Search and the Dynamics of House Prices and Construction

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We develop a theory of serial autocorrelation in both house price growth and the rate of construction in response to city-specific relative income shocks, based on search in the housing market.

- "Momentum" in these variables is driven by anticipated changes in the time it takes to sell houses—that is, their *liquidity*.

- The theory accounts well qualitatively for the joint dynamics of city-level income, house prices, construction, and population growth.
Empirical observations on city-level house prices

- Price changes exhibit strong positive serial correlation, with long-run mean reversion

- Much of the variation in prices is local, rather than aggregate

- Local income plus supply constraints help account for relative prices across cities in long run.
  - Van Nieuwerburgh & Weill (2010)
Dynamics of income, house prices, construction, and population growth for a panel of U.S. cities.

- 98 US cities (MSA’s), Annual 1980-2008
- $y_{ct}$: log per capita income less construction earnings (BEA REIS)
- $p_{ct}$: log house prices (combines FHFA repeat-sales index with Census values)
- $g^H_{ct}$: growth of housing stock (combines HUD permit data with Census stocks)
- $g^N_{ct}$: growth of population (BEA REIS)
- cross-sectional means removed at each date.
Structural Panel VAR

$$B X_{ct} = \sum_{i=1}^{K} A_i X_{c,t-i} + F_c + \varepsilon_{ct}$$

- $X_{ct} = [y_{ct}, p_{ct}, g_{ct}^H, g_{ct}^N]'$
- $B, A$: coefficient matrices
- $F_c$: vector of city fixed effects
- $\varepsilon_{ct} = [\varepsilon_{ct}^y, \varepsilon_{ct}^p, \varepsilon_{ct}^h, \varepsilon_{ct}^n]':$ vector of structural shocks
Baseline Characterization

- Estimate VAR with 2 lags

- System GMM estimator of Arellano and Bover (1995) and Blundell and Bond (1998)
  - instrument using deviations from forward mean $\implies$ just identified

- Imposed structure:
  - all shocks that affect $y_{ct}$ contemporaneously (and which persist) also affect $p_{ct}$, $g_{ct}^H$ and $g_{ct}^N$ contemporaneously

- Focus on the impact of income shocks
Figure: Response to Local Income Shock
## Summary statistics – All shocks

<table>
<thead>
<tr>
<th></th>
<th>Relative Std. Dev.</th>
<th>Corr. with Inc. growth</th>
<th>Autocorrelation year 1</th>
<th>year 2</th>
<th>year 3</th>
<th>year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income growth</td>
<td>1.00</td>
<td>1.00</td>
<td>0.24</td>
<td>0.02</td>
<td>-0.06</td>
<td>-0.08</td>
</tr>
<tr>
<td>Price Appreciation</td>
<td>2.66</td>
<td>0.41</td>
<td>0.41</td>
<td>0.12</td>
<td>-0.03</td>
<td>-0.08</td>
</tr>
<tr>
<td>Construction Rate</td>
<td>0.35</td>
<td>0.18</td>
<td>0.76</td>
<td>0.52</td>
<td>0.34</td>
<td>0.20</td>
</tr>
<tr>
<td>Population Growth</td>
<td>0.53</td>
<td>0.25</td>
<td>0.43</td>
<td>0.33</td>
<td>0.19</td>
<td>0.12</td>
</tr>
</tbody>
</table>

- Growth rates of prices, construction, and population exhibit more autocorrelation than that of local income.

- Price appreciation is relatively volatile.

- Population growth is more volatile than construction, but less persistent.

- Prices and populations strongly correlated with local income; construction less so.
## Summary – Income Shocks

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<tr>
<td>Price Appreciation</td>
<td>1.35</td>
<td>0.80</td>
<td>0.71</td>
<td>0.30</td>
<td>0.03</td>
<td>-0.11</td>
</tr>
<tr>
<td>Construction Rate</td>
<td>0.11</td>
<td>0.46</td>
<td>0.89</td>
<td>0.66</td>
<td>0.41</td>
<td>0.21</td>
</tr>
<tr>
<td>Population Growth</td>
<td>0.18</td>
<td>0.71</td>
<td>0.71</td>
<td>0.45</td>
<td>0.25</td>
<td>0.12</td>
</tr>
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</table>

- Similar to pattern for all shocks
- Income shocks account for roughly half of price volatility
- Income shocks have very persistent effects on price growth, construction, and population growth
Consider several alternative specifications

- Restrict income process to be univariate AR(2)
- Alternative estimators: within-group, no fixed effects
- Use growth rates in incomes and prices
- Alternative income measures: earnings per capita, wage per job
- Alternative construction rate measures
- Variation in ordering of variables in VAR
- Regional sub-samples of cities
Figure: Local Income Shock by Sub-sample
Price dynamics have been a challenge to theory

- “The behavior of house prices is a serious challenge to the efficient markets view.” Case & Shiller (1989)

- “As yet there is no well-developed theory of the dynamics of house prices at the city level.” Capozza, Hendershott & Mack (2004)

- “Our model fails utterly at explaining high frequency positive serial correlation of price changes.” Glaeser et al. (2010)
Search has been useful for understanding several aspects of housing markets:

- Positive co-movement of prices with sales
  Wheaton (1990); Rios-Rull & Sanchez-Marcos (2007)

- Negative correlation of prices/sales with time-on-the market
  Krainer (2008); Albrecht et al. (2007); Han and Genesove (2010)

- Negative correlation of vacancies and price growth
  Caplin & Leahy (2008)

- Different pricing protocols and volatility
  Diaz and Jerez (2010); Albrecht, Gauthier, and Vroman (2010)
We use search to consider the effect of income shocks...

Suppose that a city’s *per capita income* rises temporarily relative to that in other cities:

1. People move into that city at a faster rate than trend.

2. They need housing. At first they rent while searching for an appropriate home to buy:
   - vacant houses are offered for rent.
   - the market for homes becomes *tighter* over time reducing the time it takes to sell one and raising prices.

3. House prices and rents rise, inducing increased construction.

4. Eventually, as income returns to trend and increased supply reduces the liquidity of housing, city-level population growth, construction, and house prices return to trend.
Time is discrete

There is one city and the rest of the world.

Population, $Q_t$, (growing at rate, $\mu$) of identical households with discount factor, $\beta$.

Households in the city require housing:

- may rent at rate, $r_t$.
- may purchase for price, $P_t$, and pay maintainence, $m$, per period
- housing units are ex ante identical
Preferences

\[ \sum_{i=0}^{\infty} \beta^i E_t \left[ c_{t+i} - A^{\ell + \frac{1}{\eta}} + z_{t+i} \right] \]

- \( c_t \): consumption
- \( \ell_t \): construction labour
- \( z_t \): net housing services:

\[ z_t = \begin{cases} 
  z^H & \text{if live in own house} \\
  0 & \text{if rent or don’t like house} 
\end{cases} \]

Household income:

\[ I_t = y_t + w_t \ell \]

- autonomous income
- construction earnings

Interest rate = \( 1 / \beta \)
People and houses

- Population grows at rate $\mu$:

$$Q_t = N_t + B_t + F_t + D_t$$

$Q_t$ total population

- Stock of Houses

$$H_t = N_t + S_t + R_t$$

$H_t$ total houses

- Owners exit city at rate $\pi_n$ or become “mis-matched” at rate $\theta$

- Potential entrants draw alternative values from stationary distribution $G(\varepsilon)$
Construction

- Each new house requires one unit of land at cost $q_t$ and $1/\phi$ units of labor effort at wage, $w_t$, and takes one period to build.
- The land price satisfies
  \[ q_t = \bar{q} \left( \frac{H_t}{H^*_t} \right)^{\frac{1}{\xi}} \text{ where } H^*_t = \mu^t H_0 \]
- Construction labour supply:
  \[ H_{t+1} = H_t + \phi L_t \text{ where } L_t = (N_t + B_t + F_t) \tilde{\sigma} w_t^\eta \]
- Free entry:
  \[ \beta E_t \tilde{V}_{t+1} = \frac{w_t}{\phi} + q_t \]
Rentals

- Houses that are not owner-occupied can be either rented or held vacant–for–sale

- Value of a house which is not owner–occupied

\[
\tilde{V}_t = \max \begin{cases} 
  r_t - m + \beta E_t \tilde{V}_{t+1}, & \text{if rented} \\
  V_t & \text{if vacant}
\end{cases}
\]

- Renters may or may not be searching for a house:

\[
R_t \geq B_t + F_t
\]

- Focus on interior case:

\[
\tilde{V}_t = r_t - m + \beta E_t \tilde{V}_{t+1} = V_t
\]
House sales:

- Competitive search (Moen, 1997)

- Sub-markets characterized by pairs $(\omega, P)$ where $P$ is the price and $\omega$ the buyer-seller ratio:

  $$\omega_t = \frac{B_t}{S_t}$$

- By entering sub-market $(\omega, P)$ the seller sells at price $P$ with probability $\gamma(\omega)$:

  $$\gamma(\omega) = \frac{M(B_t, S_t)}{S_t}$$

  where $M$ is a CRS matching function.

- Free entry by sellers requires open sub-markets to offer equal expected return:

  $$\gamma(\omega_t(P_t)) = \frac{V_t - \beta E_t \tilde{V}_{t+1}}{P_t - \beta E_t \tilde{V}_{t+1}}.$$
House sales:

- Buyers choose a unique sub-market to enter knowing the price and matching rate $\lambda(\omega)$:

$$\lambda(\omega) = \frac{M(B_t, S_t)}{B_t}$$

- In equilibrium a unique “sub-market” opens with $(\omega, P)$ such that buyers’ share of surplus $= \text{elasticity of matching function w.r.t. number of buyers} = s(\omega_t)$
Buyers (searchers)

- Value of being a buyer:
  \[
  W_t = u_t^R + \lambda(\omega_t) (\beta E_t J_{t+1} - P_t) + (1 - \lambda(\omega_t)) \beta E_t W_{t+1}
  \]
  where
  \[
  u_t^R = y_t + x(w_t) - r_t
  \]

- Measure of buyers evolves according to
  \[
  B_{t+1} = (1 - \lambda(\omega_t)) B_t + \theta(1 - \pi_n) N_t + \psi G(\epsilon_{t+1}) \mu Q_t
  \]
  with
  - fail to buy
  - mis-matched
  - new entrant buyers
Non-searching renters

- Value of being a renter:

\[ W_t^f = u_t^R + \pi_f \beta Z + (1 - \pi_f) \beta E_t W_{t+1}^f. \]

- Non-searchers

\[ F_{t+1} = (1 - \pi_f) F_t + (1 - \psi) G(\varepsilon_{t+1}^c) \mu Q_t \]

\( \text{stayed} \quad \text{new entrants} \)
Entry into the City

- Value of new entrants:

\[ \bar{W}_t = \psi W_t + (1 - \psi) W^f_t \]

- Marginal entrant is such that

\[ \varepsilon^c_t = \bar{W}_t. \]

- The alternative value is lost upon entry to the city.
Home-owners

- Value of being a home-owner:

\[ J_t = u_t^H + \beta[\pi_n (Z + E_t V_{t+1}) + (1 - \pi_n)\theta (E_t W_{t+1} + E_t V_{t+1}) + (1 - \pi_n)(1 - \theta)E_t J_{t+1}] \]

where

\[ u_t^H = y_t + x(w_t) + z^H - m \]

- Measure of home-owners evolves according to:

\[ N_{t+1} = (1 - \pi_n)(1 - \theta)N_t + \left\{ \begin{array}{ll} \text{continuing} & \lambda(\omega_t)B_t \\
\text{new home buyers} & \end{array} \right. \]
House values

- Value of a vacant house for sale (mover or developer):
  \[ V_t = \gamma(\omega_t)P_t + (1 - \gamma(\omega_t))\beta E_t V_{t+1} \]

- House Price:
  \[ P_t = (1 - s(\omega_t))\beta E_t [J_{t+1} - W_{t+1}] + s(\omega_t)\beta E_t V_{t+1} \]
Stationary Competitive Search Equilibrium

We consider Markov equilibria with state \((y, h, n, b, f)\)

1. Define a deterministic steady-state with \(y_t = \bar{y}\) for all \(t\).
   Show that this is unique.

2. Choose parameters consistent with a calibration to U.S. data.

3. Specify a process for \(y_t\).
   - An arbitrary AR(1) process
   - A process consistent with observed income dynamics from U.S. cities.

4. Solve a log-linearized approximation in a neighborhood of the deterministic steady-state.
Calibration

- Cobb-Douglas matching:

\[ M = \kappa B^\delta S^{1-\delta} \]

\( \Rightarrow \) buyer’s share is constant: \( s = \delta \)

\( \leftarrow \) can interpret as efficient random search with Nash bargaining

- Elasticity of alternative value distribution:

\[ \alpha = \frac{\varepsilon^c G' (\varepsilon^c)}{G (\varepsilon^c)} \]

\( \leftarrow \) chosen to match relative volatility of population growth

- *Per capita* income follows a persistent AR(1) process in logs.
## Steady-state Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>Annual real interest rate = 4%</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.003</td>
<td>Annual population growth rate = 1.2%</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0.00025</td>
<td>Quarterly permits/construction employment (hours)</td>
</tr>
<tr>
<td>$\pi_f$</td>
<td>0.03</td>
<td>Annual cross-county mobility of renters = 12%</td>
</tr>
<tr>
<td>$\pi_n$</td>
<td>0.008</td>
<td>Annual cross-county mobility of owners = 3.2%</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.012</td>
<td>Fraction of moving owners that stay in county = 60%</td>
</tr>
<tr>
<td>$\eta$</td>
<td>5</td>
<td>Median price elasticity of new construction = 5</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>1.75</td>
<td>Median price elasticity of land supply = 1.75</td>
</tr>
<tr>
<td>$\bar{q}$</td>
<td>3.84</td>
<td>Average land price-income ratio</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.42</td>
<td>Fraction of households that rent = 32%</td>
</tr>
<tr>
<td>$m$</td>
<td>0.0125</td>
<td>Average rent to average income ratio, $r^* = 0.137$</td>
</tr>
<tr>
<td>$z^h$</td>
<td>0.025</td>
<td>Zero net-of-maintenance depreciation</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>0.76</td>
<td>Vacancy rate = 2%</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.08</td>
<td>Months to sell = months to buy</td>
</tr>
<tr>
<td>$\zeta^{1/\eta}$</td>
<td>750</td>
<td>Price to quarterly income ratio, $P^* = 12.8$</td>
</tr>
</tbody>
</table>
Compare to two simple alternative economies

- **A No-search economy based on Glaeser et al (2010)**
  
  New entrants can purchase houses immediately (supply expands)

- **A “Lucas-tree” economy:**
  
  Suppose that households can simply by a tree which represents a claim to the *per capita* income stream of the city without having to move there. Then the “house” price is given by:

  \[
  P_t^L = E_t \sum_{i=0}^{\infty} \beta^i y_{t+i}
  \]
Qualitative Dynamics

In response to a shock to autonomous local income *per capita*:

- **Population growth increases, persistently**
  - Buyers enter, and vacant houses are allocated to rentals
  - Market tightness grows slowly, and equilibrium rents grow with a lag.

- **House prices and construction increase over time**
  - Persistent reductions in the matching rate result in serially correlated increases in the value of vacant houses.
  - Both the price of houses and the construction rate experience serially correlated growth as a result.

- Eventually, mean reversion of income reduces entry and anticipated declines in the matching rate drive both the construction rate and house price back to trend.
Figure: Impulse response functions for AR(1) shock process

- Local Income
- House Price
- Construction
- Population Growth

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Figure: Impulse response functions for AR(1) shock process

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Quantitative Dynamics

- **Problem**: no quarterly city-level income data
  - annual calibration imposes excessive time-on-the-market

- **Our strategy**:
  - calibrate quarterly income shock process to replicate key features of annual process
  - feed into model to generate simulated paths of “quarterly data”
  - compute annual statistics based on simulated paths
Relative Volatilities and Co-movements

<table>
<thead>
<tr>
<th>Moment</th>
<th>US Cities</th>
<th>Lucas tree</th>
<th>No search</th>
<th>Baseline search</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_p / \sigma_y$</td>
<td>1.35</td>
<td>0.40</td>
<td>0.90</td>
<td>0.67</td>
</tr>
<tr>
<td>$\sigma_h / \sigma_y$</td>
<td>0.11</td>
<td>-</td>
<td>0.18</td>
<td>0.17</td>
</tr>
<tr>
<td>$\sigma_n / \sigma_y$</td>
<td>0.18</td>
<td>-</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>$\sigma_{py}$</td>
<td>0.80</td>
<td>0.96</td>
<td>0.91</td>
<td>0.97</td>
</tr>
<tr>
<td>$\sigma_{hy}$</td>
<td>0.46</td>
<td>-</td>
<td>0.38</td>
<td>0.35</td>
</tr>
<tr>
<td>$\sigma_{ny}$</td>
<td>0.71</td>
<td>-</td>
<td>0.38</td>
<td>0.37</td>
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### Autocorrelations

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<tr>
<td>$\rho_1^p$</td>
<td>0.71</td>
<td>-0.01</td>
<td>-0.02</td>
<td>0.23</td>
</tr>
<tr>
<td>$\rho_2^p$</td>
<td>0.30</td>
<td>-0.04</td>
<td>-0.04</td>
<td>0.08</td>
</tr>
<tr>
<td>$\rho_3^p$</td>
<td>0.03</td>
<td>-0.04</td>
<td>-0.04</td>
<td>0.0</td>
</tr>
<tr>
<td>$\rho_4^p$</td>
<td>-0.11</td>
<td>-0.04</td>
<td>-0.04</td>
<td>-0.05</td>
</tr>
<tr>
<td>$\rho_1^h$</td>
<td>0.89</td>
<td>–</td>
<td>0.89</td>
<td>0.94</td>
</tr>
<tr>
<td>$\rho_2^h$</td>
<td>0.66</td>
<td>–</td>
<td>0.79</td>
<td>0.85</td>
</tr>
<tr>
<td>$\rho_3^h$</td>
<td>0.41</td>
<td>–</td>
<td>0.70</td>
<td>0.76</td>
</tr>
<tr>
<td>$\rho_4^h$</td>
<td>0.21</td>
<td>–</td>
<td>0.61</td>
<td>0.67</td>
</tr>
<tr>
<td>$\rho_1^n$</td>
<td>0.71</td>
<td>–</td>
<td>0.89</td>
<td>0.88</td>
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<tr>
<td>$\rho_2^n$</td>
<td>0.45</td>
<td>–</td>
<td>0.79</td>
<td>0.78</td>
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<tr>
<td>$\rho_3^n$</td>
<td>0.25</td>
<td>–</td>
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<tr>
<td>$\rho_4^n$</td>
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<td>–</td>
<td>0.61</td>
<td>0.62</td>
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Sensitivity Analysis
Steady-state targets matched

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<th></th>
<th>Base line</th>
<th>Labor supply elasticity, $\eta$</th>
<th>Land elasticity, $\zeta$</th>
<th>Vacancy Rate</th>
<th>Entry elasticity, $\alpha$</th>
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<td>$\sigma_p / \sigma_y$</td>
<td>0.67</td>
<td>1.71</td>
<td>0.74</td>
<td>0.83</td>
<td>0.51</td>
</tr>
<tr>
<td>$\rho_1^p$</td>
<td>0.23</td>
<td>0.07</td>
<td>0.19</td>
<td>0.11</td>
<td>0.33</td>
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<tr>
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<th>Exit prob., $\pi_n$</th>
<th>Matching elasticity, $\delta$</th>
<th>Housing Utility, $z^H$</th>
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</tr>
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<td>$\rho_1^p$</td>
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<td>0.08</td>
<td>0.15</td>
<td>0.58</td>
</tr>
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</table>
In response to a shock to local income, a search-based theory of housing generates:

- persistent increases in population growth
- serially correlated growth of both house prices and construction rates
- volatility

These effects are driven by anticipated changes in the liquidity of houses driven by movements in market tightness.

An economy without search cannot generate them.
Conclusion

**Qualitatively**: these results are broadly consistent with the evidence:

- Relative city level price growth in response to income shocks is characterized by both short term serial correlation and long-term mean reversion.
- Construction rates have similar properties.
- Population growth is more volatile and less persistent than construction.

**Quantitatively**: it remains difficult to match both the observed degrees of momentum and volatility in prices.