What Drives U.S. Housing Prices?

James A. Kahn

June 2008
Housing market boom-bust has prompted talk of “bubbles.” But what are fundamentals? What is the right benchmark?
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- Could current financial crisis just be a reflection of a change in economic fundamentals? How far could prices fall?
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  - Flexible prices, rational expectations vs. learning
From 1995:Q4-2007:Q1, the real quality-adjusted price of new homes appreciated over 33% (2.6 percent annually).
Background

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Figure 1: Real Price of New Homes (Quality-Adjusted)

Note: logarithmic scale
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International evidence?
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Change in House Prices versus Change in Consumption

By Country

Mean Change in Consumption

Mean Change in House Prices
Related work

- Housing Prices and Growth

  - Davis and Heathcote (2005), Iacoviello and Neri (2006), Kiyotaki, Michaelides, and Nikolov (2005): Cobb-Douglass preferences, not consistent with trend facts, can't easily explain magnitudes

Learning about productivity growth

  - Edge, Laubach, Williams (2007): Use linear Kalman-Filter framework, rational expectations (no learning about parameters)

Cause and effect

  - Attanasio et al (2005) find that consumption of renters and homeowners respond similarly to changes in home prices
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Two sectors

- “Manufacturing” \((m)\) produces

A Growth Model with Housing

Regime-switching specification for productivity growth in the \(m\) sector.

Implications

- Aggregate looks like standard stochastic growth model
- Relative price changes from relative productivity changes cause sectoral reallocation over time
- Calibrated model can account for much of the sustained deviations of the housing price index from trend
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- Aggregate non-housing consumption $C_t$ (per capita $c_t$).
- $k_i \equiv K_i / N_i$, $\ell_i = L_i / N_i$, $n_i \equiv N_i / N$, ($i = m, h$), $k \equiv K / N$.
Planner’s problem

\[
\max E_0 \left\{ \sum_{t=0}^{\infty} (1 + \rho)^{-t} \ln \phi (c_t, h_t) \right\}
\]

where

\[
\phi (c_t, h_t) = \left[ \omega_c c_t^{(\epsilon-1)/\epsilon} + \omega_h h_t^{(\epsilon-1)/\epsilon} \right]^{\epsilon/(\epsilon-1)}
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\]

subject to resource constraints

\[
c_t + (1 + \nu) k_t - k_{t-1} (1 - \delta) = A_{mt} k_{mt}^\alpha \ell_{mt}^\beta n_{mt}
\]

\[
h_t = A_{ht} k_{ht}^\alpha \ell_{ht}^\beta n_{ht}
\]

\[
k_{mt} n_{mt} + k_{ht} n_{ht} = k_{t-1}
\]

\[
\ell_{mt} n_{mt} + \ell_{ht} n_{ht} = \ell_t
\]

\[
n_{mt} + n_{ht} = 1.
\]
Assume $\beta_h$ is chosen one period ahead of time, but allocated within the period. First-order conditions imply

$$k_m = \alpha^\beta_h \beta_m k_h = \beta_m \beta_h^{1/\alpha^\beta_m},$$

If $p_t$ is price of $h$ in terms of $c$, then

$$p_t = A_m k^{\alpha^1_m} m_t = A_h k^{\alpha^1_h} h_t \left( \frac{A_m}{A_h} \right)^{\beta_m \beta_h}.$$
Planner’s problem (cont.)

- Assume $\beta_h \geq \beta_m$
- $k$ is chosen one period ahead of time, but allocated within the period
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First-order conditions imply 

$$\frac{k_m}{k_h} = \frac{1 - \alpha - \beta_h}{1 - \alpha - \beta_m}$$

$$\frac{\ell_m}{\ell_h} = \frac{\beta_m}{\beta_h} \frac{1 - \alpha - \beta_h}{1 - \alpha - \beta_m}$$

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\begin{align*}
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\frac{\ell_m}{\ell_h} &= \frac{\beta_m (1 - \alpha - \beta_h)}{\beta_h (1 - \alpha - \beta_m)}
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\end{align*}
\]

If $p_t$ is price of $h$ in terms of $c$, then

\[
p_t = \frac{A_m k_{mt}^{\alpha - 1} \ell_{mt}^{\beta_m}}{A_h k_{ht}^{\alpha - 1} \ell_{ht}^{\beta_h}} \propto \left( \frac{A_{mt}}{A_{ht}} \right) \ell_{ht}^{-(\beta_h - \beta_m)}
\]
Dynamic Euler equation is

\[
\lambda_{mt} (1 + \nu) (1 + \rho) = E_t \left\{ \lambda_{mt+1} \left[ A_{mt+1} \alpha k_{mt+1}^{\alpha-1} \ell_{mt+1}^{\beta_m} + 1 - \delta \right] \right\}
\]
Balanced Aggregate Growth under Certainty

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- Let \( x \equiv c + ph \). Can show that \( \lambda_m = x^{-1} \), so \( \lambda_{mt} / \lambda_{mt-1} = x_{t-1} / x_t \).
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- **Balanced Growth**: Equilibrium path under certainty in which if \( A_m \) and \( A_h \) grow at constant rates
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**Balanced Growth:** Equilibrium path under certainty in which if $A_m$ and $A_h$ grow at constant rates

$x$ and $k$ also grow at a constant rate
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Balanced Growth: Equilibrium path under certainty in which if \( A_m \) and \( A_h \) grow at constant rates

1. \( x \) and \( k \) also grow at a constant rate
2. the interest rate is constant
Aggregate balanced growth (cont.)

- Aggregate growth rate (in terms of $m$ sector output):
  \[ g = \left[ (1 + \gamma_m) (1 + \nu)^{-\beta_m} \right]^{1/(1-\alpha)} - 1 \]
Aggregate balanced growth (cont.)

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- Dynamics:
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- Dynamics:
  \[ (1 + \nu) (1 + g) \frac{\hat{k}_t}{\hat{k}_{t-1}} = \left( \frac{\hat{k}_{t-1}}{1 + g} \right)^{\alpha-1} \]
  \[ - \left( 1 + g \right) \frac{\hat{x}_t}{\hat{k}_{t-1}} + 1 - \delta \]
  \[ \left( \frac{\hat{x}_{t+1}}{\hat{x}_t} \right) (1 + \nu) (1 + \rho) (1 + g) = \alpha \left( \frac{\hat{k}_{t-1}}{1 + g} \right)^{\alpha-1} + 1 - \delta \]

- This is just the neoclassical growth model.
Unbalanced Sectoral Growth

- The sectoral variables $p, n_m, n_h, \ell_m, \ell_h, \tilde{k}_m, \tilde{k}_h, c,$ and $h$ are nonlinear functions of the aggregate state variables.
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- Sectoral growth is unbalanced: sectoral variables do not grow at constant rates (except in knife-edge cases $\epsilon = 1$ or $\gamma_m = \gamma_h - (\beta_h - \beta_m)\nu$).
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- **Benchmark assumptions:** $\epsilon < 1$, $\gamma_m > \gamma_h - (\beta_h - \beta_m) \nu$. Get $n_h$ growing, $n_m$ shrinking ("Baumol’s disease")—in practice extremely slowly.
Rental price of land $q_t$ in terms of $c$
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 Asset price of land:

$$V_t = q_t + E_t \{ \Phi_{t+1} V_{t+1} \} = E_t \left\{ \sum_{s=t}^{\infty} \Phi_{s-t} q_s \right\}$$
Price of Land

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where

$$\Phi_{t+1} = \frac{x_t}{x_{t+1} (1 + \nu) (1 + \rho)}$$

- On the balanced growth path we have

$$\Phi^{-1} = (1 + g) (1 + \rho) (1 + \nu)$$
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- Benchmark assumptions imply growth rate of $V_t$ exceeds growth rate of income, though asymptotically approaches it.
- Price of house is fixed-weight value of $K_h + V_t L_h$
Stochastic Growth

Stochastic Growth

Stochastic Growth


![Graph showing high-growth regime probabilities over time.](image)

Calculations based on Kahn-Rich (2007)
Stochastic Growth

- Fast-forward to 2008
Stochastic Growth

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Calculations based on Kahn and Rich (2007)
Stochastic Growth

**Fast-forward to 2008**

![Graph showing high-growth regime probabilities over time]

High-Growth Regime Probabilities

Calculations based on Kahn and Rich (2007)
Simplified process for tractable model: Suppose that the growth rate of $A_h$ is fixed at $\gamma_h$, but:

$$A_{mt}/A_{mt-1} = (1 + \tilde{\gamma}_m) \eta_t/\eta_{t-1}$$
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$$\frac{A_{mt}}{A_{mt-1}} = (1 + \tilde{\gamma}_{mt}) \frac{\eta_t}{\eta_{t-1}}$$

where

$$\tilde{\gamma}_{mt} = \begin{cases} 
\gamma_m^1 & \text{if } \zeta_t = 1 \\
\gamma_m^0 & \zeta_t = 0 
\end{cases}$$

$\eta_t$ is a transitory disturbance

$\zeta_t$ is a state variable with Markov transition matrix

$$\Theta = \begin{bmatrix} 
\theta_1 & 1 - \theta_0 \\
1 - \theta_1 & \theta_0 
\end{bmatrix}.$$
Calibration

- Aggregate parameters take on standard values for quarterly data:
  \[ \alpha = 0.33, \nu = 0.025, \delta = 0.02, \rho = 0.01 \]
Calibration

- Aggregate parameters take on standard values for quarterly data:
  \( \alpha = 0.33, \nu = 0.025, \delta = 0.02, \rho = 0.01 \)
- We set \( \beta_h = 0.5 \) and \( \beta_m = 0.05 \).
Calibration

- Aggregate parameters take on standard values for quarterly data: 
  \( \alpha = 0.33, \nu = 0.025, \delta = 0.02, \rho = 0.01 \)
- We set \( \beta_h = 0.5 \) and \( \beta_m = 0.05 \).
- Since housing services represent about 20 percent of overall consumer expenditures, we set \( \omega_h = 0.2, \omega_c = 0.8 \).
From Kahn-Rich:

\[
4 \left( \gamma_1^m - \beta_m \nu \right) / (1 - \alpha) = 0.029,
\]
\[
4 \left( \gamma_0^m - \beta_m \nu \right) / (1 - \alpha) = 0.013
\]
\[
\theta_1 = 0.990
\]
\[
\theta_0 = 0.983.
\]
From Kahn-Rich:

\[
4 \left( \gamma_m^1 - \beta_m \nu \right) / (1 - \alpha) = 0.029, \\
4 \left( \gamma_m^0 - \beta_m \nu \right) / (1 - \alpha) = 0.013 \\
\theta_1 = 0.990 \\
\theta_0 = 0.983.
\]

Implies expected durations of 20 to 25 years
Evidence on $\epsilon$

- First order condition for relative expenditures is

\[
\omega_c \omega_h \epsilon_t = p_t \ln p_t h_t c_t = a + (1 - \epsilon_t) p_t
\]

Suggests looking at relationship between expenditure share and relative price for evidence about $\epsilon$.
Evidence on $\epsilon$

- First order condition for relative expenditures is
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$$\left(\frac{\omega_c}{\omega_h}\right)^\epsilon \frac{p_t h_t}{c_t} = p_t^{1-\epsilon}$$

$$\ln\left(\frac{p_t h_t}{c_t}\right) = a + (1 - \epsilon) p_t$$

- Suggests looking at relationship between expenditure share and relative price for evidence about $\epsilon$
Macro Evidence on $\epsilon$

- Aggregate behavior might suggest $\epsilon < 1$, but identification is an issue.
Match CEX micro (household) data with regional price indexes for consumption and housing services
Micro Evidence on $\epsilon$

- Match CEX micro (household) data with regional price indexes for consumption and housing services
- For household $i$ at date $t$ in region $j$:

\[
\ln \left( \frac{p_{jt} h_{it}}{(x_{it} - p_{jt} h_{it})} \right) = a_j + b \ln x_{it} + (1 - \epsilon) \ln p_{jt} + z_{it}' \theta + u_{itj}.
\]

- $a_j$ is a constant region-specific factor
- $z_{it}$ are demographic controls
- $x_{it}$ is likely to be measured with error, instrument with race, education
Micro Evidence on $\epsilon$

- Match CEX micro (household) data with regional price indexes for consumption and housing services

- For household $i$ at date $t$ in region $j$:

  $$\ln \left[ \frac{p_{jt}h_{it}}{x_{it} - p_{jt}h_{it}} \right] = a_j + b \ln x_{it} + (1 - \epsilon) \ln p_{jt} + z_{it}' \theta + u_{itj}.$$  

  - $a_j$ is a constant region-specific factor, $z_{it}$ are demographic controls (age, household size, etc.)
Micro Evidence on $\epsilon$

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  \]
  - $a_j$ is a constant region-specific factor, $z_{it}$ are demographic controls (age, household size, etc.)
  - $x_{it}$ is likely to be measured with error, instrument with race, education...
Micro Evidence on $\epsilon$

Table 1: Parameter Estimates from CEX Household Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
<th>SE</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\epsilon}$</td>
<td>0.134</td>
<td>(0.042)</td>
<td>(0.046)</td>
<td>(0.052)</td>
</tr>
<tr>
<td>$\hat{b}$</td>
<td>-0.743</td>
<td>(0.003)</td>
<td>(0.009)</td>
<td>-</td>
</tr>
<tr>
<td>Instruments for $x$</td>
<td>N</td>
<td>Y</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.575</td>
<td>0.464</td>
<td>0.317</td>
<td></td>
</tr>
</tbody>
</table>

Consistent with Flavin-Nakagawa (2004), who find $\epsilon = 0.15$. We’ll (conservatively) set $\epsilon = 0.3$, also consider $\epsilon = 0.9$. 
Simulations

- Start out in low-growth regime, at $t = 12$ switch to high-growth; no transitory shocks

![Figure 7: Housing Price Response to Low-to-High Growth Regime Switch](image-url)
Simulations

- Start out in low-growth regime, at $t = 12$ switch to high-growth; no transitory shocks
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- Start out in low-growth regime, at $t = 12$ switch to high-growth; no transitory shocks

Figure 7: Housing Price Response to Low-to-High Growth Regime Switch

$\varepsilon = 0.3$

$\varepsilon = 0.9$

$\ln(\text{HPrice})$
Simulations

- Under perfect information

Figure 12: Model Simulation of Housing Prices

Get boom-bust-boom-bust pattern, but miss timing, amplitude
Simulations

- Under perfect information

Data Model with Perfect Information

Figure 12: Model Simulation of Housing Prices

Get boom-bust-boom-bust pattern, but miss timing, amplitude
Simulations

- Under perfect information

![Figure 12: Model Simulation of Housing Prices](image)

- Get boom-bust-boom-bust pattern, but miss timing, amplitude
- Recall estimated regime probabilities under “rational expectations”

High-Growth Regime Probabilities

Calculations based on Kahn and Rich (2007)
Recall estimated regime probabilities under “rational expectations”

- Even non-smoothed probabilities are based on full-sample parameter estimates

Calculations based on Kahn and Rich (2007)
Not plausible to think people understood productivity slowdown so soon after it began
Learning

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Simulations

- Using simulated real-time probabilities in the 70s
Simulations

- Using simulated real-time probabilities in the 70s
Simulations

- Using simulated real-time probabilities in the 70s

Figure 14a: Model Simulation of Housing Prices with Learning

- Model with learning does better in both timing and amplitude
Simulations

- Residential investment

*Figure 13: Low Frequency* Residential Investment

*Based on fitting a quartic trend to detrended ln(investment)*
The model explains large bubble-like swings in prices and real activity in the housing sector.
Conclusions

- The model explains large bubble-like swings in prices and real activity in the housing sector
  - Actual prices appear to lag predicted

- Prices overshot in 1970s (monetary policy?) but boom in 1997-2005 is in line with model prediction
- Actual investment exhibits somewhat less amplitude than model predicts
- Plausible learning mechanism helps to account for timing and amplitude of peaks and troughs
- More work to be done on additional kinds of shocks (generating independent interest rate movements), labor supply, demographics, adjustment costs, more realistic (putty-clay) treatment of land in technology
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Reference Charts

- Home price indexes

![Alternative Home Price Indexes]

- Census (constant quality)
- Shiller S&P (repeat sales)
- OFHEO
Reference Charts

- Real interest rates

![Graph of "Real" 10-Year Treasury Rates]