Consumption and House Prices in the Great Recession: Model Meets Evidence

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Minnesota Workshop in Macroeconomic Theory
July 29, 2016
Four questions

1. What shock(s) drove the boom-bust in $p_h$?

   - Financial deregulation vs beliefs about future growth in $p_h$
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   - Channels: Collateral vs wealth effects
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   - Sufficient statistic approach
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4. Could a debt-forgiveness policy have cushioned the bust?
   - Study large-scale Principal Reduction program
Methodology

- Model: aggregate shocks move equilibrium $p_h$
Methodology

• Model: aggregate shocks move equilibrium $p_h$
• Parameterize: match cross-sectional and lifecycle micro data
Methodology

• Model: aggregate shocks move equilibrium $p_h$
• Parameterize: match cross-sectional and lifecycle micro data
• Simulate boom-bust
• Compare against aggregate time-series data
  • House prices
  • Consumption
  • Rent-price ratio
  • Home ownership
  • Leverage
  • Foreclosures
• Compare against micro data
Preview of main results

1. Sources of boom-bust in $p_h$ and $C$
   • Main driver is beliefs, not change in credit conditions
   • Credit conditions important for ownership, leverage and foreclosure
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   - Mostly a wealth effect, not collateral effect
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   - Caution about the sufficient statistic approach
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3. Two observations on the macro elasticity of $C$ to $p_h$
   • Magnitude depends strongly on the underlying shock
   • Caution about the sufficient statistic approach

4. Effectiveness of mortgage modification program
   • Big effect on foreclosures, but negligible impact on $p_h$ and $C$
Demographics and preferences

• Households work, retire, and live until age $J$

• **Lifetime utility** of household $i$: 

$$
\mathbb{E}_0 \left[ \sum_{j=1}^{J} \beta^{j-1} u_j(c_{ij}, s_{ij}) + \beta^J v(b_i) \right]
$$

$c$ : ND consumption, $s$ : housing services, $b$ : bequest
Demographics and preferences

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- $c$: ND consumption, $s$: housing services, $b$: bequest

- $u_j(c, s) = \varphi_j \left[ \frac{(1 - \phi)c^{1-\gamma} + \phi s^{1-\gamma}}{1 - \sigma} \right]^{\frac{1 - \sigma}{1 - \gamma}} - 1, \quad \gamma, \sigma \in [0, \infty)$

- $\phi$: relative taste for housing

- $1/\gamma$: elasticity of substitution between $(c, s)$
Endowments

- **Working households** receive idiosyncratic income endowment:
  \[
  \log y_{ij} = w(\Omega) + \chi_j + z_{ij}
  \]
  where \(w\) is the aggregate wage, \(\chi_j\) is a deterministic profile, and \(z_{ij}\) follows a discrete Markov process,

- **Retired households** receive social security benefits from govt

- **Newborn households** endowed with draw from pool of bequeathened assets, correlated with initial draw of earnings
Housing

• Finite number of house sizes $h \in \mathcal{H}$

• Households can buy at price $p_h$, or rent at rate $\rho$, per unit
Housing

- Finite number of house sizes \( h \in \mathcal{H} \)

- Households can **buy** at price \( p_h \), or **rent** at rate \( \rho \), per unit

- **Advantages** of owning vs renting:
  - Yields higher consumption flow per unit of \( h \)
  - Tax advantage: mortgage-interest deduction
  - Housing wealth can be used as collateral

- **Disadvantages** of owning vs renting:
  - Owning requires a minimum downpayment
  - Linear transaction cost \( \kappa_h \cdot (p_h h) \) for selling
Financial instruments

• **Liquid saving** \((b > 0)\): one-period bond, exogenous interest rate \(r_b\)
Financial instruments

- **Liquid saving** \((b > 0)\): one-period bond, exogenous interest rate \(r_b\)
- **Mortgages** \((m)\): long-term, fixed rate
  - Origination / (cash-out) refinancing cost \(\kappa_m\)
  - Max loan-to-value **at origination only** \(m \leq \lambda^m p_h h\)
  - Competitively determined **price schedule** \(q(h, m, b, y; \Omega)\)
  - Amortized over remaining lifetime at rate \(r_m = r_b (1 + \nu_m)\)
Financial instruments

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- **Foreclosure**
  - Default on mortgage debt: utility loss \(\xi\)
  - Bank repossess and sells, but must pay financial cost \(\delta^f\)
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• **Foreclosure**
  • Default on mortgage debt: utility loss \(\xi\)
  • Bank repossess and sells, but must pay financial cost \(\delta^f\)

• **HELOCs** \((b < 0)\)
  • One-period borrowing collateralized by housing, \(b \geq -\lambda^b p_h h\)
  • At rate \(r_b (1 + \nu_b)\), non-defaultable
Household decisions

• All households choose consumption and liquid savings

• Non-home owner
  
  Rent  choose:  \( h \in \tilde{H} \subset H \)

  Buy  choose:  \( h \in H \)
  mortgage \( \leq p_h h \) - min down payment

• Home owner
  
  Pay  mortgage payment \( \geq \) min repayment
  HELOC borrowing

  Refinance  pay old and get new mortgage (w/ Cash-Out )

  Sell  rent or buy

  Default  utility cost, must rent
Production of goods and housing

- **Final good sector**: \( Y = ZN \quad \rightarrow \quad w = Z \)
Production of goods and housing

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- **Construction sector**: goods + housing permits → new houses
  
  \[
  \max_{N_h} \quad p_h l_h - w N_h
  \]

  subject to \( l_h = (ZN_h)^\alpha (\bar{L})^{1-\alpha} \), \( 0 < \alpha < 1 \)

  where \( \bar{L} \) are new housing permits issued by government and sold at market price
Production of goods and housing

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• **Competition among builders:** aggr. housing investment function

\[
l_h = (p_h)^{\frac{\alpha}{1-\alpha}} (\alpha)^{\frac{\alpha}{1-\alpha}} \bar{L},\]

• **Housing supply elasticity** given by \( \frac{\alpha}{1-\alpha} \in [0, \infty) \)
Rental sector and government

• **Rental sector** owns rental stock

• Buys housing from sellers, transform to rentals, or vice-versa, sells rental units to home buyers

• Operating cost $\psi$ per unit of housing owned and rented out

• **Zero-profit condition** yields equilibrium rental rate $\rho$

\[
\rho = \psi + p_h - \left( \frac{1 - \delta_h - \tau_h}{1 + r^b} \right) \mathbb{E}_{p_h} \left[ p'_h \right]
\]
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$$\rho = \psi + p_h - \left( \frac{1 - \delta_h - \tau_h}{1 + r^b} \right) \mathbb{E}_{p_h}[p'_h]$$

- **Government**: spends, pays social security to the retirees, taxes workers (with mortgage interest deduction) and properties, collects revenues from selling new land permits
Housing market equilibrium

Aggregate Supply

Post-depreciation past housing stock
+ New investment of the construction sector (including maintenance)
  + Homes sold and foreclosed
  + Homes bequeathed and then liquidated

= Aggregate Demand

Housing occupied by “staying” owners
+ Net purchases of the rental company (converted into rentals)
+ Purchases by former renters and former owners up-/down-grading
Aggregate shocks

Underlying shocks cause equilibrium house price to fluctuate:
Aggregate shocks

Underlying shocks cause equilibrium house price to fluctuate:

1. **Aggregate labor income**: $Z$

2. **Credit conditions**: (i) collateral parameters $\lambda^m, \lambda^b$
   (ii) mortgage origination cost $\kappa_m$
Aggregate shocks

Underlying shocks cause equilibrium house price to fluctuate:

1. **Aggregate labor income**: $Z$

2. **Credit conditions**: (i) collateral parameters $\lambda^m, \lambda^b$
   (ii) mortgage origination cost $\kappa_m$

3. **Beliefs / News** about future housing demand:
   Three regimes for $\phi$ (share of housing services in $u$):
   (a) $\phi_L$: low housing share and **unlikely** transition to $\phi_H$
   (b) $\phi_L^*$: low housing share and **likely** transition to $\phi_H$
   (c) $\phi_H$: high housing share

**Boom-Bust**: shift from (a) to (b), and back to (a)
Parameterization
Parameterization strategy

Parameter values disciplined by facts from **household-level micro-data**

- Life-cycle profiles of **ownership** and **leverage**
Parameterization strategy

Parameter values disciplined by facts from household-level micro-data

- Distributional stats: mortgages, housing wealth, renters, and consumption

<table>
<thead>
<tr>
<th>Moment</th>
<th>Empirical value</th>
<th>Model Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction homeowners w/ mortgage</td>
<td>0.66</td>
<td>0.57</td>
</tr>
<tr>
<td>Aggr. mortgage debt / housing value</td>
<td>0.42</td>
<td>0.36</td>
</tr>
<tr>
<td>P10 LTV ratio for mortgagors</td>
<td>0.15</td>
<td>0.28</td>
</tr>
<tr>
<td>P90 LTV ratio for mortgagors</td>
<td>0.92</td>
<td>0.76</td>
</tr>
<tr>
<td>Aggr. home-ownership rate</td>
<td>0.66</td>
<td>0.65</td>
</tr>
<tr>
<td>P10 Housing NW / total NW for owners</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>P90 Housing NW / total NW for owners</td>
<td>0.95</td>
<td>0.98</td>
</tr>
<tr>
<td>Avg.-size owned house / rented</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Avg. earnings owners / renters</td>
<td>2.05</td>
<td>2.02</td>
</tr>
<tr>
<td>BPP consumption insurance coef</td>
<td>0.36</td>
<td>0.43</td>
</tr>
</tbody>
</table>
Shock Processes

1. **Aggr. labor income**: NIPA wages & salaries per capita
2. **Credit conditions**: max LTV: 85% - 100%, HELOC limit: 20% - 30%, origination costs: $2000 - $1200
3. **Beliefs**: expected house price growth from Case-Shiller survey
Shock Processes

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### Realized path for shocks

- **Productivity, Z**
- **Financial Deregulation, \( \lambda_m \)**
- **Expected Price Growth**

- The **shift in beliefs** hits in 2001 and reverts back in 2007
Computation of equilibrium

• Households require conditional forecast of prices $p'_h$

• Housing market must clear every period at $p_h$

• Given $\{p_h, p'_h\}$, $\rho$ follows from the FOC of rental company
Computation of equilibrium

• Households require conditional forecast of prices $p_h'$

• Housing market must clear every period at $p_h$

• Given $\{p_h, p_h'\}$, $\rho$ follows from the FOC of rental company

• Version of the Krusell-Smith (1998) algorithm:
  • **Forecasting rule** used by households in their DP problem:
    \[
    \log p_h' = a_0(Z, Z') + a_1(Z, Z') \log p_h
    \]
  • **Aggregate consistency**: in equilibrium, forecasting rule is also law of motion for prices
Q1

What caused the boom-bust in $\rho_h$ and $C$?
Consumption and house price dynamics

House Price

Consumption

Year
0.8
0.9
1
1.1
1.2
1.3

Model
Data
Consumption and house price dynamics

House Price

Consumption
Consumption and house price dynamics

House Price

Consumption

Year
0.8 0.9 1 1.1 1.2 1.3

Benchmark
Belief Only
Income Only

Year
0.95 1 1.05 1.1
Consumption and house price dynamics

![House Price Graph](image)

![Consumption Graph](image)
Beliefs vs actual change in preferences

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Price Benchmark</td>
<td>0.8</td>
<td>0.9</td>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>Demand Only</td>
<td>0.9</td>
<td>0.95</td>
<td>1</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Preference shock: similar rise in $p_h$, but $C$ falls!
Beliefs vs actual change in preferences

- Preference shock: similar rise in $\rho_h$, but $C$ falls!
Dynamics of rent-price ratio

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<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1</td>
</tr>
</tbody>
</table>
Dynamics of rent-price ratio

\[ \rho = \psi + p_h - \left( \frac{1 - \delta_h - \tau_h}{1 + r^b} \right) \mathbb{E}_{p_h} \left[ p_h' \right] \]

- Belief about future appreciation essential
Dynamics of home ownership

![Graph showing the dynamics of home ownership over years 2000 to 2015. The benchmark is indicated by a blue line, and the actual trend is shown by a dashed line.](image-url)
Dynamics of home ownership

- Financial deregulation drives rise in home-ownership
• It’s the young who go in/out of housing market
Why credit conditions do not affect $\rho_h$

- Max LTV and mortgage origination costs affect housing demand if renters (extensive margin) or home-owners (intensive margin) are constrained in housing choice

1. Rental market relaxes these constraints
Why credit conditions do not affect $\rho_h$

- Max LTV and mortgage origination costs affect housing demand if renters (extensive margin) or home-owners (intensive margin) are constrained in housing choice

  1. Rental market relaxes these constraints

- Prior research: 2 observations suggest importance of credit

  1. Cheaper credit for ‘low-quality’ borrowers

  2. Increase in home ownership mostly among young households

- Both observations consistent with model: endogenous relaxation in lending standards in response to belief-driven $\Delta \rho_h$
Cheaper credit for ‘low-quality’ borrowers

- Expected house appreciation reduces probability of default
Dynamics of leverage and foreclosure

![Graph showing leverage and foreclosure rate over the years.](image)
Dynamics of leverage and foreclosure

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leverage</td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Foreclosure rate</td>
<td>Benchmark</td>
<td>Belief Only</td>
<td>Income Only</td>
<td>Credit Only</td>
</tr>
<tr>
<td>2000</td>
<td>0.0</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>2005</td>
<td>0.0</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>2010</td>
<td>0.0</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>2015</td>
<td>0.0</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
</tr>
</tbody>
</table>

- Financial deregulation key for constant leverage pre-boom
- **Interaction** belief-deregulation important for foreclosure
Revisited narrative of the crisis

• **Original narrative:**
  • **Mian-Sufi:** credit growth and default concentrated in low-income and high-risk groups

• **New narrative based on refined micro data:**
  1. **Adelino et al.:** credit growth evenly distributed across risk-type
  2. **Foote et al.:** credit growth evenly distributed across income groups
  3. **Albanesi et al.:** default share increases for middle income

• **Model:**
  • Low-income hh go from rent to buy, high-income hh upsize
  • Findings consistent with new narrative, replicates facts 1.-3.
New Narrative I: Credit Growth by Income

- Mortgage debt grew uniformly across the income distribution, consistent with Foote et al. (2016)
New Narrative II: Credit Growth by Credit Score

(c) Data

(d) Model

- Mortgage debt grew **uniformly** across the credit score distribution, consistent with Adelino et al (2016)
New Narrative III: Foreclosure by Income

- Foreclosure shares increased for middle income HHs, consistent with Albanesi et al (2016)
Q2
How does the fall in $p_h$ transmit to $C$?
Consumption response by LTV during bust
Deleveraging or wealth effect in the bust?

- Deleveraging: WEAK
- Wealth effect: STRONG

Consistent with Kaplan-Mitman-Violante (2016): 'Non-durable Consumption and Housing Net Worth in the Great Recession: Evidence from Easily Accessible Data'
Deleveraging or wealth effect in the bust?

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Q4
What do we learn re: the elasticity of $C$ to $p_h$?
Model-implied macro-elasticities of $C$ to $p_h$

<table>
<thead>
<tr>
<th></th>
<th>Boom</th>
<th>Bust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark (all shocks)</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td>Productivity</td>
<td>1.60</td>
<td>1.28</td>
</tr>
<tr>
<td>Credit Conditions</td>
<td>−0.61</td>
<td>0.32</td>
</tr>
<tr>
<td>Belief Shift</td>
<td>0.15</td>
<td>0.18</td>
</tr>
<tr>
<td>Taste for housing</td>
<td>−0.28</td>
<td>−0.23</td>
</tr>
</tbody>
</table>

- Elasticity depends on the underlying shock
- Elasticity differs between boom and bust
Implications for sufficient statistic approach

• Berger et al. (BGLV, 2015) propose the following sufficient statistic:

\[
\frac{d \log c_i}{d \log p_h} = MPC_i(\Delta y_i^{trans}) \cdot \frac{p_h h_i}{c_i}
\]
Implications for sufficient statistic approach

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\frac{d \log c_i}{d \log p_h} = MPC_i(\Delta y_i^{trans}) \cdot \frac{p_h h_i}{c_i}
\]

Beliefs

Preferences

• Fairly accurate for belief shock, not for preference shock
Q4
Could a massive debt forgiveness program have cushioned the bust?
Counterfactual principal reduction program

All homeowners with LTV >95%: forgive excess debt
Counterfactual principal reduction program

All homeowners with LTV >95%: forgive excess debt

<table>
<thead>
<tr>
<th>Year</th>
<th>House Price</th>
<th>Consumption</th>
<th>Leverage</th>
<th>Foreclosure rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.8</td>
<td>0</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>2005</td>
<td>1.2</td>
<td>0.02</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>2010</td>
<td>1.05</td>
<td>0.03</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>2015</td>
<td>1.1</td>
<td>0.01</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

- Beneficiaries account for small share of $C + do not foreclose
Summary: what did we learn from the model?

1. Shift in expected house appreciation key to boom-bust in $p_h$

2. $\Delta p_h$ transmits to $\Delta C$ through wealth effects

3. Elasticity of $C$ to $p_h$ heavily dependent on the nature of the shock

4. Principal reduction programs would not have led to faster recovery
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Thanks!
Thanks!
Beliefs vs actual change in preferences

- Preference shock: similar rise in $\rho_h$, but $C$ falls!
Shock to Interest Rate

House Price

ND Consumption
Consumption response by age during Bust

<table>
<thead>
<tr>
<th>Age</th>
<th>Annual Consumption Growth by Age Bust (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>-2</td>
</tr>
<tr>
<td>30</td>
<td>-1.9</td>
</tr>
<tr>
<td>35</td>
<td>-1.8</td>
</tr>
<tr>
<td>40</td>
<td>-1.7</td>
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<tr>
<td>45</td>
<td>-1.6</td>
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<td>50</td>
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<tr>
<td>75</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

\(\Delta c\) in the baseline - \(\Delta c\) in the Income-only counterfactual
Parameterization strategy

Parameter values disciplined by facts from **household-level micro-data**

- Distributional stats: mortgages, housing wealth, renters, and consumption

<table>
<thead>
<tr>
<th>Moment</th>
<th>Empirical value</th>
<th>Model Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction homeowners w/ mortgage</td>
<td>0.66</td>
<td>0.57</td>
</tr>
<tr>
<td>Aggr. mortgage debt / housing value</td>
<td>0.42</td>
<td>0.36</td>
</tr>
<tr>
<td>P10 LTV ratio for mortgagors</td>
<td>0.15</td>
<td>0.28</td>
</tr>
<tr>
<td>P90 LTV ratio for mortgagors</td>
<td>0.92</td>
<td>0.76</td>
</tr>
<tr>
<td>Aggr. home-ownership rate</td>
<td>0.66</td>
<td>0.65</td>
</tr>
<tr>
<td>P10 Housing NW / total NW for owners</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td>P90 Housing NW / total NW for owners</td>
<td>0.95</td>
<td>0.98</td>
</tr>
<tr>
<td>Avg.-size owned house / rented</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Avg. earnings owners / renters</td>
<td>2.05</td>
<td>2.02</td>
</tr>
<tr>
<td>BPP consumption insurance coef</td>
<td>0.36</td>
<td>0.43</td>
</tr>
</tbody>
</table>
Solution and simulation

- Equilibrium computed with a version of Krusell-Smith (1998)
- Forecasting rule used by households in their problem:
  \[
  \log p'_h = a_0(Z, Z') + a_1(Z, Z') \log p_h
  \]

- **Aggregate consistency**: in equilibrium, forecasting rule is also law of motion for prices
- **Note**: \( \rho \) computable from zero-profit condition, given \( p_h \) and \( E[p'_h] \)
## Solution and simulation

**Simulation of boom-bust: realized path for shocks**

1. **Productivity**: aggregate earnings data
2. **Credit conditions**: max LTV: 85% - 100%, HELOC limit: 20% - 30%, origination costs: 1% - 0
3. **Beliefs**: expected house price growth from Case-Shiller survey

### Table: Productivity, Z

<table>
<thead>
<tr>
<th>Year</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.96</td>
</tr>
<tr>
<td>2005</td>
<td>0.98</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
</tr>
<tr>
<td>2015</td>
<td>1.02</td>
</tr>
</tbody>
</table>

### Table: Financial Deregulation, $\lambda_m$

<table>
<thead>
<tr>
<th>Year</th>
<th>$\lambda_m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.8</td>
</tr>
<tr>
<td>2005</td>
<td>0.85</td>
</tr>
<tr>
<td>2010</td>
<td>0.9</td>
</tr>
<tr>
<td>2015</td>
<td>0.95</td>
</tr>
</tbody>
</table>

### Table: Expected Price Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Expected Price Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.02</td>
</tr>
<tr>
<td>2005</td>
<td>0.03</td>
</tr>
<tr>
<td>2010</td>
<td>0.04</td>
</tr>
<tr>
<td>2015</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Household problem: Renter

- A non-homeowner can stay a renter or become an owner:
  \[ V^n(b_j, z_j; \Omega) = \max \{ V^r(b_j, z_j; \Omega), V^o(b_j, z_j; \Omega) \}, \]
  where \( \Omega \) denotes the vector of aggregate states \((\mathcal{Z}, \mu)\)

- Those who choose to rent solve:
  \[ V^r(b_j, z_j; \Omega) = \max_{c_j, h_j, b_{j+1}} u_j(c_j, s_j) + \beta \mathbb{E}_{z_j, \Omega} \left[ V^n(b_{j+1}, z_{j+1}; \Omega') \right] \]
  subject to
  \[ c_j + \rho(\Omega) h_j + q_b b_{j+1} \leq b_j + y_j - \mathcal{T}(y_j, 0) \]
  \[ b_{j+1} \geq 0 \]
  \[ s_j = h_j \in \mathcal{H} \]
  \[ z_{j+1} = \gamma(z_j) \quad \Omega' = \Gamma(\Omega) \]
Household problem: Buyer

- Those who choose to buy and become owners solve:

\[
V^o(b_j, z_j; \Omega) = \max_{c_j, b_{j+1}, h_{j+1}, m_{j+1}} \ u_j(c_j, s_j) + \beta \mathbb{E}_{z_j, \Omega} \left[V^h(x_{j+1}, z_{j+1}; \Omega')\right]
\]

s.t.

\[c_j + q_b b_{j+1} + p_h(\Omega) h_{j+1} + \kappa_m \leq b_j + y_j - \mathcal{T}(y_j, 0) + q_m(x_{j+1}, z_j; \Omega)m_{j+1}\]

\[m_{j+1} \leq \lambda^m p_h(\Omega) h_{j+1}\]

\[b_{j+1} \geq 0\]

\[h_{j+1} \in \mathcal{H}, \quad s_j = \omega h_{j+1}\]

\[z_{j+1} = \gamma(z_j), \quad \Omega' = \Gamma(\Omega)\]

where \(x_{j+1} := (b_{j+1}, h_{j+1}, m_{j+1})\)
Household problem: Homeowner

\[ V^h(x_j, z_j; \Omega) = \max \left\{ \begin{array}{l} \text{Pay:} \quad V^p(x_j, z_j; \Omega) \\ \text{Refinance:} \quad V^f(x_j, z_j; \Omega) \\ \text{Sell:} \quad V^n(b_j, z_j; \Omega) \\ \text{Default:} \quad V^d(b_j, z_j; \Omega) \end{array} \right\} \]

where \( x_j := (b_j, h_j, m_j) \)

- **Seller’s liquid assets after transaction:**

\[ \tilde{b}_j = b_j - \kappa_h p_h(\Omega)h_j - (1 + r_m)m_j + (1 - \delta_h - \tau_h)p_h(\Omega)h_j \]
Household problem: Homeowner

- A household that makes its mortgage payment solves:

\[ V^p(x_j, z_j; \Omega) = \max_{c_j, b_{j+1}, \pi_m} \ u(c_j, s_j) + \beta \mathbb{E}_{z_j, \Omega} \left[ V^h(x_{j+1}, z_{j+1}; \Omega') \right] \]

s.t.

\[ c_j + q_b(b) b_{j+1} + (\delta_h + \tau_h) p_h(\Omega) h_j + \pi_m \leq b_j + y_j - T(y_j, m_j) \]

\[ \pi_m \geq \pi_m^* \]

\[ m_{j+1} = (1 + r_m) m_j - \pi_m \]

\[ b_{j+1} \geq -\lambda^b p_h(\Omega) h_{j+1} \]

\[ s_j = \omega h_j, \quad h_{j+1} = h_j \]

\[ z_{j+1} = \gamma(z_j), \quad \Omega' = \Gamma(\Omega) \]

where \( x_j := (b_j, h_j, m_j) \)

**Note:** Collateral effect for owners only through HELOCs
Household problem: Default

\[ V^d(b_j, z_j; \Omega) = \max_{c_j, h_j, b_{j+1}} u(c_j, s_j) - \xi + \beta E_{z_j, \Omega} [V^r(b_{j+1}, z_{j+1}; \Omega')] \]

\[ \text{s.t.} \]
\[ c_j + \rho (\Omega) h_j + q_b b_{j+1} \leq b_j + y_j - T (y_j, 0) \]
\[ b_{j+1} \geq 0 \]
\[ s_j = h_j \]
\[ z_{j+1} = \gamma (z_j), \quad \Omega' = \Gamma (\Omega) \]

- Disutility of default \( \xi \)
- Household must rent for a period
Mortgage pricing

- Zero-profit condition by type $j$, $x = (b, h, m)$, $z$ yields:

$$q_m(x_{j+1}, z_j; \Omega) = \frac{1}{(1 + r_m) m_{j+1}} \cdot \mathbb{E}_{z_j, \Omega} \left\{ \left[ g^n_{j+1} + g^f_{j+1} \right] (1 + r_m) m_{j+1} \right. \\
+ g^d_{j+1} \min \left\langle \left( 1 - \delta^d_h \right) p_h(\Omega') h_{j+1}, (1 + r_m) m_{j+1} \right\rangle \\
+ \left[ 1 - g^n_{j+1} - g^f_{j+1} - g^d_{j+1} \right] \left[ \pi_m(x_{j+2}, z_{j+1}; \Omega') + q_m(x_{j+2}, z_{j+1}; \Omega') m_{j+2} \right] \right\}$$

- $g^n$: sell
- $g^f$: refinance
- $g^d$: default
- $g^n = g^f = g^d = 0 \rightarrow$ make mortgage payment
Rental company

• Rental company owns housing units and rents them out to hh

• It can buy/sell units frictionlessly on the housing market

\[
J(\tilde{H}; \Omega) = \max_{\tilde{H}'} -\psi \tilde{H}' - p_h [\tilde{H}' - (1 - \delta_h - \tau_h)\tilde{H}] + \\
\quad \rho \tilde{H}' + \left( \frac{1}{1 + r^b} \right) \mathbb{E}_\Omega [J(\tilde{H}'; \Omega')] 
\]

• Optimization implies the equilibrium rental rate:

\[
\rho = p_h + \psi - \left( \frac{1 - \delta_h - \tau_h}{1 + r^b} \right) \mathbb{E}_\Omega [p_h(\Omega')] 
\]