.
- Local Projection: for $k = 0, \dots, 5$,

$$\log(outcome_{i,t+k}) = \xi_i + \psi_t + \beta_k Z_{i,t} + \theta X_{i,t} + \epsilon_{i,t}$$

where X_t includes $Fraction_{i,t-1}$ as well as lags of instruments and credit variable.

Empirical Approach 1: Conforming Loan Limit Exposure

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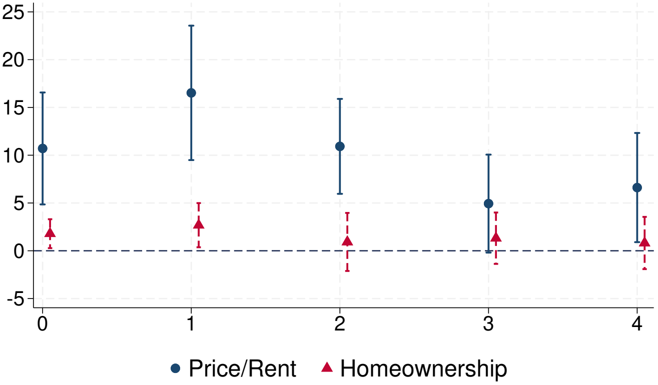
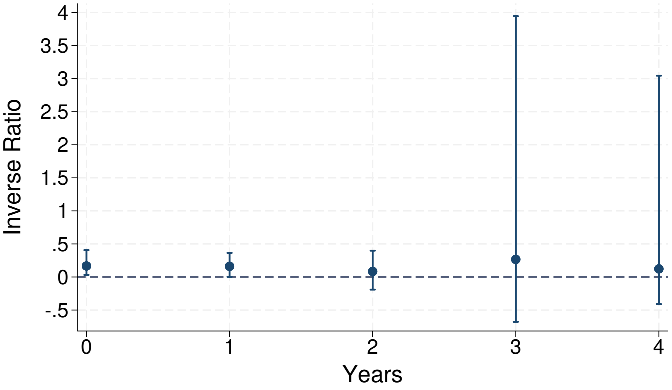
CLL Impulse Response: Credit Shock

- Price-rent ratio peaks at 16.5, compared to 2.7 for HOR.



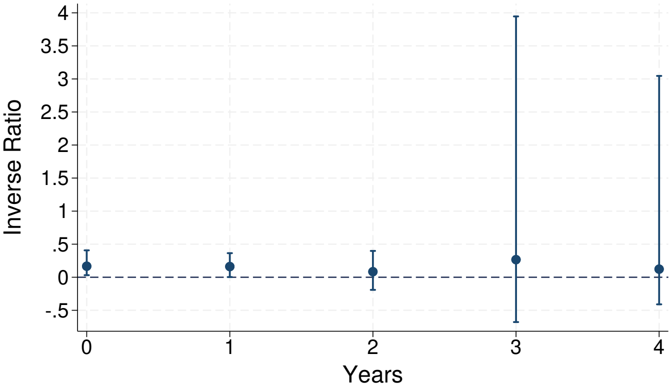
CLL Impulse Response: Credit Shock (Panel Local Projection IV)

- Compute confidence interval for slope by block bootstrapping coefficients.
  - Compute **inverse ratio** because CI for homeownership crosses zero.



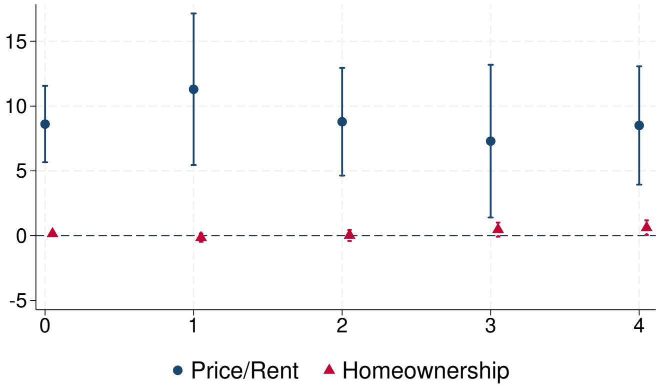
CLL Impulse Response: Credit Shock (Panel Local Projection IV)

- Ratio of point estimates range at least 3.8.
  - 95% CI lower bound at least 2.5 for 0-2 year horizon.
  - 95% CI upper bound is ∞ because cannot reject zero.



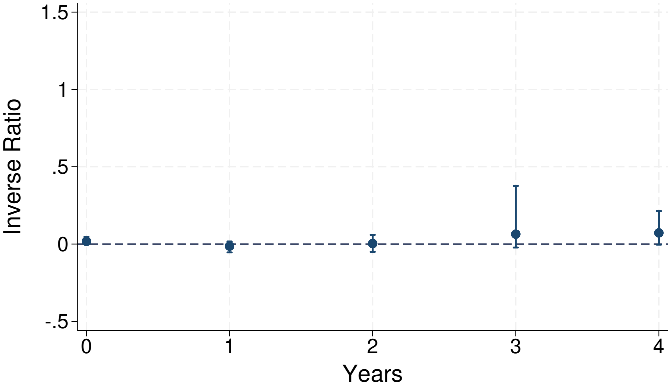
Microdata-Based Homeownership Rate

- Standard errors are large in part because HVS homeownership rate data is noisy.
- We constructed a new homeownership rate measure from deeds and address history data.
- Now find precise near-zeros for homeownership response.



Microdata-Based Homeownership Rate

- Bootstrapped confidence interval for inverse ratio similarly reduced.



Alternate Empirical Approaches

▸ DK Details ▸ MS Details

- **Di Maggio and Kermani (2017)**: Preemption of state anti-predatory-lending laws (APLs).
  - 2004 OCC preemption allows national banks to expand credit to risky borrowers.
  - Compare across states based on presence of APL and across cities within states based on OCC-regulated-bank market share.
- **Mian and Sufi (2019)**: City-level exposure to expansion in private-label securitization.
  - Variation across cities based on funding structure (non-core liabilities) of local banks.
- Despite different identification assumptions and variation that expands credit to riskier borrowers, **both approaches yield similar slope estimates**.
  - Large ratio of point estimates (15 or more) when using GG-Microdata homeownership rate.
  - Lower bound of at least 2.1 for block bootstrapped confidence intervals.
  - Complementary empirical approaches reinforce confidence in this moment.

Modeling Credit and House Prices

- Three factors generate strong house price response to credit in models:
  1. Frictions on trade with unconstrained owners of rental properties (landlords).
  2. Frictions on trade with unconstrained savers.
  3. Latent demand for credit.
- Items 1. and 2. relate to supply slope, identified by our empirical moment.
  - Single moment does not pin down relative frictions across margins.
  - We fully shut down saver margin, which occurs (unrealistically) along intensive margin.
  - Relaxing this assumption doesn't overturn results (see paper).
- Item 3. relates to gap between mortgage rate and borrower's reservation rate.
  - Influences size of demand shift following credit shock, rather than slope of supply.
- Credit strongly affects house prices only if **all three** factors are present.

Model Overview

- Adaptation of Greenwald (2018) to allow endogenous rental market.
- Endowment economy, endogenous investment in housing stock.
- Credit + rental market $\implies$ borrowers (B), landlords (L), savers (S).
- Realistic mortgages $\implies$ long term, fixed-rate, prepayable.
  - Loan-to-value (LTV) and payment-to-income (PTI) limits at origination only.
- Main modeling contribution: **borrower and landlord heterogeneity**.
  - Without any heterogeneity, 0% or 100% home ownership.
  - How heterogeneity falls on borrowers vs. landlords determines slope of demand vs. supply.

Demographics and Preferences

- Three types: borrowers (B), landlords (L), savers (S).
  - Borrowers: consume owned and rented housing, borrow in mortgages ($\beta_B < \beta_S$).
  - Landlords: risk-neutral, own housing to rent to borrowers (extension: landlord mortgages too).
  - Savers: finance borrower mortgages (extension: saver market integrated not segmented).
- Preferences:

$$V_{i,t}^B = \log\left(c_{B,t}^{1-\xi} h_{B,t}^{\xi}\right) + \beta_B E_t V_{i,t+1}^B$$

$$V_{i,t}^L = c_{i,t}^L + \beta_L E_t V_{i,t+1}^L$$

$$V_{i,t}^S = \log\left(c_{S,t}^{1-\xi} h_{S,t}^{\xi}\right) + \beta_S E_t V_{i,t+1}^S$$

- Perfect risk sharing within each type $\implies$ aggregation.

Housing Technology

- Housing asset: Divisible, requires maintenance cost, owned by borrowers or landlords.
- Produced by construction firms using investment of the nondurable good (Z_t) and land (L_t), where a fixed amount of land permits $\bar{L}$ are issued each period.
- Construction firm's problem:

$$\max_{L_t, Z_t} p_t L_t^{\varphi} Z_t^{1-\varphi} - p_{L,t} L_t - Z_t$$

- Implies elasticity of investment to prices of $\varphi/(1-\varphi)$.

Heterogeneity

- Implementation of borrower and landlord heterogeneity:
  - Borrower i gets benefit $(1+\omega^B_{i,t}) rent_t H_{i,t}$ from ownership, where $\omega^B_{i,t} \overset{iid}{\sim} \Gamma_{\omega,B}$.
  - Landlords get benefit $(1+\omega^L_{j,t}) rent_t H_{j,t}$ from ownership of property j, where $\omega^L_{j,t} \overset{iid}{\sim} \Gamma_{\omega,L}$.
- Borrower interpretation: Variation in life cycle, preferences, credit score, ability to come up with down payment, etc.
- Landlord interpretation: Variation in rental suitability by property/geography.
  - Implicit assumption: New construction has same dist of "rentability" as existing stock.
- Owned housing is reallocated to best suited agents of each type:
  - All households with $\omega^B_{i,t} \geq \bar{\omega}^B_t$ own
  - All properties with $\omega^L_{j,t} \geq \bar{\omega}^L_t$ are rented

Model Solution ‣ Landlord's Problem ‣ Saver's Problem

- Key optimality conditions ($\mathcal{C}_t = \mu_t F_t^{LTV} \theta_t^{LTV}$):

$$p_t^{\text{Demand}} = \underbrace{\left(1 - \mathcal{C}_t\right)^{-1}}_{\text{credit conditions}} E_t\left\{\Lambda_{t+1}^B \left[\underbrace{(1 + \bar{\omega}_t^B)\text{rent}_{t+1}}_{\text{housing services}} + \underbrace{\left(1 - \delta - (1 - \rho_{t+1})\mathcal{C}_{t+1}\right)p_{t+1}}_{\text{continuation value}}\right]\right\}$$

$$p_t^{\text{Supply}} = E_t\left\{\Lambda_{t+1}^L \left[\underbrace{(1 + \bar{\omega}_t^L)\text{rent}_{t+1}}_{\text{housing services}} + \underbrace{\left(1 - \delta\right)p_{t+1}}_{\text{continuation value}}\right]\right\}$$

- At equilibrium, $(\bar{\omega}_t^B, \bar{\omega}_t^L)$ ensure $p_t^{\text{Demand}} = p_t^{\text{Supply}}$ and $H_t^B + H_t^L = \hat{H}_t$, where

$$H_t^B = \left(1 - \Gamma_\omega^B(\bar{\omega}_t^B)\right)\hat{H}_t, \qquad H_t^L = \left(1 - \Gamma_\omega^L(\bar{\omega}_t^L)\right)\hat{H}_t$$

- Key parameter is dispersion of Γ_ω^L distribution (more dispersed $\Longrightarrow$ more inelastic supply).

Calibration Strategy

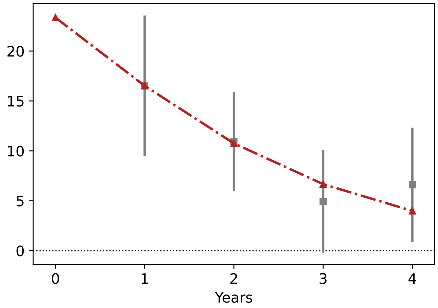
▸ Parameter Values ▸ Parameterization of Heterogeneity

- Most parameters: Match external calibration targets or standard parameters.
  - Borrower pop and income shares, utility, construction, depreciation, taxes, etc.
- Key parameter is landlord heterogeneity ($\sigma_{\omega,L}$) which we match to regressions.
- Borrower heterogeneity ($\sigma_{\omega,B}$): match uptake of First Time Homebuyer Credit estimated in Berger, Turner, Zwick (2020).
- Borrower patience controls extent to which demand shifts when credit changes.
  - Intuition: More impatience, more latent demand for credit.
  - Calibrate β_B using private mortgage insurance pricing: Indifferent between receiving 80% LTV loan and paying for FHA insurance at 95% LTV.
- Sensitivity analysis shows other parameters not important once we recalibrate to match our key empirical moment.

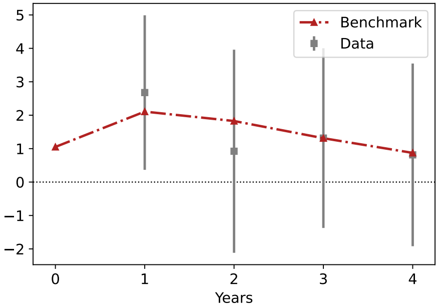
Calibration: Supply Elasticity

▸ Identification

- Model change in CLL as shock to real mortgage spreads for borrowers.
- Choose $\sigma_{\omega,L}$, along with size and persistence of shock, to minimize distance from empirical Loutskina-Strahan price-rent and homeownership IRFs.
- Fit in years 1-4 since our model lacks frictions required for hump-shaped response.



(a) Price-Rent Ratio

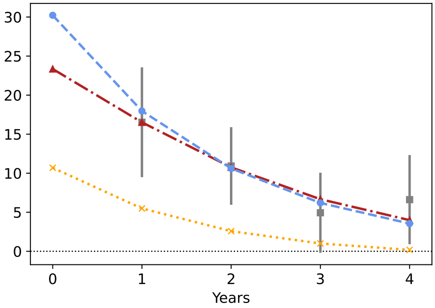


(b) Homeownership Rate

Calibration: Supply Elasticity

▸ Identification

- Requires substantial deviation from perfect rental markets.
- Benchmark has price response close to Full Segmentation model, but larger homeownership response.



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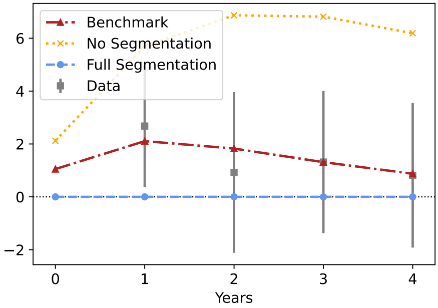
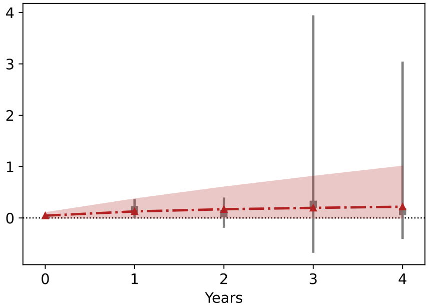


(b) Homeownership Rate

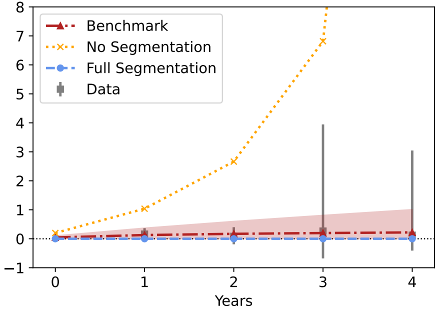
Calibration: Supply Elasticity

Identification

- For bands, turn to inverse slope estimates.
  - Characterizes joint uncertainty, drops nuisance parameter of shock size.
  - Fit upper and lower confidence interval bounds.



(a) Inverse Ratio (Bands)

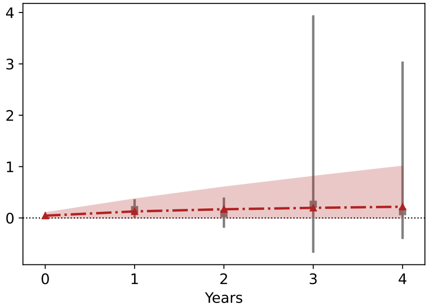


(b) Inverse Ratio (Model Comparison)

Calibration: Supply Elasticity

▸ Identification

- Provides lower bound for frictions, cannot reject Full Segmentation.
- Can easily reject No Segmentation model.
- Directly estimating $\sigma_{\omega,L}$ to match ratio point estimates would yield much steeper slope.



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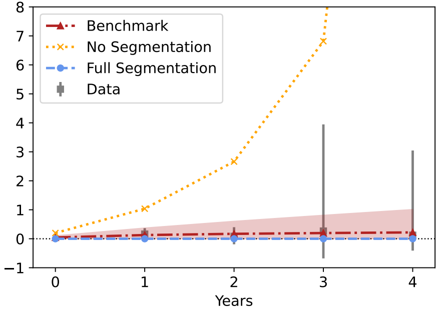
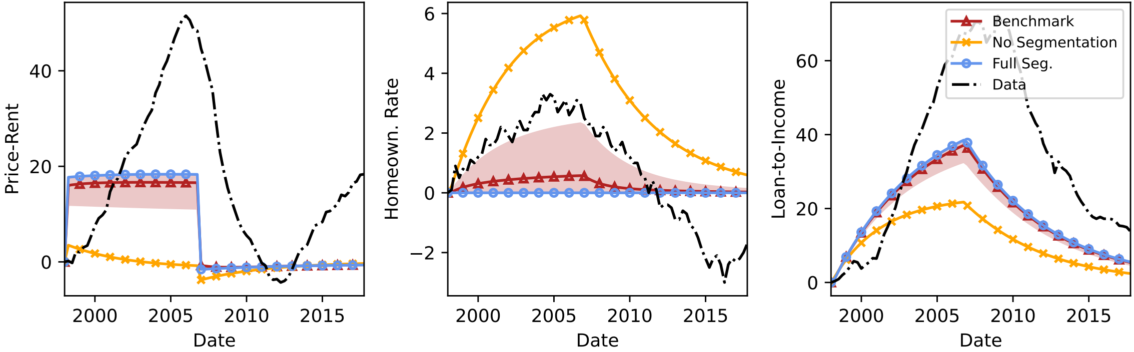


(b) Inverse Ratio (Model Comparison)

Credit Expansion Experiment

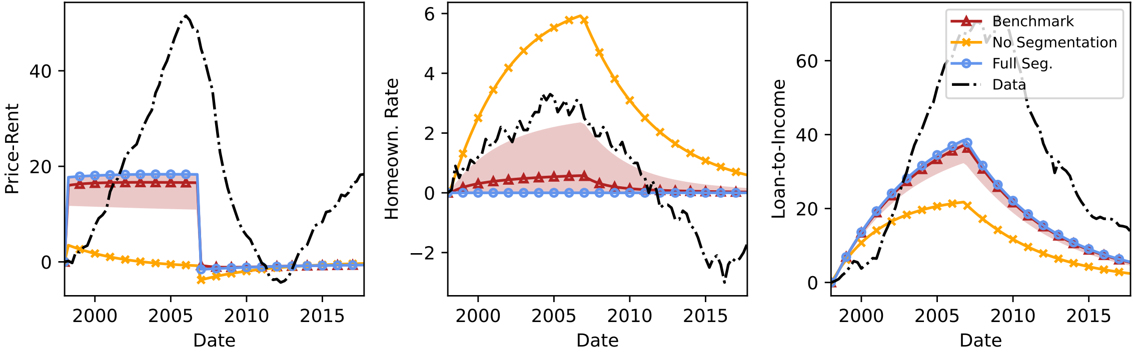
- Credit expansion: Increase max LTV from 85% to 99%, max PTI from 36% to 65%.
- Start in 1998 Q1, surprise reversal in 2007 Q1, compute nonlinear perfect foresight paths.



Credit Expansion Experiment

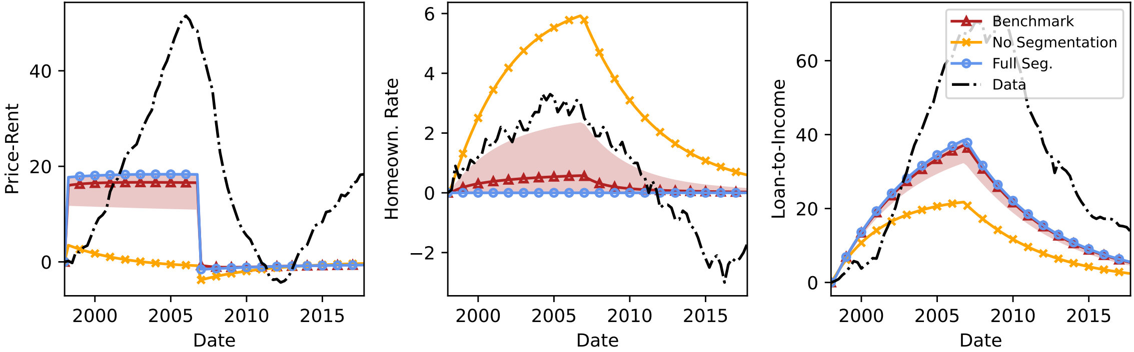
- Benchmark: Credit explains **32%** of peak price-rent increase, **51%** of peak LTI increase.
  - Using lower bound for slope, explains 22% of rise in price-rent, 45% of rise in LTI.

- Perfect rental markets: Credit explains **-2%** of price-rent, only **30%** of peak LTI increase.



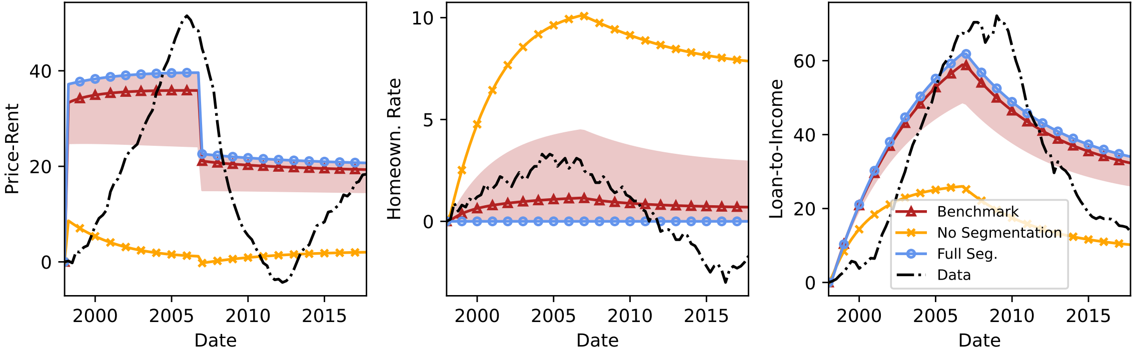
Credit Expansion Experiment

- Benchmark closer to complete segmentation: **36%** of price-rent, **53%** of peak LTI increase.
- But Benchmark allows for nontrivial movement in homeownership.



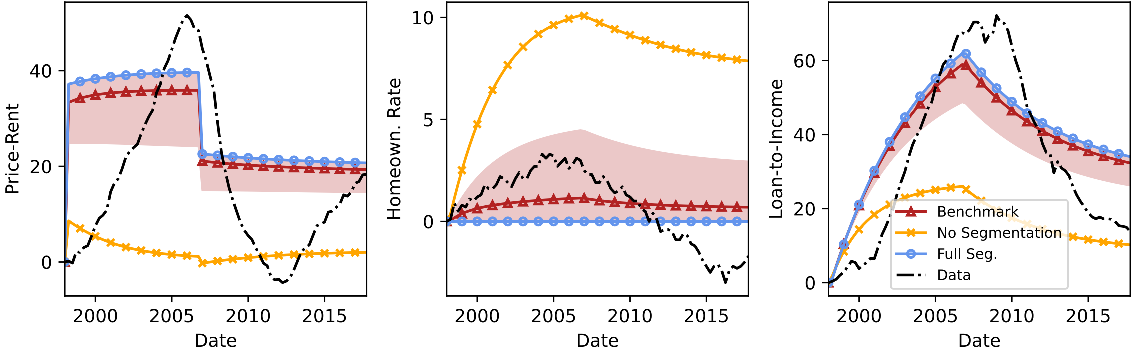
Credit Expansion Experiment

- Adding 2ppt drop in mortgage rates, we can explain **70%** of the rise in price-to-rent ratios and **82%** of the rise in loan-to-income ratios, and **35%** of the rise in homeownership.
  - Lower bound slope explains **47%** of rise in price-rent, **68%** of rise in LTI, **136%** of rise in HOR.
  - Upper bound (Full Seg) explains **77%** of rise in price-rent, **86%** of rise in LTI, **0%** of rise in HOR.



Credit Expansion Experiment

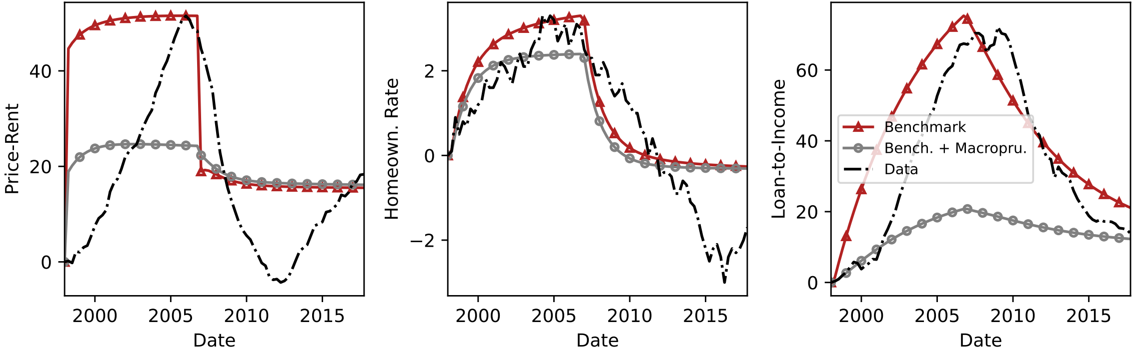
- Contrast to **2%** of rise in price-rent ratios and **36%** of rise in LTI under No Segmentation.
- Extremely favorable credit terms without price appreciation leads to rise in homeownership **306%** that of the data.



Boom Counterfactuals: Benchmark Model

▸ Beliefs Only ▸ No Heterog.

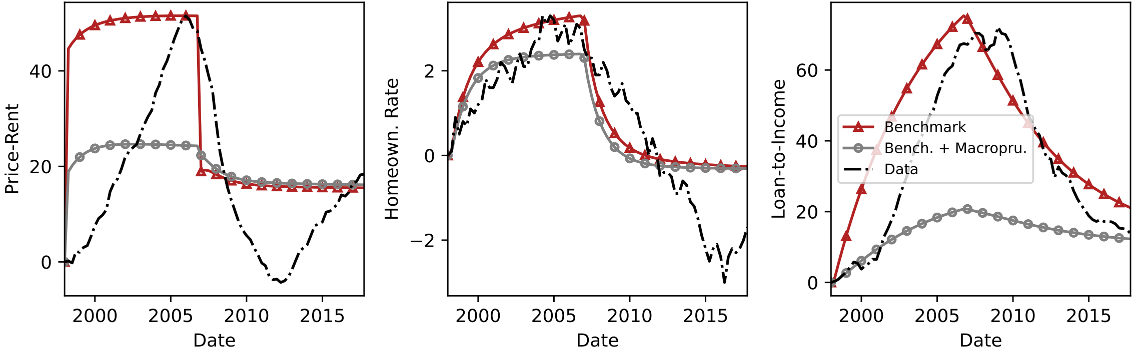
- Add observed fall in interest rates, then use demand and supply shocks (shifts in means of $\Gamma_{\omega,B}, \Gamma_{\omega,L}$ to exactly explain rise in price-rent and homeownership).
- To capture bust, return credit limits to baseline, apply (i) 3% fall in mortgage rates and landlord discount rates; (ii) exclude 10% of borrowers from credit market.



Boom Counterfactuals: Benchmark Model

▸ Beliefs Only ▸ No Heterog.

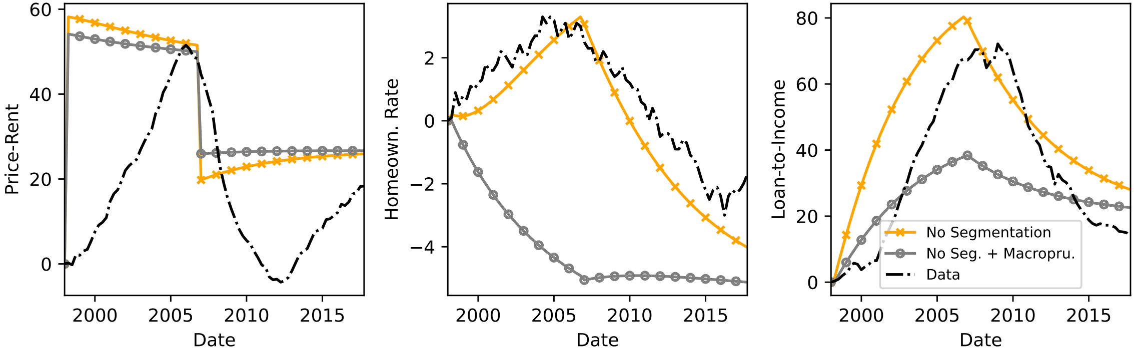
- Now **removing** credit expansion kills 53% of boom in price-rent, 71% of boom in LTI.
- Larger because of nonlinear interactions between credit and other shocks boosting house prices (Greenwald, 2018).
- Implies macroprudential, monetary policy can be effective at limiting house price booms.



Boom Counterfactuals: Benchmark Model

▸ Beliefs Only ▸ No Heterog.

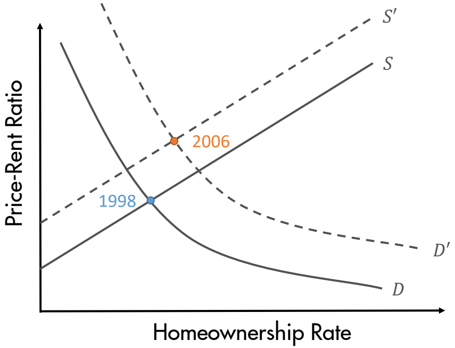
- Under No Segmentation, removing credit relaxation would remove **3%** of boom in price-rent, **47%** of boom in LTI.
- Difficult to distinguish using macro data alone, need IV estimates to tell whether macroprudential policy works.



Model Extensions: Landlord Credit

Back

- So far, have assumed landlords don't use credit.
- If landlords used credit, expansion would cause shift in the supply curve.
  - Alternative explanation for concurrent rise in price-rent and homeownership.



Model Extensions: Landlord Credit

Back

- So far, have assumed landlords don't use credit.
- If landlords used credit, expansion would cause shift in the supply curve.
  - Alternative explanation for concurrent rise in price-rent and homeownership.
- Implementation: landlords can borrow with mortgage tech., 65% LTV limit at origination.
- New equilibrium condition ($\mathcal{C}_{L,t} = \mu_{L,t}\theta^L$)

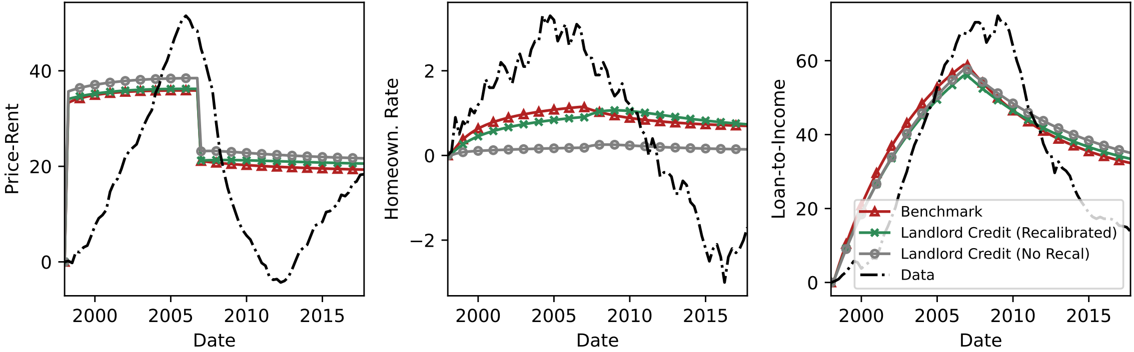
$$p_t^{\text{Supply}} = \underbrace{\left(1 - \mathcal{C}_{L,t}\right)^{-1}}_{\text{credit conditions}} E_t\left\{\Lambda_{t+1}^L\left[\underbrace{\bar{\omega}_t^L + \text{rent}_{t+1}}_{\text{housing services}} + \underbrace{\left(1 - \delta - (1 - \rho_{t+1})\mathcal{C}_{L,t+1}\right)p_{t+1}}_{\text{continuation value}}\right]\right\}$$

allows credit to directly influence supply.

Model Extensions: Landlord Credit

Back

- Results turn out to be similar under landlord credit.
- Why? Calibration pairs shift in tenure supply with flatter tenure supply slope.



Model Extensions: Flexible Saver Demand

▸ Back

- Next extension: relax assumption of fixed (segmented) saver demand.

- New equilibrium condition:

$$p_t^{\text{Saver}} = E_t\left\{\Lambda_{t+1}^S\left[\underbrace{u_{h,t}^S/u_{c,t}^S}_{\text{housing services}} + \underbrace{\left(1-\delta\right)p_{t+1}}_{\text{continuation value}}\right]\right\}$$

  where saver housing $H_{S,t}$ must equalize saver and borrower/landlord prices.

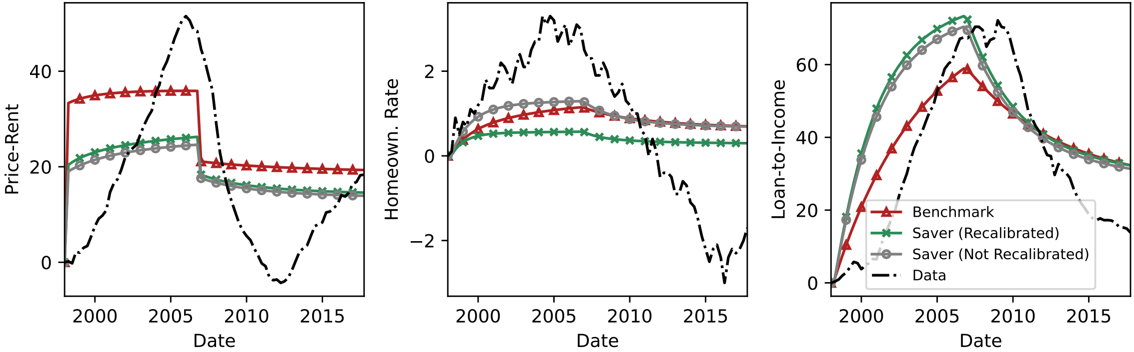
- Because saver demand not directly influenced by credit, saver housing margin can also absorb effect of credit on house prices.
  - Same mechanism highlighted in Landvoigt, Piazzesi, and Schneider (2015).

- Adjustment occurs (unrealistically) along intensive margin due to divisible housing.
  - Typically true even in models with different housing sizes/types.

Model Extensions: Flexible Saver Demand

Back

- Flexible saver demand would dampen effects on house prices somewhat.
- But credit standards relaxation + declining rates still explains 51% of observed rise in price-rent ratios.



Summary: Do Credit Conditions Move House Prices?

- What role did credit play in the housing boom and bust?
- Empirical results:
  - Larger, significant response of price-rent ratio to identified credit shocks, vs. smaller, insignificant response for homeownership.
- Quantitative model calibrated to match empirical findings (landlord supply elasticity):
  - Allows us to consider cases between fixed homeownership rate and perfect arbitrage.
  - Main finding: Credit standards explain 32% – 53% of price-rent growth during boom.
  - Frictions key to effectiveness of macroprudential/monetary policy in dampening price booms.
  - Extensions: Landlord credit (alternative comovement) and saver demand (need segmentation).
- Organizing framework/methodology we hope will be useful to future researchers.

Conclusion: Credit and House Prices

- When does credit matter for house prices?
  - When "supply" from unconstrained agents (landlords, savers) sufficiently segmented.
  - Strong frictions supported by empirical evidence.
- How did credit drive the 2000s boom bust?
  - Key change is large relaxation of PTI limits.
  - PTI relaxation directly increases prices, amplifies effect of expectations.
- Lots of room for continued research!

The Research Process

Research Question

- Asking the right question is key to the research process.
- Good papers ask questions about the world, not questions about a model.
- Bad (but common) question: “is X exactly zero?”
- Ideal question (especially for JMP): interesting/important enough that either/any outcome is a major contribution.
- Okay to refine as you go, but always keep research question in mind.

Research Process

- Should have a reason for everything you include in the setup.
  - Start as simple as possible, then build up as needed.
  - Especially key for JMP with strict deadline.
- Research is like judo: go with the data/results instead of fighting it.
  - Especially important to pull on "loose threads." If there is a result you don't understand, figure it out before moving on.
- Think about the scope of what the paper can explain.
  - If you are matching the data, make sure you are only matching what your model should explain!
- Apply more and more rigorous tests to your theory as it develops.

Research Mindset

- Your job is to find the answer, not deliver a particular result.
- All research designs are imperfect, make limitations clear.
- Complexity is costly: include element only if it is first-order for your main question.
- Get feedback earlier than you think you should.