The Mortgage Credit Channel of Macroeconomic Transmission

Daniel L. Greenwald

MIT Sloan

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Introduction

- Mortgage markets are big.
  - US: nearly 70% of household credit, more than half of annual GDP.
- Empirical research shows strong associations between mortgage credit and macro variables.
- But still a lot we don't know about core mechanisms connecting mortgage credit, house prices, economic activity:
  - Relationship between interest rates and house prices?
  - Macro impact of mortgage refinancing?
  - Causes of recent boom-bust?
- Mortgage markets are complex, macro models usually abstract from details.
  - This paper: institutional features matter for dynamics.

Introduction

- Main question: if and how mortgage credit issuance amplifies and propagates shocks.
  - Mortgage credit channel.
- Approach: General equilibrium framework centered on two important but largely unstudied features of US mortgage markets:
  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.

Main Findings

Main Finding #1: When calibrated to US mortgage microdata, novel features amplify transmission from interest rates into debt, house prices, economic activity.

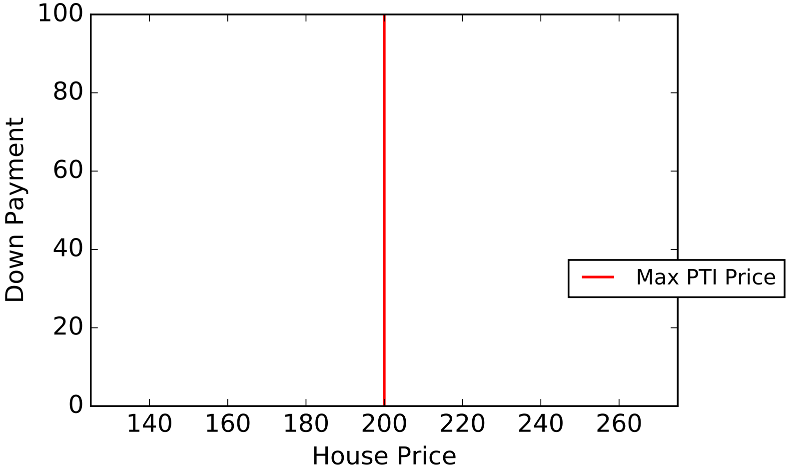
- Initial source: PTI limits are highly sensitive to nominal interest rates.
  - Change by $\sim$ 8% in response to 1% change in nominal rates.
- Key propagation mechanism: changes in which constraint is binding for borrowers move house prices (constraint switching effect).
  - Price-rent ratios rise by 3% after persistent 1% fall in nominal rates.

Main Finding #2: PTI liberalization appears essential to boom-bust.

- Partially sufficient: 35% of observed rise in price-rent ratios, 33% of the rise in debt-household income from PTI relaxation alone.
- Necessary: other forces (LTV liberalization, house price expectations) dramatically dampened without loose PTI.

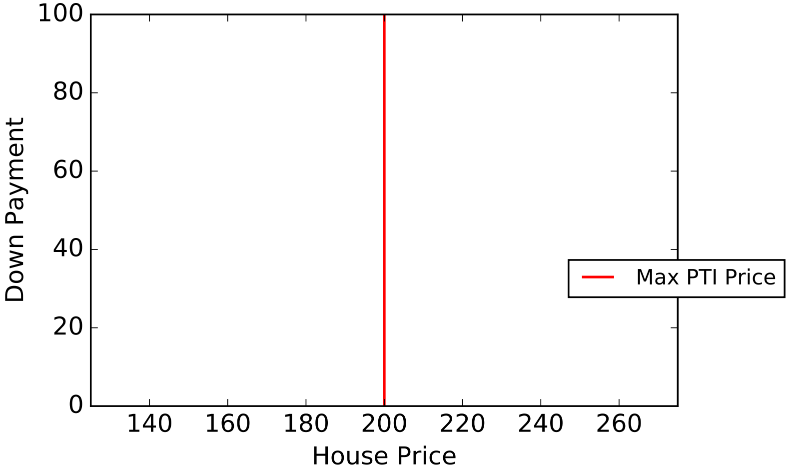
Simple Example

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



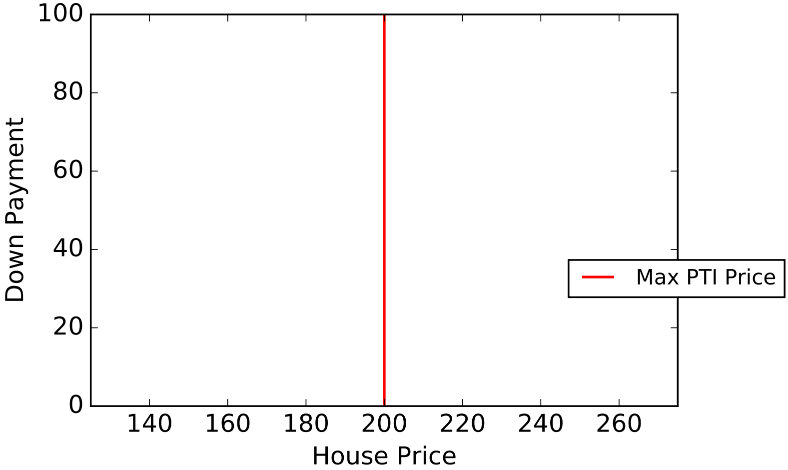
Simple Example

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



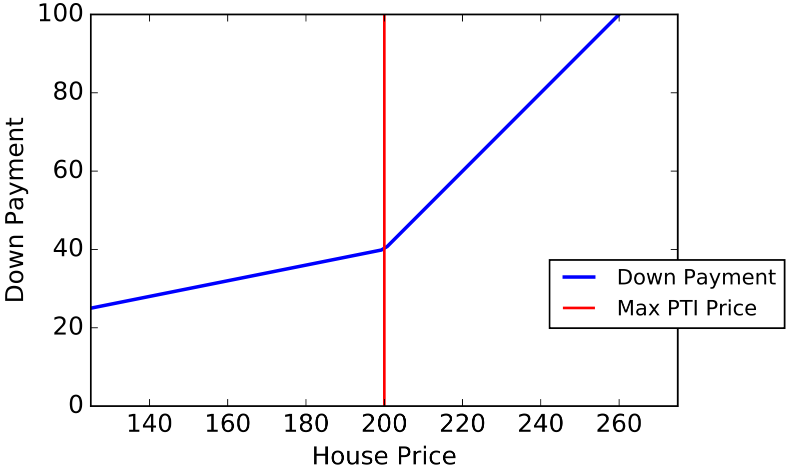
Simple Example

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



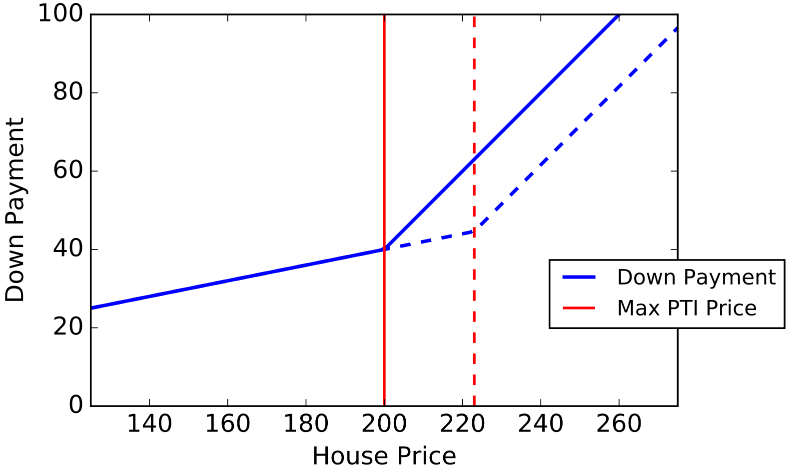
Simple Example

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



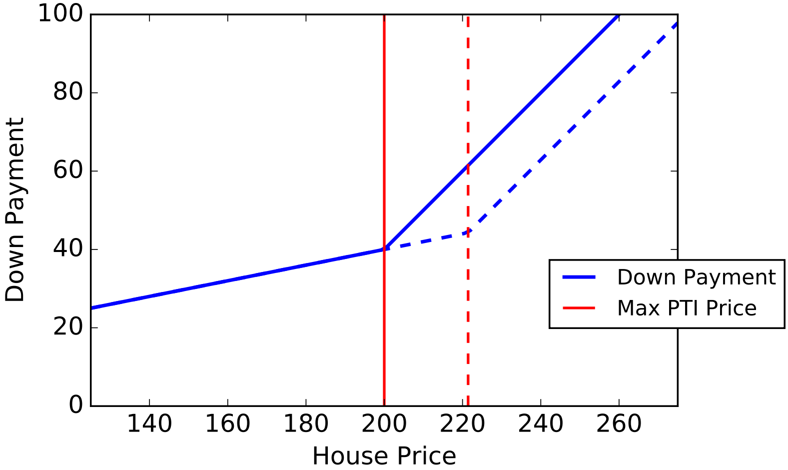
Simple Example

- 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.



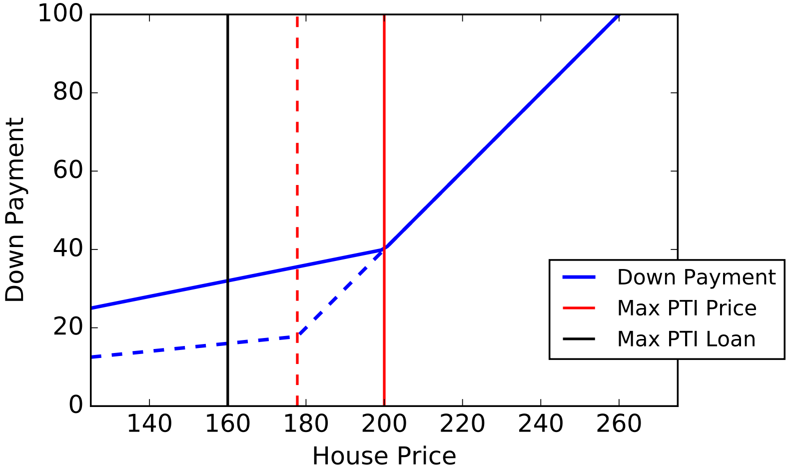
Simple Example

- 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

Model Overview

- Borrowing $\implies$ impatient borrowers/patient savers. ▸ Details
  - TANK model with representative agent for each type.
- Mortgage debt $\implies$ durable housing. ▸ Details
  - Divisible, cannot change stock without prepaying mortgage.
  - Fixed housing stock, saver housing demand, no rental market.
- Realistic mortgages $\implies$ long-term, fixed-rate, prepayable ▸ Details
  - Endogenous fraction ρ_t prepay, update balance and interest rate.
- Movements in long rates $\implies$ Taylor rule, shock to inflation target $\bar{\pi}_t$ (nominal), "term premium" shock (real).
  - Any shock to real rates or term premia should activate channel.
- Effects on real economy $\implies$ labor supply, sticky prices, TFP shocks.

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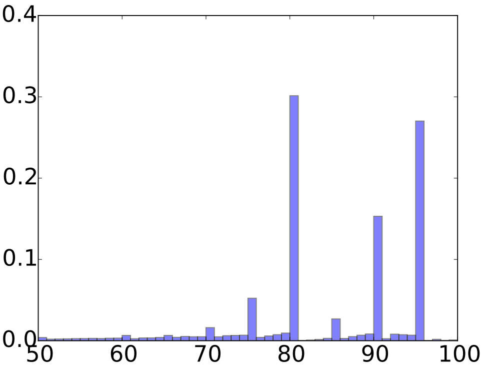
Credit Limits

- 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: $(q^*_t + \alpha) m^*_{i,t} \leq (\theta^{PTI} - \omega) \cdot \text{income}_{i,t}$.
  - Real constraint affecting all US borrowers, largely unstudied in macro.
  - Key property: moves with interest rates (elasticity $\simeq 8$).
  - $\bar{m}^{PTI}_{i,t} \equiv (\theta^{PTI} - \omega) \cdot \text{income}_{i,t} / (q^*_t + \alpha)$.
- Overall limit: $m^*_{i,t} \leq \min\left(\bar{m}^{LTV}_{i,t}, \bar{m}^{PTI}_{i,t}\right)$.

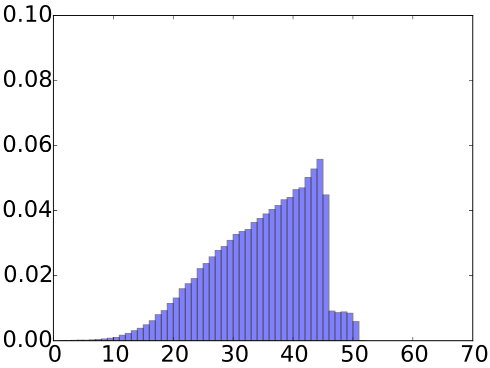
Underwriting

LTV and PTI in the Data

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



(a) CLTV Histogram: 2014 Q3

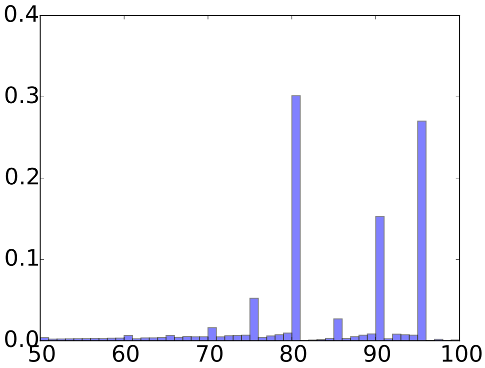


(b) PTI Histogram: 2014 Q3

More

LTV and PTI in the Data

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



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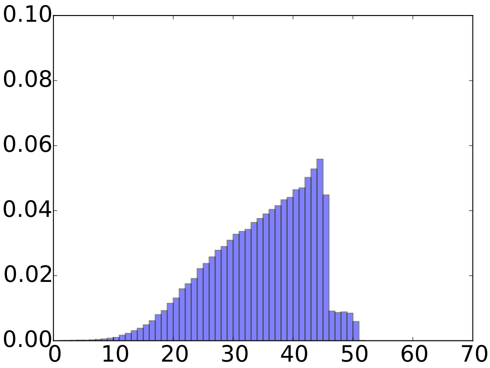
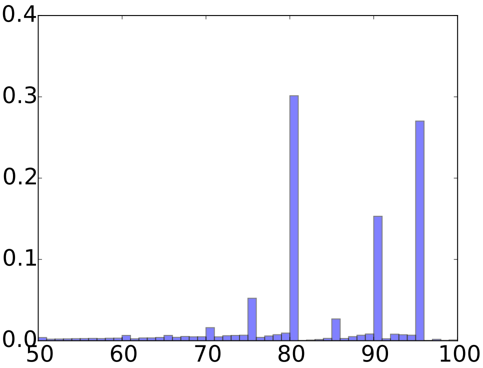


(b) PTI Histogram: 2014 Q3

▸ More

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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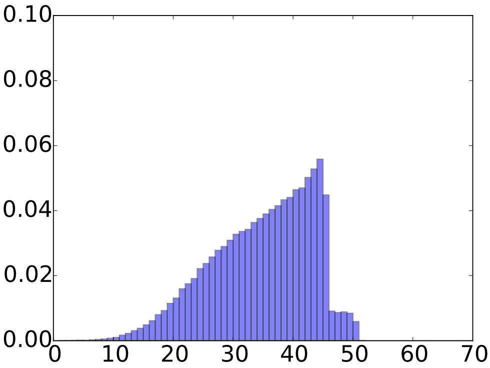
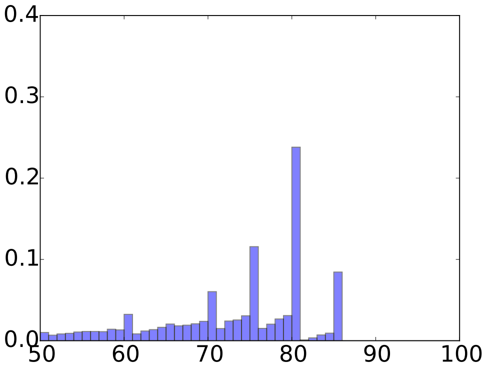


(b) PTI Histogram: 2014 Q3

More

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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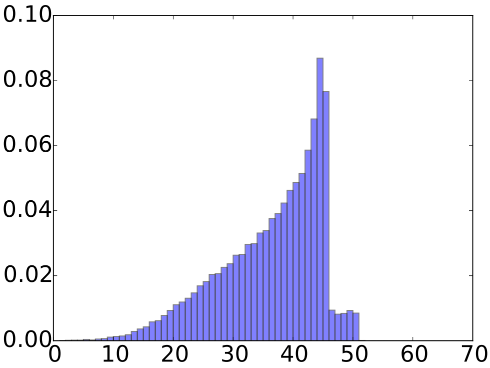

(b) PTI Histogram: 2014 Q3

More

Representative Borrower's Housing Decision

- Housing optimality condition, unconstrained or no LTV:

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

- $\Lambda_{b,t+1}$ 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 used to collateralize a new loan.

Representative Borrower's Housing Decision

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

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Representative Borrower's Housing Decision

- Housing optimality condition, Benchmark model:

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

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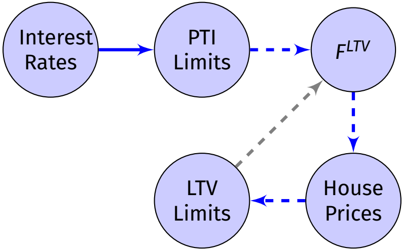
  where F_t^{LTV} is fraction constrained by LTV.

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

Constraint Switching Effect

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

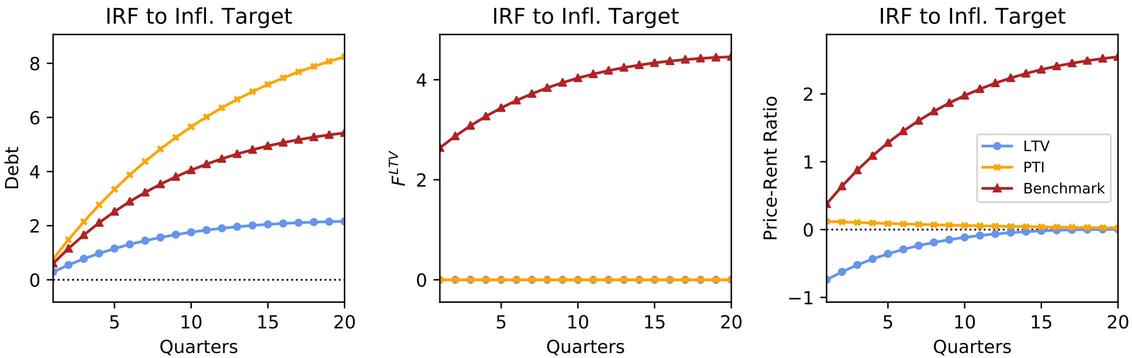


Comparison of Models

- **Main Result #1:** Strong transmission from interest rates into debt, house prices, economic activity.
- **Experiment:** compare propagation of shocks in economies that differ by credit limit:
  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 (Inflation Target Shock)

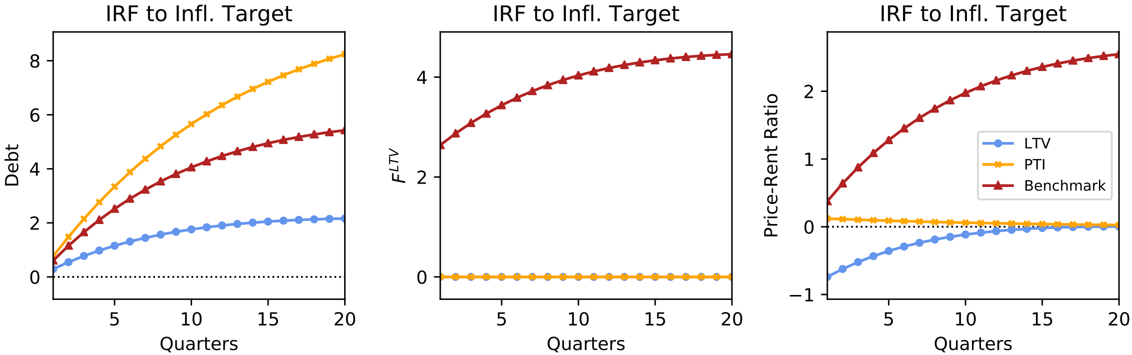
- IRF to near-permanent -1% (annualized) fall in nominal rates.



More Series | Exog. Prepay Version | TFP IRFs | Credit Standards IRFs | 43% PTI

Constraint Switching Effect (Inflation Target Shock)

- Debt response of Benchmark Economy closer to PTI Economy even though most borrowers constrained by LTV (73% in steady state).



▸ More Series ▸ Exog. Prepay Version ▸ TFP IRFs ▸ Credit Standards IRFs ▸ 43% PTI

Credit Standards and the Boom-Bust

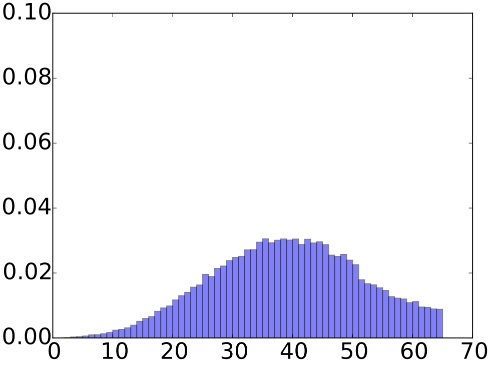
- **Main Result #2:** PTI liberalization essential to the boom-bust.
  - So far, have been treating maximum ratios $\theta^{LTV}, \theta^{PTI}$ as fixed, but credit standards can change.
  - Fannie/Freddie origination data: substantial increase in PTI ratios in boom. ▸ Time Series ▸ Fannie Mae Docs ▸ News Article

- **Experiment**: unexpectedly change parameters, unexpectedly return to baseline 36Q later (1998 Q1 - 2007 Q1).
  1. **PTI Liberalization**: θ^{PTI} from $0.36 \rightarrow 0.54$.
  2. **LTV Liberalization**: θ^{LTV} from $0.85 \rightarrow 0.99$.

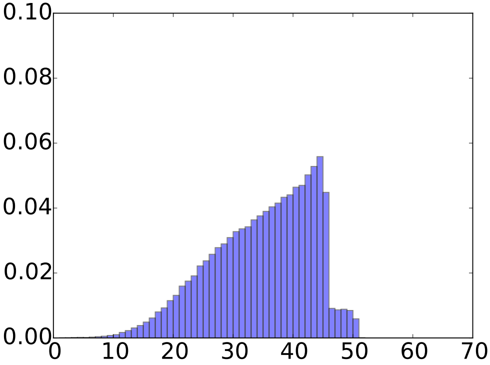
- Computation: nonlinear transition paths.

Credit Standards and the Boom-Bust

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



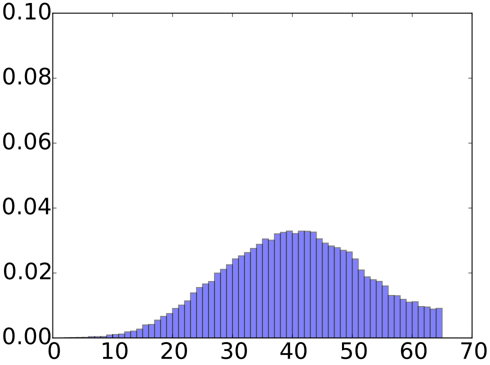
(a) PTI Histogram: 2006 Q1



(b) PTI Histogram: 2014 Q3

Credit Standards and the Boom-Bust

- Cash-out refi plots even more striking.



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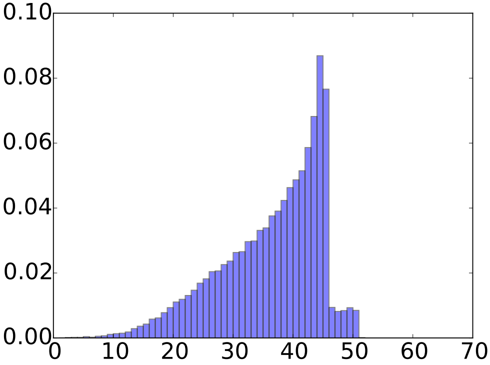

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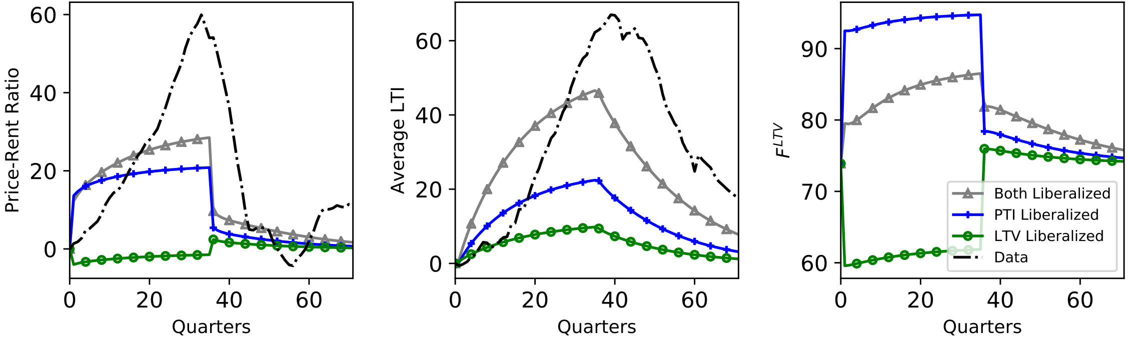
Credit Liberalization Experiment

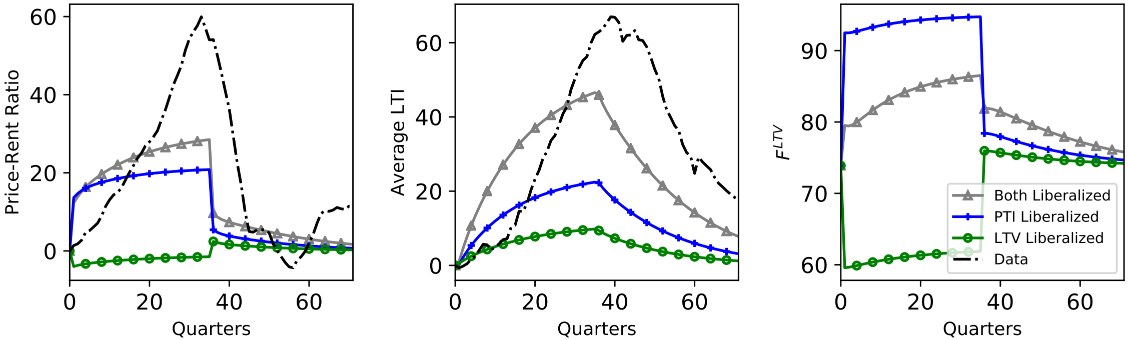
- LTV liberalization generates small rise in debt-to-household income (10% of observed). Price-rent ratios **fall** (-1% of observed).



▸ More Series ▸ LTV Intuition ▸ PTI Intuition

Credit Liberalization Experiment

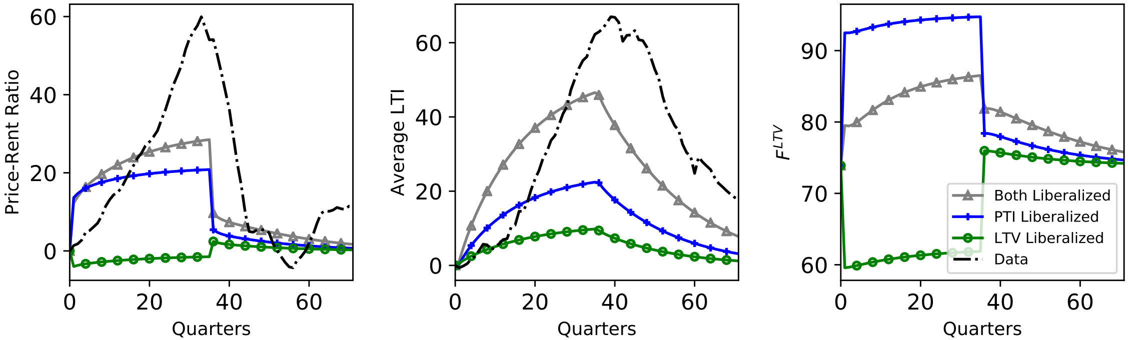
- PTI liberalization generates large boom in price-rent ratios (35% of observed), debt-household income (33% of observed).



More Series | LTV Intuition | PTI Intuition

Credit Liberalization Experiment

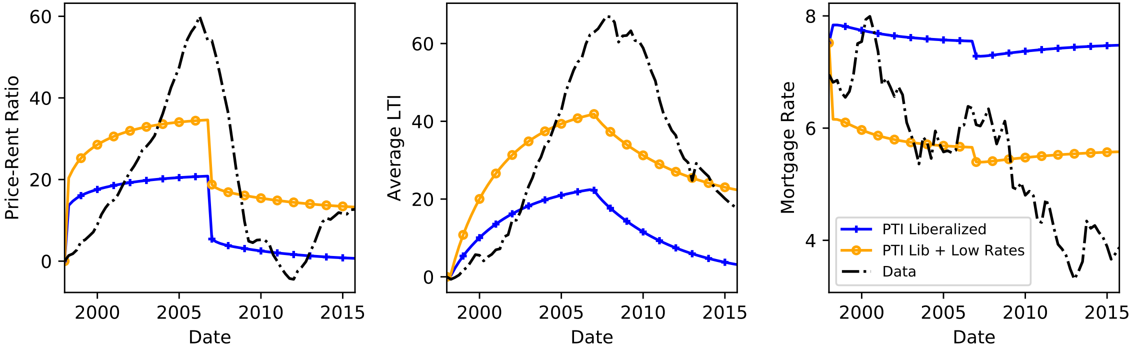
- Liberalizing both shows that loose PTI amplifies LTV, but increases debt much more than prices.



▸ More Series ▸ LTV Intuition ▸ PTI Intuition

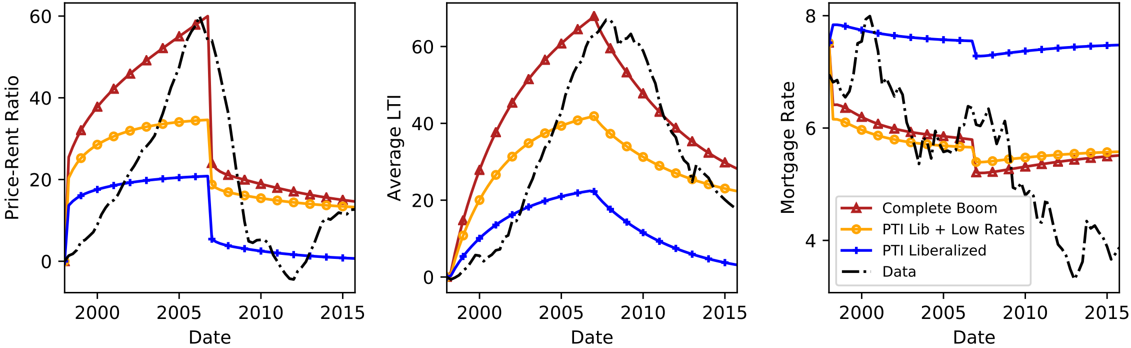
Explaining the Boom

- 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.



Explaining the Boom

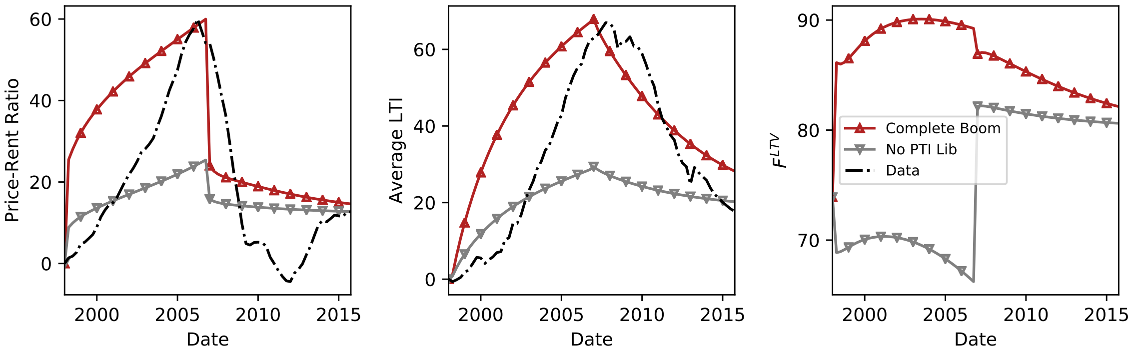
- Overoptimistic HP beliefs (anticipated 24% increase in utility) small increase in LTV limit (85% $\rightarrow$ 88%) can explain remaining share.



More Series

Macroprudential Policy

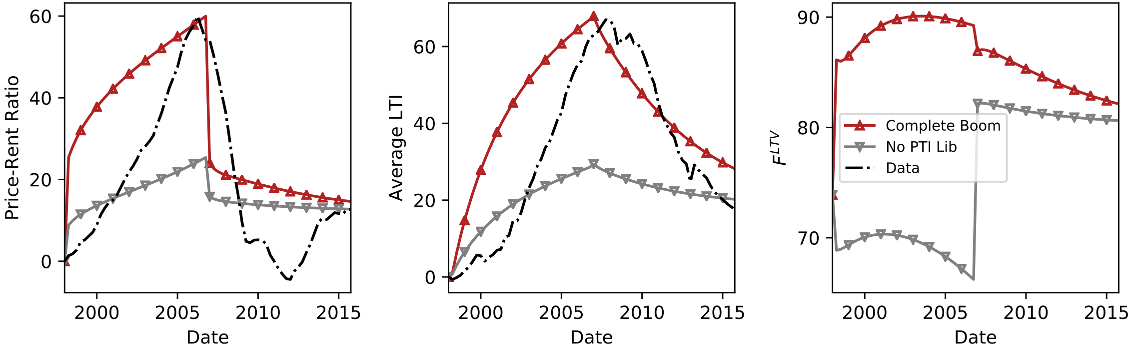
- But without PTI liberalization, other forces severely diminished, explain only 58% of price-rent, 52% of debt-income $\implies$ necessary condition.



▸ More Series

Macroprudential Policy

- Implication: PTI limit, not LTV limit, more effective macroprudential policy for limiting boom-bust cycles.



More Series

Conclusion

- Macro model with two novel features:
  - Payment-to-income constraint.
  - Endogenous prepayment of long-term debt.
- Novel transmission channel from interest rates into credit, house prices, economic activity.
  - Credit, house prices through constraint switching effect.
  - Output through frontloading effect (see paper).
  - Monetary policy more effective, but may pose tradeoff (see paper).
- PTI liberalization appears essential to boom-bust.
  - Necessary and partially sufficient.
  - Cap on PTI ratios, not LTV ratios more effective macroprudential policy.

APPENDIX

Representative Borrower's Problem

- State variables: principal balance m_{t-1}, mortgage payment x_{t-1}, housing stock $h_{b,t-1}$.
- Control variables: nondurable consumption $c_{b,t}$, labor supply $n_{b,t}$, prepayment rate ρ_t, size of new houses $h^*_{b,t}$, size of new loans m^*_t.
- Budget constraint:

$$
\begin{aligned}
c_{b,t} \leq\ & \underbrace{\rho_t \left(m^*_t - (1-\nu)\pi_t^{-1} m_{t-1}\right)}_{\text{new issuance}} - \underbrace{\left(\pi_t^{-1} x_{t-1} - \tau \pi_t^{-1}(x_{t-1} - \nu m_{t-1})\right)}_{\text{mortgage payment}} \\
& + \underbrace{(1-\tau) w_t n_{b,t}}_{\text{labor income}} - \underbrace{\delta p^h_t h_{b,t-1}}_{\text{maintenance}} - \underbrace{\rho_t p^h_t \left(h^*_{b,t} - h_{b,t-1}\right)}_{\text{net housing purchases}} \\
& - \underbrace{\left(\text{Cost}(\rho_t) - \text{Rebate}_t\right) m^*_t}_{\text{transaction costs}} + T_{b,t}
\end{aligned}
$$

- Credit constraint:

$$
m^*_t \leq \int \min\left(\bar{m}^{LTV}_{i,t}, \bar{m}^{PTI}_{i,t}\right) d\Gamma_e(e_i)
$$

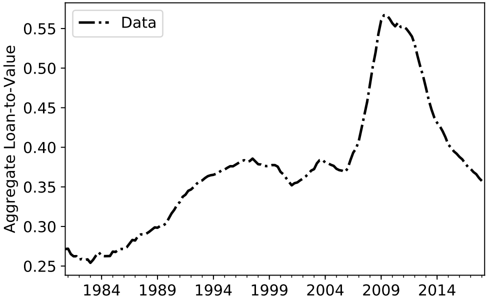
Agg. LOM | Borr. Optimality | Saver's Problem | Eqm. Defn. | Monetary Policy | Prod. Tech.

Matching Debt Dynamics

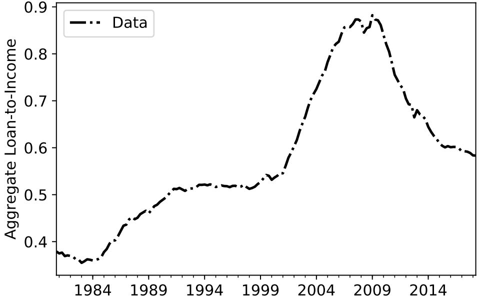
- Calibrate transaction cost distribution (average prepayment rate and sensitivity to macro conditions) to match debt dynamics.

- These dynamics cannot be matched by existing models.

- $LTV_t = (\text{total debt})/(\text{total value})$, $LTI_t = (\text{total debt})/(\text{total disp. inc.})$



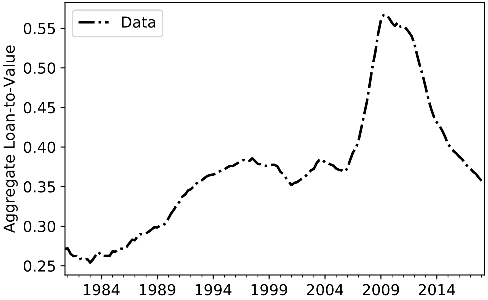
(a) Aggregate LTV



(b) Aggregate LTI

Matching Debt Dynamics

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1}LTV_{t-1}$
- ν_t is amortization, G_t is house value growth.
- Most macro-housing models have a law of motion of this form, specifying ρ_t and LTV_t^*.



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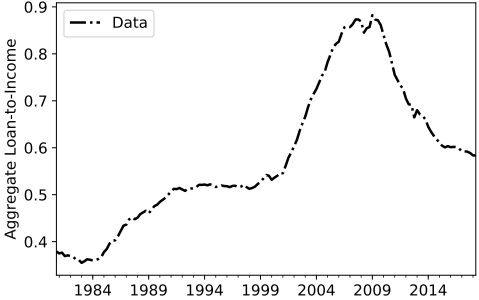

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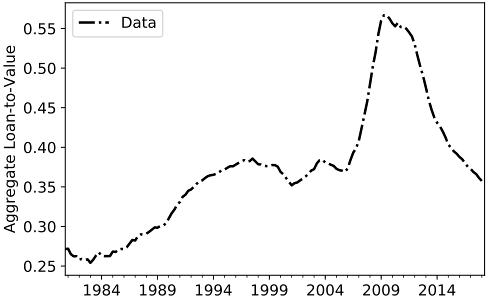
Matching Debt Dynamics

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1} LTV_{t-1}$
- ν_t is amortization, G_t is house value growth.
- Exercise: feed in *true* path of G_t, compare implied $\widehat{LTV}_t$ and $\widehat{LTI}_t$.



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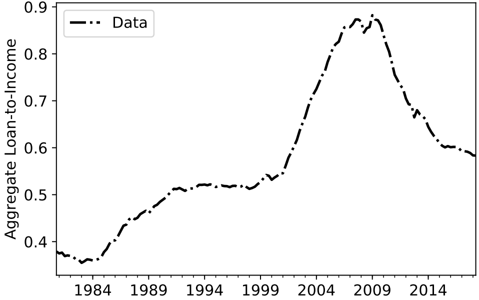
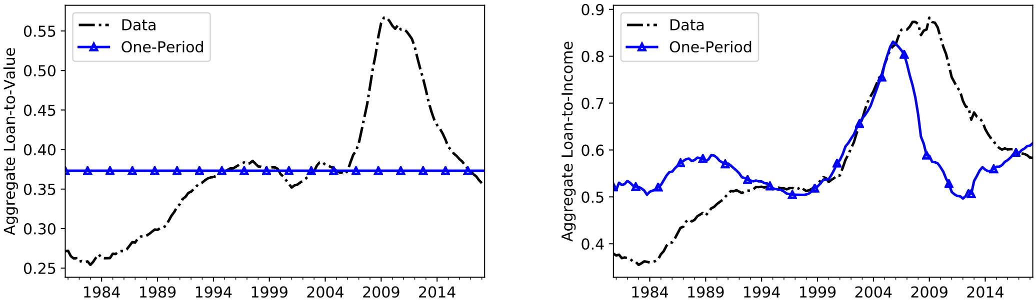


(b) Aggregate LTI

Traditional Models

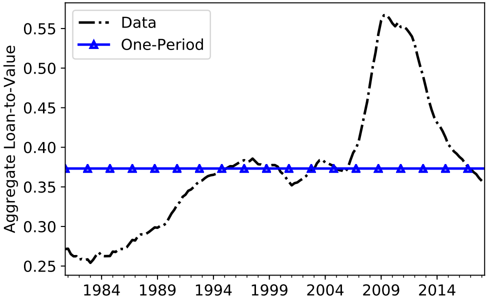
- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t) G_t^{-1} LTV_{t-1}$
- Most traditional is one-period debt: $\rho_t = 1$, $LTV_t^* = \overline{LTV}^*$.
- Fit $\overline{LTV}^*$ to minimize $||LTV_t - \widehat{LTV}_t||$.



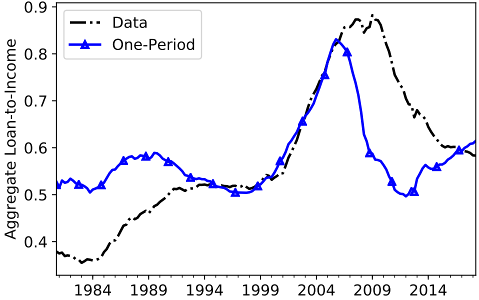
(a) Aggregate LTV (b) Aggregate LTI

Traditional Models

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t) G_t^{-1} LTV_{t-1}$
- Most traditional is one-period debt: $\rho_t = 1$, $LTV_t^* = \overline{LTV}^*$.
- Fits reasonably well during boom (high turnover), but deleveraging too fast in bust, pre-boom leverage too high



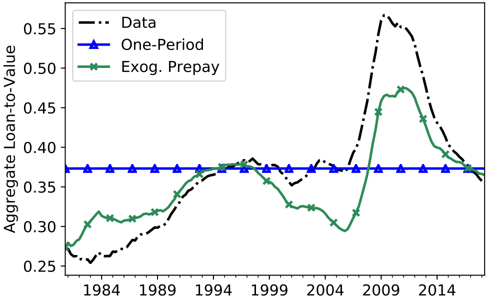
(a) Aggregate LTV



(b) Aggregate LTI

Traditional Models

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t) G_t^{-1} LTV_{t-1}$
- Constant prepayment: $\rho_t = \bar{\rho}$, $LTV_t^* = \overline{LTV}^*$. Choose $\bar{\rho}$ for best fit.
- Performs better during pre-boom period, but seriously understates debt accumulation in boom



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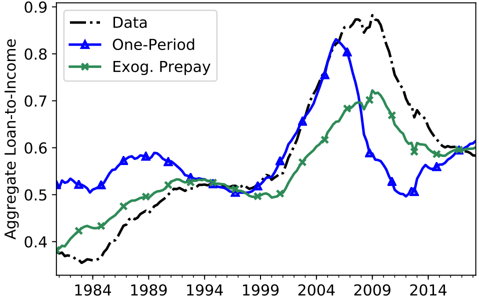
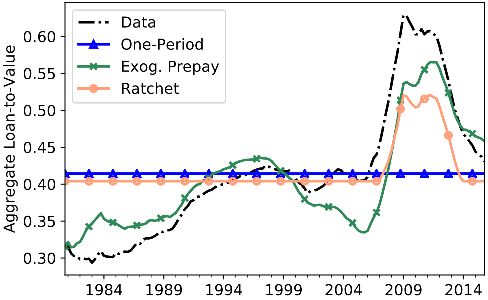


(b) Aggregate LTI

Traditional Models

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1} LTV_{t-1}$
- "Ratchet": $\rho_t = 1$ if $\overline{LTV}^* > (1 - \nu_t)G_t^{-1} LTV_{t-1}$, otherwise $\rho_t = 0$.
- Fit $\overline{LTV}^*$ to match data from 1998 on.



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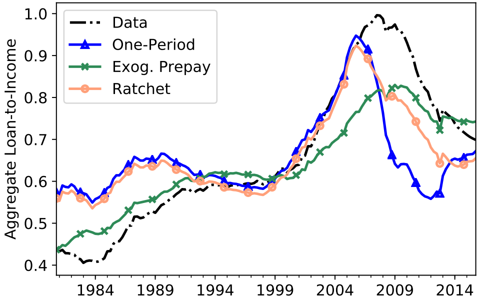
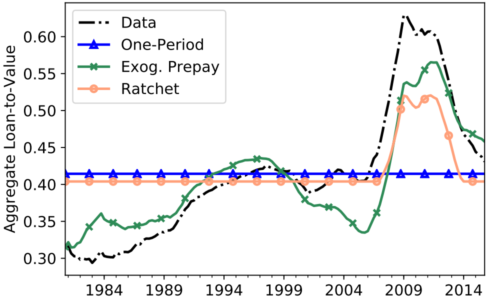


(b) Aggregate LTI

Traditional Models

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t) G_t^{-1} LTV_{t-1}$
- "Ratchet": $\rho_t = 1$ if $\overline{LTV}^* > (1 - \nu_t) G_t^{-1} LTV_{t-1}$, otherwise $\rho_t = 0$.
- Performs reasonably during boom-bust, but says nothing about pre-period.



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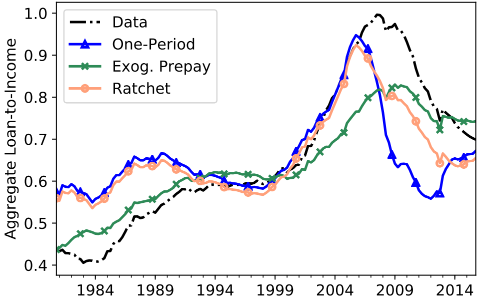
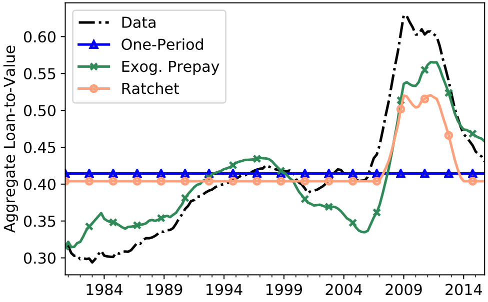


(b) Aggregate LTI

Traditional Models

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t) G_t^{-1} LTV_{t-1}$
- "Ratchet": $\rho_t = 1$ if $\overline{LTV}^* > (1 - \nu_t) G_t^{-1} LTV_{t-1}$, otherwise $\rho_t = 0$.
- Overall, existing models cannot reproduce leverage dynamics.



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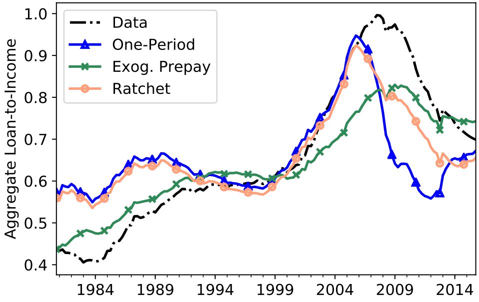
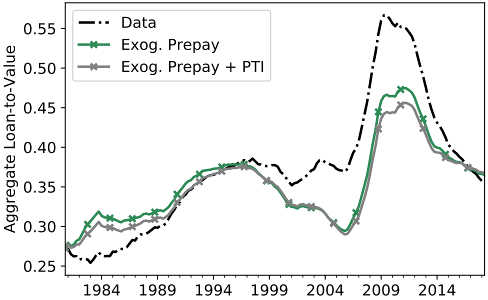


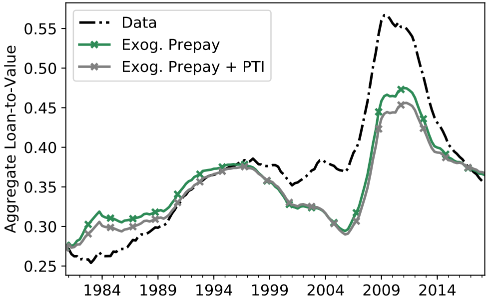
(b) Aggregate LTI

Adding PTI Limits

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1} LTV_{t-1}$
- This paper introduces PTI limits and endogenous prepayment.
- Start by imposing PTI limit as in model to create endogenous LTV_t^*.



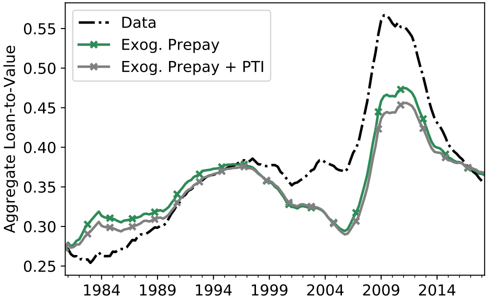
(a) Aggregate LTV



(b) Aggregate LTI

Adding PTI Limits

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1} LTV_{t-1}$
- This paper introduces PTI limits and endogenous prepayment.
- Fit actually becomes *worse*. PTI limit implies tight constraint in boom that doesn't match the data.



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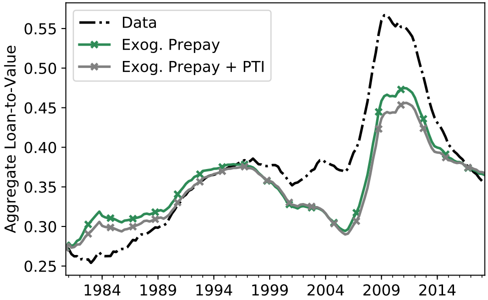
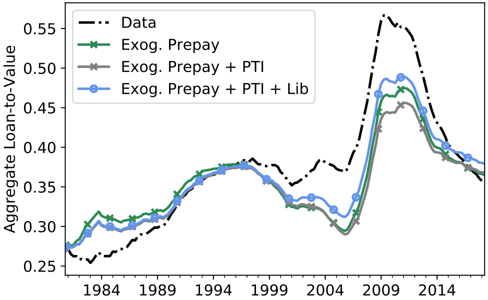
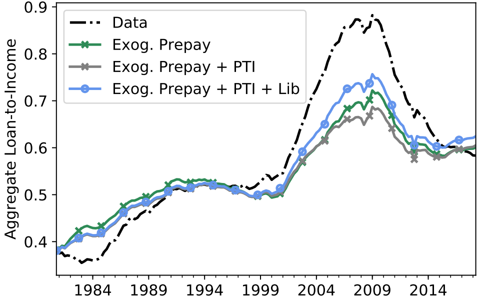


(b) Aggregate LTI

Adding PTI Limits

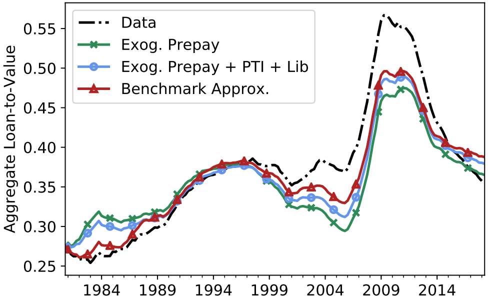
- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1} LTV_{t-1}$
- Incorporating observed relaxation of PTI limits in boom improves fit, generating much larger debt boom.



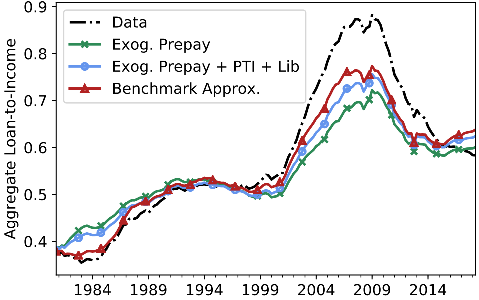


Full Benchmark

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1}LTV_{t-1}$
- Finally, incorporate (approximately) endogenous prepayment, fit transaction cost parameters $(\mu_\kappa, \sigma_\kappa)$.
- Improved empirical fit matches boom (high ρ_t), early 1980s (low ρ_t).



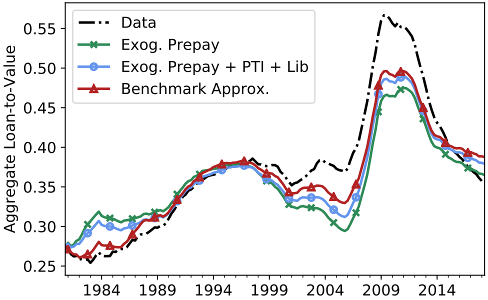
(a) Aggregate LTV



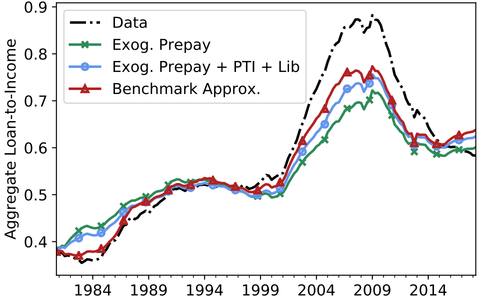
(b) Aggregate LTI

Full Benchmark

- General specification: $LTV_t = \rho_t LTV_t^* + (1 - \rho_t)(1 - \nu_t)G_t^{-1} LTV_{t-1}$
- Finally, incorporate endogenous prepayment.
- Use these transaction cost parameters so model inherits empirical performance.



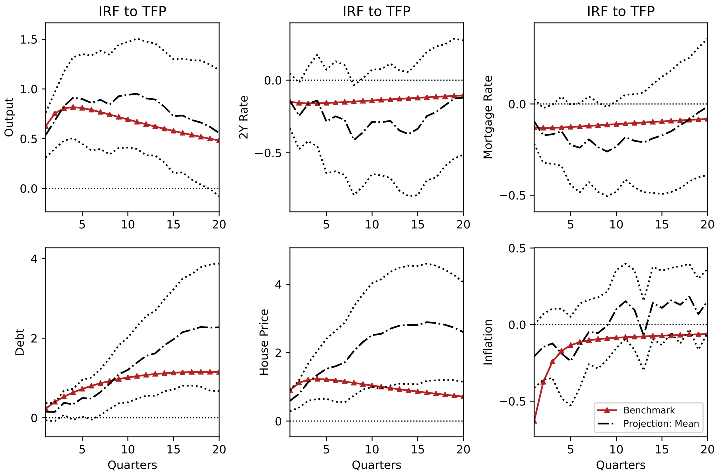
(a) Aggregate LTV



(b) Aggregate LTI

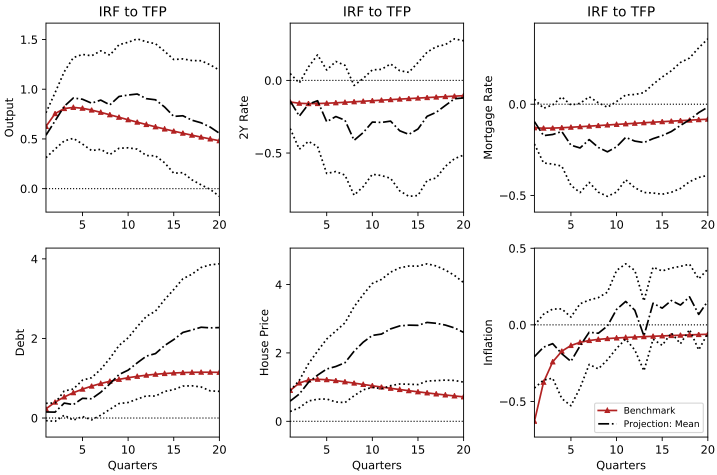
Model vs. Local Projections

- Compare TFP shocks in model and data (local projections).



▸ Back

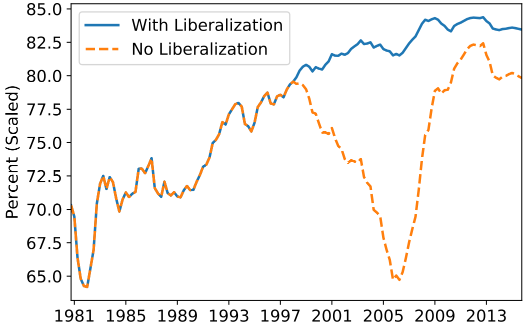
Model vs. Local Projections



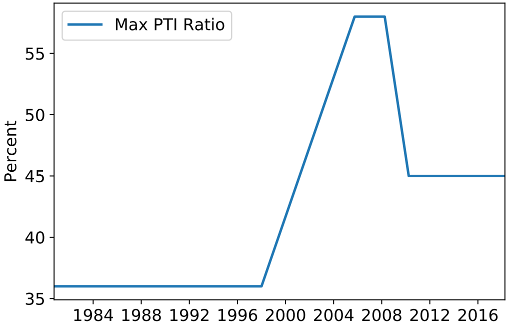
▸ Back

Adding PTI Limits

- Without PTI liberalization, deep tightening of LTV_t^* in boom.



(a) Implied LTV_t^* (Scaled)

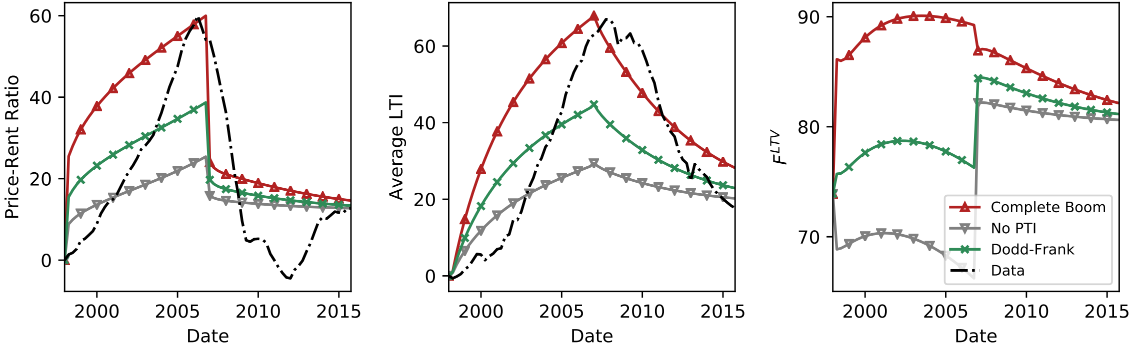


(b) θ_t^{LTV}: Liberalization

Back

Macroprudential Policy

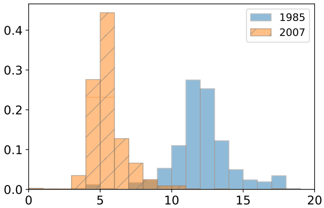
- Liberalizing PTI only to Dodd-Frank limit of (36% $\to$ 43%) would have made a big difference (down to 75% of price-rent, 72% of debt-income).



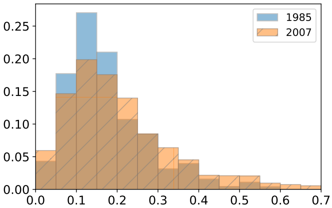
▸ More Series

Historical Ratios (AHS)

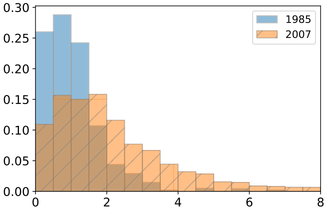
- Cross-section of recent mortgages (3 Years). ▸ Back



(a) Interest Rates



(b) PTI Ratios



(c) LTI Ratios

Demographics and Preferences

- Two types of infinitely lived agents:
  - Family of borrowers (b) with measure χ_b.
  - Family of savers (s) with measure $\chi_s = 1 - \chi_b$.
- Both types provide labor: $n_t = n_{b,t} + n_{s,t}$, taxed at rate τ.
- Complete set of contracts over consumption and housing services traded within each family, but not across families.
- Separable, expected utility preferences over consumption, housing services, and labor supply (for $j \in \{b, s\}$):

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

- Borrowers are more impatient than savers: $\beta_b < \beta_s$.
  - Motivation to borrow.

Back

Asset Technology

Housing:

- Divisible, owned by both types, requires maintenance cost.
- Cannot change housing stock without prepaying mortgage.
- Fixed housing stock $\bar{H}$, saver demand $\bar{H}_s$.
  - Total collateral value, not price, crucial to constraints.
  - Price effects are upper bound.

One-Period Bonds

- Nominal risk-free bond in zero net supply with rate R_t.
- No short positions/borrowing in one-period bond $\implies$ traded by savers only in equilibrium.

Back

Asset Technology

Mortgages:

- Only source of borrowing in the economy.
- Long-term nominal bonds with fixed interest rates.
  - See paper for adjustable-rate version.
- Originated with principal balance m_t^*, borrower repays fraction ν of principal each period.
- Contract specifies fixed coupon rate q_t^* (interest + principal), saver receives

$$\$(1-\nu)^k(1-\tau_{q,t})q_t^* m_t^*$$

  at all $t+k$ until prepayment.
- $\tau_{q,t}$ is a "tax" on all mortgage payments from a given vintage of loan.
  - Cheap way of introducing shocks to term premium.
- Borrower pays $\$(1-\nu)^k q_t^* m_t^*$, which is tax deductible.

▸ Overview ▸ Frontloading

Idiosyncratic Heterogeneity

1. Income shocks: An endogenous fraction of borrowers (those with low enough income draws) are constrained by PTI, the rest by LTV.
   - Equivalent to any shock that creates dispersion in house value-to-income ratio. ▸ Details ▸ PTI by Income
   - Effect: smooth out constraint, dampen mechanism.
2. Prepayment cost shocks: An endogenous fraction of borrowers (those with low enough costs) prepay their loans.
   - Simplifying assumption: borrower must choose whether to prepay based only on aggregate state. ▸ Details ▸ Redistribution Effects
   - Can still respond to: average existing rate vs. new rate, total extractable equity, forward looking expectations.

Income Shocks

- Want heterogeneity so that endogenous fraction are constrained by PTI.
- Idiosyncratic labor efficiency shocks $e_{i,t} \overset{iid}{\sim} \Gamma_e$, so individual borrower's income is

$$\text{income}_{i,t} = w_t n_{b,t} e_{i,t}.$$

- Shocks affect only credit limits, not consumption or labor supply (due to insurance, timing).
  - Equivalent to any shock causing variation in house price/income ratios.
- PTI binds for

$$e_{i,t} \leq \bar{e}_t \equiv \frac{\theta^{ltv} p_t^h h_t}{(\theta^{pti} - \omega) w_t n_{b,t} / (q_t^* + \alpha)}.$$

- Fraction constrained by LTV:

$$F_t^{ltv} = 1 - \Gamma_e(\bar{e}_t).$$

PTI by Income

Income Shocks

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PTI by Income

Monetary Policy

- Monetary policy follows a Taylor rule with time-varying inflation target.

$$\begin{aligned}\log R_t = \log \bar{\pi}_t + \phi_r(\log R_{t-1} - \log \bar{\pi}_{t-1}) \\ + (1-\phi_r)\left[\log \bar{R}^{real} + \psi_\pi(\log \pi_t - \log \bar{\pi}_t)\right]\end{aligned}$$

for

$$\log \bar{\pi}_t = (1-\phi_{\bar{\pi}}) \log \pi^{ss} + \phi_{\bar{\pi}} \log \bar{\pi}_{t-1} + \varepsilon_{\bar{\pi},t}.$$

- Why consider near-permanent policy shocks?
  - "Level factor" shocks needed to move long-term nominal rates.
  - But movements in term premia would also be amplified.
  - With ARMs, amplification of transitory monetary policy shocks.

Productive Technology

- Embed in simple New Keynesian environment (e.g., Gali (2008)).
- Intermediate goods producers operate the linear production function

$$y_t(i) = a_t n_t(i)$$

  where a_t is productivity, and $n_t(i)$ are labor hours.
- TFP process a_t:

$$\log a_{t+1} = \phi_a \log a_t + \varepsilon_{a,t+1}.$$

- Monopolistic intermediate producers with Calvo price rigidity (can't reset price with probability ζ_p). ▸ Details

Calibration: Key Parameters

Parameter	Name	Value	Internal	Target/Source
Demographics and Preferences				
Fraction of borrowers	χ_b	0.35	N	SCF
Income dispersion	σ_e	0.411	N	Fannie Mae
Borr. discount factor	β_b	0.95	N	Standard
Saver discount factor	β_s	0.993	Y	Real rate = 3% (ann.)
Borr. housing preference	ξ	0.292	Y	SCF
Housing and Mortgages				
Mortgage amortization	ν	1/120	N	30-year duration
Max PTI ratio	θ^{pti}	0.36	N	See text
Max LTV ratio	θ^{ltv}	0.85	N	See text
Issuance cost mean	μ_κ	0.350	Y	$\rho_{ss} = 4.5\%$
Issuance cost scale	s_κ	0.139	Y	See text
PTI offset (taxes, etc.)	α	0.003	Y	$q^*_{ss} + \alpha = 10.6\%$ (ann.)
PTI offset (other debt)	ω	0.08	N	See text
Exogenous Shocks				
TFP (pers.)	ϕ_a	0.9641	N	Garriga et al. (2015)
Taylor rule (inflation)	ψ_π	1.5	N	Standard

Frontloading Effect

- Endogenous prepayment critical to transmission into real activity.
- New Keynesian models: demand can affect output, but depends on timing.
  - Spending must occur in short run, before intermediate firms reset prices.
- Exogenous prepayment: debt limits change with rates, but few borrowers take advantage right away.
  - Most new spending too far in the future to affect output.
- Endogenous prepayment: wave of new issuance when rates fall.
  - Frontloaded spending generates large output effects.

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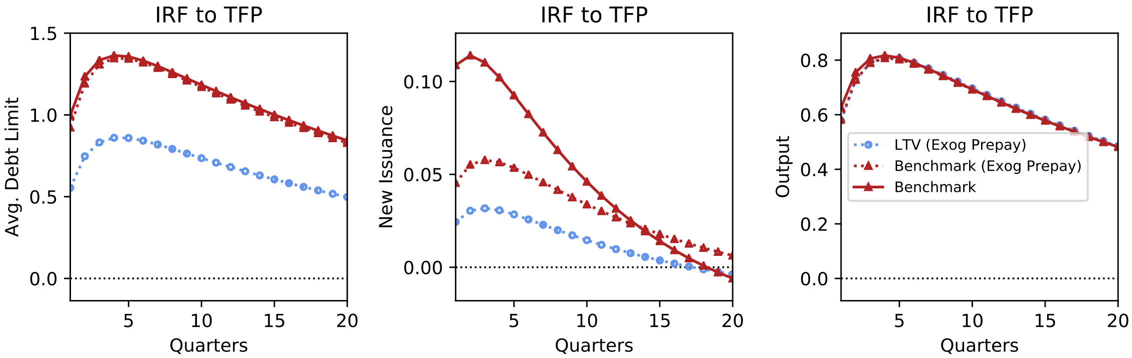
Frontloading Effect (TFP Shock)

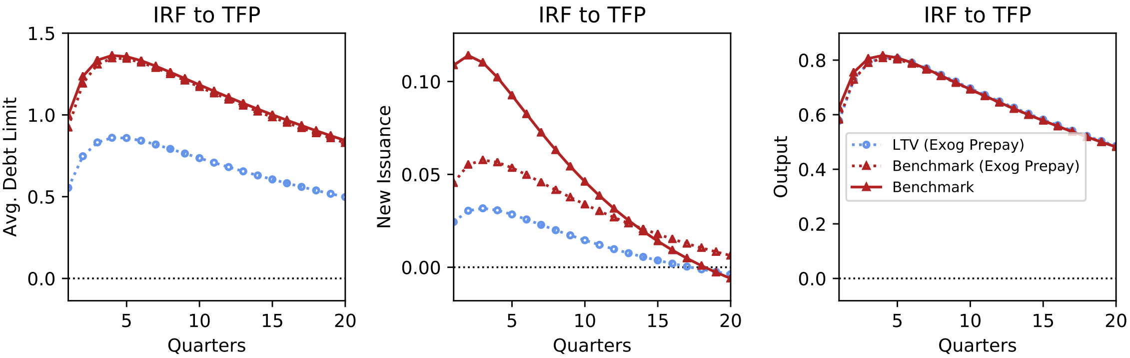
- TFP shock lowers nominal rates (deflationary) and raises labor income $\Longrightarrow$ loosens PTI limits.



▸ More Series ▸ π^* IRFs ▸ 43% PTI

Frontloading Effect (TFP Shock)

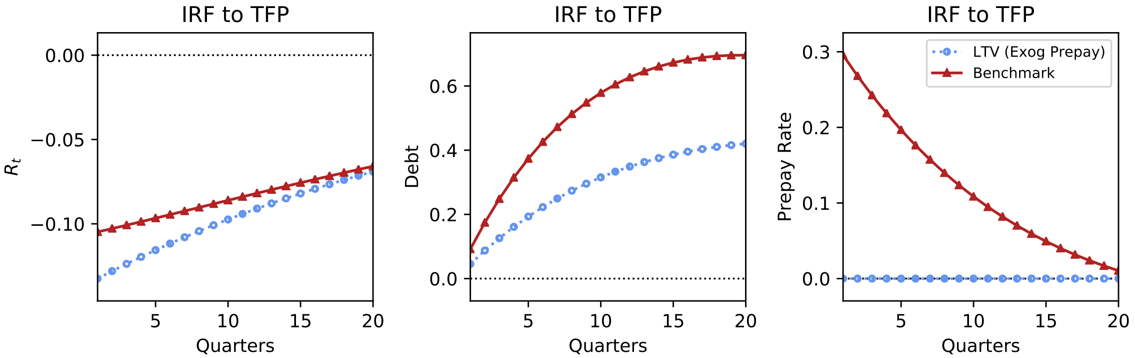
- Effects large: output response to 1% TFP shock increased by 52% (0.50 to 0.76) on impact.



More Series | π^* IRFs | 43% PTI

Inflation Stabilization (TFP Shock)

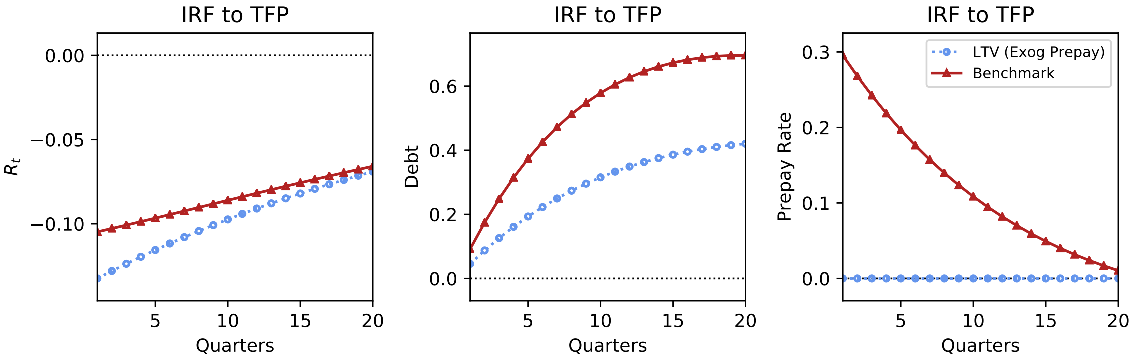
- Monetary policy experiment: how much does central bank need to move policy rate to fully stabilize inflation, $\pi_t = \bar{\pi}$?



More Series

Inflation Stabilization (TFP Shock)

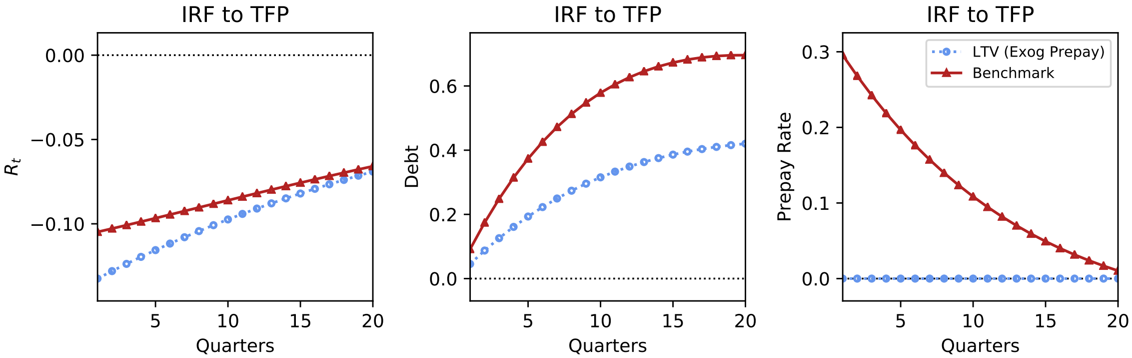
- Monetary policy “stronger” under Benchmark model: smaller movement in policy rate required to stabilize.



More Series

Inflation Stabilization (TFP Shock)

- But smaller movement in policy rate comes with larger movement in debt. Potential trade-off for policymakers.



▸ More Series

Intensive Margin: Credit Constraints

- Actual 2015 underwriting standards from Fannie Mae (“DTI” = PTI).

Standard Eligibility Requirements - Manual Underwriting
Excludes: Refi Plus, HomeStyle Renovation, and HomeReady

			Maximum DTI ≤ 36%		Maximum DTI ≤ 45%	
Transaction Type	**Number of Units**	**Maximum LTV, CLTV, HCLTV**	**Credit Score/LTV**	**Minimum Reserves**	**Credit Score/LTV**	**Minimum Reserves**
Principal Residence						
Purchase Limited Cash-Out Refinance	1 Unit	FRM: 95% ARM: 90%	FRM: 680 if > 75% FRM: 620 if ≤ 75% ARM: 680 if > 75% ARM: 640 if ≤ 75%	0	700 if > 75% 640 if ≤ 75%	0
			660 if > 75%	6	FRM: 680 if > 75% FRM: 620 if ≤ 75% ARM: 680 if > 75%	2
	2 Units	FRM: 85% ARM: 75%	680 if > 75% 640 if ≤ 75%	6	700 if > 75% 660 if ≤ 75%	6
					680 if > 75% 640 if ≤ 75%	12
	3-4 Units	FRM: 75% ARM: 65%	660	6	680	6
					660	12

Loan Level Price Adjustments

- PTI not priced, strictly a limit.

Table 1: All Eligible Mortgages (excluding MCM) – LLPA by Credit Score/LTV Ratio

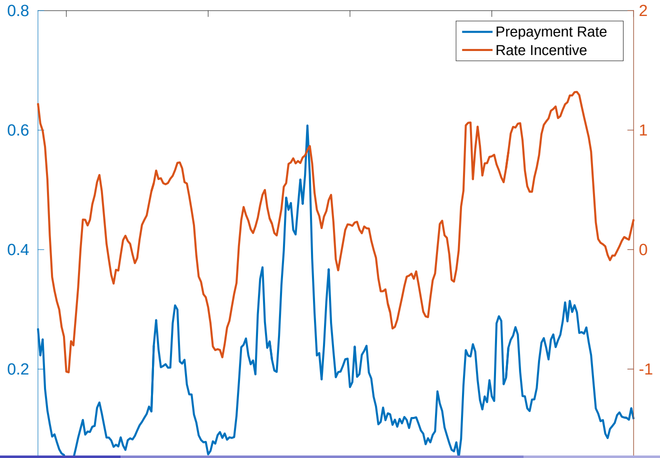
Representative Credit Score	LTV Range Applicable for all mortgages with terms greater than 15 years								
	< 60.00%	60.01 – 70.00%	70.01 – 75.00%	75.01 – 80.00%	80.01 – 85.00%	85.01 – 90.00%	90.01 – 95.00%	95.01 – 97.00%	SFC
≥ 740	0.000%	0.250%	0.250%	0.500%	0.250%	0.250%	0.250%	0.750%	N/A
720 – 739	0.000%	0.250%	0.500%	0.750%	0.500%	0.500%	0.500%	1.000%	N/A
700 – 719	0.000%	0.500%	1.000%	1.250%	1.000%	1.000%	1.000%	1.500%	N/A
680 – 699	0.000%	0.500%	1.250%	1.750%	1.500%	1.250%	1.250%	1.500%	N/A
660 – 679	0.000%	1.000%	2.250%	2.750%	2.750%	2.250%	2.250%	2.250%	N/A
640 – 659	0.500%	1.250%	2.750%	3.000%	3.250%	2.750%	2.750%	2.750%	N/A
620 – 639	0.500%	1.500%	3.000%	3.000%	3.250%	3.250%	3.250%	3.500%	N/A
< 620 (1)	0.500%	1.500%	3.000%	3.000%	3.250%	3.250%	3.250%	3.750%	N/A

(1) A minimum required credit score of 620 applies to all mortgage loans delivered to Fannie Mae in accordance with the *Selling Guide*; exceptions to this requirement are limited to loans in which all borrowers have nontraditional credit.

Back to Intro | Back to Credit Limits

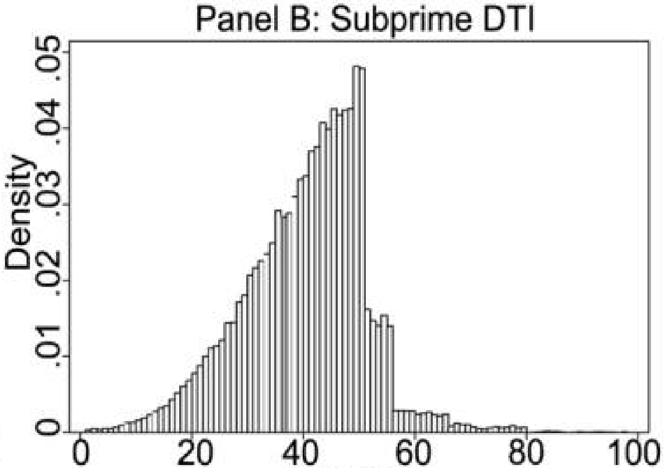
Prepayment Rates

- Fraction prepaying small, but volatile and highly responsive to interest rate incentives.



Subprime PTIs

- Plot from Foote, Gerardi, Willen (2009) shows subprime PTIs bunch at 50 and 55.



LTV and PTI in the Data

- Individual borrower's process:
  1. Given income, interest rates, compute max loan size $\bar{m}^{pti}_{i,t}$.
  2. Given max loan size, compute min house price associated with this loan: $p^h_t \bar{h}_{i,t} = \bar{m}^{pti}_{i,t} / \theta^{ltv}_t$.
  3. Search for house such that $h_{i,t} \leq \bar{h}_{i,t}$.
  4. Obtain largest possible loan given house value:

$$m^*_{i,t} = \bar{m}^{ltv}_{i,t} = \theta^{ltv}_t p^h_t h_{i,t} < \theta^{ltv}_t p^h_t \bar{h}_{i,t} = \bar{m}^{pti}_{i,t}.$$

- Result: LTV exactly at limit, PTI slightly below.
- Why asymmetry? Can choose house price, not income/rates.

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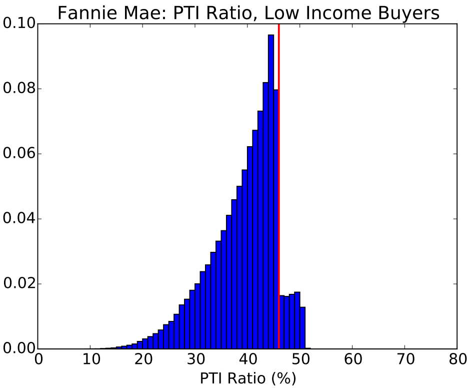
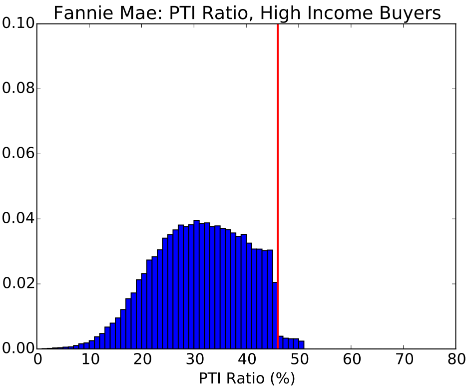
PTI by Income

- PTI appear more binding for low income. High (low) income is top (bottom) quartile.



(a) PTIs: 2014 Q3 (Low Income)

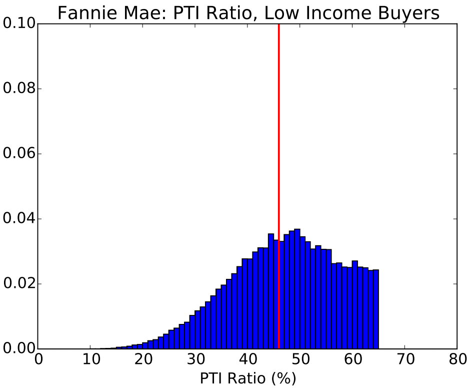


(b) PTIs: 2014 Q3 (High Income)

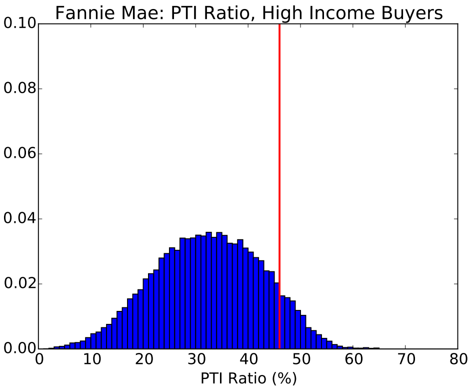
Back

PTI by Income

- Very high PTIs for low-income borrowers at height of boom.



(a) PTIs: 2006 Q1 (Low Income)

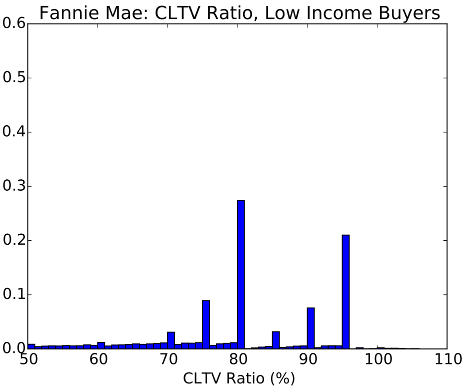


(b) PTIs: 2006 Q1 (High Income)

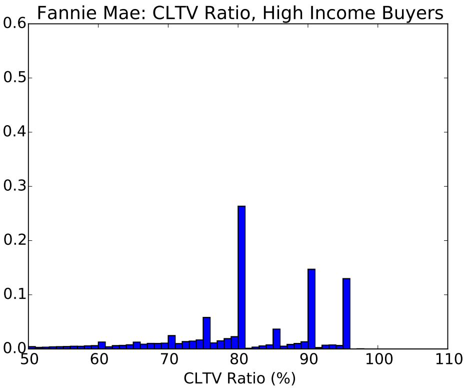
Back

CLTV by Income

- In contrast, CLTVs look very similar across income groups during boom and bust.



(a) CLTVs: 2014 Q3 (Low Income)

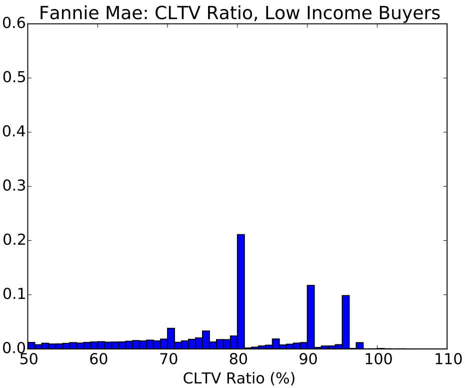


(b) CLTVs: 2014 Q3 (High Income)

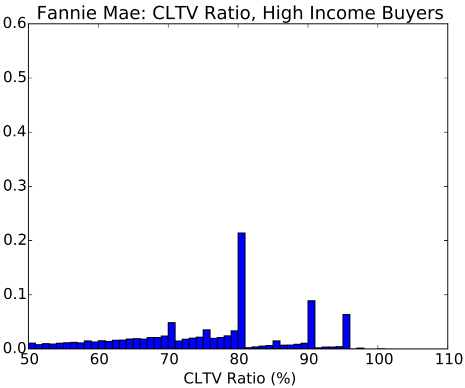
Back

CLTV by Income

- In contrast, CLTVs look very similar across income groups during boom and bust.



(a) CLTVs: 2006 Q1 (Low Income)



(b) CLTVs: 2006 Q1 (High Income)

Back

Prepayment

- Prepayment:
  - Borrower pays remaining principal to lender, cancels future payments.
  - Borrower can immediately take out new loan, adjust housing holdings.
- Transaction cost shocks:
  - Borrower must pay cost $\kappa_{i,t} m_t^*$, to obtain a new loan where $\kappa_{i,t} \overset{iid}{\sim} \Gamma_\kappa$.
  - If $\kappa_{i,t} \leq \bar{\kappa}_{i,t}$, then the borrower executes transaction, prepays.
- Timing within the period:
  1. Borrowers choose labor supply $n_{b,t}$, threshold transaction cost $\bar{\kappa}_t$, target house size h_t^* (conditional on prepaying).
  2. Borrowers draw $\kappa_{i,t}$, prepay if $\kappa_{i,t} \leq \bar{\kappa}_t$.
  3. Borrowers draw $e_{i,t}$, obtain new loan of size $m_{i,t}^* = \min(\bar{m}_{i,t}^{ltv}, \bar{m}_{i,t}^{pti})$.
  4. Insurance claims are paid out, equalizing consumption across borrowers.

Back

Credit or Redistribution?

- Prepayment has two effects:
  - Allows borrower to obtain new debt (credit channel).
  - Changes payments on existing debt (redistribution channel).
- Unlike previous work (Rubio (2011), Calza et al. (2013), Auclert (2015)), this framework can generate large redistributions in fixed-rate mortgage environment from prepayment.
- However, impact on aggregate demand is very small.
- Key is persistence of transfers.
  - Impatient borrower consumes out of current income, while patient saver consumes out of permanent income.
  - But with FRMs, prepayment leads to constant change in payments each month for decades.
  - Changes in current and permanent income nearly identical $\Longrightarrow$ offsetting consumption responses.

Back

Aggregation

- Aggregate laws of motion:

$$
\begin{aligned}
m_t &= \rho_t m_t^* + (1-\rho_t)(1-\nu)\pi_t^{-1} m_{t-1} \\
x_t &= \rho_t q_t^* m_t^* + (1-\rho_t)(1-\nu)\pi_t^{-1} x_{t-1} \\
h_{b,t} &= \rho_t h_{b,t}^* + (1-\rho_t) h_{b,t-1}.
\end{aligned}
$$

Back

Borrower Optimality

- Labor supply ($n_{b,t}$) condition:

$$w_t = -\frac{u^n_{b,t}}{u^c_{b,t}}.$$

- New loan size (m^*_t) condition:

$$1 = \Omega^m_{b,t} + q^*_t \Omega^x_{b,t} + \mu_t$$

where μ_t is multiplier, $\Omega^m_{b,t}$ and $\Omega^x_{b,t}$ are marginal continuation costs of extra unit of face value debt and promised payments:

$$\Omega^m_{b,t} = \mathbb{E}_t \left\{ \Lambda^\$_{b,t+1} \left[(1-\nu)\rho_{t+1} + (1-\nu)(1-\rho_{t+1})\Omega^m_{b,t+1} \right] \right\}$$
$$\Omega^x_{b,t} = \mathbb{E}_t \left\{ \Lambda^\$_{b,t+1} \left[1 + (1-\nu)(1-\rho_{t+1})\Omega^x_{b,t+1} \right] \right\}$$

and $\Lambda^\$_{b,t+1}$ is the nominal SDF.

Back

Borrower Optimality

- Prepayment optimality condition:

$$\rho_t = \Gamma\Bigg((m_t^*)^{-1}\Big\{\underbrace{(1-\Omega_{b,t}^m)(m_t^* - (1-\nu)\pi_t^{-1}m_{t-1})}_{\text{new debt}} - \underbrace{\Omega_{b,t}^x(q_t^* m_t^* - (1-\nu)\pi_t^{-1}x_{t-1})}_{\text{new payments}}\Big\}\Bigg).$$

- $\Omega_{b,t}^m$ and $\Omega_{b,t}^x$ are the marginal costs of extra unit of principal balance and promised payment:

$$\Omega_{b,t}^m = \mathbb{E}_t\left\{\Lambda_{b,t+1}^{\$}\left[(1-\nu)\rho_{t+1} + (1-\nu)(1-\rho_{t+1})\Omega_{b,t+1}^m\right]\right\}$$

$$\Omega_{b,t}^x = \mathbb{E}_t\left\{\Lambda_{b,t+1}^{\$}\left[1 + (1-\nu)(1-\rho_{t+1})\Omega_{b,t+1}^x\right]\right\}.$$

Back

Saver's Problem

- Budget constraint:

$$c_{s,t} \leq \Pi_t + w_t n_{s,t} - \underbrace{\rho_t(m_t^* - (1-\nu)\pi_t^{-1} m_{t-1})}_{\text{New Issuance}} + \pi_t^{-1}(1-\tau_{q,t})x_{t-1}$$
$$- p_t^h(h_{s,t} - (1-\delta)h_{s,t-1}) - R_t^{-1} b_t + b_{t-1}.$$

- Optimality conditions:

$$(b): \qquad 1 = R_t \mathbb{E}_t\left[\Lambda_{s,t+1}^{\$}\right]$$
$$(m^*): \qquad 1 = \Omega_{s,t}^m + \Omega_{s,t}^x (q_t^* - \tau_{q,t})$$

- $\Omega_{s,t}^m$ and $\Omega_{s,t}^x$ are the marginal benefits of extra unit of principal balance and promised payment:

$$\Omega_{s,t}^m = \mathbb{E}_t\left\{\Lambda_{s,t+1}^{\$}\left[(1-\nu)\rho_{t+1} + (1-\nu)(1-\rho_{t+1})\Omega_{s,t+1}^m\right]\right\}$$
$$\Omega_{s,t}^x = \mathbb{E}_t\left\{\Lambda_{s,t+1}^{\$}\left[1 + (1-\nu)(1-\rho_{t+1})\Omega_{s,t+1}^x\right]\right\}.$$

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Equilibrium Definition

A competitive equilibrium in this model is defined as a sequence of endogenous states $(m_{t-1}, q_{t-1}, h_{b,t-1}, h_{s,t-1})$, allocations $(c_{j,t}, n_{j,t}, h_{j,t})$, mortgage market quantities (m_t^*, ρ_t), and prices $(\pi_t, w_t, p_t^h, R_t, q_t^*)$ such that:

1. Given prices, $(c_{b,t}, n_{b,t}, h_{b,t}^*, m_t^*, \rho_t)$ solve the borrower's problem.
2. Given prices and borrower refinancing behavior, $(c_{s,t}, n_{s,t}, h_{s,t}, m_t^*)$ solve the saver's problem.
3. Given wages and consumer demand, π_t is the outcome of the intermediate firm's optimization problem.
4. Given inflation and output, R_t satisfies the monetary policy rule.
5. The resource, bond, and housing markets clear:

$$y_t = c_{b,t} + c_{s,t} + x_t^h, \qquad b_{s,t} = 0$$
$$h_t = \bar{H}, \qquad h_{s,t} = \bar{H}_s.$$

▸ Back

Calvo Pricing

Solution to intermediate firm's problem:

$$
\begin{aligned}
y_t &= \left[\int y_t(i)^{\frac{\lambda-1}{\lambda}}\, di\right]^{\frac{\lambda}{\lambda-1}} = \frac{a_t n_t}{\Delta_t} \\
\mathcal{N}_t &= y_t \left(\frac{mc_t}{mc^{ss}}\right) + \zeta_p \mathbb{E}_t \left[\Lambda_{s,t+1} \left(\frac{\pi_{t+1}}{\pi^{ss}}\right)^{\lambda} \mathcal{N}_{t+1}\right] \\
\mathcal{D}_t &= y_t + \zeta_p \mathbb{E}_t \left[\Lambda_{s,t+1} \left(\frac{\pi_{t+1}}{\pi^{ss}}\right)^{\lambda-1} \mathcal{D}_{t+1}\right] \\
\tilde{p}_t &= \frac{\mathcal{N}_t}{\mathcal{D}_t} \\
\pi_t &= \pi^{ss} \left[\frac{1-(1-\zeta_p)\tilde{p}^{1-\lambda}}{\zeta_p}\right]^{\frac{1}{\lambda-1}} \\
\Delta_t &= (1-\zeta_p)\tilde{p}^{-\lambda} + \zeta_p(\pi_t/\pi^{ss})^{\lambda}\Delta_{t-1}
\end{aligned}
$$

where $\mathcal{N}_t$ and $\mathcal{D}_t$ are auxiliary variables, $\tilde{p}_t$ is the ratio of the optimal price for resetting firms relative to the average price, and Δ_t is price dispersion. ▸ Back

Calibration: Other Parameters

Parameter	Name	Value	Internal	Target/Source
		Demographics and Preferences		
Borr. housing preference	ξ	0.25	Y	Davis and Ortalo-Magne (2011)
Disutility of labor scale	η_b	8.189	Y	$n_{b,ss} = 1/3$
Disutility of labor scale	η_s	5.662	Y	$n_{s,ss} = 1/3$
Inv. Frisch elasticity	φ	1.0	N	Standard
Tax rate	τ	0.204	N	Elenev et al. (2016)
		Productive Technology		
TFP (mean)	μ_a	1.099	Y	$y_{ss} = 1$
TFP (pers.)	ϕ_a	0.9641	N	Garriga et al. (2015)
Variety elasticity	λ	6.0	N	Standard
Price stickiness	ζ	0.75	N	Standard
		Monetary Policy		
Steady state inflation	π_{ss}	1.0075	N	3% (ann.)
Taylor rule (inflation)	ψ_π	1.5	N	Standard
Taylor rule (smoothing)	ϕ_r	0.89	N	Campbell et al. (2014)
Trend infl (pers.)	$\phi_{\bar{\pi}}$	0.994	N	Garriga et al. (2015)

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Calibration: Fraction of Borrowers

- Calibrate borrower/saver division to match 2001 Survey of Consumer Finances (SCF).
- Borrowers in the model: have house and mortgage but no liquid assets, save in home equity.
  - Match to households in 2001 SCF with less than one month's income in liquid assets (Kaplan and Violante (2014)) with a mortgage (24.3%).
  - Use housing preference ξ to match housing wealth / income for borrowers.
- Savers in the model: unconstrained agents with liquid assets.
  - Match to households in 2001 SCF with more than one month's income in liquid assets (45.4%).
- Remove households with no liquid assets and no mortgage (mostly renters) who are not represented in the model and normalize: $\chi_b = 0.35$.

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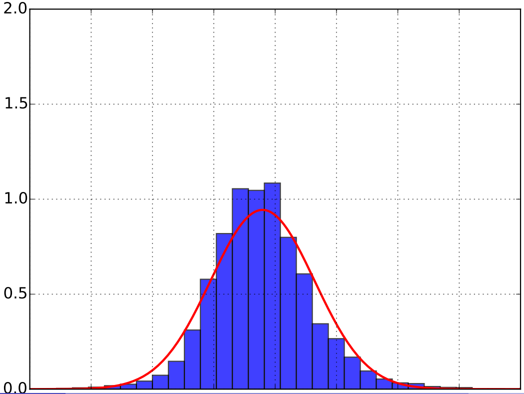
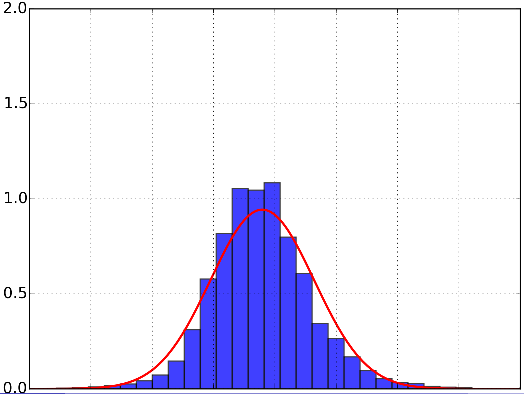
Calibration: Income Shock Distribution

- Parameterize e_i shocks to be lognormal, only need to calibrate σ_e.



Calibration: Income Shock Distribution

- Choose σ_e to match cross-sectional dispersion of $\log \text{value}_{i,t} - \log \text{income}_{i,t}$ in Fannie Mae loan-level origination data (average over 2000-2014).
  - This ratio determines which constraint is binding, given aggregates.



Calibration: Issuance Costs

- Choose Γ_κ so that approx. annualized prepayment rate $\widetilde{cpr}_t = 4\rho_t$ has a logistic functional form:

$$\widetilde{cpr}_t = \frac{1}{1 + \exp\left(-\frac{\kappa - \mu_\kappa}{s_\kappa}\right)}.$$

- To calibrate s_k, estimate prepayment regression

$$\text{logit}(cpr_{i,t}) = \gamma_{0,t} + \gamma_1(q_t^* - \bar{q}_{i,t-1}) + e_{i,t}$$

using pool-level MBS data (Fannie Mae 30-Year FRMs, 1994-2015).

- Choose s_κ so that model equation

$$\text{logit}(\widetilde{cpr}_t) = \gamma_{0,t} - \frac{\Omega_{b,t}^x}{s_\kappa}\left(q_t^* - \bar{q}_{t-1}\frac{(1-\nu)\pi_t^{-1} m_{t-1}}{m_t^*}\right)$$

satisfies $\Omega_b^x / s_\kappa = \hat{\gamma}_1$ in steady state.

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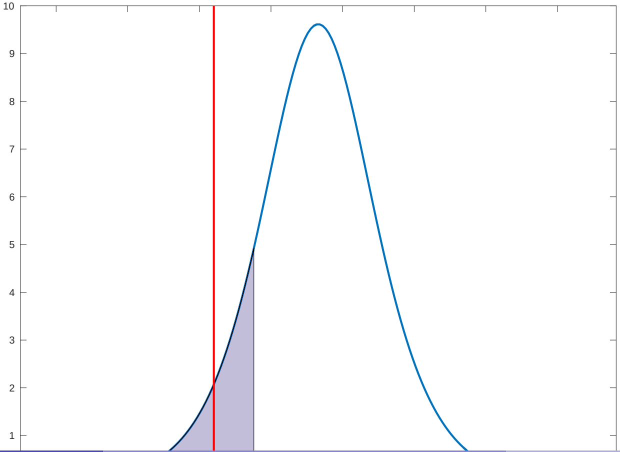
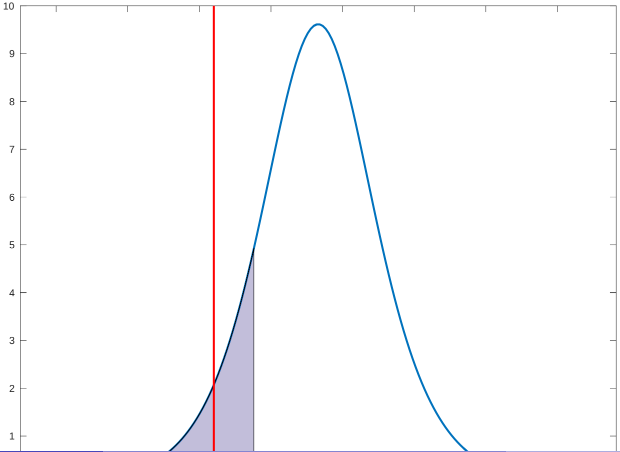
Calibration: Issuance Costs

- Given s_κ can choose μ_κ to match average prepayment rates on the same MBS series.



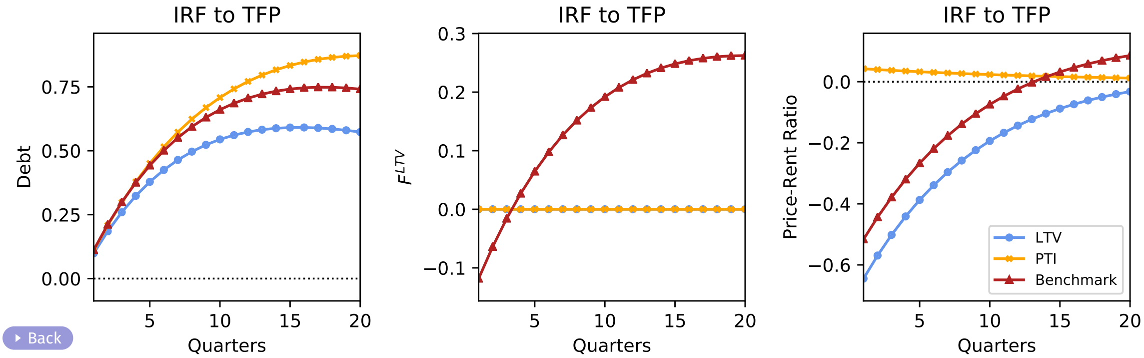
Calibration: Issuance Costs

- Resulting costs are high (threshold prepayer pays 13.8%, average prepayer pays 11%). Needed to match “inertial” behavior.



Constraint Switching Effect (TFP Shock)

- TFP shock lowers nominal rates (deflationary) and raises labor income $\implies$ loosens PTI limits.



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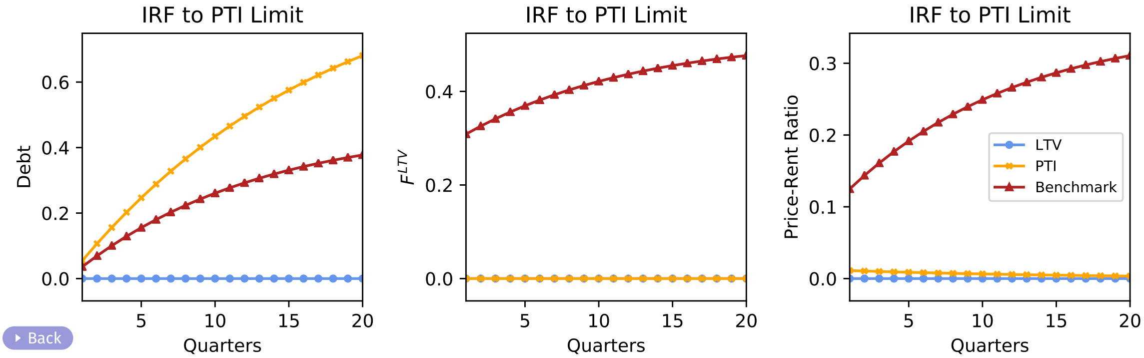
Credit Liberalization: PTI

- Loosening PTI (10%) causes increase in collateral value, house prices and price-rent ratios rise in Benchmark model.



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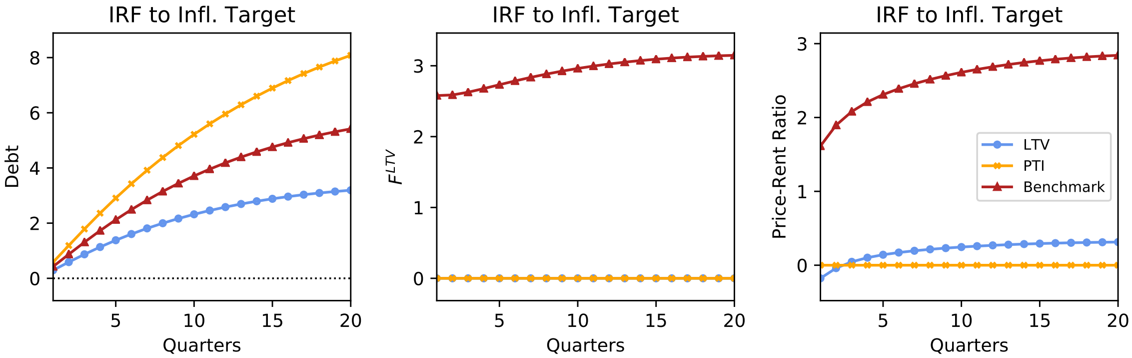
Constraint Switching Effect (Monetary Policy Shock)

- $\theta^{pti} = 43\%$ (Dodd-Frank): only 11% constrained by PTI.



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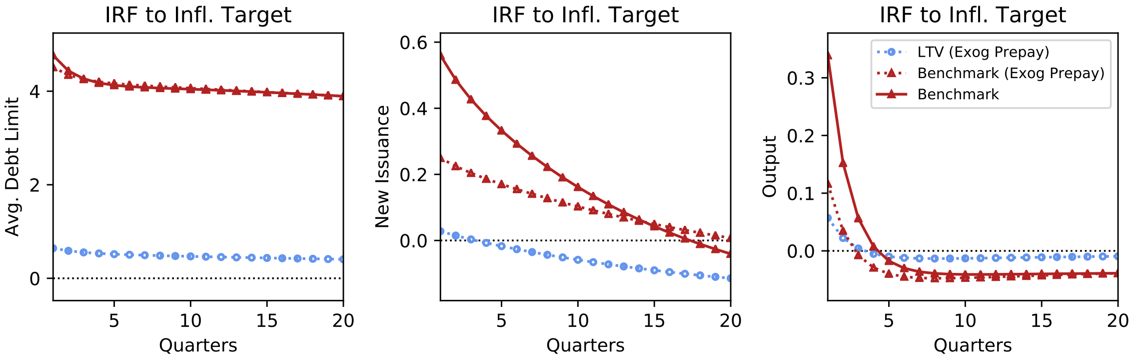
Frontloading Effect (Monetary Policy Shock)

- Large response of output to -1% near-permanent monetary policy shock.



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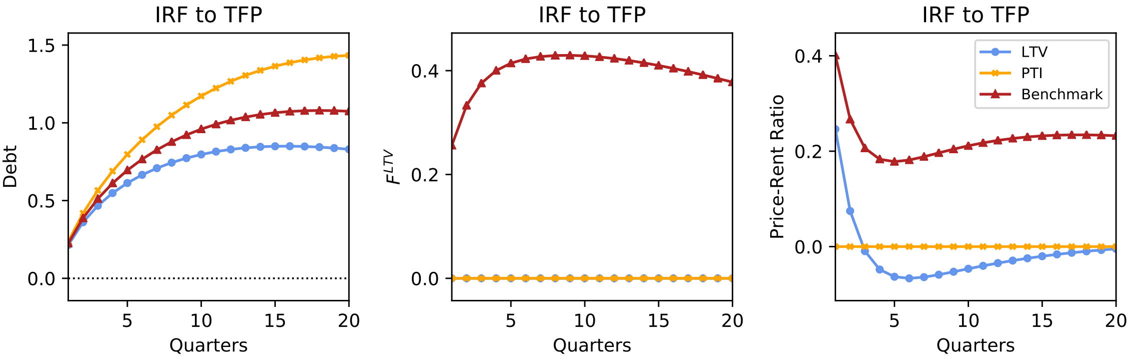
Frontloading Effect (TFP Shock)

- $\theta^{pti} = 43\%$ (Dodd-Frank): only 13% constrained by PTI.



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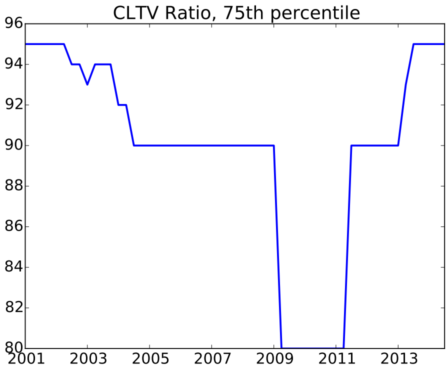
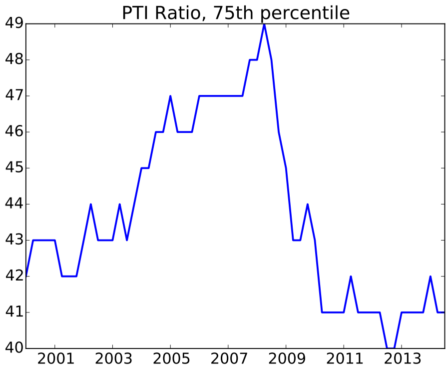
Credit Standards and the Boom-Bust

- Large rise in PTI ratios relative to CLTV ratios.



(a) CLTV: 75th Percentile



(b) PTI: 75th Percentile

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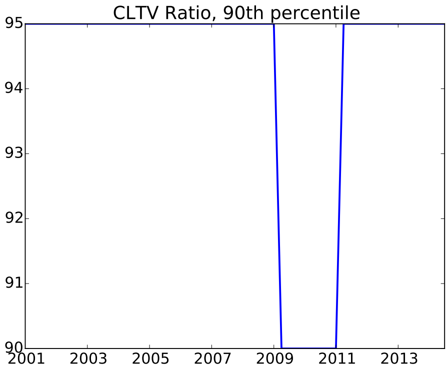
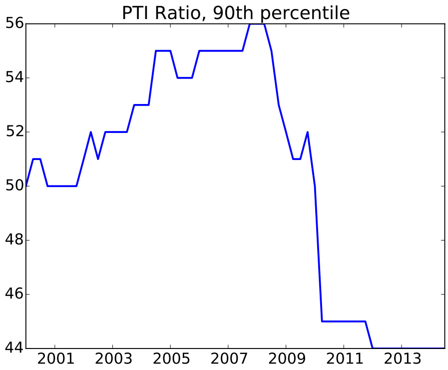
Credit Standards and the Boom-Bust



(a) CLTV: 90th Percentile



(b) PTI: 90th Percentile

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Credit Standards and the Boom-Bust

Fannie Mae 2007 Selling Guide

- Although we have established a benchmark qualifying debt-to-income ratio, we recognize that often there are legitimate reasons for exceeding this guideline. Therefore, a lender may use a ratio that is higher than our benchmark guideline, as long as its assessment of the comprehensive risk of the mortgage identifies and documents factors that justify the higher ratio...Our benchmark debt-to-income ratio is 36 percent of the borrower's monthly income.

Fannie Mae 2009 Selling Guide

- For manually underwritten loans, Fannie Mae's benchmark total debt-to-income ratio is 36% of the borrower's stable monthly income. The benchmark can be exceeded up to a maximum of 45% with strong compensating factors... For loan casefiles underwritten through DU [Desktop Underwriter], DU determines the maximum allowable debt-to income ratio based on the overall risk assessment of the loan casefile. DU will apply a maximum allowable total expense ratio of 45%, with flexibilities offered up to 50% for certain loan casefiles with strong compensating factors.

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Credit Standards and the Boom-Bust

“A New Method for Evaluating Your Debt” (Los Angeles Times: January 28, 2002)

- “In the 1970s and 1980s, a common rule of thumb was that your mortgage-related payments shouldn’t eat up more than 25% of your monthly household income. During the late 1980s and into the 1990s, that rule began to stretch into the 31% to 33% range and sometimes higher.”
- “In the 1990s, acceptable ratios began creeping above 40%. Late in the decade, even Freddie Mac confirmed that it no longer had hard and fast rules on total monthly debt to monthly income ratios, and lenders reported selling loans to Freddie with debt-to-income ratios of 55% and higher.”

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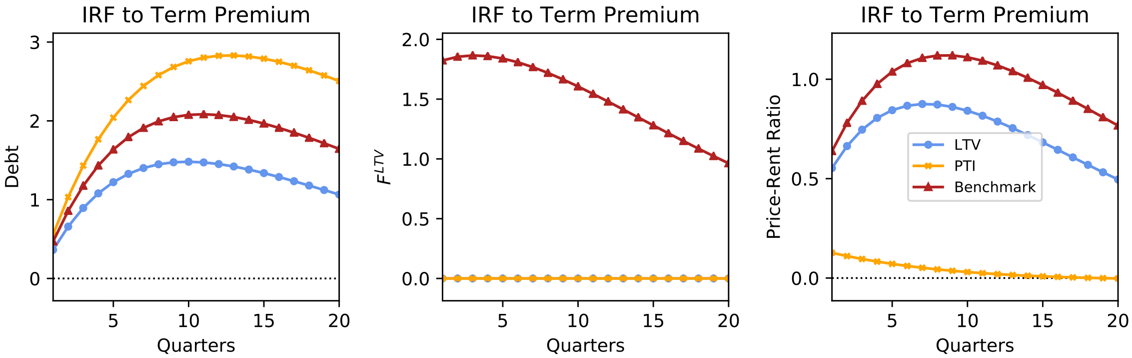
Constraint Switching Effect (Term Premium Shock)

- Shock to term premium (real cost of debt) affects LTV economy much more, but still observe differential response.



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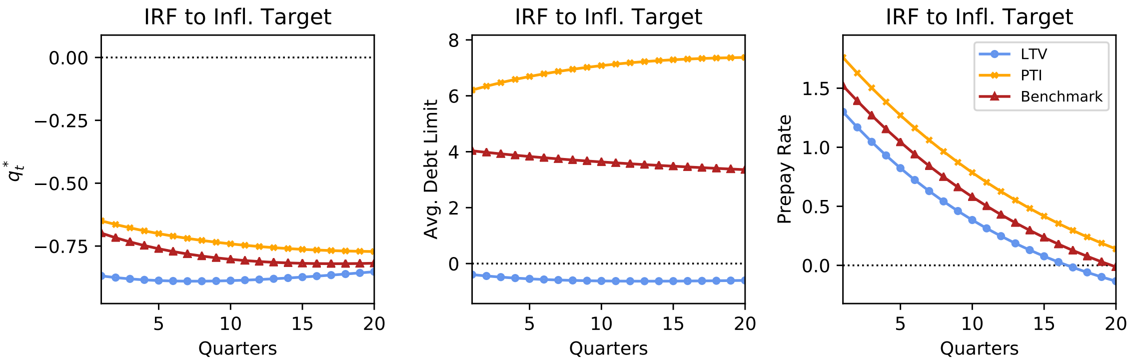
Constraint Switching Effect (Inflation Target Shock)

- Inflation target shock: additional variables.



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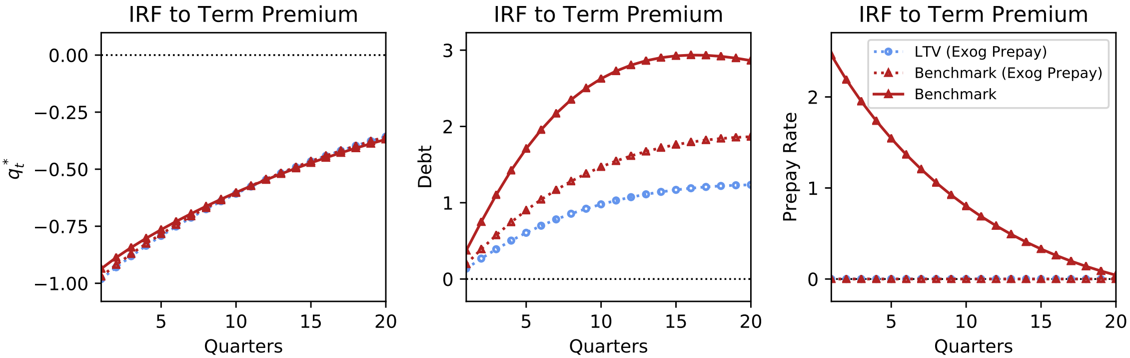
Frontloading Effect (Term Premium Shock)

- Term premium shock: additional variables.



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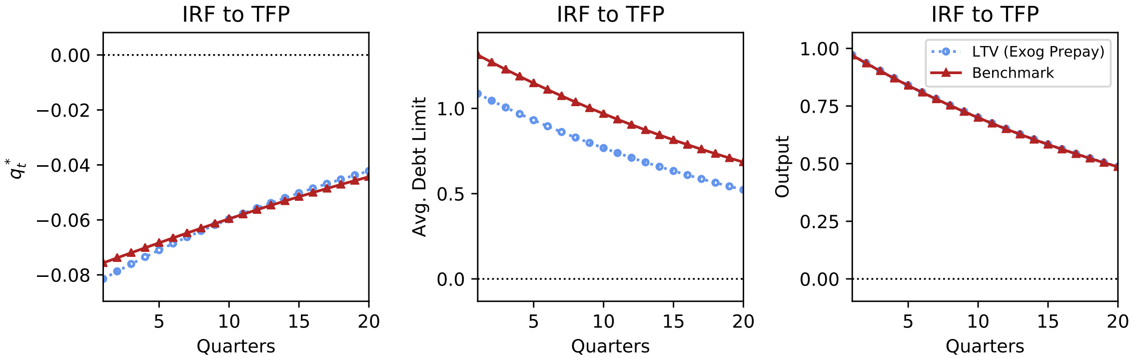
Inflation Stabilization (TFP Shock)

- Monetary policy experiment: how much does central bank need to move policy rate to fully stabilize inflation, $\pi_t = \bar{\pi}$?



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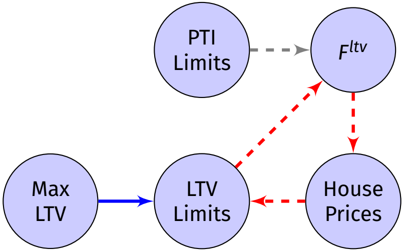
Credit Liberalization Experiment (Intuition)

- Changes to LTV standards cannot explain the boom-bust with PTI limits at traditional levels.
  - Direct effect: PTI constraints limit debt boom.
  - GE effect: constraint switching limits house price boom.



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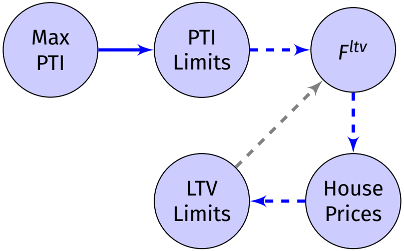
Credit Liberalization Experiment (Intuition)

- Relaxation of PTI standards increases house prices, price-rent ratios through constraint switching effect.
- High house prices relax LTV limits $\implies$ large increase in debt.



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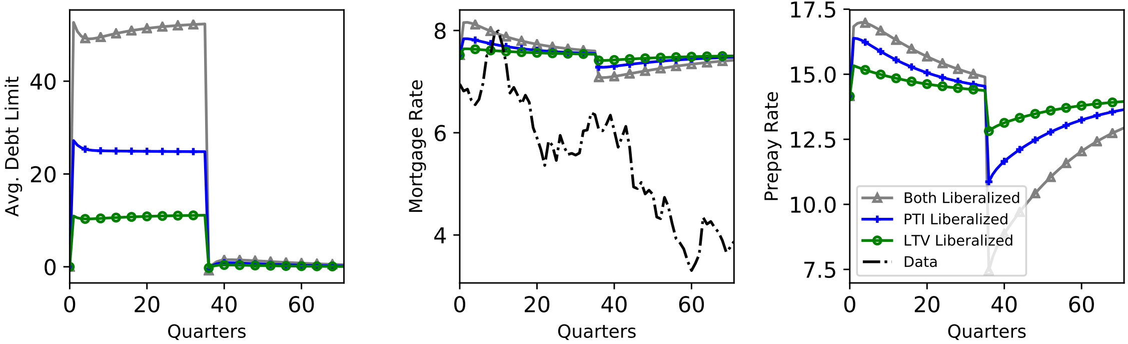
Credit Liberalization Experiment (Additional Series)



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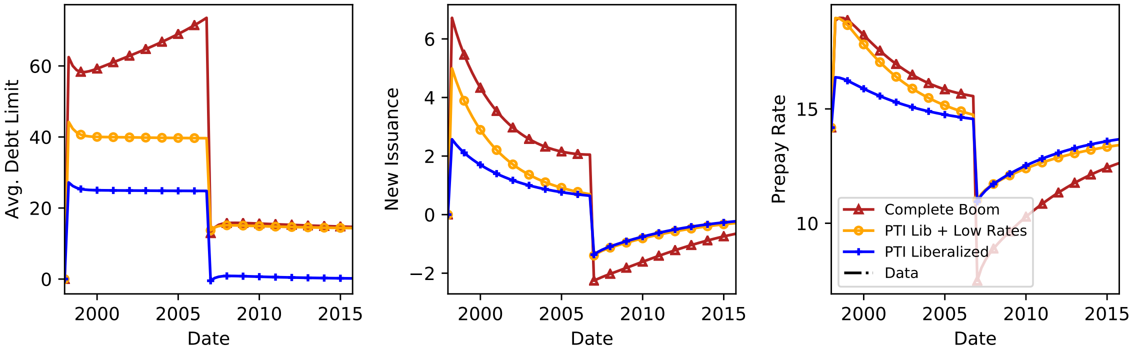
Explaining the Boom (Additional Series)



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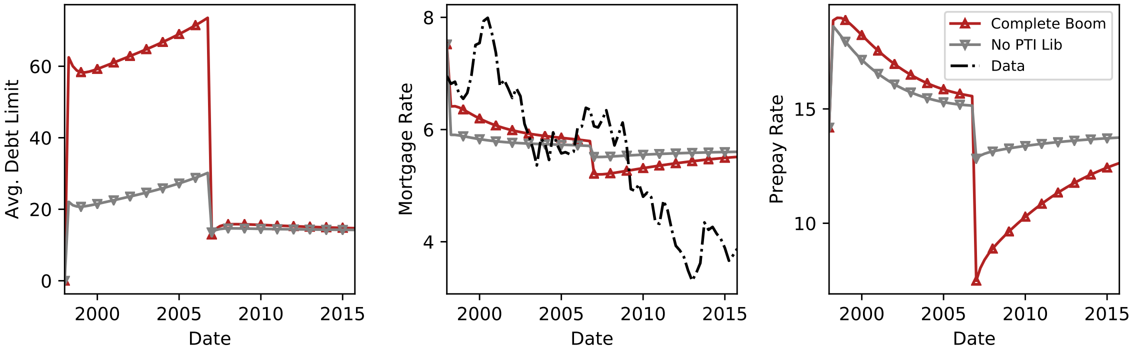
Explaining the Boom (Additional Series)



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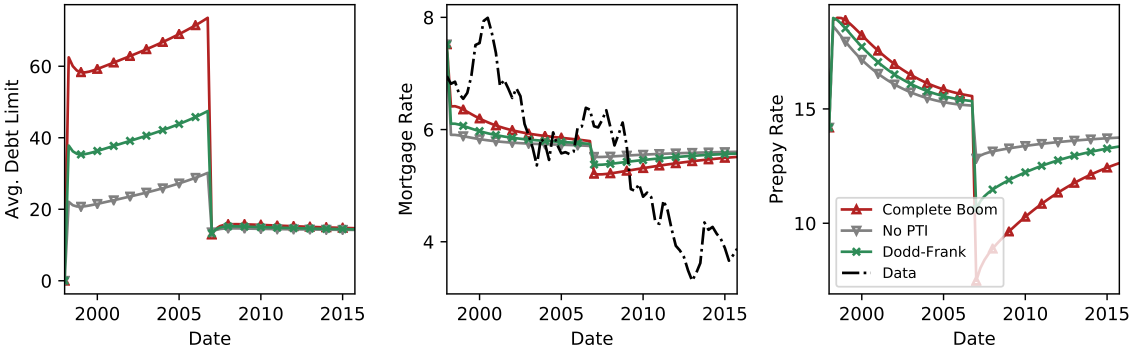
Explaining the Boom (Additional Series)



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