Spatial Equilibrium Across Cities

Urban Economics: Week 3

Giacomo A. M. Ponzetto

CREI – UPF – Barcelona GSE

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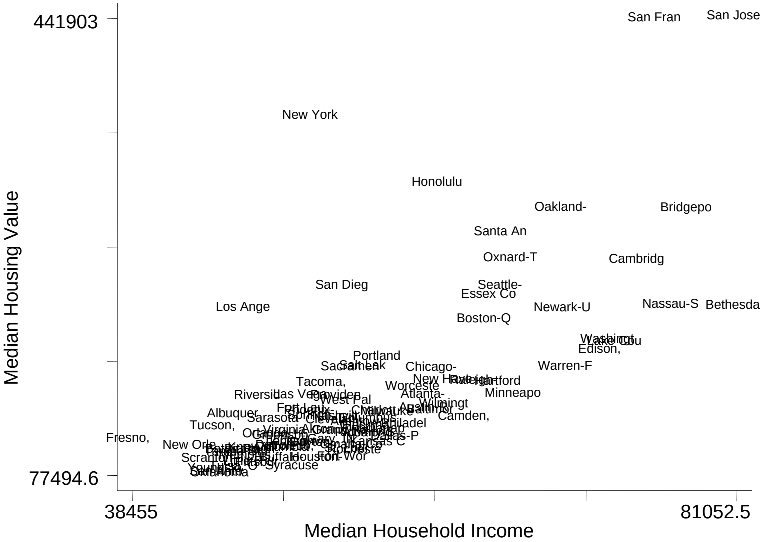
Three Simultaneous Equilibria

1. Individuals are optimally choosing which city to live in
   - There is a group of homogeneous individuals
   - Some of them are living in different cities

   $\Rightarrow$ Their utility level is the same in all those cities
2. Firms earn zero expected profits
   - Free entry of firms
   - Firm profits are equalized across cities
3. The construction sector operates optimally
   - If a city is growing, house prices equal construction costs
   - If a city is declining, house prices $\leq$ construction costs
   - Free entry, zero profit for builders
   - Construction profits are equalized across cities

Housing Prices and Income



Housing Affordability

- Starting point: Net income = Wages – Housing Costs
  - Every household consumes a unit of housing
- Measuring affordability by Housing Costs / Wages is a mistake
  - A common mistake in policy discussions
  - Bias understating the affordability of high-income areas
- House prices are strongly positively correlated with income levels
- The regression coefficient is too low for constant net income
  - The user cost of housing is 7-10% of house value
  - The coefficient is only 5.2
- Measurement error
  - The coefficient on the reverse regression is an appropriate .092
  - Income is measured without controlling for human capital
  - Current income is a noisy measure of permanent income
  - Mean reversion predicts income declines in richer cities

Hedonics

- Cities also differ in their amenities
- Rosen (1979): spatial hedonics with varying incomes
- Utility $u(w-p,a)$ implies spatial equilibrium

$$\partial p = \partial w + \frac{u_a}{u_c}\partial a$$

- Consumption amenities are identified because they are associated with lower incomes, controlling for housing prices
- Utility $u(c,h,a)$ implies indirect utility $v(w,p,a)$ such that

$$|v_p|\,\partial p = v_w \partial w + v_a \partial a$$

and by Roy's lemma

$$h\partial p = \partial w + \frac{v_a}{v_w}\partial a$$

Individuals' Optimal Location Choice

- Cobb-Douglas utility with housing share $\lambda \approx 0.3$

$$u(c, h, a) = (1 - \lambda) \log \frac{c}{1 - \lambda} + \lambda \log \frac{h}{\lambda} + \log a$$

- Every location must yield the reservation utility $\underline{u}$

$$v(w, p, a) = \log w - \lambda \log p + \log a = \underline{u}$$

- Identifying the amenity value of any observable x:

$$\frac{\partial \log a}{\partial \log x} = \lambda \frac{\partial \log p}{\partial \log x} - \frac{\partial \log w}{\partial \log x}$$

- Beware again of affordability statistics: $p^{0.3}/w$, not p/w
    1. $w_1 = 40,000$ €, $p_1 = 10,000$ € $\Rightarrow p_1/w_1 = 25\%$
    2. $w_2 = 60,000$ €, $p_2 = 25,884$ € $\Rightarrow p_2/w_2 = 43\%$

Income and Housing Prices

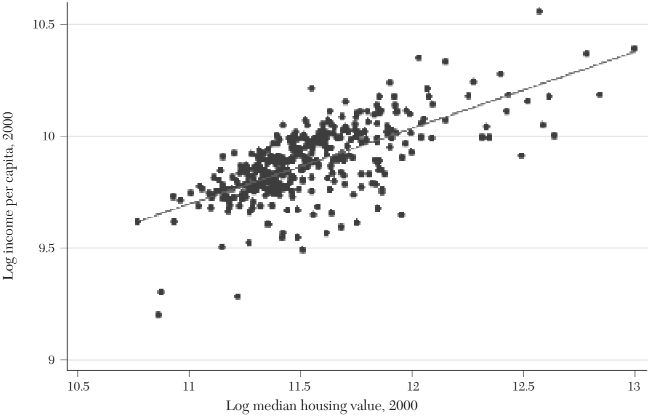


Figure 3. Housing Prices and Income

Notes: Units of observation are Metropolitan Statistical Areas under the 2006 definitions. Data are from the Census, as described in the Data Appendix.

The regression line is $\log \mathit{income} = 0.34\ [0.02] \times \log \mathit{value} + 5.97\ [0.22]$.
$R^2 = 0.46$ and $N = 363$.

Production Technology

- Three factors of production:
  1. Labor n
  2. Tradable capital k
  3. Non-tradable capital z
- Cobb-Douglas production function with constant returns to scale:

$$y = An^{\beta}k^{\gamma}z^{\zeta}$$

- Constant returns to scale: $\beta + \gamma + \zeta = 1$
- All firms have the same factor proportions
- Firm size is indeterminate
- Aggregating at the city level

$$wN = \beta y, \; p_K K = \gamma y \text{ and } p_Z Z = \zeta y$$

Labor Demand

- City-specific production amenities
  1. Productivity A
  2. Non-tradable capital $\bar{Z}$
- Economy-wide price of capital p_K
  1. Small open economy: p_K fixed on international markets; e.g., $p_K = 1$
  2. Closed economy: aggregate capital $\bar{K}$ is given $\Rightarrow$ endogenous p_K
- The competitive wage in each city is

$$w = \beta \left[\left(\frac{\gamma}{p_K} \right)^{\gamma} A \left(\frac{\bar{Z}}{N} \right)^{\zeta} \right]^{\frac{1}{1-\gamma}}$$

- The model is well defined with fewer factors: $\gamma = 0$ and/or $\zeta = 0$
- The city must have one source of decreasing returns: land suffices

Construction

- Exogenous amount of land $\bar{L}$ in each city
  - Natural and regulatory constraints
- Housing supply is the product of land L and building height f
- Height is built with tradable capital at a convex cost $\psi p_K \left(f/\delta\right)^\delta$ for $\psi > 0$ and $\delta > 1$
- Free entry of developers

$$r = \max_h \left\{ p_H f - \psi p_K \left(\frac{f}{\delta}\right)^\delta \right\} = (\delta - 1) \left(\frac{p_H^\delta}{\psi p_K}\right)^{\frac{1}{\delta-1}}$$

The maximum profit per unit of land is paid to landowners

- Optimal height

$$f = \delta \left(\frac{p_H}{\psi p_K}\right)^{\frac{1}{\delta-1}}$$

Housing Prices

- The user cost of housing is given dynamically by

$$p_t = (1+m)\, p_{H,t} - \frac{\mathbb{E} p_{H,t+1}}{1+i}$$

  - Maintenance and tax costs m
  - Constant interest rate i

- The pricing equation implies the non-bubble value

$$p_{H,t} = \sum_{\tau=0}^{\infty} \frac{\mathbb{E} p_{t+\tau}}{(1+m)^{1+\tau} (1+i)^{\tau}}$$

- Let expected rental prices have a constant growth rate g_p

$$\mathbb{E} p_{t+\tau} = (1+g_p)^{\tau} p_t$$

- Under these hypotheses the model is stationary: regardless of t,

$$\frac{p_{H,t}}{p_t} = \frac{1+i}{i+im+m-g_p}$$

Housing Market Equilibrium

- The user cost of housing is $p = \mu p_H$ for $\mu \approx 0.1$
- Housing demand

$$H = \frac{\lambda w}{\mu p_H} N$$

- Housing supply

$$H = \delta \left(\frac{p_H}{\psi p_K} \right)^{\frac{1}{\delta - 1}} \bar{L}$$

- Market-clearing price

$$p_H = \left[\psi p_K \left(\frac{\lambda}{\delta \mu} \frac{wN}{\bar{L}} \right)^{\delta - 1} \right]^{\frac{1}{\delta}}$$

Spatial Equilibrium

Three equilibrium conditions

1. Individuals' optimal location choice

$$\log w - \lambda \log p_H + \log a = \underline{u} + \kappa_1$$

2. Firms' labor demand

$$(1-\gamma)\log w + \zeta\left(\log N - \log \bar{Z}\right) - \log A = \kappa_2 - \gamma \log p_K$$

3. Housing market equilibrium

$$\delta \log p_H - (\delta - 1)\left(\log w + \log N - \log \bar{L}\right) - \log \psi = \log p_K + \kappa_3$$

- The constants κ_1, κ_2 and κ_3 are functions of exogenous parameters

"Small" Cities

- Three endogenous city characteristics
  1. Population N
  2. Wages w
  3. House prices p_H
- Three exogenous city characteristics
  1. Consumption amenities a
  2. Production amenities $\tilde{A} \equiv A\bar{Z}^{\zeta}$
  3. Construction amenities $\tilde{L} \equiv \bar{L}\psi^{-1/(\delta-1)}$
- Two economy-wide variables:
  1. Reservation utility $\underline{u}$
  2. Price of tradable capital p_K
- We need cities to be "small" so each doesn't affect $\underline{u}$ and p_K
  1. The entire system of cities is small: $\underline{u}$ and p_K are exogenous
  2. There is a continuum of cities: $\underline{u}$ and p_K are endogenous, but they depend on aggregates and not on $\left(a, \tilde{A}, \bar{L}\right)$ in any single city

Equilibrium Characterization

1. Equilibrium wages

$$\log w = \kappa_w + \frac{(\delta-1)\,\lambda\left(\log\tilde{A}-\zeta\log\tilde{L}\right)-\delta\zeta\log a}{\beta\,(\delta-1)\,\lambda+\delta\zeta}$$

2. Equilibrium housing prices

$$\log p_H = \kappa_p + \frac{(\delta-1)\left(\log\tilde{A}+\beta\log a-\zeta\log\tilde{L}\right)}{\beta\,(\delta-1)\,\lambda+\delta\zeta}$$

3. Equilibrium population

$$\log N = \kappa_N + \frac{\left[\delta\,(1-\lambda)+\lambda\right]\log\tilde{A}+(\beta+\zeta)\left[\delta\log a+(\delta-1)\,\lambda\log\tilde{L}\right]}{\beta\,(\delta-1)\,\lambda+\delta\zeta}$$

- Population density reflects the different impacts of ψ and $\bar{L}$

$$\log\frac{N}{L} = \kappa_N + \frac{[\delta(1-\lambda)+\lambda]\left(\log\tilde{A}+\zeta\log\bar{L}\right)+(\beta+\zeta)(\delta\log a-\lambda\log\psi)}{\beta(\delta-1)\lambda+\delta\zeta}$$

Congestion in Construction Alone

- For $\zeta = 0$ production has constant returns at the city level

$\Rightarrow$ City size N does not influence the marginal product of labor

1. Wages are determined by production amenities only

$$\log w = \kappa_w + \frac{1}{\beta} \log A$$

2. Construction amenities $\tilde{L}$ do not influence prices

$$\log p_H = \kappa_p + \frac{\log A + \beta \log a}{\beta \lambda}$$

3. Density reflects construction costs ψ but not the supply of land $\bar{L}$

$$\log \frac{N}{L} = \kappa_N + \frac{[\delta (1 - \lambda) + \lambda] \log \tilde{A} + \beta (\delta \log a - \lambda \log \psi)}{\beta (\delta - 1) \lambda}$$

Congestion in Production Alone

- For $\delta = 1$ construction has constant returns

$\Rightarrow$ Height is a perfect substitute for land: $p_L = 0$

1. The price of housing is determined by construction costs only

$$\log p_H = \kappa_p + \log \psi$$

2. Production amenities $\tilde{A}$ do not influence wages

$$\log w = \kappa_w + \log \psi - \log a$$

3. Population reflects construction costs ψ but not the supply of land $\bar{L}$

$$\log N = \kappa_N + \frac{1}{\zeta}\left[\log \tilde{A} + (\beta + \zeta)(\log a - \lambda \log \psi)\right]$$

Comparative Statics

From the equilibrium conditions, for any exogenous city characteristic X

1. Individuals' optimal location choice

$$\frac{\partial \log w}{\partial X} - \lambda \frac{\partial \log p_H}{\partial X} + \frac{\partial \log a}{\partial X} = 0$$

2. Firms' labor demand

$$(1-\gamma)\frac{\partial \log w}{\partial X} + \zeta \frac{\partial \log N}{\partial X} - \frac{\partial \log \tilde{A}}{\partial X} = 0$$

3. Housing market equilibrium

$$\frac{\delta}{\delta - 1}\frac{\partial \log p_H}{\partial X} - \frac{\partial \log w}{\partial X} + \frac{\partial \log N}{\partial X} - \frac{\partial \log \tilde{L}}{\partial X} = 0$$

- To a first order, we can bring these to the data

Linear Model

Assume that for a measurable exogenous city characteristic X

1. $\log a = \kappa_a + \xi_a X + \varepsilon_a$
2. $\log \tilde{A} = \kappa_A + \xi_A X + \varepsilon_A$
3. $\log \tilde{L} = \kappa_L + \xi_L X + \varepsilon_L$

▷ Independent homoskedastic errors ε

Log-linearity of these and of the equilibrium conditions implies

1. $\log w = \kappa_w + \xi_w X + \varepsilon_w$ for $\xi_w = \frac{(\delta-1)\lambda(\xi_A - \zeta\xi_L) - \delta\zeta\xi_a}{\beta(\delta-1)\lambda+\delta\zeta}$
2. $\log p_H = \kappa_p + \xi_p X + \varepsilon_p$ for $\xi_p = \frac{(\delta-1)(\xi_A + \beta\xi_a - \zeta\xi_L)}{\beta(\delta-1)\lambda+\delta\zeta}$
3. $\log N = \kappa_N + \xi_N + \varepsilon_N$ for $\xi_N = \frac{[\delta(1-\lambda)+\lambda]\xi_A + (\beta+\zeta)[\delta\xi_a + (\delta-1)\lambda\xi_L]}{\beta(\delta-1)\lambda+\delta\zeta}$

▷ Independent homoskedastic errors ε

The Rosen–Roback Approach

Inverting the definitions of ξ_w, ξ_p and ξ_N yields the comparative statics from the equilibrium conditions in global instead of local form

$$\begin{aligned} \xi_a &= \lambda\xi_p - \xi_w \\ \xi_A &= \zeta\xi_N + (1-\gamma)\,\xi_w \\ \xi_L &= \xi_N + \xi_w - \frac{\delta}{\delta-1}\xi_p \end{aligned}$$

- ξ_w, ξ_p and ξ_N can be estimated regressing w, p_H and N on X
- Calibration
  1. Budget share of housing $\lambda \approx 0.3$
  2. Factor shares $\beta \approx 0.6$ and $\gamma \approx 0.3$
  3. Housing supply elasticity $1/(\delta - 1) \approx$?
- Derived estimates of ξ_a and ξ_A, and less credibly of ξ_L

Suggestive Empirics

January temperatures

1. A consumption amenity: $\xi_a > 0$
   - Lower wages in warmer U.S. cities
2. Correlated with production disamenities: $\xi_A < 0$
   - Omitted production amenities justify the existence cold cities
3. Housing supply?
   1. Glaeser (2008): $\xi_L > 0$; more permissive regulation in the South
   2. Glaeser and Gottlieb (2009): $\xi_L < 0$; old houses in declining cold cities

- Correlations to understand the data
  - No identification of causal relationships

The Original Rosen–Roback Framework

Roback (1982) classic contribution building upon Rosen's ideas

1. Endogeneity is not addressed adequately
2. Unclustered standard errors are probably meaningless

▷ Historical paper: you can no longer write empirics like this

Two prices for the largest U.S. cities

1. Wages w from the 1973 Current Population Survey
2. House prices p for 1973 from the Federal Housing Administration
    - Overrepresents the poor, but gives \$/sq. ft.

- Estimates of consumption (and potentially production) amenities
- Attenuation bias from self-sorting of heterogeneous agents

City Characteristics

1. Crime level
   - At low frequencies it cannot possibly be exogenous
2. Pollution: particulate level
3. Unemployment rate
   - Harris and Todaro's (1970) model of rural-urban migration
   - High wages compensate for high unemployment rates
   - Hall (1972) found some evidence of this across U.S. cities
   - Not much since then: possibly related to decline in unionization
4. Population, population density, and population growth
   - These seem to belong on the left-hand side
5. Climate: heating degree days, snowfall, cloudy days, clear days
   - The most plausible exogeneity

Wage Regression

	1	2	3	4
TCRIME 73	$.94 \times 10^{-5}$ (2.58)	$.44 \times 10^{-5}$ (1.17)	$.74 \times 10^{-5}$ (1.93)	$.86 \times 10^{-5}$ (2.21)
UR 73	$.36 \times 10^{-2}$ (1.29)	$.12 \times 10^{-2}$ (.43)	$.32 \times 10^{-2}$ (1.14)	$.27 \times 10^{-2}$ (.97)
PART 73	$.24 \times 10^{-3}$ (1.55)	$.13 \times 10^{-3}$ (.86)	$.37 \times 10^{-3}$ (2.33)	$.34 \times 10^{-3}$ (2.15)
POP 73	$.16 \times 10^{-7}$ (7.97)	$.15 \times 10^{-7}$ (7.74)	$.16 \times 10^{-7}$ (8.04)	$.16 \times 10^{-7}$ (8.11)
DENSSMSA	$.81 \times 10^{-6}$ (.29)	$.24 \times 10^{-5}$ (.86)	$.20 \times 10^{-5}$ (.73)	$.38 \times 10^{-5}$ (1.40)
GROW 6070	$.21 \times 10^{-2}$ (7.84)	$.14 \times 10^{-2}$ (5.66)	$.15 \times 10^{-2}$ (6.06)	$.17 \times 10^{-2}$ (6.47)
HDD	$.20 \times 10^{-4}$ (8.48)			
TOTSNOW		$.72 \times 10^{-3}$ (3.54)		
CLEAR			$-.64 \times 10^{-2}$ (-4.80)	
CLOUDY				$.72 \times 10^{-2}$ (5.21)
R^2	.4980	.4955	.4960	.4962
F-ratio	424.2	420.0	420.8	421.1
N = 12,001				

NOTE.—Regressions include all personal characteristics. Sample includes 98 cities; t-statistics are in parenthese (see App. for variable definitions).

Housing Price Regression

	1	2	3	4
TCRIME 73	2.5×10^{-5} (.65)	1.5×10^{-5} (.38)	-4.5×10^{-7} (−.01)	7.0×10^{-6} (.16)
UR 73	8.9×10^{-2} (3.45)	8.8×10^{-2} (3.35)	9.2×10^{-2} (3.53)	9.1×10^{-2} (3.52)
PART 73	2.2×10^{-4} (.15)	1.1×10^{-4} (.08)	-3.8×10^{-5} (−.02)	1.4×10^{-4} (.09)
POP 73	6.8×10^{-8} (1.80)	6.9×10^{-8} (1.78)	6.8×10^{-8} (1.76)	6.8×10^{-8} (1.76)
DENSSMSA	1.9×10^{-4} (3.02)	2.0×10^{-4} (3.12)	2.0×10^{-4} (3.17)	2.0×10^{-4} (3.18)
GROW 6070	1.1×10^{-2} (4.34)	1.0×10^{-2} (4.11)	9.9×10^{-3} (4.03)	1.0×10^{-2} (4.00)
HDD	3.5×10^{-5} (1.44)			
TOTSNOW		1.3×10^{-3} (.69)		
CLEAR			1.2×10^{-4} (.09)	
CLOUDY				3.2×10^{-4} (.21)
INTERCEPT	−1.73 (−5.92)	−1.54 (−5.99)	−1.44 (−6.51)	−1.53 (−3.32)
R^2	.5741	.5650	.5623	.5625
F-ratio	14.44	13.92	13.77	13.78

SOURCE.—Data are from U.S. Department of Housing and Urban Development 1973. $N = 83$.

Consumption Amenities

Implicit Prices of Amenities Computed from Tables 1 and 3

	1	2	3	4
TCRIME 73 (crimes/100 population)	$−9.25	$ .90	$ −8.05	$ −9.15
UR 73 (fraction unemployed)	−5.55	20.65	−.70	5.00
PART 73 (micrograms/cubic meter)	−2.50	−1.40	−4.00	−3.70
POP 73 (10,000 persons)	−1.50	−1.40	−1.50	−1.50
DENSSMSA (100 persons/square mile)	6.30	4.90	5.35	3.35
GROW 6070 (percentage change in population)	−1.85	−11.95	−13.05	−15.2
HDD (1° F colder for one day	−.20			
TOTSNOW (inches)		−7.30		
CLEAR (days)			69.55	
CLOUDY (days)				−78.25

Note.—Measurement units of amenities shown under variable name. Each entry is computed using eq. (5) in tl text and evaluated at mean annual earnings. $p_s^* = [k_l(d \log r/ds) - (d \log w/ds)]w$. Average annual earnings = $10,86 Average budget share of land = .035. Negative numbers indicate disamenities, while positive numbers indica amenities.

Government-Related Amenities

Gyourko and Tracy (1991) on local public finance

1. Local government provides important amenities
2. Local taxes create tax wedges on p and w
3. A rent-seeking public sector might extract the value of amenities

- Local government is exogenous for each potential resident or firm
  - But econometrically exogenous?
- Random effects estimation
  - Exogeneity of the random effects is rarely easy to accept
  - Still no clustering

Natural and Fiscal Amenities

City Trait	Annual Housing Expenditure Hedonic* (1)	Weekly Wage Hedonic† (2)	Annualized Trait Prices‡ Housing (3)	Wage (4)	Full (5)
Precipitation	−.0139	−.0027	−$22.82	−$21.59	−$1.22
	(.0030)	(.0009)	(4.98)	(6.83)	(8.45)
Cooling degree days (thousands)	−.1344	.0031	−7.97	.89	−8.86
	(.0562)	(.0157)	(3.33)	(4.49)	(5.59)
Heating degree days (thousands)	−.0277	.0172	−5.65	16.93	−22.58
	(.0248)	(.0069)	(5.06)	(6.82)	(8.49)
Relative humidity	.0145	.0033	36.53	40.14	−3.61
	(.0053)	(.0015)	(13.36)	(18.67)	(22.95)
Sunshine (percentage possible)	.0079	−.0005	21.84	−6.03	27.87
	(.0056)	(.0016)	(15.38)	(21.97)	(26.82)
Wind speed (mph)	−.0427	−.0192	−18.18	−39.57	21.39
	(.0179)	(.0055)	(7.62)	(11.31)	(13.64)
Particulate matter	−.0019	−.0003	−6.36	−4.34	−2.01
	(.0013)	(.0004)	(4.20)	(−5.79)	(7.15)
Coast	.1345	−.0201	654.15	−435.70	1,089.86
	(.0694)	(.0199)	(360.15)	(429.20)	(560.28)
Cost of living	.6496	.2633	28.89	56.58	−27.70
	(1.6197)	(.4208)	(71.94)	(90.42)	(115.55)
Violent crime	.0574	.0705	2.51	14.91	−12.40
	(.0425)	(.0109)	(1.86)	(2.31)	(2.97)

Natural and Fiscal Amenities

Student/teacher ratio	−.0107	−.0010	−6.84	−3.09	−3.76
	(.0096)	(.0027)	(6.14)	(8.31)	(10.33)
Fire rating	.0498	.0156	6.93	10.48	−3.55
	(.0255)	(.0078)	(3.55)	(5.28)	(6.36)
Hospital beds	.0031	−.0036	1.82	−10.03	11.85
	(.0037)	(.0010)	(2.12)	(2.82)	(3.53)
Property tax rate	−.1037	. . .	−6.14	. . .	−6.14
	(.0399)		(2.37)		(2.37)
State and local income tax rate	−.0287	.0020	−3.99	1.37	−5.36
	(.0101)	(.0029)	(1.41)	(1.95)	(2.41)
State corporate tax rate	.0208	−.0067	5.97	−9.33	15.30
	(.0100)	(.0029)	(2.88)	(3.98)	(4.91)
Percentage public union organized	−.1646	−.0041	−3.29	−.39	−2.89
	(.1302)	(.0385)	(2.60)	(3.72)	(4.54)
SMSA population (millions)	.0376	.0096	1.27	1.57	−.30
	(.0223)	(.0057)	(.76)	(.93)	(1.20)
Percentage working in other SMSA	1.4693	.1052	5.34	1.85	3.49
	(.6325)	(.1969)	(2.30)	(3.46)	(4.15)
Summary statistics:					
σ_α^2	.0434	. . .			
σ_ϵ^2	.1801	. . .			
σ_δ^2	. . .	.2905			
σ_η^2	. . .	.0023			
Number of observations	5,263	38,870			

* The housing hedonic contains 20 structural trait controls. All results are available on request. Estimated standard errors are in parentheses.

† The wage hedonic contains 11 worker quality variables and controls for 22 major industry and occupation groups. All results are available on request. Estimated standard errors are in parentheses.

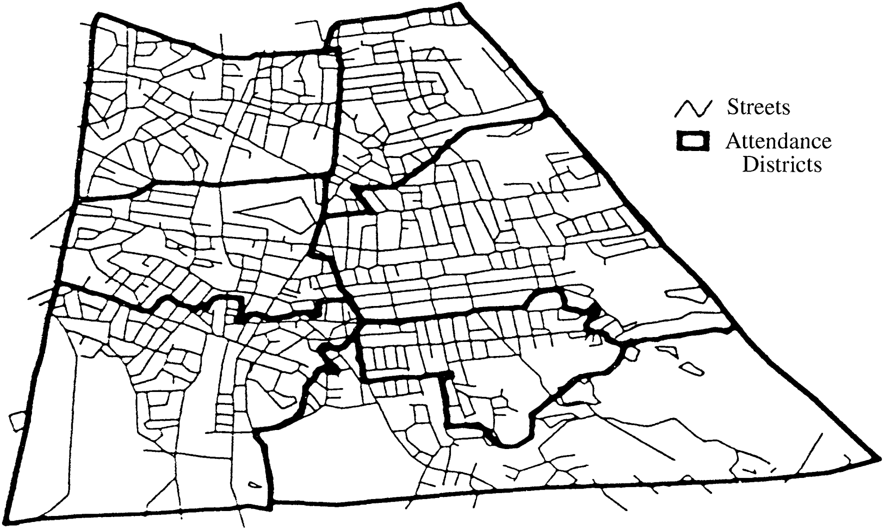
‡ The calculations in cols. 3–5 are based on a 1 percent change about the mean of the variables except for the dichotomous coast variable. Its prices are based on a discrete change from noncoast to coastal status. All figures in these three columns are annualized. We assume 1.5 wage earners per household and 49 work weeks per year. These are the sample averages. Standard errors of the implicit prices are in parentheses. They are calculated via the "delta" method.

Micro-Geography

Black (1999) on public schools in the Boston area

- Tax rates and school spending vary by school district
- Average test scores measure quality at the school level
- Attendance districts within a school district determine a child's school
- Identification off of discontinuity at administrative boundaries
  - 39 school districts, 181 attendance district boundaries
- Within-city hedonics on p only
  - Transaction prices for 22,679 single-family homes

Attendance District Boundaries



House Prices and School Quality

Distance from boundary:	(1) All houses[d]	(2) 0.35 mile from boundary (616 yards)	(3) 0.20 mile from boundary (350 yards)	(4) 0.15 mile from boundary (260 yards)	(5) 0.15 mile from boundary (260 yards)
Elementary school test score[c]	.035	.016	.013	.015	.031
	(.004)	(.007)	(.0065)	(.007)	(.006)
Bedrooms	.033	.038	.037	.033	.035
	(.004)	(.005)	(.006)	(.007)	(.007)
Bathrooms	.147	.143	.135	.167	.193
	(.014)	(.018)	(.024)	(.027)	(.028)
Bathrooms squared	−.013	−.017	−.015	−.024	−.025
	(.003)	(.004)	(.005)	(.006)	(.007)
Lot size (1000s)	.003	.005	.005	.005	.004
	(.0003)	(.0005)	(.0005)	(.0007)	(.0006)
Internal square footage (1000s)	.207	.193	.191	.195	.191
	(.007)	(.01)	(.01)	(.02)	(.012)
Age of building	−.002	−.002	−.003	−.003	−.002
	(.0003)	(.0002)	(.0005)	(.0006)	(.0004)
Age squared	.000003	.000003	.00001	.000009	.000005
	(.000001)	(.0000006)	(.000002)	(.000003)	(.000002)
Boundary fixed effects	NO	YES	YES	YES	NO
Census variables	Yes	No	No	No	Yes

House Prices and School Quality

N	22,679	10,657	6,824	4,594	4,589
Number of boundaries	N/A	175	174	172	N/A
Adjusted R^2	0.6417	0.6745	0.6719	0.6784	.6564

a. Each regression includes quarter year dummies. Dummies are also included to indicate missing bedroom data, bathroom data, lot size data, and age of establishment data.

b. Standard errors are adjusted for clustering at the attendance district level.

c. Test scores are measured at the elementary school level and represent the sum of the reading and math scores from the fourth grade MEAP test averaged over three years (1988, 1990, and 1992). *Source:* Massachusetts Department of Education.

d. This regression also includes neighborhood characteristics such as the percentage of Hispanics, the percentage of non-Hispanic blacks, the age distribution of the neighborhood, the percentage of female-headed households with children, the educational distribution of the neighborhood, and the median household income, all of which are measured at the census block group level from the 1990 Census, along with school district characteristics such as per-pupil spending in 1993, the pupil/teacher ratio, the existence of a low-cost or free preschool program, and the property tax rate, all of which are measured at the school district level. See Appendix 1 for these estimates.

Differences at the Boundary

Differences in Means[a]

Distance from boundary:	Full sample		0.35 mile		0.20 mile		0.15 mile	
	Difference in means	*T*-statistic	Ratio of 0.35 to full sample[d]	*T*-statistic	Ratio of 0.20 to full sample[d]	*T*-statistic	Ratio of 0.15 to full sample[d]	*T*-statistic
ln (house price)	.045	3.82	0.85	3.32	0.85	3.17	0.93	3.17
Test score (sum of reading and math)	1.0	32.90	1.03	27.28	1.06	24.44	1.06	22.57
House characteristics								
Bedrooms	0.02	1.68	0.90	0.91	−0.35	−0.30	0.25	0.18
Bathrooms	0.03	2.98	0.23	0.52	−0.02	−0.05	−0.07	−0.12
Lot size	2011	11.39	0.22	2.14	0.24	1.95	0.12	0.83
Internal square footage	31	2.93	0.61	1.32	0.61	1.07	0.84	1.17
Age of building	−3.13	−6.92	0.75	−3.71	0.94	−3.76	1.09	−3.52
Neighborhood characteristics[c]								
Percent Hispanic	−.0008	−0.79	2.50	−1.35	2.50	−1.21	2.50	−1.26
Percent non-Hispanic black	−.0007	−1.50	0.43	−0.54	0.00	−0.07	−0.14	0.16
Percent 0–9 years old	.005	3.30	0.16	0.63	−0.08	−0.31	−0.30	−1.21
Percent 65+ years old	−.01	−2.04	0.40	−0.72	0.67	−1.28	0.60	−0.95
Percent female-headed households with children	−.001	−3.67	1.00	−3.17	1.20	−2.53	1.00	−2.38
Percent with bachelor's degree	.002	1.06	0.75	0.64	1.00	0.74	0.75	0.67
Percent with graduate degree	.008	3.32	0.88	2.77	0.88	3.02	0.88	3.31
Percent with less than high school diploma	−.005	−2.19	1.20	−2.02	0.80	−1.57	0.34	−0.64
Median household income	2,135	2.87	0.60	1.90	0.65	2.11	0.52	1.61

a. *T*-statistics represent the *t*-statistic for the null that the difference in means between the better and worse sides of the boundary (as measured by the sum of the reading and math fourth grade MEAP test scores averaged over 1988, 1990, and 1992) are equal. All *t*-statistics are adjusted for clustering at the attendance district level.

b. Test scores are measured at the elementary school level and represent the sum of the reading and math scores from the fourth grade MEAP test averaged over three years (1988, 1990, and 1992). *Source*: Massachusetts Department of Education.

c. Neighborhood characteristics are measured at the census block group level and are from the 1990 Census.

d. The ratios represent the difference in means of houses on opposite sides of the boundary for the restricted sample over the difference in means of houses on opposite sides of the boundary for the whole sample.

Capitalized Prices of Better Test Scores

	(1) Basic hedonic regression[d]	(2) 0.35 sample boundary fixed effects	(3) 0.20 sample boundary fixed effects	(4) 0.15 sample boundary fixed effects
Coefficient on elementary school test score[b]	.035 (.004)	.016 (.007)	.013 (.0065)	.015 (.007)
Magnitude of effect (percent change in house price as a result of a 5% change in test scores)[c]	4.9%	2.3%	1.8%	2.1%
$ Value (at mean tax-adjusted house price of $188,000 in $1993)	$9212	$4324	$3384	$3948
$ Value (at median tax-adjusted house price of $158,000 in $1993)	$7742	$3634	$2844	$3318

a. The results presented here are based on estimates from Table II, columns (1)–(4).

b. Test scores are measured at the elementary school level and represent the sum of the reading and math scores from the fourth grade MEAP test averaged over three years (1988, 1990, and 1992). *Source*: Massachusetts Department of Education.

c. Approximately a one-standard-deviation change in the average test scores at the mean.

d. Regression includes house characteristics, school characteristics measured at the school district level, and neighborhood characteristics measured at the census block group level. See Table II, column (1), and Appendix 1 for more complete results.

Repeated Static Equilibrium

1. Individuals can relocate every period at no cost

$$\log w_t - \lambda \log p_t + \log a_t = \underline{u}_t$$

or in first differences

$$\log \frac{w_{t+1}}{w_t} - \lambda \log \frac{p_{t+1}}{p_t} + \log \frac{a_{t+1}}{a_t} = \underline{u}_{t+1} - \underline{u}_t$$

2. Firms rent tradable capital in every period

$$(1-\gamma) \log w_t + \zeta \log N_t - \log \tilde{A}_t = \kappa_2 - \gamma \log p_{K,t}$$

or in first differences

$$(1-\gamma) \log \frac{w_{t+1}}{w_t} + \zeta \log \frac{N_{t+1}}{N_t} - \log \frac{\tilde{A}_{t+1}}{\tilde{A}_t} = -\gamma \log \frac{p_{K,t+1}}{p_{K,t}}$$

- The right-hand sides are time- but not city-specific
  - "Small" cities do not influence $\underline{u}_t$ nor $p_{K,t}$

Simplified Housing Dynamics

- Housing prices are forward-looking and complicate a dynamic model
- If $\mathbb{E}p_{t+\tau}$grows at a rate g_p constant across cities and over time, then

$$p_t = \mu p_{H,t} \Rightarrow \log \frac{p_{t+1}}{p_t} = \log \frac{p_{H,t+1}}{p_{H,t}}$$

- The housing market equilibrium is

$$\delta \log p_{H,t} - (\delta - 1) \left(\log w_t + \log N_t - \log \tilde{L}_t \right) = \log p_{K,t} + \kappa_3$$

or in first differences

$$\delta \log \frac{p_{t+1}}{p_t} - (\delta - 1) \left(\log \frac{w_{t+1}}{w_t} + \log \frac{N_{t+1}}{N_t} - \log \frac{\tilde{L}_{t+1}}{\tilde{L}_t} \right) = \frac{\log p_{K,t+1}}{\log p_{K,t}}$$

- We can treat growth rates just as we did log levels

Linear Growth Rates for Exogenous Variables

Assume that for a measurable exogenous city characteristic X_t

1. $\log a_{t+1} - \log a_t = \kappa_{\Delta a} + \Delta_a X_t + \varepsilon_{\Delta a,t}$
2. $\log \tilde{A}_{t+1} - \log \tilde{A}_t = \kappa_{\Delta A} + \Delta_A X_t + \varepsilon_{\Delta A,t}$
3. $\log \tilde{L}_{t+1} - \log \tilde{L}_t = \kappa_{\Delta L} + \Delta_L X_t + \varepsilon_{\Delta L,t}$

▷ Independent homoskedastic errors ε

Assume that aggregate dynamics satisfy

1. $\underline{u}_{t+1} - \underline{u}_t = \kappa_{\Delta u} + \varepsilon_{\Delta u,t}$
2. $\log p_{K,t+1} - \log p_{K,t} = \kappa_{\Delta K} + \varepsilon_{\Delta K,t}$

▷ Independent homoskedastic errors ε

- The aggregate assumptions could be relaxed
  - Time-varying intercept, i.e., time fixed effects

Linear Growth Rates for Endogenous Variables

If $\mathbb{E}p_{t+\tau}$ grows at a rate g_p constant across cities and over time, then

1. $\log w_{t+1} - \log w_t = \kappa_{\Delta w} + \Delta_w X_t + \varepsilon_{\Delta w,t}$
2. $\log p_{H,t+1} - \log p_{H,t} = \kappa_{\Delta p} + \Delta_p X_t + \varepsilon_{\Delta p,t}$
3. $\log N_{t+1} - \log N_t = \kappa_{\Delta N} + \Delta_N X_t + \varepsilon_{\Delta N,t}$

▷ Independent homoskedastic errors ε

Given estimates of Δ_w, Δ_p and Δ_N from growth regressions

1. $\Delta_a = \lambda \Delta_p - \Delta_w$
2. $\Delta_A = \zeta \Delta_N + (1 - \gamma) \Delta_w$
3. $\Delta_L = \Delta_N + \Delta_w - \Delta_p \delta / (\delta - 1)$

Consistency Check

- We assumed

$$\mathbb{E}p_{t+1} = (1 + g_p)\, p_t$$

- We derived

$$p_{t+1} = p_t \exp\left(\kappa_{\Delta p} + \Delta_p X_t + \varepsilon_{\Delta p,t}\right)$$

- Consistent if $\mathbb{E}\exp\left(\Delta_p X_t\right)$ is constant across cities and over time
  1. X_t is i.i.d. across cities and over time
  2. X_t is realized after period t construction
- The best exogenous variables are not i.i.d: e.g., climate
  1. Incomplete modelling of the housing sector
  2. Simplified microfoundation of construction
  3. Full-fledged housing dynamics

Perfectly Elastic Housing Supply

1. Perfectly elastic supply of housing at unit cost ψp_K $(\delta = 1)$

$$\log p_{H,t} - \log \psi_t = \log p_{K,t}$$

2. Growth rate of construction costs independent of X_t

$$\log \psi_{t+1} - \log \psi_t = \kappa_{\Delta\psi} + \varepsilon_{\Delta\psi,t}$$

▷ Rental prices

$$p_t = (1+m)\, p_{H,t} - \frac{\mathbb{E} p_{H,t+1}}{1+i} = \mu p_{H,t}$$

for

$$\mu = 1 + m - \frac{\exp\left(\kappa_{\Delta\psi} + \varepsilon_{\Delta\psi,t}\right) \mathbb{E} \exp\left(\varepsilon_{\Delta\psi,t} + \varepsilon_{\Delta K,t}\right)}{1+i}$$

- We could let μ vary across cities and over time: then $\tilde{a}_t = a_t \mu_t^{-\lambda}$
  - Higher expected housing appreciation is appealing to residents
  - We need μ to be independent of $p_{H,t}$ and X_t

Perfectly Inelastic Housing Supply

- Perfectly inelastic supply of housing $H_t = \bar{L}_t$ $(\delta \to \infty)$

$$\log p_t - \log w_t + \log \bar{L}_t - \log N_t = \kappa_3$$

- Equilibrium in terms of rental price p_t
  1. $\Delta_a = \lambda \Delta_p - \Delta_w$
  2. $\Delta_A = \zeta \Delta_N + (1-\gamma)\,\Delta_w$
  3. $\Delta_L = \Delta_N + \Delta_w - \Delta_p$
- We typically have and prefer data on house prices p_H, not rents p
- If $X_t = X$ is an invariant city characteristic

$$p_{t+\tau} = p_t \exp\left[\tau\left(\kappa_{\Delta p} + \Delta_p X\right) + \sum\nolimits_{s=0}^{\tau-1} \varepsilon_{\Delta p, t+s}\right]$$

$$\Rightarrow \frac{p_{H,t}}{p_t} = \frac{1}{1+m} \sum_{\tau=0}^{\infty} \left[\frac{\exp\left(\kappa_{\Delta p} + \Delta_p X\right)}{(1+m)\,(1+i)}\right]^{\tau} \mathbb{E} \exp\left(\sum\nolimits_{s=0}^{\tau-1} \varepsilon_{\Delta p, t+s}\right)$$

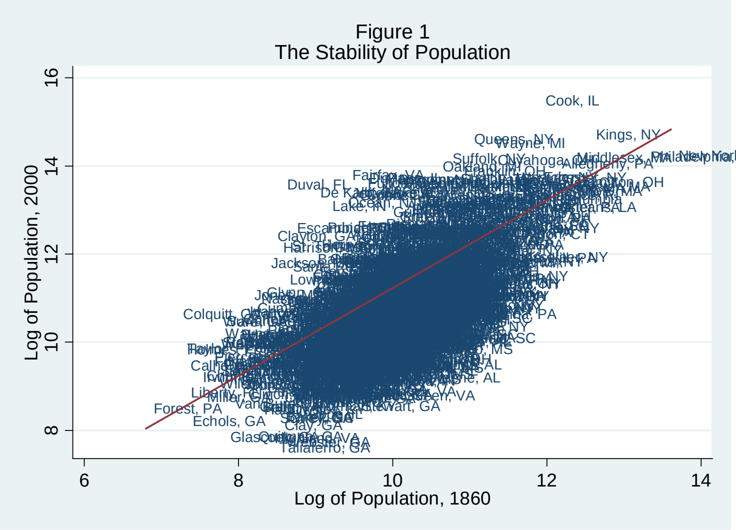
$$\Rightarrow \log p_{H,t+1} - \log p_{H,t} = \log p_{t+1} - \log p_t$$

Urban and Regional Dynamics

1. Population patterns are very persistent in the long run ▸ Figure
2. Population growth rates are persistent in the short run ▸ Figure
    - Employment growth rates have the same behavior ▸ Figure
    - Growth rates of housing supply have the same behavior ▸ Figure
    - Persistence need not apply to the long run ▸ Figure
3. Gibrat's law: growth rates are independent of initial levels
    - Often true of population (cf. 1 above) ▸ USA ▸ France ▸ Japan
    - Often false of population ▸ Table
4. Mean reversion of income ▸ Figure
5. Correlation of population growth and initial income ▸ Figure

- Documented for U.S. cities, counties, and states
- Seemingly true in other countries as well

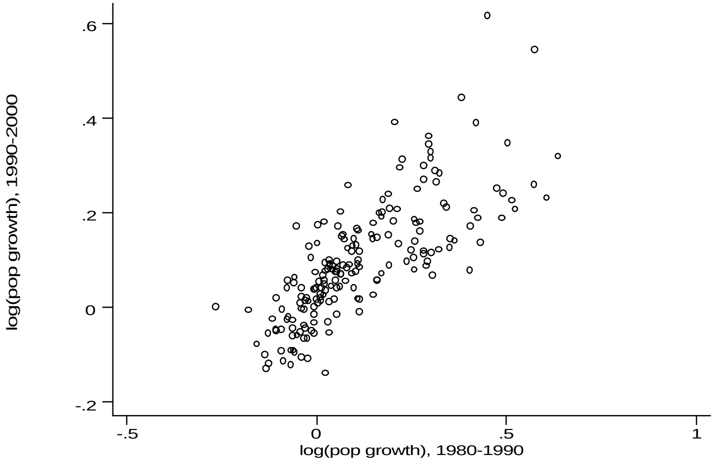
▸ Forward



$$\log N_{2000} = \underset{(.32)}{1.268} + \underset{(.03)}{.996} \log N_{1860}$$

Back

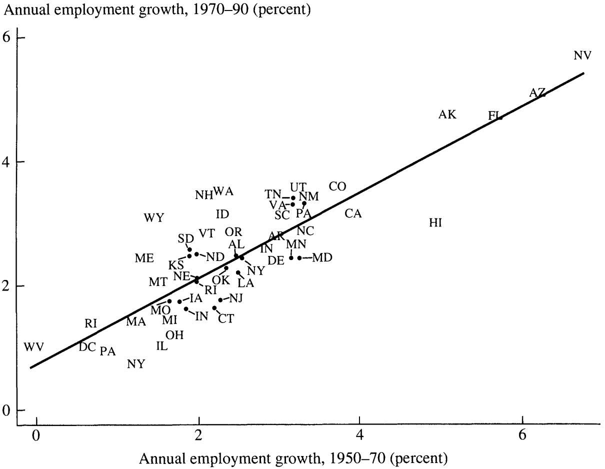
Persistence in City Growth Rates



Sample is all cities with population of 100,000 or more in 1990 and available population data for 1980 (193 observations).

Back

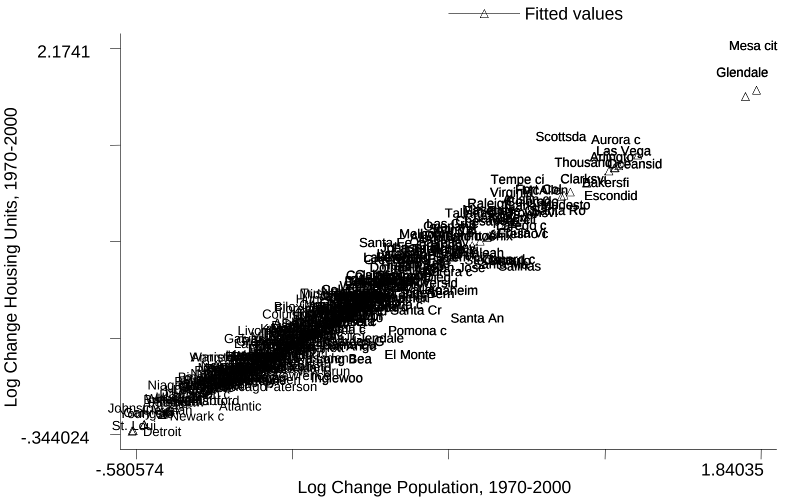
Persistence of Employment Growth Rates



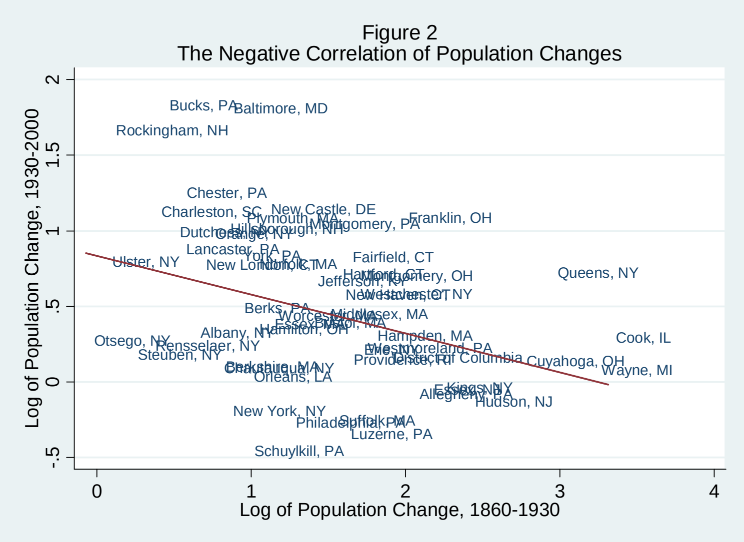
Source: Authors' calculations using data from *Employment and Earnings*. See the appendix for more information. Annual employment growth is measured by the average annual change in log employment over the specified time span.

Back

Changes in Population and Housing Stock



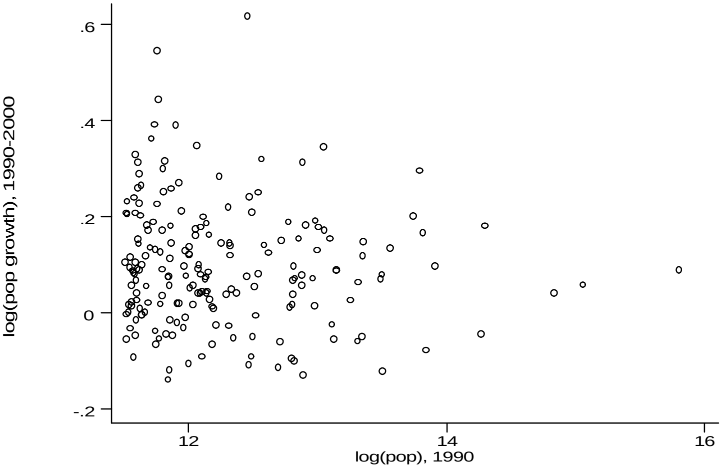
Back



The figure shows the 54 counties that had more than 50,000 people in 1860

Back

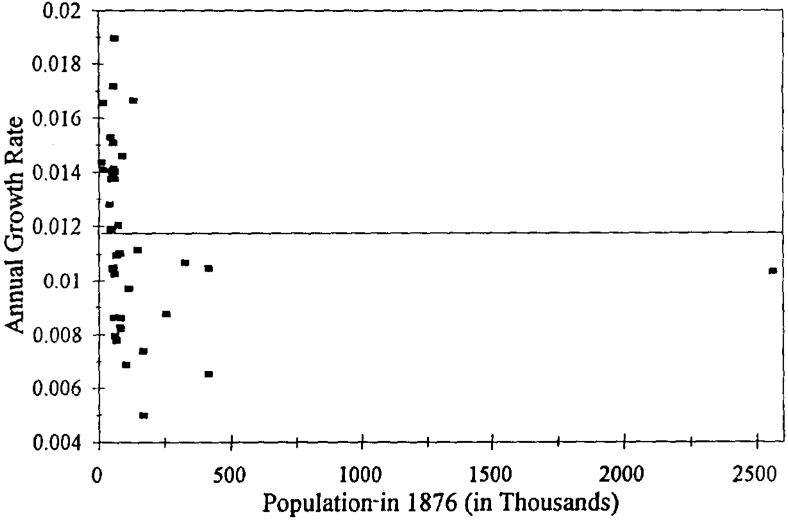
Gibrat's Law in the U.S.



Sample is all cities with population of 100,000 or more in 1990 (195 observations).

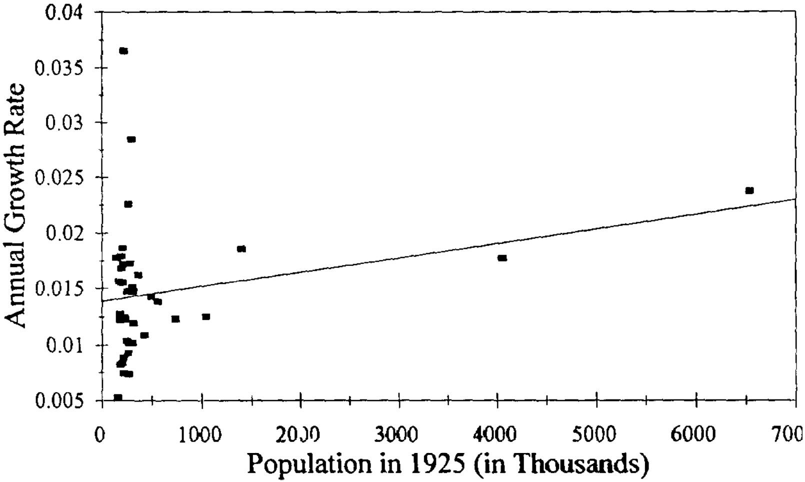
France | Japan | Back

Gibrat's Law for 39 French Cities



USA | Japan | Back

Gibrat's Law for 40 Japanese Cities



USA France Back

Table 1:
Population Growth Correlations

Decades	(1) Correlation with Lagged Population Change	(2) Correlation with Lagged Population Change (50,000+)	(3) Correlation with Initial Log Population	(4) Correlation with Initial Log Population (50,000+)
1790s	.	.	-0.4681	-0.9505
1800s	0.3832	0.6462	-0.5625	0.1316
1810s	0.3256	0.4766	-0.5674	-0.0463
1820s	0.4423	0.5231	-0.5136	0.4178
1830s	0.4452	0.9261	-0.6616	0.241
1840s	0.4634	0.8978	-0.5122	0.3922
1850s	0.4715	0.7661	-0.319	-0.0392
1860s	0.3985	0.4631	0.0111	0.0065
1870s	-0.1228	0.4865	-0.3614	-0.0205
1880s	0.3978	0.4541	-0.1252	0.3323
1890s	0.4935	0.5382	-0.1181	0.3691
1900s	0.4149	0.6454	0.1754	0.2947
1910s	0.5027	0.5778	0.2747	0.0903
1920s	0.476	0.4675	0.3381	0.1494
1930s	0.3005	0.4887	0.0415	-0.1585
1940s	0.4151	0.6752	0.3863	-0.0649
1950s	0.7397	0.7327	0.3985	0.0444
1960s	0.7225	0.8196	0.2922	0.0311
1970s	0.3821	0.4349	-0.2247	-0.4462
1980s	0.641	0.7096	0.1062	-0.0693
1990s	0.737	0.7863	-0.0197	-0.157

Source: County level data from ICPSR 2896 - Historical, Demographic, Economic, and Social Data: The United States, 1790-2000.

▸ Back

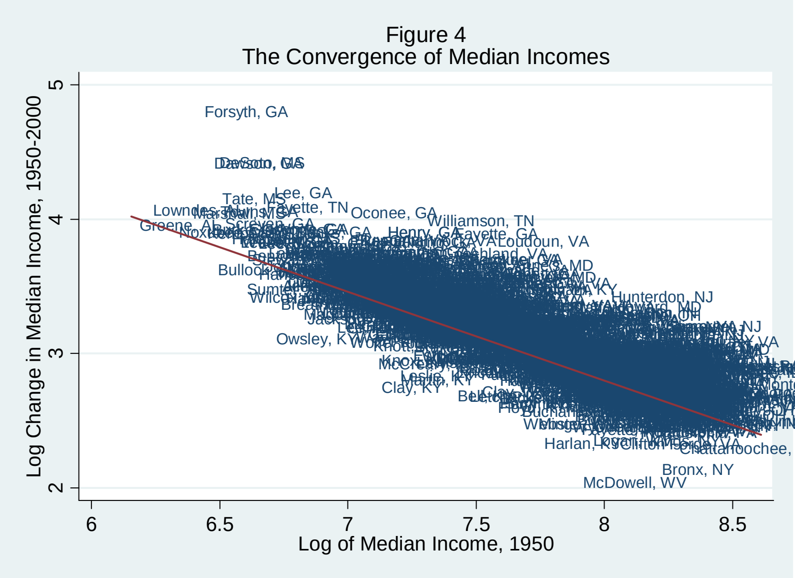


Figure 4
The Convergence of Median Incomes
Log Change in Median Income, 1950-2000
Log of Median Income, 1950
Forsyth, GA
Lee, GA
Tate, MS
Oconee, GA
Williamson, TN
Loudoun, VA
Bulloch
Hunterdon, NJ
Owsley, KY
Clay, KY
Montgomery, MD
Church, VA
Harlan, KY
Chattahoochee, GA
Bronx, NY
McDowell, WV
2
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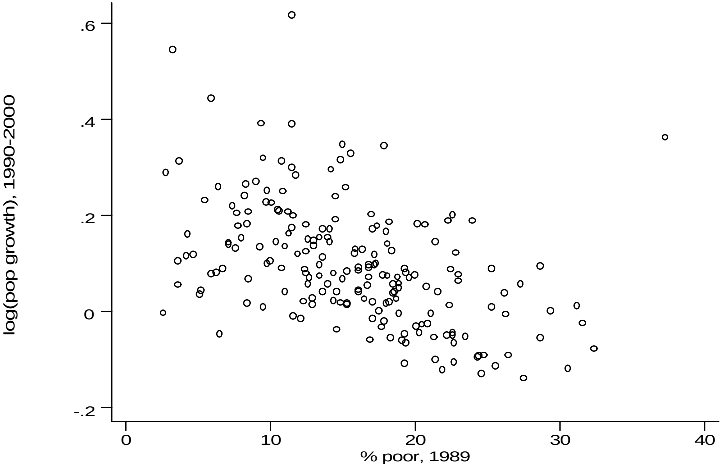
6.5
7
7.5
8
8.5

Back

Growth and Poverty



Sample is all cities with population of 100,000 or more in 1990 (195 observations).

Back

Post-War U.S. Urban and Regional Growth

1. Dispersion of manufacturing
   - Manufacturing predicts the decline of cities ▸ Figure
     - ★ Specialization in health services even more so ▸ Figure
   - Manufacturing does not predict the decline of counties ▸ Figure
2. Education predicts population ▸ Figure and income ▸ Table growth
   - Also predicts growth in education itself ▸ Figure
   - Greater impact in larger cities (Glaeser and Resseger 2010)
   - Seemingly true in the past as well (Simon and Nardinelli 2002)
3. Small firm size predicts employment ▸ Figure and income growth ▸ Table
   - Effect at the city-industry level (Glaeser, Kerr and Ponzetto 2010)
4. Good weather predicts population ▸ Figure and income ▸ Figure growth

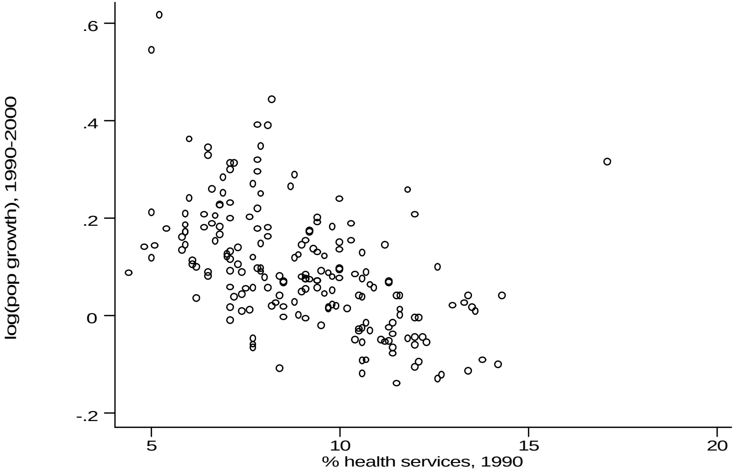
- Productivity channel: population and income co-move

▸ Back ▸ Forward

Manufacturing and Urban Decline

Back

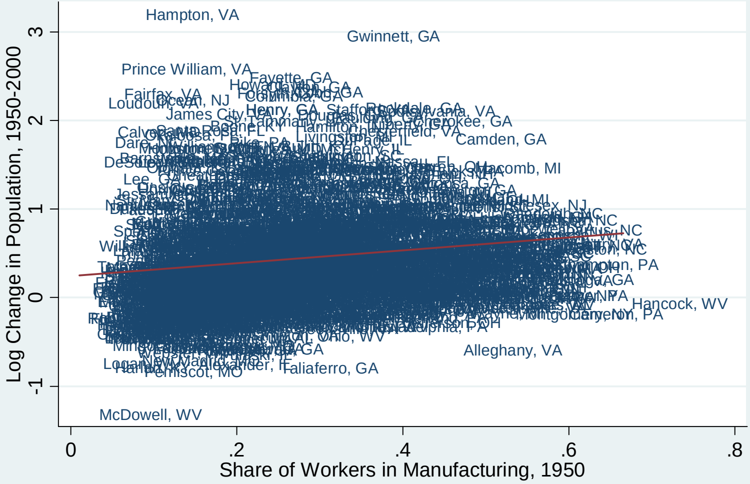
Growth and Health Services



Sample is all cities with population of 100,000 or more in 1990 (195 observations).

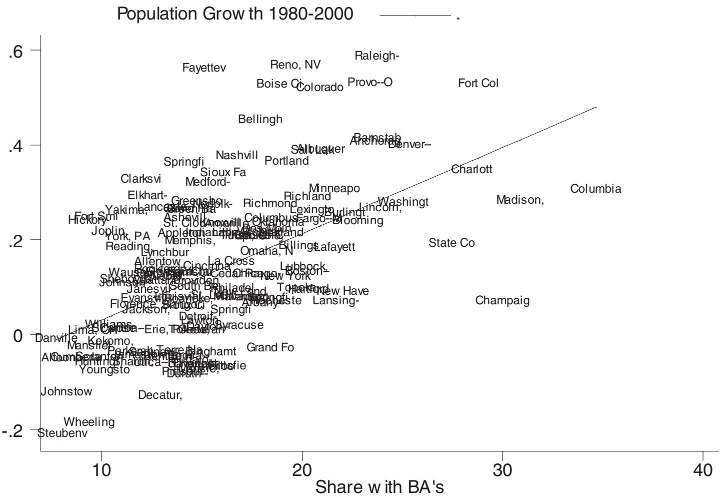
Back

Figure 5
Population Growth and Share in Manufacturing in 1950



Back

City Growth and Education



Back

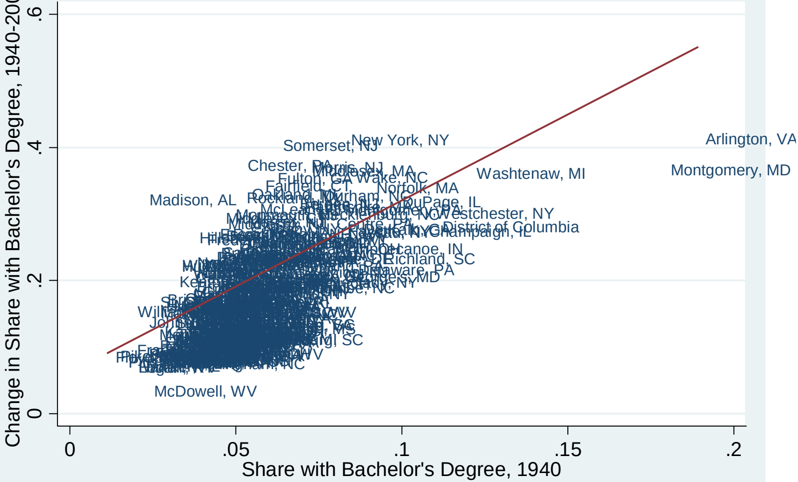
Table 6: Income and Population Growth Regressions, 1950-2000

	Income Growth	*Population Growth*
Share of Workers in Manufacturing, 1950	0.3025	0.5597
	(0.05)	(0.1369)
Log of Population, 1950	-0.0868	-0.2817
	(0.0139)	(0.0381)
Mean January Temperature	-0.0003	0.0198
	(0.0008)	(0.0022)
Longitude	0.0048	0.0107
	(0.0012)	(0.0032)
Distance to Center of Nearest Great Lake	-0.0009	-0.0007
	(0.0002)	(0.0006)
Share with Bachelor Degrees, 1950	2.5141	4.3104
	(0.3098)	(0.8479)
Log of Population/Bachelor Degree Interaction, 19	1.1749	2.7005
	(0.2127)	(0.5822)
Log of Median Income, 1950	-0.7392	0.4600
	(0.0221)	(0.0605)
Constant	8.8912	-3.2321
	(0.2083)	(0.57)
Observations	1328	1328
R-squared	0.7476	0.1833

Sources: County level data from ICPSR 2896 - Historical, Demographic, Economic, and Social Data: The United States, 1790-2000. Geographical information from ESRI GIS data.

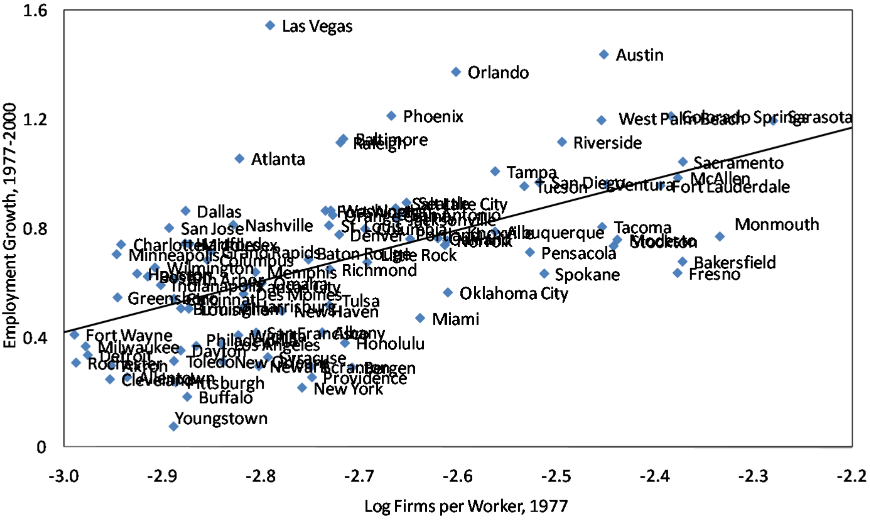
Back

Figure 6
Growth in Share of Population with a Bachelor Degree



Back

Figure 1: Employment Growth and Firms per Worker



Back

Table 8: Income and Population Growth Regressions, 1980-2000

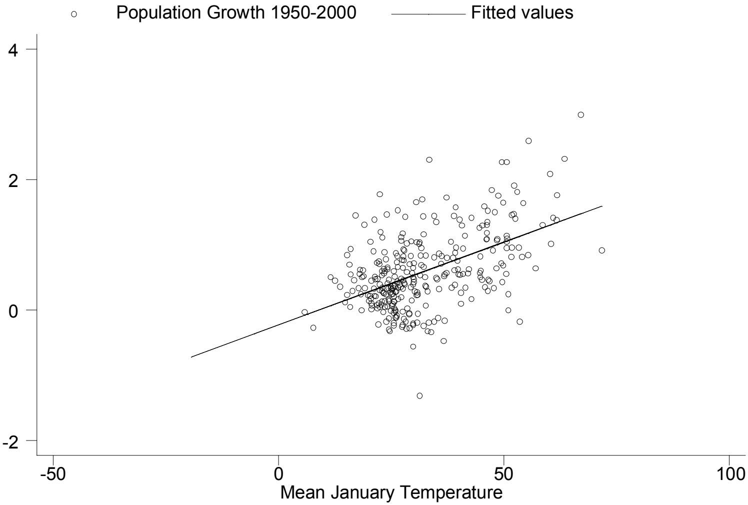
	Log Change in Population, 1980-2000		*Log Change in Median Income, 1980-2000*	
	(1) *Full Sample*	(2) *Counties with 50,000+*	(3) *Full Sample*	(4) *Counties with 50,000+*
Share of Workers in Manufacturing, 1980	0.338	0.600	0.390	0.434
	(0.063)**	(0.117)**	(0.031)**	(0.052)**
Log of Population, 1980	-0.017	-0.039	0.001	0.008
	(0.007)*	(0.013)**	(0.003)	(0.006)
Share with Bachelor's Degree, 1980	0.493	0.830	0.966	0.846
	(0.145)**	(0.188)**	(0.071)**	(0.084)**
Distance to Center of Nearest Great Lake	0.000	0.000	0.000	0.000
	(0.000)*	(0.000)**	(0.000)**	(0.000)**
Average Establishment Size, 1977	-0.016	-0.022	-0.011	-0.012
	(0.002)**	(0.003)**	(0.001)**	(0.001)**
Log of Median Income, 1980	0.519	0.646	-0.065	0.062
	(0.039)**	(0.071)**	(0.019)**	(0.032)
Longitude	0.005	0.001	0.006	0.007
	(0.002)**	(0.002)	(0.001)**	(0.001)**
Mean January Temperature	0.010	0.009	-0.003	-0.004
	(0.002)**	(0.002)**	(0.001)**	(0.001)**
Constant	-4.629	-6.027	1.982	0.737
	(0.382)**	(0.663)**	(0.187)**	(0.297)*
Observations	1336	444	1336	444
R-squared	0.28	0.45	0.31	0.52

Note: Standard Errors in parenthesis (* significant at 5%; ** significant at 1%).

Sources: County level data from ICPSR 2896 - Historical, Demographic, Economic, and Social Data: The United States, 1790-2000. Geographical information from ESRI GIS data. Average establishment size in 1977 from County Business Patterns.

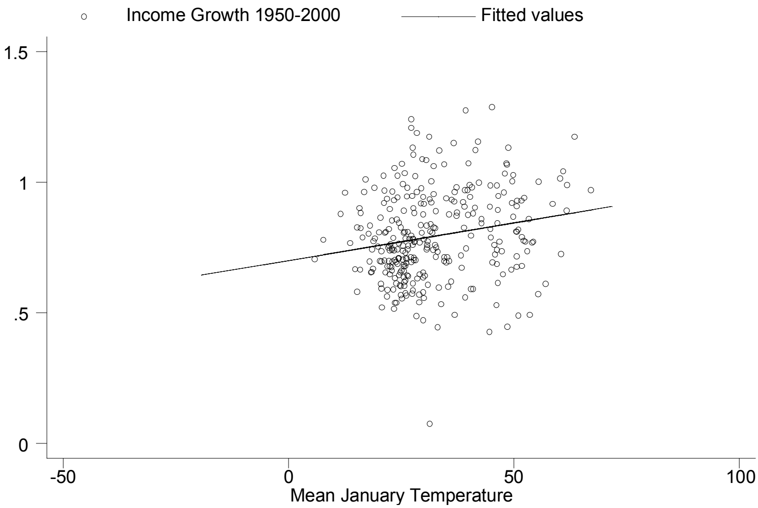
Back

Population Growth and January Temperature



Back

Income Growth and January Temperature



Back

Unemployment

1. Unemployment is hardly persistent ▸ Figure
2. Unemployment predicts lower population and income growth ▸ Table
3. Education predicts lower unemployment in the Great Recession ▸ Figure

- Education predicts lower unemployment at the individual level
- Compositional effect at the city level

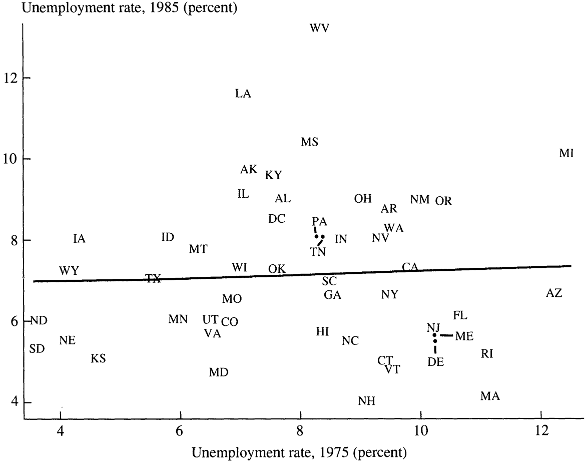
$$\text{Predicted Unemployment} = \sum_{\text{Groups}} \text{Share}^{\text{MSA}}_{\text{Group}} \cdot U^{\text{USA}}_{\text{Group}}$$

  - $\text{Share}^{\text{MSA}}_{\text{Group}}$ = share of city's adult labor force in each group in 2000
  - $U^{\text{USA}}_{\text{Group}}$ = national unemployment rate for each group
    - = 5.1% for college graduates
    - = 10.25% for high school graduates
    - = 17.6% for high school dropouts

- Actual city-level effect > predicted compositional effect
  - The regression line has a slope of 1.78 ▸ Figure

▸ Back ▸ Forward

Persistence of Unemployment Rates



Source: Authors' calculations using data from the Current Population Survey (CPS) and from the Bureau of Labor Statistics unemployment rates for Labor Market Areas.

Back

City growth and unemployment, dependent variable: growth in log of variable (1960–1990)

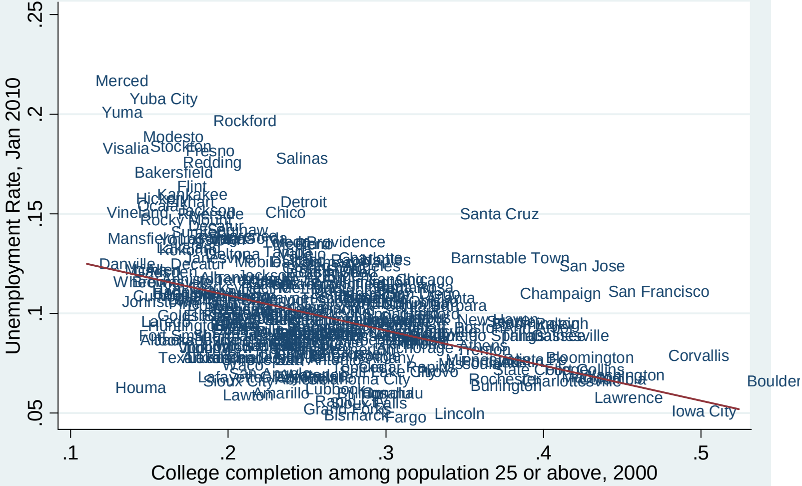
Variable	(1) City population	(2) City unemployed	(3) City employed	(4) SMSA[a] population	(5) City income
Intercept	1.777	4.544	3.787	0.963	15.944
Log (population 1960)	– 0.050	– 0.172	– 0.166	0.030	– 0.015
	(0.024)	(– 0.048)	(0.045)	(0.025)	(0.009)
Per capita income 1960 ($1000)	– 0.116	– 0.354	– 0.278	– 0.050	– 0.084
	(0.074)	(0.149)	(0.141)	(0.111)	(0.0297)
Unemployment rate 1960	– 0.057	– 0.164	– 0.086	– 0.047	– 0.022
	(0.016)	(0.031)	(0.030)	(0.017)	(0.006)
Manufacturing share 1960	– 0.631	– 0.623	– 1.381	– 0.888	– 0.225
	(0.250)	(0.490)	(0.463)	(0.227)	(0.095)
Geographical dummies					
South	– 0.370	– 0.121	– 0.243	– 0.172	0.116
	(0.085)	(0.168)	(0.159)	(0.079)	(0.033)
Central	– 0.521	– 0.067	– 0.269	– 0.356	0.006
	(0.084)	(0.165)	(0.156)	(0.079)	(0.032)
Northeast	– 0.570	– 0.462	– 0.321	– 0.266	– 0.018
	(0.086)	(0.169)	(0.160)	(0.160)	(0.032)
N	203	201	201	133	201
Adj. R^2	0.364	0.268	0.203	0.387	0.426

Numbers in parentheses are standard errors.

[a]SMSA regression excludes Las Vegas SMSA.

Back

Figure 7
Unemployment in January 2010 and Education in 2000



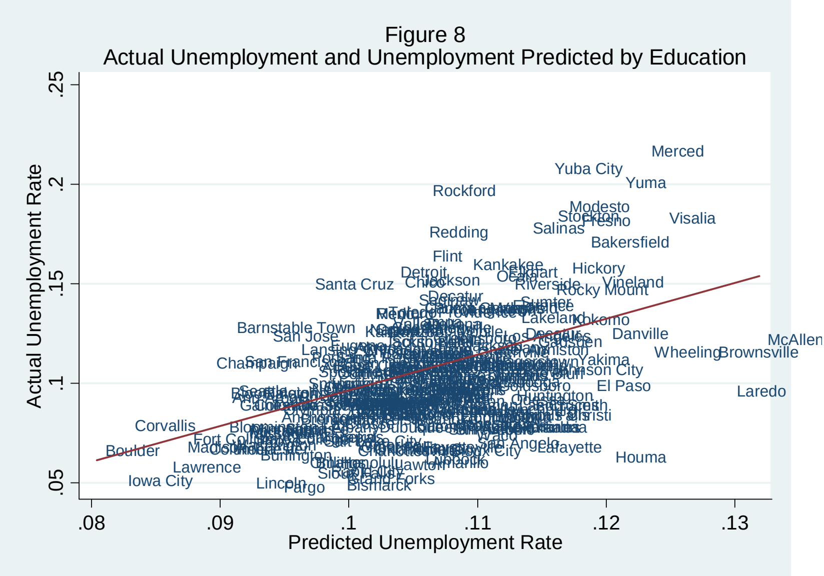
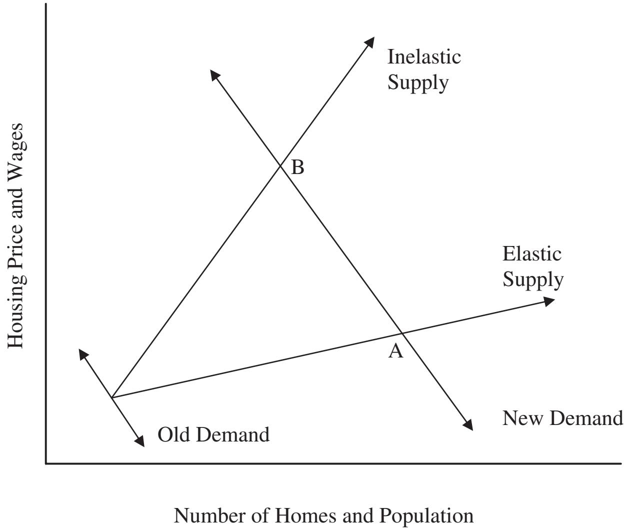


Figure 8
Actual Unemployment and Unemployment Predicted by Education
Actual Unemployment Rate
Predicted Unemployment Rate
.05
.1
.15
.2
.25
.08
.09
.1
.11
.12
.13
Merced
Yuba City
Yuma
Rockford
Modesto
Visalia
Salinas
Redding
Bakersfield
Flint
Hickory
Santa Cruz
Vineland
Rocky Mount
Kokomo
Barnstable Town
San Jose
Danville
McAllen
Wheeling
Brownsville
Yakima
El Paso
Laredo
Corvallis
Boulder
Lafayette
Houma
Lawrence
Iowa City
Fargo
Bismarck

Back

Housing Supply and the Impact of Productivity Shocks

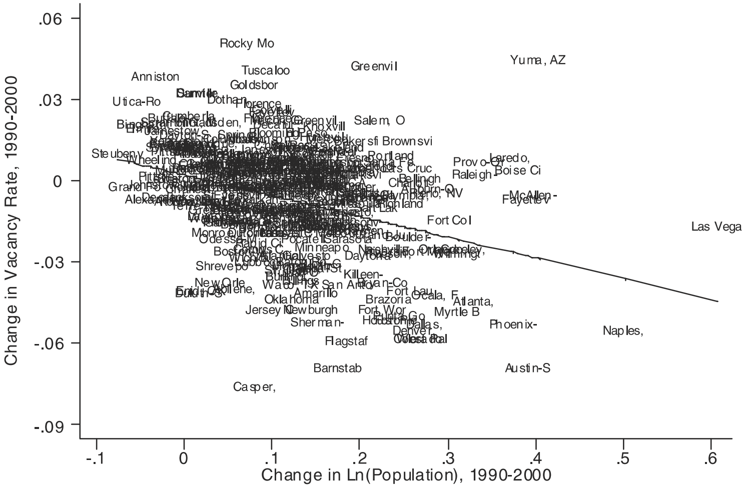


Housing and Urban Dynamics

- Population and the stock of housing units co-move almost perfectly
  1. Variation in vacancy rates is modest
     - ★ 10th percentile: 4.9% – 90th percentile: 14.8%
     - ★ Small effect of population growth on vacancies ▸ Figure
  2. Variation in household size is modest
     - ★ Overall decline: 1970 average: 3.15 – 1980 average: 2.75
     - ★ The R^2 of household size on population is 0.06 ▸ Figure
- Housing is extremely durable
  - Permament loss of housing units below 1% per year
  - The downward elasticity of housing supply is very low
  - Cities grow faster than they decline ▸ Table
- The upward elasticity of housing supply is variable
  - Differences in zoning and regulation (Glaeser, Gyourko, and Saks 2005)
  - Differences in topography (Saiz 2010)

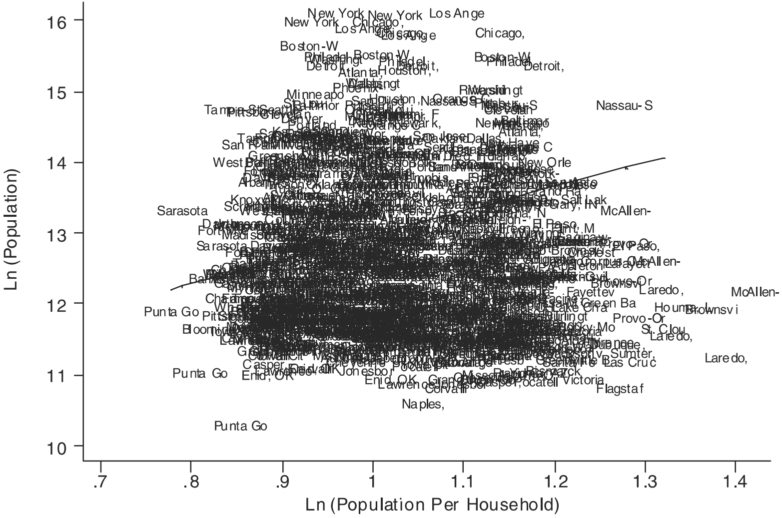
▸ Results

Changes in Population and Vacancy Rates



Back

Population and Household Size



Back

Housing Unit Growth in Cities with 100,000+ Residents

Bottom five		Top five	
1970–1980			
St. Louis	−16.5%	Colorado Springs	64.1%
Detroit	−11.5%	Austin	53.7%
Cleveland	−9.8%	Albuquerque	52.2%
Buffalo	−6.0%	Stockton	48.4%
Pittsburgh	−5.8%	San Jose	46.4%
1980–1990			
Newark	−16.9%	Las Vegas	49.1%
Gary	−14.5%	Raleigh	47.1%
Detroit	−14.0%	Virginia Beach	46.9%
Youngstown	−10.0%	Austin	39.3%
Dayton	−7.7%	Fresno	37.7%
1990–2000			
Gary	−10.5%	Las Vegas	53.5%
Hartford	−10.3%	Charlotte	28.8%
St. Louis	−10.2%	Raleigh	25.0%
Youngstown	−9.6%	Austin	22.3%
Detroit	−9.3%	Winston-Salem	21.3%

Data source: Decennial censuses for 1970, 1980, 1990, 2000. Housing units defined to include owner-occupied and rental units.

Back

Housing Supply and the Impact of Productivity Shocks

Table 4. Effects of productivity shocks on changes in income/capita, housing prices and population, 1980–2000

	ΔLn(Population)	Δ Income/capita	Δ Housing prices
Labor demand			
Labor demand	1.28** (.40)	9240* (5148)	–19294 (74217)
Labor demand × high regulation	–0.63* (0.37)	–244 (6903)	190597* (97074)
Share of population with Bachelors Degree[a]			
Pop. share	0.091** (0.035)	2223** (425)	17286 (11271)
Pop. Share × high regulation	–0.063 (0.043)	3161** (1434)	23764** (8167)
Both productivity shocks			
Both shocks (normalized)	0.0040** (0.0012)	45** (12)	195 (197)
Productivity × high regulation	–0.0023* (0.0013)	66 (48)	851** (293)

Notes: [a]Share of population with a BA degree in initial year (1980 for 1980–1990 changes and 1990 for 1990–2000 changes). Each cell shows results from a separate regression with 118 observations. All regressions include a dummy variable for high regulation and a dummy variable for the 1990–2000 period. Standard errors are in parentheses and are clustered by state. *Significant at the 10% level; significant at the 5% level.

Regional Productivity Fluctuations

- All variables are log deviations from national averages
  - Relative wage w_{it}
  - Relative employment n_{it}
- Labor demand $w_{it} = -dn_{it} + z_{it}$
  - $d > 0$ reflects decreasing demand for a state's product bundle
- Labor demand shocks $z_{i,t+1} - z_{it} = x_i^d - aw_{it} + \varepsilon_{i,t+1}^d$
  - State-specific trend x_i^d captures productive amenities
  - $a = 0$ if each state keeps the same product bundle over time
  - $a > 0$ if a state with low wages attracts new industries
  - $\varepsilon_{i,t+1}^d$ is white noise
- Labor supply $n_{i,t+1} - n_{it} = x_i^s + bw_{it} + \varepsilon_{i,t+1}^s$
  - State-specific trend x_i^s captures consumption amenities
  - $b > 0$ because a state with higher wages attracts migration
  - $\varepsilon_{i,t+1}^s$ is white noise

Full Employment Equilibrium

Relative wage dynamics

$$w_{i,t+1} = (1 - a - bd)\, w_{it} + x_i^d - dx_i^s + \varepsilon_{i,t+1}^d - d\varepsilon_{i,t+1}^s$$

- Stationary levels

$$\mathbb{E} w_i = \left(x_i^d - dx_i^s \right) / \left(a + bd \right)$$

- Mean reversion in wages

Relative employment growth

$$\Delta n_{i,t+1} = (1 - a - bd)\, \Delta n_{it} + ax_i^s + bx_i^d + b\varepsilon_{it}^d - (1 - a)\, \varepsilon_{it}^s + \varepsilon_{i,t+1}^s$$

- Stationary growth rates

$$\mathbb{E} \Delta n_i = \left(ax_i^s + bx_i^d \right) / \left(a + bd \right)$$

- Unit root of employment

Impulse Responses

- A negative labor demand shock $\varepsilon^d_{i,0} = -1$
- Deviation of wages from its base path $\left(\varepsilon^d_{it} = \varepsilon^s_{it} = 0 \forall t\right)$

$$\hat{w}_{it} = -\left(1 - a - bd\right)^t \to 0$$

1. Decrease on impact
2. Gradual recovery to the initial equilibrium
   - ★ Job creation (a) and worker out-migration (b)

- Deviation of employment from its base path $\left(\varepsilon^d_{it} = \varepsilon^s_{it} = 0 \forall t\right)$

$$\Delta \hat{n}_{i,t} = -b\left(1 - a - bd\right)^{t-1}$$

$$\hat{n}_{i,t} = \sum_{\tau=1}^{t} \Delta \hat{n}_{i,\tau} = -\frac{b}{a+bd}\left[1 - \left(1 - a - bd\right)^t\right] \to -\frac{b}{a+bd}$$

1. No change on impact
2. Long-run decline depending on short-run elasticities
   - ★ Firms moving in faster (a) or workers moving out faster (b)

Unemployment

- Labor force n^*_{it}, unemployment rate u_{it}

$\Rightarrow$ Employment $n_{it} \approx n^*_{it} - u_{it}$

$\Rightarrow$ Labor demand $w_{it} = -d\left(n^*_{it} - u_{it}\right) + z_{it}$
Labor demand shocks $z_{i,t+1} - z_{it} = x^d_i - aw_{it} + \varepsilon^d_{i,t+1}$

- Wage curve $cw_{it} = -u_{it}$
- Labor force $n^*_{i,t+1} - n^*_{it} = x^s_i + bw_{it} - gu_{it} + \varepsilon^s_{i,t+1}$
    - $g > 0$ because a state with lower unemployment attracts migration

1. u_{it} and w_{it} move in opposite directions: $\partial \mathbb{E} u_i / \partial x^s_i > 0 > \partial \mathbb{E} u_i / \partial x^d_i$
2. Falls in w_{it} attract firms, increases in u_{it} only repel workers
    - By assumption: $\partial \Delta z_{i,t+1} / \partial u_{it} = 0$
    - If u_{it} reacts more than w_{it} in the short-run, n_{it} reacts more in the long-run

Identification

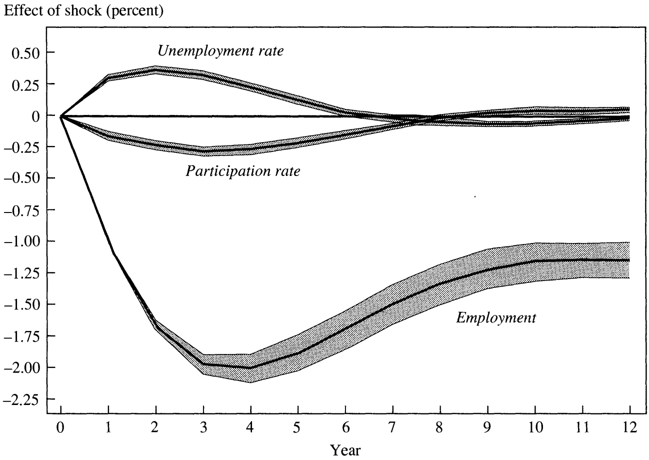
How can we separate ε_{it}^{d} from ε_{it}^{s}?

1. Simply assume all high-frequency fluctuations are ε_{it}^{d}
   - Intuitively plausible
   - In practice, wages and employment co-move
2. Construct observable labor demand shocks
   - The Bartik (1991) instrument: $\sum_j \frac{n_{j,i,t}}{n_{i,t}} \frac{N_{j,t+1}}{N_{j,t}}$
     - $n_{j,i,t}$ is employment in industry j in region i at time t
     - $n_{i,t} = \sum_j n_{j,i,t}$ is total employment in region i at time t
     - $N_{j,t} = \sum_i n_{j,i,t}$ is national employment in sector j at time t
   - Growth predicted by industry mix and national industry growth
     - Valid if national growth rates are uncorrelated with regional shocks
     - Broad industries and fine regions to avoid geographic concentration
   - You can also predict $N_{j,t+1}/N_{j,t}$ with exchange rate fluctuations

Regional Evolutions

1. Short-run employment fluctuations are mostly nation-wide
   - Most procyclical in manufacturing states
   - More idiosyncratic in farm states and oil states
2. The importance of aggregate fluctuations declines with the horizon
3. Negative employment shocks increase u_{it} on impact
4. States recover from employment shocks by out-migration Figure
5. Nominal wages decline, then recover in about ten years Figure
   - Insufficient decline to cushion the employment shock Figure
6. Real wages decline modestly, as housing prices fall sharply Figure
   - Migration is driven by unemployment

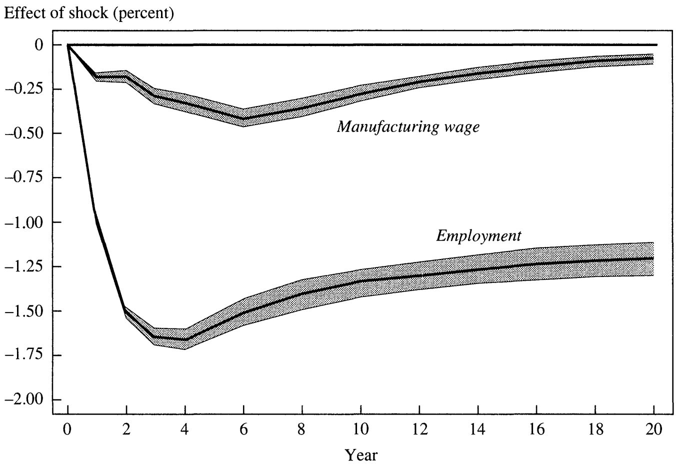
Unemployment Response to an Employment Shock



Source: Authors' calculations based on the system of equations described in the text, using data described in the appendix. All 51 states are used in the estimation. The shock is a −1 percent shock to employment. Bands of one standard error are shown around each line.

Back

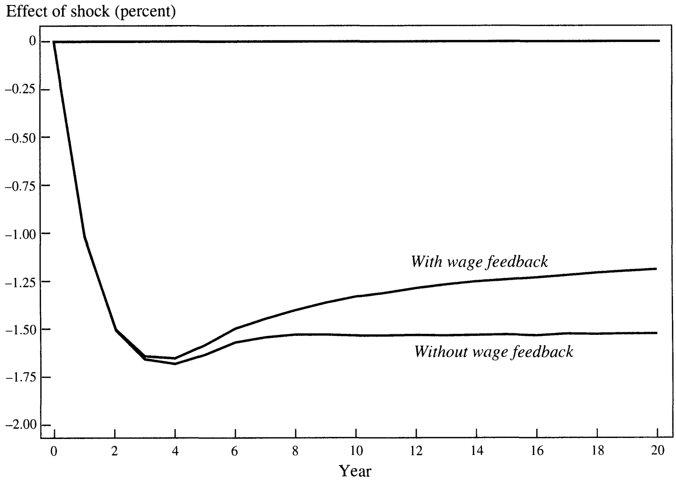
Wage Response to an Employment Shock



Source: Authors' calculations using data described in the appendix. The shock is a -1 percent shock to employment. Bands of one standard error are shown around each line.

Back

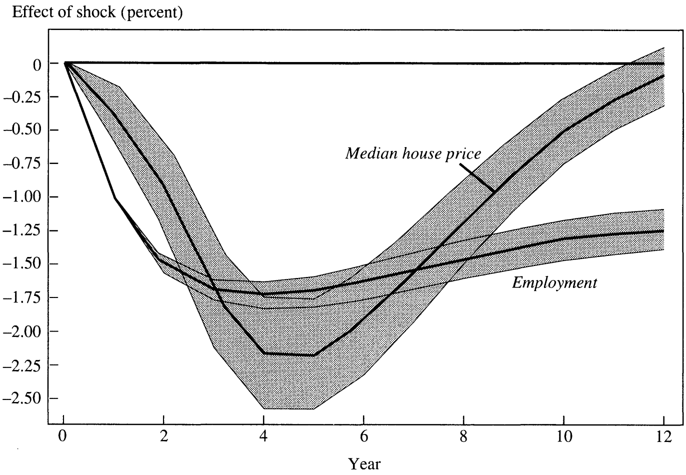
Wage Adjustment Dampening the Employment Response



Source: Authors' calculations using data described in the appendix. The shock is a –1 percent shock to employment. Bands of one standard error are shown around each line.

Back

House Price Response to an Employment Shock



Source: Authors' calculations using data described in the appendix. The shock is a −1 percent shock to employment. Bands of one standard error are shown around each line.

Back