Search and the Dynamics of House Prices and Construction

Allen Head, Huw Lloyd-Ellis, Amy Hongfei Sun

Queen's University

Chicago Fed Summer Workshop

August 17, 2011

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
  - Glaeser, Gyourko, Morales & Nathanson (2010)
  - Abraham & Hendershott (1996), Meen (2002)
- Much of the variation in prices is local, rather than aggregate
  - Del Negro & Otrok (2006), Allen, Amano, Byrne & Gregory (2007)
- 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_{ct}^{H}: growth of housing stock (combines HUD permit data with Census stocks)
- g_{ct}^{N}: growth of population (BEA REIS)
- cross-sectional means removed at each date.

Structural Panel VAR

$$\mathbf{BX}_{ct} = \sum_{i=1}^{K} \mathbf{A}_i \mathbf{X}_{c,t-i} + \mathbf{F}_c + \boldsymbol{\varepsilon}_{ct}$$

- $\mathbf{X}_{ct} = [y_{ct}, p_{ct}, g^H_{ct}, g^N_{ct}]'$
- $\mathbf{B}, \mathbf{A}$: coefficient matrices
- $\mathbf{F}_c$: vector of city fixed effects
- $\boldsymbol{\varepsilon}_{ct} = [\varepsilon^y_{ct}, \varepsilon^p_{ct}, \varepsilon^h_{ct}, \varepsilon^n_{ct}]'$: 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 $\Longrightarrow$ 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

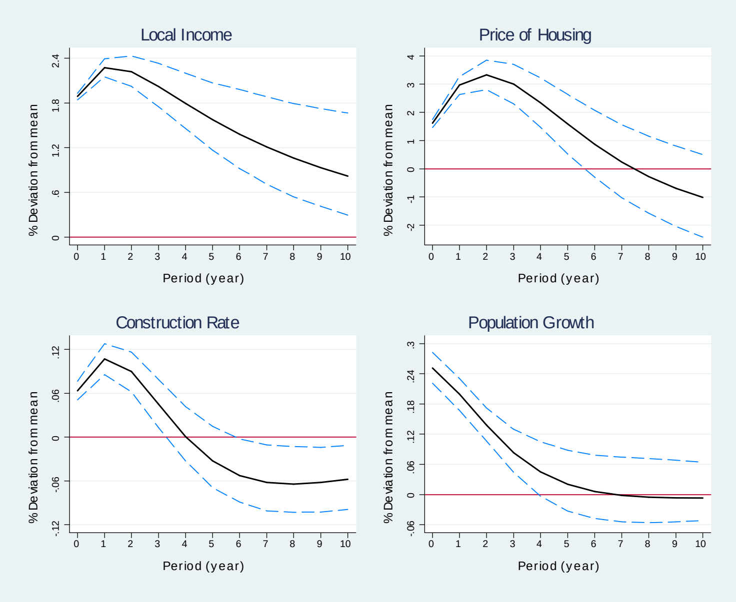


Figure: Response to Local Income Shock

Summary statistics– All shocks

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

- 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

	Relative Std. Dev.	Corr. with Inc. growth	Autocorrelation year 1	year 2	year 3	year 4
Income growth	1.00	1.00	0.24	0.02	-0.05	-0.08
Price Appreciation	1.35	0.80	0.71	0.30	0.03	-0.11
Construction Rate	0.11	0.46	0.89	0.66	0.41	0.21
Population Growth	0.18	0.71	0.71	0.45	0.25	0.12

- 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

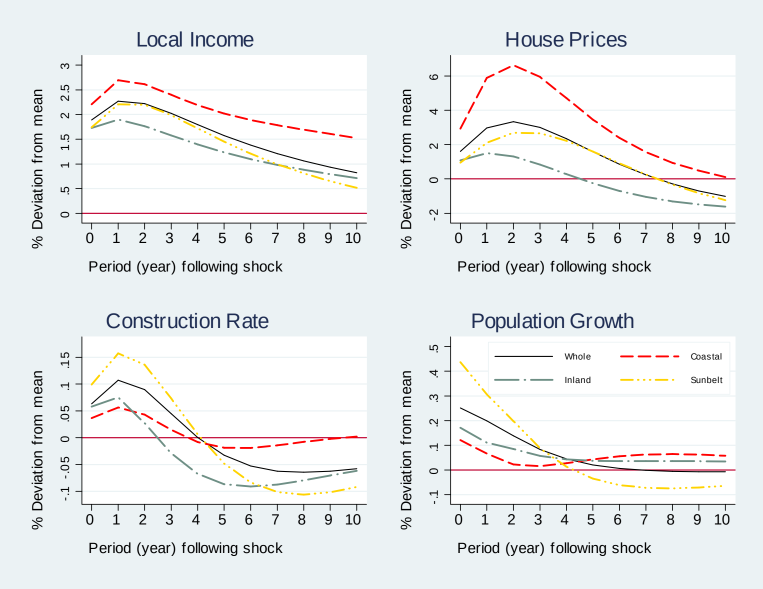


Figure: Local Income Shock by Sub-sample

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.

An Economy with Housing, Construction, and Search

- Time is discrete
- There is one *city* and the rest of the world.
- Population, Q_t, (growing at rate, μ) of identical households with discount factor, β.
- 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

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

  - c_t: consumption
  - ℓ_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:

$$I_t = \underbrace{y_t}_{\text{autonomous income}} + \underbrace{w_t \ell}_{\text{construction earnings}}$$

- Interest rate $= 1/\beta$

People and houses

- Population grows at rate μ:

$$\underbrace{Q_t}_{\text{total population}} = \overbrace{\underbrace{N_t}_{\text{home-owners}} + \underbrace{B_t}_{\text{searchers}} + \underbrace{F_t}_{\text{renters}}}^{\text{the city}} + \overbrace{D_t}^{\text{non-residents}}$$

- Stock of Houses

$$\underbrace{H_t}_{\text{total houses}} = \underbrace{N_t}_{\text{owner-occupied houses}} + \underbrace{S_t}_{\text{vacancies}} + \underbrace{R_t}_{\text{rented}}$$

- Owners exit city at rate π_n or become "mis-matched" at rate θ
- 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

$$q_t = \overline{q}\left(\frac{H_t}{H_t^*}\right)^{\frac{1}{\xi}} \qquad \text{where} \qquad H_t^* = \mu^t H_0$$

- Construction labour supply:

$$H_{t+t} = H_t + \phi L_t \qquad \text{where} \qquad L_t = (N_t + B_t + F_t)\,\zeta w_t^{\eta}$$

- 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

$$\widetilde{V}_t = \max\left[\underbrace{r_t - m + \beta E_t \widetilde{V}_{t+1}}_{\text{if rented}}, \quad \underbrace{V_t}_{\text{if vacant}}\right]$$

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

$$R_t \geq B_t + F_t$$

- Focus on interior case:

$$\widetilde{V}_t = r_t - m + \beta E_t \widetilde{V}_{t+1} = V_t$$

House sales:

- Competitive search (Moen, 1997)

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

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

- By entering sub-market (ω, 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:

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

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 (ω, P) such that

$$\text{buyers' share of surplus} = \begin{array}{c}\text{elasticity of matching function} \\ \text{w.r.t. number of buyers}\end{array} = s(\omega_t)$$

Buyers (searchers)

- Value of being a buyer:

$$W_t = u_t^R + \lambda(\omega_t)\left(\beta E_t J_{t+1} - P_t\right) + (1 - \lambda(\omega_t))\beta E_t W_{t+1}$$

where

$$u_t^R = y_t + x(w_t) - r_t$$

- Measure of buyers evolves according to

$$B_{t+1} = \underbrace{(1 - \lambda\left(\omega_t\right))B_t}_{\text{fail to buy}} + \underbrace{\theta(1 - \pi_n)N_t}_{\text{mis-matched}} + \underbrace{\psi G(\varepsilon_{t+1}^c)\mu Q_t}_{\text{new entrant buyers}}$$

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

$$F_{t+1} = \underbrace{(1 - \pi_f) F_t}_{\text{stayed}} + \underbrace{(1 - \psi) G(\varepsilon_{t+1}^c) \mu Q_t}_{\text{new entrants}}$$

Entry into the City

- Value of new entrants:

$$\bar{W}_t = \psi W_t + (1 - \psi) W_t^f$$

- Marginal entrant is such that

$$\varepsilon_t^c = \bar{W}_t.$$

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

Home-owners

- Value of being a home-owner:

$$\begin{aligned} J_t &= u_t^H + \beta[\pi_n\left(Z + E_t V_{t+1}\right) + (1-\pi_n)\theta\left(E_t W_{t+1} + E_t V_{t+1}\right) \\ &\qquad + (1-\pi_n)(1-\theta)E_t J_{t+1}] \end{aligned}$$

where

$$u_t^H = y_t + x(w_t) + z^H - m$$

- Measure of home-owners evolves according to:

$$N_{t+1} = \underbrace{(1-\pi_n)(1-\theta)N_t}_{\text{continuing}} + \underbrace{\lambda(\omega_t)B_t}_{\text{new home buyers}}$$

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:

$$P_t = (1 - s(\omega_t)) \beta E_t \left[J_{t+1} - W_{t+1} \right] + s(\omega_t) \beta E_t V_{t+1}$$

Stationary Competitive Search Equilibrium

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

1. Define a deterministic steady-state with $y_t = \overline{y}$ 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: $s = \delta$

$\hookrightarrow$ can interpret as efficient random search with Nash bargaining

- Elasticity of alternative value distribution:

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

$\hookrightarrow$ chosen to match relative volatility of population growth

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

Steady-state Calibration

Parameter	Value	Target
β	0.99	Annual real interest rate $= 4\%$
μ	0.003	Annual population growth rate $= 1.2\%$
ϕ	0.00025	Quarterly permits/construction employment (hours)
π_f	0.03	Annual cross-county mobility of renters $= 12\%$
π_n	0.008	Annual cross-county mobility of owners $= 3.2\%$
θ	0.012	Fraction of moving owners that stay in county $= 60\%$
η	5	Median price elasticity of new construction $= 5$
ξ	1.75	Median price elasticity of land supply $= 1.75$
$\overline{q}$	3.84	Average land price-income ratio
ψ	0.42	Fraction of households that rent $= 32\%$
m	0.0125	Average rent to average income ratio, $r^* = 0.137$
z^h	0.025	Zero net-of-maintenance depreciation
κ	0.76	Vacancy rate $= 2\%$
δ	0.08	Months to sell $=$ months to buy
$\zeta^{\frac{1}{\eta}}$	750	Price to quarterly income ratio, $P^* = 12.8$

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:

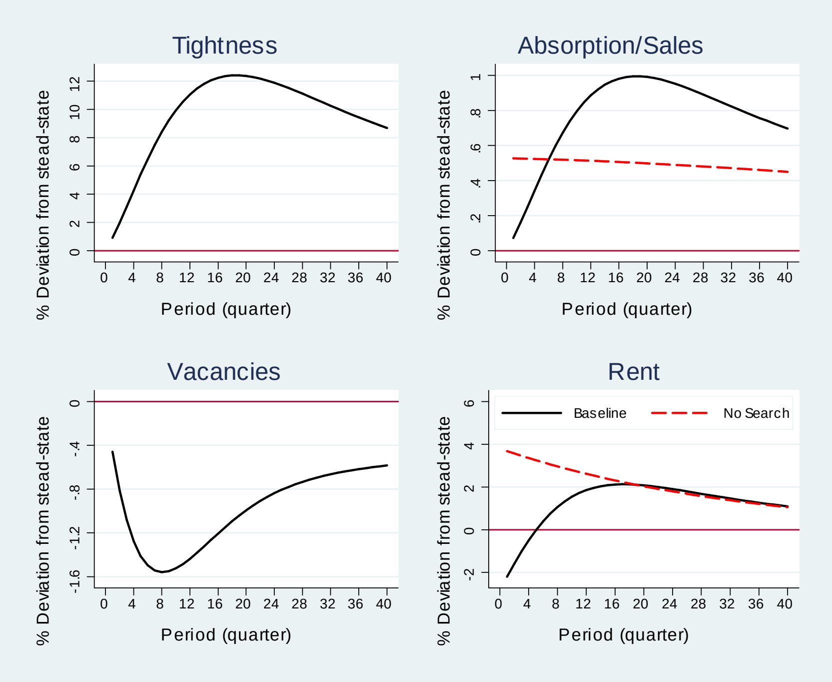
$$P_t^L = E_t \sum_{i=0}^{\infty} \beta^i y_{t+i}$$

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.**


Local Income
House Price
Construction
Population Growth
% Deviation from stead-state
Period (quarter)
Baseline
No Search
0
.25
.5
.75
1
0
2
4
6
8
0 4 8 12 16 20 24 28 32 36 40


Tightness
% Deviation from stead-state
0
2
4
6
8
10
12
0 4 8 12 16 20 24 28 32 36 40
Period (quarter)
Absorption/Sales
% Deviation from stead-state
0
.2
.4
.6
.8
1
0 4 8 12 16 20 24 28 32 36 40
Period (quarter)
Vacancies
% Deviation from stead-state
0
-.4
-.8
-1.2
-1.6
0 4 8 12 16 20 24 28 32 36 40
Period (quarter)
Rent
% Deviation from stead-state
-2
0
2
4
6
Baseline
No Search
0 4 8 12 16 20 24 28 32 36 40
Period (quarter)

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

Moment	US Cities	Lucas tree	No search	Baseline search
σ_p/σ_y	1.35	0.40	0.90	0.67
σ_h/σ_y	0.11	-	0.18	0.17
σ_n/σ_y	0.18	-	0.18	0.18
σ_{py}	0.80	0.96	0.91	0.97
σ_{hy}	0.46	-	0.38	0.35
σ_{ny}	0.71	-	0.38	0.37

Autocorrelations

Moment	US Cities	Lucas tree	No search	Baseline search
ρ_1^p	0.71	-0.01	-0.02	0.23
ρ_2^p	0.30	-0.04	-0.04	0.08
ρ_3^p	0.03	-0.04	-0.04	0.0
ρ_4^p	-0.11	-0.04	-0.04	-0.05
ρ_1^h	0.89	–	0.89	0.94
ρ_2^h	0.66	–	0.79	0.85
ρ_3^h	0.41	–	0.70	0.76
ρ_4^h	0.21	–	0.61	0.67
ρ_1^n	0.71	–	0.89	0.88
ρ_2^n	0.45	–	0.79	0.78
ρ_3^n	0.25	–	0.70	0.70
ρ_4^n	0.21	–	0.61	0.62

Sensitivity Analysis

Steady-state targets matched

	Base -line	Labor supply elasticity, η		Land elasticity, ξ		Vacancy Rate		Entry elasticity, α	
		2	20	0.5	5	1%	3%	5	20
σ_p/σ_y	0.67	1.71	0.16	0.74	0.65	0.83	0.53	0.51	1.52
ρ_1^p	0.23	0.07	0.48	0.19	0.24	0.11	0.33	0.33	0.05

	Base -line	Exit prob., π_n		Matching elasticity, δ		Housing Utility, z^H	
		.004	.012	.01	.50	.01	.04
σ_p/σ_y	0.67	0.81	0.58	0.74	0.41	0.46	0.72
ρ_1^p	0.23	0.08	0.35	0.15	0.40	0.58	0.15

Conclusion

- 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.