The Mortgage Credit Channel of Macroeconomic Transmission

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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 the details. But do they matter for dynamics?
  - This paper: yes.
Introduction

Main question: if and how mortgage credit issuance amplifies and propagates fundamental 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 ~ 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 up to 4% after persistent 1% fall in nominal rates.

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

- Partially sufficient: 42% of observed rise in price-rent ratios, 51% of the rise in debt-household income from PTI relaxation alone.
- Necessary: other forces (LTV liberalization, house price expectations) dramatically dampened without loose PTI.
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 $\Rightarrow$ max monthly payment of $\sim$ $1,200.
At 6% interest rate, $1,200 payment $\Rightarrow$ maximum PTI loan size $160k$. Plus 20% down payment $\Rightarrow$ house price of $200k.$
Kink in down payment at price $200k. Below this point size of loan limited by LTV, above by PTI. Kink likely optimum for homebuyers.
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.
Increasing the maximum PTI ratio from 28% to 31% has a similar effect to fall in rates, increases max loan size and corresponding price.
In contrast, increasing maximum LTV ratio from 80% to 90% means that $160k loan associated with only $178k house. Housing demand falls.
Literature Review


**New:** Embed into monetary DSGE, transmission through PTI.


**New:** Realistic mortgage structure, transmission through PTI.


**New:** PTI liberalization critical to boom-bust.


**New:** Transmission through credit growth, not mortgage payments.
MODEL
Model Overview

- **Borrowing** ➞ impatient borrowers/patient savers.
  - Permanent types with fixed measure $\chi_j$ for $j \in \{b, s\}$.
  - Preferences:
    \[
    V_{j,t} = \log\left(\frac{c_{j,t}}{\chi_j}\right) + \bar{\xi} \log\left(\frac{h_{j,t}}{\chi_j}\right) - \eta \frac{\left(\frac{n_{j,t}}{\chi_j}\right)^{1+\varphi}}{1 + \varphi} + \beta_j E_t V_{j,t+1}
    \]
- **Mortgage debt** ➞ durable housing.
  - Divisible, cannot change stock without prepaying mortgage.
  - Fixed housing stock, saver housing demand, no rental market.
- **Realistic mortgages** ➞ long-term, fixed-rate, prepayable loans.
  - Endogenous fraction $\rho_t$ prepay each period, update balance and interest rate.
- **Movements in long rates** ➞ Taylor rule, shock to inflation target $\bar{\pi}_t$.
  - Any shock to real rates or term premia should activate channel.
- **Effects on real economy** ➞ labor supply, sticky prices, TFP shocks.
Borrowing \(\Rightarrow\) impatient borrowers/patient savers.
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Credit Limits

- Borrowers face two credit limits at origination only.

- Loan-to-value constraint: \( m_{i,t}^* \leq \theta_{ltv} p_t^h h_{i,t}^* \).
  - Widely studied in the literature.
  - Key property: moves with house prices.
  - \( \bar{m}_{i,t}^{ltv} \equiv \theta_{ltv} p_t^h h_{i,t}^* \).

- 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, but largely unstudied in macro.
  - Key property: moves with interest rates (elasticity \( \sim 8 \)).
  - \( \bar{m}_{i,t}^{pti} \equiv (\theta_{pti} - \omega) \cdot \text{income}_{i,t} / (q_t^* + \alpha) \).

- Overall limit: \( m_{i,t}^* \leq \min \left( \bar{m}_{i,t}^{ltv}, \bar{m}_{i,t}^{pti} \right) \).
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

More
LTV and PTI in the Data

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

(a) CLTV Histogram: 2014 Q3

(b) PTI Histogram: 2014 Q3
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.
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).

(a) CLTV Histogram: 2014 Q3

(b) PTI Histogram: 2014 Q3
Representative Borrower’s Problem

- State variables: average 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 $\rho_t$, size of new houses $h_{b,t}^*$, size of new loans $m_t^*$.

- Budget constraint:

$$c_{b,t} \leq \rho_t (m_t^* - (1 - \nu)\pi_t^{-1}m_{t-1}) - \pi_t^{-1}x_{t-1} + \tau\pi_t^{-1}(x_{t-1} - \nu m_{t-1})$$

$$+ (1 - \tau)\omega_t n_{b,t} - \delta p_t^h h_{b,t-1} - \rho_t p_t^h (h_{b,t}^* - h_{b,t-1})$$

$$- (\text{Cost}(\rho_t) - \text{Rebate}_t) m_t^* + T_{b,t}$$

- Credit constraint:

$$m_t^* \leq \int \min \left( \bar{m}_{i,t}^{ltv}, \bar{m}_{i,t}^{pti} \right) d\Gamma_e(e_i).$$
Representative Borrower’s Housing Decision

- Housing optimality condition (unconstrained or no LTV):

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

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

- \( C_t \) (”collateral value”) is marginal value of relaxing constraint via extra $1 of house value:

\[ C_t = \mu_t F_{t}^{ltv} \theta^{ltv} \]

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):

$$p^h_t = \frac{u^h_{b,t}/u^c_{b,t} + \mathbb{E}_t \left\{ \Lambda_{b,t+1}p^h_{t+1} \left[ 1 - \delta \right] \right\}}{1 - \mu_t \theta_{ltv}}$$

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

- $C_t$ ("collateral value") is marginal value of relaxing constraint via extra $1$ of house value:

$$C_t = \mu_t F^l_{ltv} \theta_{ltv}$$

where $F^l_{ltv}$ is fraction constrained by LTV.

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Representative Borrower’s Housing Decision

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

$$
 p^h_t = \frac{u^h_{b,t} / u^c_{b,t} + \mathbb{E}_t \left\{ \Lambda_{b,t+1} p^h_{t+1} \left[ 1 - \delta \right] \right\}}{1-C_t}
$$

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$$
 C_t \equiv \mu_t F_{ltv}^t \theta_{ltv}
$$

where $F_{ltv}^t$ is fraction constrained by LTV.

- Note: $p^h_t$ is the price of housing that can be used to collateralize a new loan.
Representative Borrower’s Housing Decision

- Housing optimality condition (Benchmark model):

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

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

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

\[ C_{t} \equiv \mu_{t} F_{t}^{ltv} \theta^{ltv} \]

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- to LTV-constrained, increasing $F_{ltv}^t$.
- 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:** 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)

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

- **Experiment:** unexpectedly change parameters, unexpectedly return to baseline 32Q later.
  1. **PTI Liberalization:** $\theta_{pti}$ from 0.36 $\rightarrow$ 0.54.
  2. **LTV Liberalization:** $\theta_{ltv}$ 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.

(a) PTI Histogram: 2006 Q1

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Computation: nonlinear transition paths.
Credit Liberalization Experiment

- LTV liberalization generates small rise in debt-to-household income (20%). Price-rent ratios fall (-3%).

![Graphs showing changes in Price-Rent Ratio, Debt, and F^ht over quarters for LTV Liberalized and PTI Liberalized cases.](image)
PTI liberalization generates large boom in house prices, price-rent ratios (42%), debt-household income (51%).
Credit Liberalization Experiment

- Liberalized PTI amplifies contribution of other factors (e.g., LTV liberalization) to boom.
Loose/absent PTI limits likely necessary condition for alternative sources of boom.
House Price Expectations Experiment

- Expected (but not realized) increase in housing pref s explains entire rise in price-rent (101%) and debt-income (93%) ratios in LTV Economy.
House Price Expectations Experiment

- Much smaller impact in Benchmark Economy (41% of price-rent rise, 22% of debt-income rise).
Macroprudential policy: cap on PTI ratios more effective at limiting boom-bust cycles.
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.
  - Cap on PTI ratios, not LTV ratios more effective macroprudential policy.
Boom-Bust Paths (Data)

- Percent deviations from price-rent trough (1997Q4).

(a) Log Price-Rent

(b) Log Debt-Household Income

- LTV/PTI
- Both
- Dodd-Frank
Macroprudential Policy: Dodd-Frank Limit

- Counterfactual with Dodd-Frank cap, \((\theta^{ltv}, \theta^{pti}) \rightarrow (0.99, 0.43)\) substantially dampens cycle, cuts price-rent ratio rise by 61%.
Demographics and Preferences

- Two types of infinitely lived agents:
  - Family of **borrowers** \( (b) \) with measure \( \chi_b \).
  - 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 \( \tau \).
- 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 \( j \in \{b, s\} \)):
  
  \[ V_{j,t} = \log(c_{j,t} / \chi_j) + \zeta \log(h_{j,t} / \chi_j) - \eta \frac{(n_{j,t} / \chi_j)^{1+\varphi}}{1 + \varphi} + \beta_j \mathbb{E}_t V_{j,t+1} \]

- Borrowers are more impatient than savers: \( \beta_b < \beta_s \).
  - Motivation to borrow.
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.
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 \( \nu \) of principal each period.
- Contract specifies fixed coupon rate \( q_t^* \) (interest + principal), saver receives
  \[
  (1 - \nu)^k q_t^* m_t^*
  \]
at all \( t + k \) until prepayment.
- Interest payments are tax deductible.
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.
   - 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.
   - 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 \( e_{i,t} \sim \Gamma_e \), 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

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

- Fraction constrained by LTV:

\[
F_{ltv}^t = 1 - \Gamma_e(\bar{e}_t).
\]
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- Fraction constrained by LTV:
  \[ F_{ltv}^t = 1 - \Gamma_e(\bar{e}_t). \]
Monetary Policy

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

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

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.
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 \( a_t \):

\[ \log a_{t+1} = \phi_a \log a_t + \epsilon_{a,t+1}. \]

Monopolistic intermediate producers with Calvo price rigidity (can’t reset price with probability \( \zeta_p \)).
## Calibration: Key Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
<th>Value</th>
<th>Internal</th>
<th>Target/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics and Preferences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraction of borrowers</td>
<td>$\chi_b$</td>
<td>0.35</td>
<td>N</td>
<td>SCF</td>
</tr>
<tr>
<td>Income dispersion</td>
<td>$\sigma_e$</td>
<td>0.411</td>
<td>N</td>
<td>Fannie Mae</td>
</tr>
<tr>
<td>Borr. discount factor</td>
<td>$\beta_b$</td>
<td>0.95</td>
<td>N</td>
<td>Standard</td>
</tr>
<tr>
<td>Saver discount factor</td>
<td>$\beta_s$</td>
<td>0.993</td>
<td>Y</td>
<td>Real rate = 3% (ann.)</td>
</tr>
<tr>
<td>Borr. housing preference</td>
<td>$\zeta$</td>
<td>0.300</td>
<td>Y</td>
<td>SCF</td>
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<tr>
<td><strong>Housing and Mortgages</strong></td>
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<tr>
<td>Mortgage amortization</td>
<td>$\nu$</td>
<td>1/120</td>
<td>N</td>
<td>30-year duration</td>
</tr>
<tr>
<td>Max PTI ratio</td>
<td>$\theta_{pti}$</td>
<td>0.36</td>
<td>N</td>
<td>See text</td>
</tr>
<tr>
<td>Max LTV ratio</td>
<td>$\theta_{ltv}$</td>
<td>0.85</td>
<td>N</td>
<td>See text</td>
</tr>
<tr>
<td>Issuance cost mean</td>
<td>$\mu_\kappa$</td>
<td>0.183</td>
<td>Y</td>
<td>$\rho_{ss} = 4.5%$</td>
</tr>
<tr>
<td>Issuance cost scale</td>
<td>$s_\kappa$</td>
<td>0.026</td>
<td>Y</td>
<td>See text</td>
</tr>
<tr>
<td>PTI offset (taxes, etc.)</td>
<td>$\alpha$</td>
<td>0.005</td>
<td>Y</td>
<td>$q_{ss}^* + \alpha = 10.6%$ (ann.)</td>
</tr>
<tr>
<td>PTI offset (other debt)</td>
<td>$\omega$</td>
<td>0.08</td>
<td>N</td>
<td>See text</td>
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<tr>
<td><strong>Exogenous Shocks</strong></td>
<td></td>
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</tr>
<tr>
<td>TFP (pers.)</td>
<td>$\phi_a$</td>
<td>0.9641</td>
<td>N</td>
<td>Garriga et al. (2015)</td>
</tr>
<tr>
<td>Taylor rule (inflation)</td>
<td>$\psi_\pi$</td>
<td>1.5</td>
<td>N</td>
<td>Standard</td>
</tr>
</tbody>
</table>
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.
Frontloading Effect

- Endogenous prepayment critical to transmission into real activity.
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  - Spending must occur in short run, before intermediate firms reset prices.
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  - Frontloaded spending generates large output effects.
Frontloading Effect (TFP Shock)

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

![Graphs showing IRF to TFP for Avg. Debt Limit, New Issuance, and Output](image)

- More Series
- $\pi^*$ 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.
Monetary policy experiment: how much does central bank need to move policy rate to fully stabilize inflation, $\pi_t = \bar{\pi}$?
Inflation Stabilization (TFP Shock)

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

![IRF to TFP](chart1)

![IRF to TFP](chart2)

![IRF to TFP](chart3)
But smaller movement in policy rate comes with larger movement in debt. Potential trade-off for policymakers.
Actual 2015 underwriting standards from Fannie Mae ("DTI" = PTI).

### Standard Eligibility Requirements - Manual Underwriting

<table>
<thead>
<tr>
<th>Transaction Type</th>
<th>Number of Units</th>
<th>Maximum LTV, CLTV, HCLTV</th>
<th>Credit Score/LTV</th>
<th>Minimum Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal Residence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase Limited Cash-Out Refinance</td>
<td>1 Unit</td>
<td>FRM: 95% ARM: 90%</td>
<td>FRM: 680 if &gt; 75%</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FRM: 620 if ≤ 75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARM: 680 if &gt; 75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ARM: 640 if ≤ 75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>660 if &gt; 75%</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2 Units</td>
<td>FRM: 85% ARM: 75%</td>
<td>680 if &gt; 75%</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>640 if ≤ 75%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3-4 Units</td>
<td>FRM: 75% ARM: 65%</td>
<td>660</td>
<td>6</td>
</tr>
</tbody>
</table>

Excludes: Refi Plus, HomeStyle Renovation, and HomeReady

Maximum DTI ≤ 36%

- FRM: 680 if > 75%
- FRM: 620 if ≤ 75%
- ARM: 680 if > 75%
- ARM: 640 if ≤ 75%

Minimum Reserves:
- 0
- 6
- 6

Maximum DTI ≤ 45%

- FRM: 680 if > 75%
- FRM: 620 if ≤ 75%
- ARM: 680 if > 75%
- ARM: 640 if ≤ 75%

Minimum Reserves:
- 0
- 2
- 6
- 12
PTI not priced, strictly a limit.

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

<table>
<thead>
<tr>
<th>Representative Credit Score</th>
<th>LTV Range</th>
<th>SFC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 60.00%</td>
<td>60.01 – 70.00%</td>
</tr>
<tr>
<td>≥ 740</td>
<td>0.000%</td>
<td>0.250%</td>
</tr>
<tr>
<td>720 – 739</td>
<td>0.000%</td>
<td>0.250%</td>
</tr>
<tr>
<td>700 – 719</td>
<td>0.000%</td>
<td>0.500%</td>
</tr>
<tr>
<td>680 – 699</td>
<td>0.000%</td>
<td>0.500%</td>
</tr>
<tr>
<td>660 – 679</td>
<td>0.000%</td>
<td>1.000%</td>
</tr>
<tr>
<td>640 – 659</td>
<td>0.500%</td>
<td>1.250%</td>
</tr>
<tr>
<td>620 – 639</td>
<td>0.500%</td>
<td>1.500%</td>
</tr>
<tr>
<td>&lt; 620 (1)</td>
<td>0.500%</td>
<td>1.500%</td>
</tr>
</tbody>
</table>

(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.
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.

![Panel B: Subprime DTI](image)
LTV and PTI in the Data

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

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

- Result: LTV exactly at limit, PTI slightly below.

- Why asymmetry? Can choose house price, not income/rates.
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)
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)
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)
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)
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 $\kappa_{i,t} \simiid \Gamma_\kappa$.
  - 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 $m_{i,t}^* = \min(\bar{m}^{ltv}_{i,t}, \bar{m}^{pti}_{i,t})$.
  4. Insurance claims are paid out, equalizing consumption across borrowers.
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 $\Rightarrow$ offsetting consumption responses.
Aggregation

- Aggregate laws of motion:

\[
\begin{align*}
m_t &= \rho_t m^*_t + (1 - \rho_t)(1 - \nu)\pi_t^{-1} m_{t-1} \\
\text{pay}_t &= \rho_t q^*_t m^*_t + (1 - \rho_t)(1 - \nu)\pi_t^{-1}\text{pay}_{t-1} \\
h_{b,t} &= \rho_t h^*_{b,t} + (1 - \rho_t) h_{b,t-1}.
\end{align*}
\]
Borrower Optimality

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

\[
\omega_t = -\frac{u_{b,t}^n}{u_{b,t}^c}.
\]

- New loan size \((m_t^*)\) condition:

\[
1 = \Omega_{b,t}^m + q_t^* \Omega_{b,t}^{pay} + \mu_t
\]

where \(\mu_t\) is multiplier, \(\Omega_{b,t}^m\) and \(\Omega_{b,t}^{pay}\) are marginal continuation costs of extra unit of face value debt and promised payments:

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

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

and \(\Lambda_{b,t+1}^s\) is the nominal SDF.
Borrower Optimality

- Prepayment optimality condition:

\[
\rho_t = \Gamma \left( (m_t^*)^{-1} \right) \left\{ (1 - \Omega_{b,t}^m) (m_t^* - (1 - \nu) \pi_t^{-1} m_{t-1}) \right\} \]

\[
\text{new debt}
\]

\[
- \Omega_{b,t}^{pay} \left( q_t^* m_t^* - (1 - \nu) \pi_t^{-1} \text{pay}_{t-1} \right) \]

\[
\text{new payments}
\]

\[
- C_t p_t^h \left( h_t^* - (1 - \delta) h_{b,t-1} \right) \}
\]

\[
\text{cost of collateral}
\]

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

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

\[
\Omega_{b,t}^{pay} = \mathbb{E}_t \left\{ \Lambda_{b,t+1} \left[ 1 + (1 - \nu) (1 - \rho_{t+1}) \Omega_{b,t+1}^{pay} \right] \right\}.
\]
Saver’s Problem

- **Budget constraint:**

\[
c_{s,t} \leq \Pi_t + w_t n_{s,t} - \rho_t (m^*_t - (1 - \nu)\pi_t^{-1}m_{t-1}) + \pi_t^{-1}\text{pay}_{t-1} - p^h_t (h_{s,t} - (1 - \delta)h_{s,t-1}) - R_t^{-1}b_t + b_{t-1}.
\]

- **Optimality conditions:**

\[(b) : \quad 1 = R_t \mathbb{E}_t \left[ \Lambda_{s,t+1}^s \right] \]

\[(m^*) : \quad 1 = \Omega_{s,t}^m + \Omega_{s,t}^{\text{pay}} q^*_t \]

- \(\Omega_{s,t}^m\) and \(\Omega_{s,t}^{\text{pay}}\) are the marginal benefits of extra unit of principal balance and promised payment:

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

\[
\Omega_{s,t}^{\text{pay}} = \mathbb{E}_t \left\{ \Lambda_{s,t+1}^s \left[ 1 + (1 - \nu)(1 - \rho_{t+1})\Omega_{s,t+1}^{\text{pay}} \right] \right\}.
\]
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 \((m^*_t, \rho_t)\), and prices \((\pi_t, w_t, p^h_t, R_t, q^*_t)\) 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, \(\pi_t\) 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:

\[
\begin{align*}
    y_t &= c_{b,t} + c_{s,t} + x^h_t, \\
    h_t &= \bar{H}, \\
    b_{s,t} &= 0 \\
    h_{s,t} &= \bar{H}_s.
\end{align*}
\]
Calvo Pricing

Solution to intermediate firm’s problem:

\[ y_t = \left[ \int y_t(i)^{\frac{\lambda-1}{\lambda}} \, di \right]^{\frac{\lambda}{\lambda-1}} = \frac{a_t n_t}{\Delta_t} \]

\[ N_t = y_t \left( \frac{mc_t}{mcs} \right) + \zeta_p \mathbb{E}_t \left[ \Lambda_{s,t+1} \left( \frac{\pi_{t+1}}{\pi^{ss}} \right)^{\lambda} N_{t+1} \right] \]

\[ D_t = y_t + \zeta_p \mathbb{E}_t \left[ \Lambda_{s,t+1} \left( \frac{\pi_{t+1}}{\pi^{ss}} \right)^{\lambda-1} D_{t+1} \right] \]

\[ \tilde{p}_t = \frac{N_t}{D_t} \]

\[ \pi_t = \pi^{ss} \left[ \frac{1 - (1 - \zeta_p)\tilde{p}^{1-\lambda}}{\zeta_p} \right]^{\frac{1}{\lambda-1}} \]

\[ \Delta_t = (1 - \zeta_p)\tilde{p}^{-\lambda} + \zeta_p \left( \frac{\pi_t}{\pi^{ss}} \right)^{\lambda} \Delta_{t-1} \]

where \( N_t \) and \( D_t \) are auxiliary variables, \( \tilde{p}_t \) is the ratio of the optimal price for resetting firms relative to the average price, and \( \Delta_t \) is price dispersion.
## Calibration: Other Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
<th>Value</th>
<th>Internal</th>
<th>Target/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics and Preferences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disutility of labor scale</td>
<td>η</td>
<td>6.351</td>
<td>Y</td>
<td>n_{ss} = 1/3</td>
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<tr>
<td>Inv. Frisch elasticity</td>
<td>φ</td>
<td>1.0</td>
<td>N</td>
<td>Standard</td>
</tr>
<tr>
<td>Tax rate</td>
<td>τ</td>
<td>0.204</td>
<td>N</td>
<td>Elenev et al. (2016)</td>
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<tr>
<td><strong>Productive Technology</strong></td>
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<tr>
<td>TFP (mean)</td>
<td>μ_α</td>
<td>1.099</td>
<td>Y</td>
<td>y_{ss} = 1</td>
</tr>
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<td>TFP (pers.)</td>
<td>φ_α</td>
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<td>N</td>
<td>Garriga et al. (2015)</td>
</tr>
<tr>
<td>Variety elasticity</td>
<td>λ</td>
<td>6.0</td>
<td>N</td>
<td>Standard</td>
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<tr>
<td>Price stickiness</td>
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<tr>
<td><strong>Monetary Policy</strong></td>
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</tr>
<tr>
<td>Steady state inflation</td>
<td>π_{ss}</td>
<td>1.0075</td>
<td>N</td>
<td>3% (ann.)</td>
</tr>
<tr>
<td>Taylor rule (inflation)</td>
<td>ψ_π</td>
<td>1.5</td>
<td>N</td>
<td>Standard</td>
</tr>
<tr>
<td>Taylor rule (smoothing)</td>
<td>ϕ_r</td>
<td>0.89</td>
<td>N</td>
<td>Campbell et al. (2014)</td>
</tr>
<tr>
<td>Trend infl (pers.)</td>
<td>φ_π</td>
<td>0.994</td>
<td>N</td>
<td>Garriga et al. (2015)</td>
</tr>
</tbody>
</table>
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 $\zeta$ 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: $\chi_b = 0.35$. 
Calibration: Income Shock Distribution

- Parameterize $e_i$ shocks to be lognormal, only need to calibrate $\sigma_e$.

**Figure:** House Price / Income Ratio: 2000 Q1
Choose $\sigma_e$ 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.

Figure: House Price / Income Ratio: 2000 Q1
Calibration: Issuance Costs

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

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

- To calibrate $s_\kappa$, estimate prepayment regression

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

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

- Choose $s_\kappa$ so that model equation

$$
\logit(\tilde{cpr}_t) = \gamma_{0,t} - \frac{\Omega^\text{pay}_{b,t}}{s_\kappa} \left( q^*_t - \bar{q}_{t-1} \frac{(1 - \nu) \pi_t^{-1} m_{t-1}}{m^*_t} \right)
$$

satisfies $\Omega^\text{pay}_b / s_\kappa = \hat{\gamma}_1$ in steady state.
Calibration: Issuance Costs

Given $s_K$ can choose $\mu_K$ 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.
Focus on mechanism: exogenous prepayment ($\rho_t = \bar{\rho}$).
TFP shock lowers nominal rates (deflationary) and raises labor income $\implies$ loosens PTI limits.
For IRFs, assume log $\theta_t$ is AR(1) with persistence 0.9.
Loosening LTV (10%) causes decrease in collateral value, house prices and price-rent ratios fall in Benchmark model.
Loosening PTI (10%) causes increase in collateral value, house prices and price-rent ratios rise in Benchmark model.
Constraint Switching Effect (Monetary Policy Shock)

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

- [Graphs showing IRF to Infl. Target, Debt, Price-Rent Ratio, and Ftv over quarters.]

Back
Frontloading Effect (Monetary Policy Shock)

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

![IRF to Infl. Target plots]

- IRF to Infl. Target for various economic indicators over time.
Frontloading Effect (TFP Shock)

- $\theta_{pti} = 43\%$ (Dodd-Frank): only 13% constrained by PTI.
Credit Standards and the Boom-Bust

- Large rise in PTI ratios relative to CLTV ratios.

(a) CLTV: 75th Percentile

(b) PTI: 75th Percentile
Credit Standards and the Boom-Bust

(a) CLTV: 90th Percentile

(b) PTI: 90th Percentile
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.
Credit Standards and the Boom-Bust

“A New Method for Evaluating Your Debt” (Los Angeles Times: January 27, 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.”
Constraint Switching Effect (Monetary Policy Shock)

- IRF to near-permanent -1% (annualized) shock to inflation target.
Frontloading Effect (TFP Shock)

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

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

![Graphs showing changes in average debt limit, prepay rate, and g^* over quarters.]

- **Average Debt Limit**: Shows a sharp decline followed by stabilization.
- **Prepay Rate**: Displays a rapid decrease followed by an increase.
- **g^***: Demonstrates a significant decline with a recovery phase.

Daniel L. Greenwald (MIT Sloan)

The Mortgage Credit Channel

March 10, 2017
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.
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.

Diagram:

- Max PTI → PTI Limits → $F_{ltv}$
- $F_{ltv}$ → LTV Limits → House Prices
- LTV Limits → PTI Limits → Max PTI
Credit Liberalization Experiment

The Mortgage Credit Channel