Cities, Ideas, and Human Capital

Urban Economics: Week 6

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The Obligatory Marshall Quotation

> *When an industry has thus chosen a locality for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighbourhood to one another.* **The mysteries of the trade become no mysteries; but are as it were in the air**, *and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas.*

Alfred Marshall. 1890. Principles of Economics. London: Macmillan. Book IV, Ch. X, § 3: The advantages of localized industries; hereditary skill.

Boston: Commerce to Manufacturing

- Founded in 1630 as Winthrop's "City upon a Hill"
  - A religious community, not a production-oriented colony
  - Human capital: Boston Latin (1635), Harvard College (1636)
- Exports foodstuff and wood to other colonies
  - New England had cheaper land than the South and the Caribbean
- Overtaken by New York and Philadelphia after 1740
- Maritime reinvention, 1820-1850
  - New York provides the port
  - Boston provides the ships, sailors, merchants
  - Sail-specific human capital declines after 1840
- Manufacturing reinvention, 1860-1920
  - China-trade capital and immigrant Irish workers
  - Switch from water to steam power
  - New England's railroad hub

Boston: Manufacturing to Services

- Decades of population decline
  1. Relative to the U.S., 1920-1950
  2. Absolute, 1950-1980
- Nation-wide trends working against Boston
  - Manufacturing left cities
  - Car cities replaced higher-density old cities
  - People fled cold places
  - The rich fled local redistribution
- Nadir in the 1970s
  - 75% of homes were worth less than construction costs
- Skill-driven reinvention
  - Higher education
  - Professional, scientific, and technical services
  - Finance

Three Kinds of Externalities

1. Marshall-Arrow-Romer
   Local knowledge spillovers between firms in the same industry
   $\Rightarrow$ Specialization and concentration promote growth
   - Local monopoly helps growth by internalizing externalities
2. Porter
   Innovation in competitive industry clusters with many small firms
   $\Rightarrow$ Specialization and fragmentation promote city growth
   - Local competition requires firms to innovate or die
3. Jacobs
   Local knowledge transfers across industries
   $\Rightarrow$ Diversification and fragmentation promote city growth
   - Weitzman's (1998) "recombinant growth"

Extremes of City-Industry Growth

City-Industry	Growth	Nondiversity	Competition	Concentration
	Five Fastest-Growing City-Industries*			
Albuquerque Business services	3.325	.217	1.500	1.090
San Jose, Calif. Electric machinery	2.765	.290	.835	2.582
San Jose, Calif. Durable wholesale trade	2.407	.310	1.008	.883
San Jose, Calif. Transportation equipment	2.403	.311	.930	.876
Atlantic City, N.J. Hotels	2.345	.373	.418	11.221
	Five Slowest-Growing City-Industries			
Scranton, Pa. Anthracite coal mining	−5.417	.387	.931	113.139
Manchester, N.H. Leather products	−5.161	.331	.272	19.559
Wilkes-Barre–Hazleton, Pa. Tobacco products	−5.078	.466	.279	21.193
Hamilton-Middletown, Ohio Primary metal industries	−4.813	.513	.326	4.271
Gadsden, Ala. Textile mills	−4.714	.406	.185	4.876

* Growth is log(employment in 1987/employment in 1956). Nondiversity is city's other top five industries' share of 1956 total city employment. Competition is establishments per employee relative to establishments per employee in the U.S. industry. Concentration is the city-industry's share of city employment relative to U.S. industry's share of U.S. employment in 1956.

City-Industry Employment Growth, 1956-1987

Dependent Variable	Log(Employment in 1987/Employment in 1956) in the City-Industry			
	(1)	(2)	(3)	(4)
Constant	−.423 (.129)	−.923 (.129)	−.181 (.159)	−.513 (.149)
Log(U.S. employment in 1987/ U.S. employment in 1956) in the industry outside the city	1.140 (.059)	1.209 (.052)	1.237 (.055)	1.148 (.056)
Wage in the city-industry in 1956	.0137 (.109)	.0226 (.104)	.0379 (.109)	.027 (.104)
Employment in the city-industry in 1956 (in millions)	−2.898 (1.099)	−3.280 (1.055)	−3.91 (1.131)	−4.080 (1.073)
Dummy variable indicating presence in the South	.426 (.057)	.416 (.054)	.370 (.058)	.378 (.055)
City-industry's share of city employment relative to industry's share of U.S. employment in 1956	−.0128 (.003)	...	...	−.00799 (.003)
Establishments per employee in the city-industry relative to establishments per employee in the U.S. industry in 1956	...	.587 (.057)	...	.561 (.057)
City's other top five industries' share of total city employment in 1956	...	...	−.894 (.259)	−.913 (.245)
Adjusted R^2	.392	.439	.387	.450
Number of observations	1,016	1,016	1,016	1,016

Note.—Standard errors of parameter estimates are in parentheses beneath these estimates.

City-Industry Wage Growth, 1956-1987

Variable	Log(Wage in 1987/Wage in 1956) in the City-Industry (1)	(2)	(3)	(4)
Constant	.332	.379	.398	.440
	(.065)	(.064)	(.069)	(.068)
Log(U.S. wage in 1987/U.S. wage in 1956) in the industry outside the city	.961	.975	.959	.973
	(.043)	(.042)	(.043)	(.042)
Wage in the city-industry in 1956	−.270	−.270	−.266	−.267
	(.027)	(.027)	(.027)	(.027)
Employment in the city-industry in 1956 (in millions)	1.025	1.111	.849	.938
	(.270)	(.266)	(.276)	(.271)
Dummy variable indicating presence in the South	.0175	.0161	.0094	.0085
	(.013)	(.013)	(.013)	(.013)
City-industry's share of city employment relative to industry's share of U.S. employment in 1956	.00053	...	...	−.00023
	(.0007)			(.0007)
Establishments per employee in the city-industry relative to establishments per employee in the U.S. industry in 1956	...	−.0850	...	−.0845
		(.014)		(.014)
City's other top five industries' share of 1956 city employment	...	...	−.172	−.161
			(.060)	(.059)
Adjusted R^2	.3832	.4099	.3889	.4139
Number of observations	833	833	833	833

Note.—Standard errors of parameter estimates are in parentheses beneath these estimates.

Separation of Innovation and Mass Production

Duranton and Puga's (2001) assumptions

1. Localization economies
    - Input suppliers are shared by local producers using the same process
    - Static advantages to urban specialization
2. Experimentation in process innovation
    - Start-ups need to try out alternative processes available locally
    - Dynamic advantages to urban diversity
3. Congestion
    - Monocentric cities with scarce land and commuting costs
    - Endogenous limit to city size

Steady state with two types of cities

1. Diversified cities where innovation takes place
2. Specialized cities where mass production takes place

Non-Tradable Intermediates

- m intermediate sectors employ sector-specific human capital
- Standard model of input-sharing at the sector level
  - The output of the sector is a CES aggregate of differentiated varieties
  - Intermediates cannot be traded across cities
  - Monopolistic competition, increasing returns to scale, free entry
- Sector j in city i employs l_i^j workers with sector-specific human capital
  - Employment l_i^j at wages w_i^j
  - Workers can move across cities but not across sectors
- Price index for intermediate sector j in city i

$$Q_i^j = w_i^j \left(l_i^j \right)^{-\varepsilon}$$

  - You can always normalize units so that constants disappear

Tradable Final Goods

- Final goods are tradable at no cost
- Two types: prototypes and mass-produced goods
  - Cobb-Douglas utility with budget share $\mu \in (0,1)$ for prototypes
  - CES aggregation of varieties within each type
  - Monopolistic competition
- m technologies: using intermediates from a single sector j
  - The variety produced is independent of the technology used
- Cost function for firm h producing $\tilde{x}_i^j(h)$ prototypes with technology j

$$\tilde{C}_i^j(h) = Q_i^j \tilde{x}_i^j(h) = w_i^j \left(l_i^j\right)^{-\varepsilon} \tilde{x}_i^j(h)$$

- Cost advantages of mass production

$$C_i^j(h) = \rho Q_i^j x_i^j(h) = \rho w_i^j \left(l_i^j\right)^{-\varepsilon} x_i^j(h) \text{ with } \rho \in (0,1)$$

The Product Life Cycle

1. Creating a final-good firms requires a start-up cost
   - F units of the composite final good
   - Financed by perfectly competitive, frictionless capital markets
2. A new firm produces prototypes
   - It can try out all m technologies, one at a time
   - By trial and error it can identify its idiosyncratic ideal technology
   - It could also stop searching without learning its ideal technology
3. A firm that has learnt its ideal technology can start mass production

- Relocating causes a firm to lose one period's output
- Firms die at a homogeneous exogenous rate δ
- No storage technology, zero rate of time preference

Congestion and Labor Supply

- There is a continuum L of infinitely lived workers
- Fraction $1/m$ of workers have skill j for all $j = 1, ..., m$
- L_i^j workers with skill j live in city i
- Congestion costs in each city reduce labor supply to

$$l_i^j = L_i^j \left(1 - \tau \sum_{j=1}^{m} L_i^j\right)$$

- Linear monocentric city with linear commuting costs
  - Direct assumption with partial microfoundation
  - If a city hosted many sectors with different wages ...

City-Industry Equilibrium

- Firms in a given city-industry are all identical
  - Prices $\tilde{p}_i^j = Q_i^j \sigma / (\sigma - 1)$ and $p_i^j = \rho Q_i^j \sigma / (\sigma - 1)$
  - Output $\tilde{x}_i^j$ and x_i^j
  - Derived demand for labor $\left(l_i^j\right)^{-\varepsilon} \tilde{x}_i^j$ and $\rho \left(l_i^j\right)^{-\varepsilon} x_i^j$
- Labor-market clearing

$$\tilde{n}_i^j \tilde{x}_i^j + \rho n_i^j x_i^j = \left(l_i^j\right)^{1+\varepsilon}$$

- Since $p_i^j = \rho \tilde{p}_i^j$, output per worker in city i with technology j is

$$\frac{\tilde{n}_i^j \tilde{x}_i^j + \rho n_i^j x_i^j}{L_i^j} = \left(L_i^j\right)^{\varepsilon} \left(1 - \tau \sum_{j=1}^{m} L_i^j\right)^{1+\varepsilon}$$

Optimal City Size

- Regardless of specialization, cities have optimal size

$$L^* = \arg\max_{L_i} \left\{ L_i^{\varepsilon} \left(1 - \tau L_i\right)^{1+\varepsilon} \right\} = \frac{\varepsilon}{\left(1 + 2\varepsilon\right)\tau}$$

  - Increasing in localization economies: $\partial L^* / \partial \varepsilon > 0$
  - Decreasing with congestion costs: $\partial L^* / \partial \tau < 0$
- There are no coordination failures with respect to city creation
  - E.g., perfectly competitive profit-maximizing developers
- The Henry George Theorem applies
  - All cities have the optimal size L^*
  - Each worker earns $w_i^j \left(1 - \tau L^*\right)$ net of house prices and transfers

Two Types of Cities

1. Specialized cities
   - All workers have the same skill j
   - All firms use the same technology j
2. Perfectly diversified cities
   - Fraction $1/m$ of workers have skill j for all $j = 1, ..., m$
   - Fraction $1/m$ of firms use technology j for all $j = 1, ..., m$

- Other equilibrium configurations are assumed away
  - Workers know only if a city is perfectly diversified
  - Otherwise, they believe it is fully specialized in its dominant industry
  - Self-fulfilling beliefs

Nursery Configuration

- N_D diversified and mN_S specialized cities coexist
- N_S specialized cities host each skill $j = 1, \ldots, m$
- Each new firm locates in a specialized city and produces prototypes using a different technology each period
- As soon as it learns its ideal technology, it relocates to a city specialized in that technology and starts mass production

Existence of a steady-state nursery configuration depends on

1. The relative production costs in the two types of cities
2. The relative number of prototype to mass producers
3. The expected duration of each stage of the life cycle

Relative Costs

- Unit production costs for final goods in specialized cities

$$Q_S = \left[L^* \left(1 - \tau L^*\right)\right]^{-\varepsilon} w_S$$

- Unit production costs for final goods in diversified cities

$$Q_D = \left[\frac{L^*}{m} \left(1 - \tau L^*\right)\right]^{-\varepsilon} w_D$$

- Spatial equilibrium

$$w_S = w_D \Rightarrow \frac{Q_D}{Q_S} = m^{\varepsilon}$$

- Relative profitability of specialized cities

$$\frac{\tilde{\pi}_S}{\tilde{\pi}_D} = \frac{\pi_S}{\pi_D} = \left(\frac{Q_D}{Q_S}\right)^{\sigma - 1} = m^{\varepsilon(\sigma-1)}$$

Relative Profits

- Relative profitability of mass production

$$\frac{\pi_S}{\tilde{\pi}_D} = \frac{1-\mu}{\mu}\left(\frac{P}{\rho Q_S}\frac{Q_D}{\tilde{P}}\right)^{\sigma-1} = \frac{1-\mu}{\mu}\frac{N_D \tilde{n}_D}{N_S n_S}$$

  - $\tilde{n}_D$ prototype producers using each technology in each nursery city
  - n_S mass producers in each specialized city

- The equilibrium aggregate ratio of prototype to mass producers

$$\Omega \equiv \frac{N_D \tilde{n}_D}{N_S n_S}$$

  reflects how unlikely a firm is to find the ideal technology

  - Less likely if there is more uncertainty: $\partial\Omega/\partial m > 0$
  - Less likely if there is more exogenous failure: $\partial\Omega/\partial\delta > 0$

Leaving the Nursery

- Firms are born at a constant rate $\dot{n}$
- A firm in the nursery find its ideal technology at age t with probability

$$\frac{(1-\delta)^t}{m} \text{ for } 1 \leq t \leq m-2 \text{ or } \frac{2(1-\delta)^{m-1}}{m} \text{ for } t = m-1$$

- A fraction δ of relocating firms die in transit
- Constant number of firms n_S in each specialized city

$$\delta m N_S n_S = (1-\delta)\left[\sum_{t=1}^{m-2}(1-\delta)^t + 2(1-\delta)^{m-1}\right]\frac{\dot{n}}{m}$$

- Constant aggregate number of firms

$$\delta\left(N_D m \tilde{n}_D + \frac{\delta m N_S n_S}{1-\delta} + m N_S n_S\right) = \dot{n}$$

$\Rightarrow$ These two conditions yield an explicit solution for Ω

Expected Production Periods

- Nursery strategy
  1. Expected number of periods in the nursery $\tilde{\Delta}$
  2. Expected number of periods in mass production Δ
- Deviation: produce each prototype in a different specialized city
  1. Expected number of periods producing prototypes $\tilde{\Delta}_{OSC}$
  2. Expected number of periods in mass production Δ_{OSC}
- All these durations have explicit but very tedious solutions

Existence of the Nursery Steady State I

1. Firms relocate to a specialized city after finding their ideal technology

$$(1-\delta)\,\frac{\pi_S}{\delta} \geq \frac{\pi_D}{\delta}$$

2. Firms switch to mass production after finding their ideal technology

$$\frac{\tilde{\pi}_S}{\pi_S} = \frac{\tilde{\pi}_D}{\pi_D} \leq 1$$

3. Firms do not abandon diversified cities after $m-2$ trials

$$(1-\delta)\left[\tilde{\pi}_S + \frac{1-\delta+(1-\delta)^2}{2}\,\frac{\pi_S}{\delta}\right] \leq \tilde{\pi}_D + (1-\delta)^2\,\frac{\pi_S}{\delta}$$

Existence of the Nursery Steady State II

4. Firms do not settle on a random specialized city

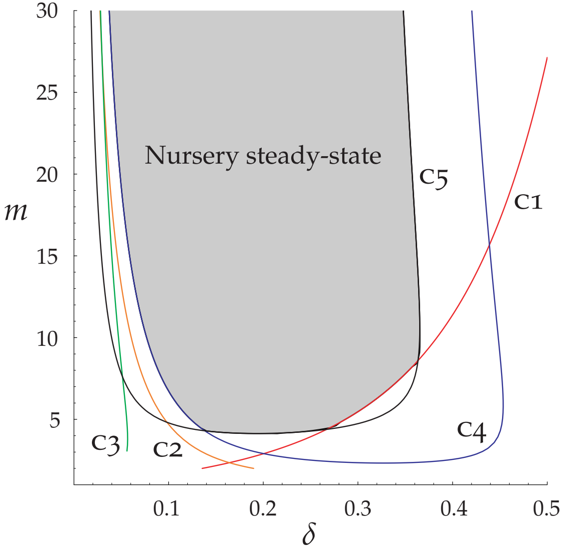
$$\frac{\tilde{\pi}_S}{\delta} + \frac{1-\delta}{m}\frac{\pi_S - \tilde{\pi}_S}{\delta} \leq \tilde{\Delta}\tilde{\pi}_D + \Delta\pi_S$$

5. Firms do not relocate across specialized cities to produce prototypes

$$\tilde{\Delta}_{OSC}\tilde{\pi}_S + \Delta_{OSC}\pi_S \leq \tilde{\Delta}\tilde{\pi}_D + \Delta\pi_S$$

- Other possible deviations do not create binding conditions

Existence in the Parameter Space



Stability and Uniqueness

Stability: The nursery steady state is stable with respect to small perturbations in the spatial distribution of workers

- Competitive developers create both types of city with optimal size L^*

Uniqueness: Whenever the nursery steady state exists it is unique

1. All mass producers are in specialized cities (1)
2. The nursery strategy maximizes the duration of mass production (4)
3. If some firms deviate, Ω increases to Ω'
4. $\Omega' > \Omega$ slackens the conditions for optimality of the nursery strategy

$\Rightarrow$ If the nursery strategy is a best response when all firms follow it, a fortiori it is a best response when some firms are deviating

Establishment Relocations in France, 1993-1996

	Percentage of relocations from diversified to specialised areas[a]	Relocations as a percentage of the stock[b]	Geographic concentration[c]
R&D	93.0	8.1	0.023
Pharmaceuticals and cosmetics	88.3	6.4	0.020
IT and consultancy services	82.1	7.3	0.030
Business services	75.8	5.0	0.015
Printing and publishing	73.3	5.4	0.026
Aerospace, rail and naval equipment	71.6	3.3	0.026
Electrical and electronic equipment	69.1	4.2	0.011
Motor vehicles	62.5	2.7	0.020
Electrical and electronic components	60.9	5.9	0.007
Textiles	46.4	2.5	0.024
Chemical, rubber and plastic products	38.3	3.9	0.009
Metal products and machinery	37.6	3.2	0.005
Clothing and leather	36.3	3.4	0.013
Food and beverages	34.6	0.8	0.007
Furniture and fixtures	32.6	2.7	0.008
Wood, lumber, pulp and paper	30.6	1.7	0.009
Primary metals	30.0	2.5	0.009
Non-metallic mineral products	27.3	2.0	0.012
Aggregate	72.0	4.7	

Spatial Concentration of Innovative Activity

SIC[a]	Industry[b]	State	Number of innovations	State share of industry innovations	Industry share of state innovations
3573	Computers (n = 821)	California	342	41.7	35.1
		Massachusetts	78	9.5	21.7
		New York	58	7.1	12.7
		Texas	39	4.8	23.1
		New Jersey	38	4.6	8.9
		Illinois	28	3.4	12.1
3823	Process control instruments (n = 464)	California	80	17.2	8.2
		Massachusetts	61	13.1	16.9
		New York	45	9.7	9.9
		Pennsylvania	40	8.6	16.5
		Illinois	32	6.9	13.9
3662	Radio and TV communications equipment (n = 339)	California	105	31.0	10.8
		New York	40	11.8	8.8
		Massachusetts	32	9.4	8.9
3674	Semiconductors (n = 172)	California	84	48.8	8.6
		Massachusetts	17	9.9	4.7
		Texas	13	7.6	7.7
3842	Surgical appliances (n = 152)	New Jersey	43	28.3	10.1
		California	17	11.2	1.7
		Pennsylvania	10	7.9	4.1
2834	Pharmaceuticals (n = 127)	New Jersey	50	39.4	11.7
		New York	18	14.2	3.9
		Pennsylvania	10	7.9	4.1
		Michigan	8	6.3	7.1
3825	Measuring instruments for electricity (n = 115)	California	37	32.2	3.8
		Massachusetts	22	19.1	16.9
		New York	13	11.3	2.9

[a] The SIC is the standard industrial classification used in the U.S. Small Business Administration's Innovation Citation Data Base.
[b] The total number of innovations recorded in the four-digit industry is listed in parentheses.

The Geography of Innovation and Production

- Innovative activity tends to cluster spatially
  1. Geographic concentration of innovation varies by industry
  2. Does not coincide with geographic concentration of production
- Traditional arguments for concentration of production
  - Dependency on natural resources
  - Low transportation costs
  - Large economies of scales
- Clustering of innovation when new knowledge is particularly important
  - Industry expenditure on R&D relative to sales
  - Share of skilled workers in industry employment
  - University research relevant to the industry

$\Rightarrow$ Indirect evidence of knowledge spillovers

OLS Regression Across States

	Gini of production			Gini of innovation		
	(1)	(2)	(3)[b]	(4)	(5)	(6)[b]
Gini of innovation	—	0.768	−0.125	—	—	—
		(0.143)	(−1.741)			
Natural resources	0.326	0.330	0.384	—	—	−0.108
	(4.950)	(5.261)	(5.058)			(−1.228)
Scale	−0.137	−0.160	−0.244	—	—	−0.007
	(−4.162)	(−4.173)	(−0.695)			(1.986)
Transportation costs	1.223	1.419	1.741	—	—	0.006
	(4.439)	(4.838)	(5.631)			(1.674)
Industry R&D/sales	0.455	0.436	0.608	0.469	0.565	0.543
	(7.791)	(7.170)	(2.860)	(2.137)	(2.405)	(2.341)
Skilled labor	1.094	1.058	1.318	0.466	0.657	0.645
	(15.044)	(12.483)	(15.031)	(4.910)	(4.581)	(4.686)
University research	—	—	0.034	0.108	0.116	0.118
			(2.147)	(7.920)	(8.093)	(8.139)
Gini of production	—	—	—	—	−0.119	−0.146
					(−1.587)	(−1.741)
Sample size	163	163	163	163	163	163
R^2	0.951	0.952	0.970	0.827	0.908	0.921
Standard error	0.15034	0.15079	0.18601	0.21443	0.21469	0.18487

[a] *t* values are given in parentheses.

[b] Columns (3) and (6) provide the unrestricted regression results. When the regression estimated for the Gini of production in column (2) is compared with the estimate of the unrestricted regression in column (3), the *F* test statistic (2,156) of 0.087 is computed for the overidentifying restrictions. Similarly, when the regression estimated for the Gini of innovation in column (5) is compared to the estimate of the unrestricted regression in column (6), the *F* test statistic (3,156) equals 2.662 for the overidentifying restrictions.

3SLS Regression Across States

	Gini of production	Gini of innovation	Gini of production	Gini of innovation
Gini of innovation	—	—	0.224	—
			(0.416)	
Natural resources	0.331	—	0.347	—
	(5.145)		(5.261)	
Scale	−0.160	—	−0.166	—
	(−4.333)		(−3.589)	
Transportation costs	1.432	—	1.506	—
	(5.052)		(3.974)	
Industry R&D/sales	0.440	0.572	0.460	0.557
	(7.290)	(2.421)	(6.723)	(2.341)
Skilled labor	1.075	0.687	1.193	0.683
	(14.846)	(3.707)	(5.599)	(3.736)
University research	—	0.119	—	0.140
		(7.887)		(3.480)
Gini of production	—	−0.135	—	−0.158
		(−1.247)		(−1.391)
Sample size	163	163	163	163
Standard error	0.15523	0.21733	0.15571	0.21767

[a] *t* values are given in parentheses.

Three-Fold Interest in Human Capital Externalities

1. Labor and education policy
    - Social returns to skill $>$ private returns to skill
    - Education as a public good
    - Rationale for vast government intervention
2. Endogenous growth theory
    - Lucas (1988) allows a country's average human capital to increase TFP
    - Constant returns for the economy, decreasing returns for each firm
    - Implied elasticity of output to aggregate human capital $\simeq 0.4$
3. Urban economics
    - Human capital predicts city growth
    - Human capital predicts housing values
    - Human capital predicts wage residuals

Basic Intuition

- Suppose the true relation between wages and human capital is

$$\log w_{ic} = \alpha + \beta \log h_{ic} + \gamma \log \bar{h}_c + \varepsilon_{ic}$$

1. Omitted-variable bias

$$\frac{\partial \log w_{ic}}{\partial h_{ic}} = \beta + \gamma \frac{Cov\left(h_{ic}, \bar{h}_c\right)}{Var\left(h_{ic}\right)}$$

2. Controlling for city fixed effects

$$\left.\frac{\partial \log w_{ic}}{\partial h_{ic}}\right|_c = \beta$$

3. Across cities

$$\frac{\partial \log \bar{w}_c}{\partial \bar{h}_c} = \beta + \gamma$$

Basic Facts

- Lucas (1988) proposed estimating skill externalities with city data
- Rauch (1993) is the seminal Rosen-Roback test
- One more year of average education yields a 3.1% TFP increase
  - Reduced to 2.8% if we subtract one year of average experience
- The social return to education is roughly 1.7 times the private return

1. Random effects but not clustering
2. A single price regression for owners and tenants
3. Average human capital is treated as an exogenous city characteristic
4. The Rosen-Roback model is derived with homogeneous agents
   - We know the theory does not properly work with heterogeneous agents
   - We have not yet figured out exactly how to do it right

Wages and Human Capital Spillovers

Education (SMSA average)	0.051^a	0.034^a	0.039^a	0.033^a	0.028^c
(12.86)	(0.013)	(0.013)	(0.013)	(0.012)	(0.016)
Experience (SMSA average)	0.0046	0.0071^b	0.0060^c	0.0028	0.0017
(17.36)	(0.0036)	(0.0036)	(0.0036)	(0.0035)	(0.0041)
West		0.105^a	0.102^a	0.090^a	0.091^a
(0.19)		(0.017)	(0.017)	(0.017)	(0.017)
North Central		0.071^a	0.073^a	0.078^a	0.077^a
(0.28)		(0.015)	(0.014)	(0.014)	(0.014)
Northeast		0.035^b	0.035^b	0.032^b	0.031^c
(0.22)		(0.017)	(0.017)	(0.016)	(0.016)
Culture per capita			-0.000056^b	-0.000060^b	-0.000059^b
(310.40)			(0.000025)	(0.000025)	(0.000025)
Climate				0.000070	0.000064
(591.68)				(0.000060)	(0.000061)
Coast				0.055^a	0.050^a
(0.36)				(0.013)	(0.016)
Population					0.000008
(2027.91)					(0.000014)
Dependent variable					
Log (hourly wage)					
(1.70)					

Note. Standard errors are shown in parentheses. Significance levels are given only for the variables below the broken line: [a]Significantly different from zero at the 1% level. [b]Significantly different from zero at the 5% level. [c]Significantly different from zero at the 10% level.

Wages and Worker Characteristics

Intercept		−0.237	−0.106	−0.138	−0.059	0.024
		(0.207)	(0.200)	(0.199)	(0.190)	(0.245)
Education	0.048	0.048	0.048	0.048	0.048	0.048
(12.86)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Experience	0.035	0.035	0.035	0.035	0.035	0.035
(17.36)	(0.001)	(0.001)	(0.001)	(0.0009)	(0.0009)	(0.0009)
Experience squared	−0.00051	−0.00051	−0.00051	−0.00051	−0.00051	−0.00051
(519.41)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Health (limitation = 1)	−0.115	−0.116	−0.116	−0.116	−0.116	−0.116
(0.049)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Marital status (married = 1)	0.185	0.185	0.185	0.185	0.185	0.185
(0.59)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Enrollment (in school = 1)	−0.096	−0.097	−0.097	−0.097	−0.097	−0.097
(0.14)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Unionization rate	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052
(22.64)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Race (non-white = 1)	−0.110	−0.109	−0.107	−0.107	−0.107	−0.107
(0.15)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Sex (female = 1)	−0.080	−0.080	−0.080	−0.080	−0.080	−0.080
(0.45)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Sex × experience	−0.012	−0.012	−0.012	−0.012	−0.012	−0.012
(7.54)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Sex × (experience squared)	0.00021	0.00021	0.00021	0.00021	0.00021	0.00021
(224.09)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00002)
Sex × (marital status)	−0.182	−0.182	−0.182	−0.181	−0.182	−0.182
(0.24)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Sex × race	0.113	0.114	0.114	0.114	0.114	0.114
(0.074)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Sex × (children under 18)	−0.024	−0.025	−0.025	−0.025	−0.025	−0.025
(1.11)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Professional or managerial	0.339	0.339	0.340	0.340	0.340	0.340
(0.22)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Technical or sales	0.174	0.174	0.174	0.175	0.175	0.175
(0.32)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Farming	−0.027	−0.027	−0.030	−0.030	−0.030	−0.029
(0.013)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Craft	0.204	0.203	0.203	0.203	0.204	0.204
(0.12)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Operator or laborer	0.119	0.118	0.118	0.118	0.119	0.119
(0.18)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)

Rents and Human Capital Spillovers

	(1)	(2)	(3)	(4)	(5)
Education (SMSA average) (12.87)	0.199^a	0.128^a	0.131^a	0.112^a	0.128^a
	(0.023)	(0.019)	(0.019)	(0.017)	(0.021)
Experience (SMSA average) (17.48)	0.027^a	0.021^a	0.020^a	0.013^a	0.017^a
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
West (0.19)		0.308^a	0.306^a	0.276^a	0.274^a
		(0.028)	(0.028)	(0.025)	(0.025)
North Central (0.27)		0.139^a	0.140^a	0.157^a	0.159^a
		(0.023)	(0.023)	(0.020)	(0.020)
Northeast (0.24)		0.246^a	0.246^a	0.232^a	0.235^a
		(0.027)	(0.027)	(0.024)	(0.024)
Culture per capita (309.87)			−0.000034	−0.000033	−0.000035
			(0.000038)	(0.000034)	(0.000034)
Climate (595.11)				0.000250^a	0.000277^a
				(0.000087)	(0.000090)
Coast (0.38)				0.144^a	0.161^a
				(0.019)	(0.022)
Population (2242.61)					−0.000034
					(0.000024)
Dependent variable Log (monthly housing expenditure) (5.82)					

Note. Standard errors are shown in parentheses. Significance levels are given only for the variables below the broken line: [a]Significantly different from zero at the 1% level. [b]Significantly different from zero at the 5% level. [c]Significantly different from zero at the 10% level.

Rents and House Characteristics

Intercept		2.059	2.933	2.916	3.105	2.845
		(0.369)	(0.299)	(0.299)	(0.262)	(0.321)
Dwelling rented						
(renter = 1)	−0.105	−0.104	−0.104	−0.104	−0.104	−0.104
(0.41)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
Units at address	−0.0088	−0.0088	−0.0087	−0.0087	−0.0087	−0.0087
(2.71)	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)	(0.0029)
× renter	0.0029	0.0030	0.0028	0.0028	0.0029	0.0029
	(0.0030)	(0.0030)	(0.0030)	(0.0030)	(0.0030)	(0.0030)
Age of structure	−0.0052	−0.0052	−0.0052	−0.0052	−0.0052	−0.0052
(23.39)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
× renter	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Number of floors	0.016	0.016	0.016	0.016	0.016	0.016
(2.52)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
× renter	−0.030	−0.030	−0.030	−0.030	−0.030	−0.030
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Number of rooms	0.097	0.098	0.097	0.098	0.098	0.098
(5.29)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
× renter	−0.011	−0.011	−0.011	−0.011	−0.011	−0.011
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Number of bedrooms	0.021	0.021	0.021	0.021	0.021	0.021
(2.46)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
× renter	−0.017	−0.017	−0.017	−0.017	−0.017	−0.017
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Number of bathrooms	0.158	0.159	0.159	0.159	0.159	0.159
(1.66)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
× renter	−0.014	−0.014	−0.014	−0.014	−0.014	−0.014
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Condominium (= 1)	−0.098	−0.095	−0.096	−0.096	−0.096	−0.096
(0.03)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
× renter	0.158	0.158	0.159	0.159	0.159	0.159
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Central air cond. (= 1)	0.165	0.162	0.163	0.163	0.163	0.163
(0.32)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
× renter	0.125	0.125	0.125	0.125	0.125	0.125
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
City sewer						
connection (= 1)	−0.013	−0.013	−0.013	−0.013	−0.013	−0.013
(0.86)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
× renter	−0.037	−0.036	−0.037	−0.037	−0.037	−0.037
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Lot size > 1 acre (= 1)	0.156	0.155	0.155	0.155	0.156	0.156
(0.075)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
× renter	−0.183	−0.183	−0.183	−0.183	−0.184	−0.184
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)

Endogeneity

1. Omitted variables
    - Skill-complementary city characteristics
    - Rauch (1993) uses a few controls
        - Regional dummies
        - Cultural amenities
        - Climate and coastal location
        - Federal R&D funding per capita and presence of major universities
    - How can we add all the right controls with the right functional forms?
2. Self selection
    - Sorting by unobserved human capital
    - Correlation between observed and unobserved skill
        - Endogenous educational choices

Compulsory Schooling Laws

Acemoglu and Angrist's (2000) identification strategy

- Compulsory schooling in an individual's state of birth when he was 14
  - Or state of residence out of concern for migration-inducing shocks

1. Instrument for current average schooling in the state
   - Around 66% of agents live in their state of birth
   - Plausibly exogenous to other state conditions 30 years later
2. Instrument for individual schooling
   - Analogous to Angrist and Krueger's (1991) quarter of birth
   - Biased by correlation with $\bar{h}$ in the presence of externalities
   - Appropriate use of one instrument for $\bar{h}$ and the other for h

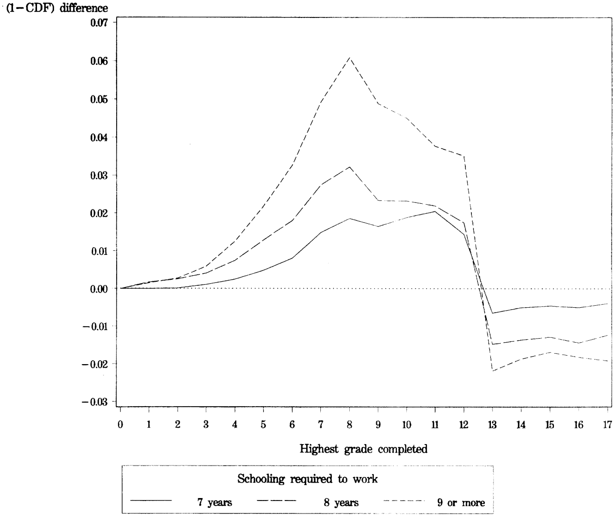
- Impact on middle- and high-school completion

OLS Estimates of Returns to Schooling

	1960–1980 (1)	1950–1980 (2)	1950–1990 (3)	1950 (4)	1960 (5)	1970 (6)	1980 (7)	1990 (8)
(a) Private Returns								
Private return to schooling	0.073 (0.0003)	0.068 (0.0003)	0.075 (0.0003)	0.055 (0.002)	0.069 (0.001)	0.076 (0.001)	0.075 (0.001)	0.102 (0.001)
State of residence main effects?	Yes	Yes	Yes	No	No	No	No	No
(b) Private and External Returns								
Private return to schooling	0.073 (0.000)	0.068 (0.000)	0.074 (0.000)	0.055 (0.002)	0.068 (0.001)	0.075 (0.001)	0.074 (0.000)	0.102 (0.001)
External return to schooling	0.073 (0.016)	0.061 (0.004)	0.072 (0.003)	0.136 (0.017)	0.136 (0.016)	0.128 (0.021)	0.160 (0.027)	0.168 (0.047)
State of residence main effects?	Yes	Yes	Yes	No	No	No	No	No
N	609,852	626,511	729,695	16,659	72,344	161,029	376,479	103,184

Notes: Standard errors corrected for state–year clustering are shown in parentheses. The data are from the Census IPUMS for 1950 through 1990, with the sample restricted to white males aged 40–49 in the Census year. All regressions contain Census-year, year-of-birth, and state-of-birth main effects.

Child Labor Laws and Individual Schooling



The figure shows the difference in the probability of schooling greater than or equal to the grade level on the X-axis. The reference group is 6 or fewer years of required schooling.

2SLS Estimates of Returns to Schooling

	Individual Schooling Endogenous				*Individual Schooling Exogenous*			
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Second-Stage Estimates								
Instrument set	QOB & CL	QOB & CA	QOB, CA & CL	QOB, CA & CL, interactions	CL	CA	CL & CA	QOB, CA & CL, interactions
Private return to schooling	0.074 (0.012)	0.074 (0.012)	0.075 (0.012)	0.060 (0.013)	0.073 (0.0003)	0.073 (0.0003)	0.073 (0.0003)	0.073 (0.0003)
External return to schooling	0.003 (0.040)	0.017 (0.043)	0.004 (0.035)	0.005 (0.033)	0.002 (0.038)	0.018 (0.042)	0.006 (0.033)	−0.011 (0.030)
First-Stage Estimates for State–Year Average Schooling								
CL7	0.080 (0.028)		0.062 (0.025)		0.084 (0.028)		0.062 (0.025)	
CL8	0.107 (0.035)		0.068 (0.031)		0.107 (0.035)		0.068 0.031)	
CL9	0.227 (0.036)		0.184 (0.034)		0.226 (0.035)		0.183 (0.034)	
CA9		0.128 (0.026)	0.102 (0.023)			0.128 (0.026)	0.104 (0.030)	
CA10		0.122 (0.030)	0.104 (0.029)			0.122 (0.030)	0.104 (0.029)	
CA11		0.144 (0.038)	0.094 (0.036)			0.143 (0.038)	0.094 (0.036)	

Notes: Standard errors corrected for state–year clustering are reported in parentheses. All entries are two-stage least-squares estimates of returns to schooling, using the excluded instruments indicated above and discussed in the text. QOB refers to a set of dummies interacting quarter of birth and year of birth. CL refers to a set of dummies indicating state- and year-specific child labor laws. CA refers to a set of dummies indicating state- and year-specific compulsory attendance laws. These are assigned according to the laws in effect in the individual's state of birth when he was 14. The data are from the Census IPUMS for 1960 through 1980, with the sample restricted to white males aged 40–49 in the Census year. All regressions contain Census-year, year-of-birth, state-of-birth, and state-of-residence main effects. The sample size for all columns is 609,852.

Lack of Evidence for Human Capital Spillovers

- State fixed effects halve the OLS estimates
  - Suggestive of omitted state characteristics
  - Also persistence of human capital in a state
- Individual IV with compulsory schooling or quarter of birth
  - The difference is positive as predicted
  - It is small and statistically insignificant
- 2SLS estimates are always insignificant
  - The confidence intervals do not rule out a small spillover: 1-3%
  - They rule out the OLS estimates
- Is the state the right geographic scope for externalities?
  - Theory more often considers metropolitan areas
- Do we expect spillovers from edging up minimum education?
  - Theory more often suggests trickling down from the top

Colleges and Higher Education Spillovers

Moretti's (2004) identification strategy

1. Longitudinal data to control for self-selection
   - City-individual fixed effects
   - Estimate of the impact on residents of time variation in average skill
   - Returns to unobserved ability may vary by city but not over time
2. Controls for estimated city-specific labor demand shocks
   - Katz and Murphy (1992) instrument based on industry mix
3. Instruments for the share of college graduates in a city
   1. Nation-wide trends for the city's lagged age-gender mix
   2. Presence of a land-grant college (federal program, 1862-1890)

Land-Grant Colleges and Individual Schooling

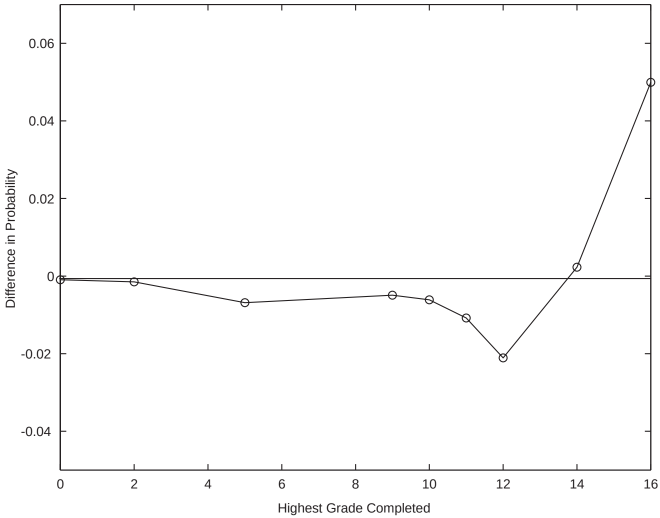


Fig. 4. Difference in distribution of schooling between cities with and without a land-grant college. (Source: 1990 Census).

Longitudinal Data

	(1)	City effects (2)	City, indiv. effects (3)	City×indiv. effects (4)	City×indiv. effects (5)	City×indiv. effects (6)	City×indiv. effects (7)	City×indiv. eff. only manuf. (8)
(A) *Allowing the private return to education to vary by year*								
College share	1.31 (0.20)	1.13 (0.36)	1.14 (0.31)	1.08 (0.32)	1.08 (0.32)	1.27 (0.33)	1.29 (0.33)	1.26 (0.88)
Years of Educ.*80	0.07(0.01)	0.07 (0.01)	−0.01 (0.03)	−0.00 (0.02)	−0.00 (0.02)	−0.01 (0.03)	−0.01 (0.02)	0.09 (0.03)
Years of Educ.*81	0.07 (0.01)	0.07 (0.01)	−0.02 (0.02)	−0.01 (0.02)	−0.01 (0.02)	−0.01 (0.02)	−0.01 (0.02)	0.07 (0.03)
Years of Educ.*82	0.07 (0.01)	0.07 (0.01)	−0.01 (0.02)	−0.00 (0.02)	−0.00 (0.02)	−0.01 (0.02)	−0.01 (0.02)	0.07 (0.03)
Years of Educ.*83	0.07 (0.00)	0.07 (0.01)	−0.01 (0.02)	−0.00 (0.02)	−0.01 (0.02)	−0.01 (0.02)	−0.01 (0.02)	0.07 (0.02)
Years of Educ.*84	0.07 (0.00)	0.07 (0.00)	−0.01 (0.02)	0.00 (0.02)	0.00 (0.02)	−0.01 (0.02)	−0.01 (0.02)	0.07 (0.02)
Years of Educ.*85	0.08 (0.01)	0.08 (0.00)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)	−0.01 (0.02)	−0.01 (0.02)	0.07 (0.02)
Years of Educ.*86	0.08 (0.00)	0.08 (0.00)	0.01 (0.02)	0.01 (0.02)	0.01 (0.02)	−0.01 (0.02)	−0.01 (0.02)	0.07 (0.02)
Years of Educ.*87	0.08 (0.00)	0.08 (0.00)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.00 (0.02)	0.00 (0.02)	0.07 (0.02)
Years of Educ.*88	0.09 (0.01)	0.09 (0.00)	0.01 (0.02)	0.02 (0.02)	0.02 (0.02)	0.01 (0.02)	0.01 (0.02)	0.07 (0.02)
Years of Educ.*89	0.09 (0.00)	0.09 (0.00)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.01 (0.02)	0.01 (0.02)	0.07 (0.02)
Years of Educ.*90	0.09 (0.01)	0.09 (0.00)	0.01 (0.02)	0.02 (0.02)	0.02 (0.02)	0.01 (0.02)	0.01 (0.02)	0.07 (0.02)
Years of Educ.*91	0.09 (0.00)	0.09 (0.00)	0.02 (0.02)	0.03 (0.02)	0.02 (0.02)	0.01 (0.02)	0.01 (0.02)	0.07 (0.02)
Years of Educ.*92	0.10 (0.00)	0.10 (0.00)	0.03 (0.02)	0.03 (0.02)	0.03 (0.02)	0.02 (0.02)	0.01 (0.02)	0.07 (0.02)
Years of Educ.*93	0.10 (0.00)	0.10 (0.00)	0.02 (0.02)	0.03 (0.02)	0.03 (0.02)	0.02 (0.02)	0.01 (0.02)	0.07 (0.02)
Years of Educ.*94	0.10 (0.00)	0.10 (0.00)	0.03 (0.02)	0.03 (0.02)	0.03 (0.02)	0.02 (0.02)	0.02 (0.02)	0.07 (0.02)
Experience	0.04 (0.00)	0.04 (0.00)	0.02 (0.02)	0.03 (0.02)	0.03 (0.02)	0.01 (0.02)	0.02 (0.02)	0.08 (0.02)
Experience sq./100	−0.05 (0.02)	−0.06 (0.01)	−0.13 (0.01)	−0.14 (0.01)	−0.14 (0.01)	−0.14 (0.01)	−0.14 (0.01)	−0.17 (0.03)
Female	−0.19 (0.01)	−0.19 (0.00)	—	—	—	—	—	—
Black	−0.19 (0.01)	−0.20 (0.01)	—	—	—	—	—	—
Hispanic	−0.02 (0.02)	−0.07 (0.01)	—	—	—	—	—	—
R^2	0.23	0.28	0.72	0.75	0.75	0.76	0.76	0.88
(B) *Allowing the private return to education to vary by year and city*								
College share	1.42 (0.38)	1.16 (0.36)	1.17 (0.31)	1.02 (0.33)	1.02 (0.33)	1.23 (0.33)	1.23 (0.33)	1.10 (0.91)
Experience	0.04 (0.00)	0.04 (0.00)	0.02 (0.02)	0.03 (0.02)	0.03 (0.02)	0.01 (0.02)	0.01 (0.02)	0.09 (0.03)
Experience sq./100	−0.04 (0.02)	−0.07 (0.01)	−0.13 (0.01)	−0.14 (0.01)	−0.14 (0.01)	−0.14 (0.01)	−0.14 (0.01)	−0.17 (0.03)
Female	−0.18 (0.01)	−0.19 (0.00)	—	—	—	—	—	—
Black	−0.20 (0.01)	−0.20 (0.01)	—	—	—	—	—	—
Hispanic	−0.07 (0.02)	−0.07 (0.01)	—	—	—	—	—	—
R^2	0.28	0.29	0.72	0.75	0.75	0.76	0.76	0.88
Unemployment rate					Yes	Yes	Yes	Yes
City controls, Katx-Murphy						Yes	Yes	Yes
City rent							Yes	

Notes: Standard errors, corrected for city year clustering, in parenthesis. Estimated equation is 6. Year effects are included in all models. Returns to education are not reported in panel B. Sample size is 44,891; in column 8, sample size is 7629.

Strong Evidence of Human Capital Spillovers

- A 1% increase in a city's college share increases wages by about 1%
  - A 1 year increase in average schooling increases wages by 25%
  - Extrapolating to an increase far larger than any in the sample
- Not immediate evidence of spillovers
  - Imperfect substitutability of workers with different skills
  - A greater share of college graduates raises wages for the unskilled
- Cross-section evidence of both spillovers and factor-abundance effects
  1. Wages of college graduates increase with their share
  2. The wage increase may be larger for less educated workers
     - ★ Using one instrument, but not the other

Differential Effects by Education Level

	1980–1990				1990		1980	
	OLS (1)	OLS (2)	2SLS (3)	2SLS (4)	OLS (5)	2SLS (6)	OLS (7)	2SLS (8)
First stage								
Age structure			3.36	3.52				
			(0.67)	(0.67)				
Land Grant						0.05		0.05
						(0.01)		(0.01)
Second stage								
Less than high-school	1.47	1.44	2.22	1.91	0.75	0.77	0.67	0.58
	(0.15)	(0.15)	(0.51)	(0.52)	(0.06)	(0.20)	(0.07)	(0.17)
High-school	1.38	1.34	2.08	1.67	0.85	0.84	0.74	0.74
	(0.13)	(0.13)	(0.45)	(0.45)	(0.06)	(0.18)	(0.06)	(0.14)
Some college	1.29	1.25	1.66	1.24	0.86	0.94	0.70	0.63
	(0.12)	(0.12)	(0.42)	(0.42)	(0.06)	(0.18)	(0.06)	(0.14)
College +	0.87	0.83	0.86	0.47	0.74	0.55	0.70	0.45
	(0.11)	(0.10)	(0.35)	(0.37)	(0.06)	(0.19)	(0.07)	(0.17)
City effects	Yes	Yes	Yes	Yes				
Region effects					Yes	Yes	Yes	Yes
Unempl. and other city controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Katz and Murphy Index		Yes		Yes				

Notes: Each entry is a separate regression. Years effects are included in all models. Dependent variables are education-city-time specific intercepts in a regression of log wages on sex, race, Hispanic origin, US citizenship and a quadratic term in potential experience. Entries are the coefficients on the percentage college graduates. Instrument in columns 3 and 4 is age structure. Instrument in columns 6 and 8 is land-grant college. Standard errors in parentheses.

Skill Upgrading

- Skill levels take integer values
- Wages are linear in skill
  - Linear production technology for globally tradable goods
- People become skilled by interacting with skilled people
- Interactions occur among randomly drawn members of the population
- If a person with skill j interacts with someone with skill $j' > j$, her own skill increases to $j + 1$ with probability c
  - The more skilled person gets nothing from the encounter
- The frequency of meetings $D(N)$ increases with density: $D'(N) > 0$
  - Reduced-form assumption driving agglomeration economies

Population Dynamics

- Population or density N is assumed to be stationary
- Agents live in the same city for all their life
  - Prohibitive moving costs
- The cost of living in the city reflects expected lifetime earnings
- All agents have a constant survival rate of δ per period
  - Probability $\delta^{1/D}$ of surviving from a meeting to the next
- Dying agents are replaced by an inflow of agents with zero skill

Binary Skill

- Two skill levels with wages w_0 and w_1
- Fraction $\pi_1(t)$ of the population has skill 1 at time t
- Transition equation

$$\pi_1\left(t+\frac{1}{D}\right)=\delta^{\frac{1}{D}}\pi_1(t)+\delta^{\frac{1}{D}}c\left[1-\pi_1(t)\right]\pi_1(t)$$

  1. Agents who already skill 1 and survived
  2. Agents who upgraded from skill 0 and also survived

- Steady state

$$\pi_1=1-\frac{\delta^{-\frac{1}{D}}-1}{c}\text{ for }\delta^{-\frac{1}{D}}<1+c$$

  - Average skill increases in the imitation rate: $\partial\pi_1/\partial c>0$
  - Average skill increases in density: $\partial\pi_1/\partial D>0$
  - Average skill increases in longevity: $\partial\pi_1/\partial\delta>0$

Spatial Equilibrium

- Monocentric linear city
- Everyone consumes one unit of land
- The cost of commuting is kd at distance d from the center
- The opportunity cost of land is zero
- The outside opportunity is w_0 forever, without commuting costs

1. Rent and commuting costs sum up to $kN/2$ for everyone
2. Spatial equilibrium in steady state

$$\sum_{t=0}^{\infty} (\beta\delta)^t \left\{ w_0 (1 - c\pi_1)^t + w_1 \left[1 - (1 - c\pi_1)^t\right] - \frac{kN}{2} \right\} = \frac{w_0}{1 - \beta\delta}$$

$$\frac{\beta\delta c\pi_1}{1 - \beta\delta (1 - c\pi_1)} (w_1 - w_0) = \frac{kN}{2}$$

City Size

- Spatial equilibrium

$$\frac{\beta\delta\left(1+c-\delta^{-\frac{1}{D}}\right)}{1+\beta\delta c-\beta\delta^{1-\frac{1}{D}}}\left(w_1-w_0\right)=\frac{kN}{2}$$

- Stable (in the usual heuristic sense) if and only if

$$\frac{-\log\delta\left(1-\beta\delta\right)\beta\delta^{1-\frac{1}{D}}}{\left(1+\beta\delta c-\beta\delta^{1-\frac{1}{D}}\right)^2}\left(w_1-w_0\right)\frac{D'}{D^2}<\frac{k}{2}$$

- Under the stability condition
  - City size increases in the skill premium: $\partial N/\partial\left(w_1-w_0\right)>0$
  - City size decreases with commuting costs: $\partial N/\partial k<0$
  - City size increases in the imitation rate: $\partial N/\partial c>0$
  - City size increases in patience: $\partial N/\partial\beta>0$
  - City size increases in longevity: $\partial N/\partial\delta>0$

Multiple Skill Levels

- Fraction $\pi_j(t)$ of the population has skill j at time t
- Fraction of the population with skill of at least j at time t

$$\Pi_j(t) = \sum_{i=j}^{J} \pi_i(t)$$

- Let J be the maximum skill level in the city
- Transition equation for all $j = 1, ..., J$

$$\Pi_j\left(t + \frac{1}{D}\right) = \delta^{\frac{1}{D}} \Pi_j(t) + \delta^{\frac{1}{D}} c \pi_{j-1}(t) \Pi_j(t)$$

- Steady state for $\delta^{-\frac{1}{D}} < 1 + c$

$$\pi_j = \frac{\delta^{-\frac{1}{D}} - 1}{c} \equiv \bar{\pi} \text{ for } j = 0, ..., J-1$$

Skill Distribution

- Steady state population share with skill of at least $j \leq J$

$$\Pi_j = 1 - \bar{\pi} j$$

- Steady state population share with maximum skill: $\pi_J = 1 - \bar{\pi} J$
- Maximum skill level the city can support

$$J = \max \left\{ j \in \mathbb{N} : j < \frac{1}{\bar{\pi}} \right\}$$

- Average skill level

$$\mathbb{E} j = \left(1 - \bar{\pi} \frac{1 + J}{2} \right) J$$

- Π_j,J, $\mathbb{E} j$ and $Var\left(j\right)$ are all
    - Increasing in the imitation rate: $\partial \bar{\pi} / \partial c < 0$
    - Increasing in density: $\partial \bar{\pi} / \partial D < 0$
    - Increasing in longevity: $\partial \bar{\pi} / \partial \delta < 0$

Evolution of Individual Skill

- An agent with skill $j < J$ upgrades to $j+1$ with probability

$$c\left[1-(j+1)\,\bar{\pi}\right]$$

- This also applies to $j = J$ if we get rid of the integer constraint:

$$\bar{\pi}^{-1} \in \mathbb{N} \Rightarrow J = \bar{\pi}^{-1} - 1$$

- Then the expectation of skill evolves as

$$\mathbb{E}\left[j\left(t+D^{-1}\right)|j\left(t\right)\right] = c\left(1-\bar{\pi}\right) + \left(1-c\bar{\pi}\right)j\left(t\right)$$

- The unconditional expectation

$$\mathbb{E}\left[j\left(t+D^{-1}\right)\right] = c\left(1-\bar{\pi}\right) + \left(1-c\bar{\pi}\right)\mathbb{E}\left[j\left(t\right)\right]$$

- For an agent born at 0:

$$\mathbb{E}\left[j\left(t\right)\right] = \frac{1-\bar{\pi}}{\bar{\pi}}\left[1-\left(1-c\bar{\pi}\right)^{Dt}\right]$$

Earnings

- Linear skill premium

$$w_j = w_0 + \alpha j$$

- Spatial equilibrium

$$\alpha \sum_{t=0}^{\infty} (\beta\delta)^t \mathbb{E}[j(t)] = \frac{kN}{2(1-\beta\delta)}$$

$$\alpha\beta\delta \frac{1-(1-c\bar{\pi})^D}{1-\beta\delta(1-c\bar{\pi})^D} \frac{1-\bar{\pi}}{\bar{\pi}} = \frac{kN}{2}$$

$$\alpha\beta\delta \frac{1-\left(2-\delta^{-\frac{1}{D}}\right)^D}{1-\beta\delta\left(2-\delta^{-\frac{1}{D}}\right)^D} \left(\frac{c}{\delta^{-\frac{1}{D}}-1}-1\right) = \frac{kN}{2}$$

- The comparative statics are identical to the case of binary skills
  - $D'(N)$ must be sufficiently small for a stable equilibrium

Reminder

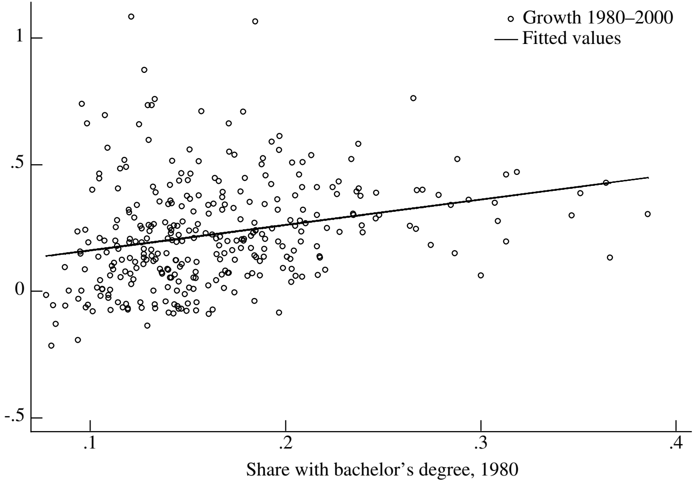
Human Capital and City Growth

- Cities with more educated residents have faster population growth
  - $+\sigma \approx 1\%$ share of college graduates $\Rightarrow +\sigma/4 \approx 0.5\%$ decadal growth

1. *Consumer City*: cities increasingly depend on consumption amenities
   - Educated neighbors are a consumption amenity
2. *Information City*: cities exist to facilitate the flow of ideas
   - Educated workers specialize in ideas
3. *Reinvention City*: cities survive by adapting to new technologies
   - Educated people are the drivers of change

- Demand-side theories: declining real wages are a necessary condition
- Supply-side theories: rising nominal wages are a sufficient condition

Human Capital and Urban Growth, 1980-2000



Fitted line from the regression: log(pop2000/pop1980) = 0.0611 + 1.001 × share with bachelor's degree in 1980.
(0.036) (0.209)

R squared: 0.067, N: 318.

MSA Growth and Education

	Δlog(population)					
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Share with bachelor's degree (age 25+) at t-10	0.47 (0.096)***	0.582 (0.113)***	0.456 (0.117)***	0.508 (0.215)**	0.414 (0.153)***	
Log of population at t-10		–0.015 (0.004)***	–0.011 (0.005)**	–0.316 (0.030)***	–0.014 (0.004)***	0.003 (0.005)
Log average heating degree days (1961–90)		–0.082 (0.011)***	–0.075 (0.020)***		–0.084 (0.011)***	–0.07 (0.011)***
Log average annual precipitation (1961–90)		–0.026 (0.015)*	–0.001 (0.014)		–0.026 (0.015)*	–0.024 (0.015)
Share of workers in manufacturing at t-10		–0.173 (0.088)*	–0.167 (0.073)**	0.255 (0.125)**	–0.162 (0.085)*	–0.174 (0.084)**
Share of workers in professional services at t-10		–0.328 (0.145)**	–0.166 (0.132)	0.148 (0.203)	–0.238 (0.142)*	0.082 (0.117)
Share of workers in trade at t-10		0.034 (0.260)	0.113 (0.215)	0.229 (0.281)	0.007 (0.279)	–0.129 (0.219)
Unemployment rate at t-10					–0.427 (0.235)*	
Share of high school dropouts (age 25+) at t-10					–0.06 (0.089)	
Log colleges per capita in 1940						0.035 (0.008)***
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	No	Yes	No	No	Yes	Yes
State fixed effects	No	No	Yes	No	No	No
MSA fixed effects	No	No	No	Yes	No	No
Observations	918	918	918	954	918	816
R squared	0.56	0.51	0.6	0.89	0.51	0.5

Note: Robust standard errors in parentheses
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

City Growth and Education

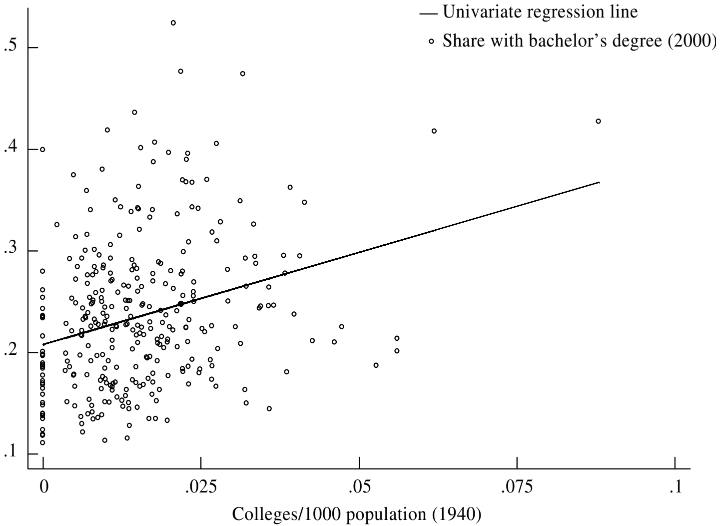
	Δlog(population)					
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Share with bachelor's degree (age 25+) at t-10	0.202 (0.044)***	0.217 (0.053)***	0.166 (0.050)***	0.121 (0.086)	0.061 (0.078)	
Log of population at t-10		–0.009 (0.004)**	–0.017 (0.005)***	–0.512 (0.017)***	–0.007 (0.004)	–0.010 (0.004)**
Log average heating degree days (1961–90)		–0.021 (0.009)**	0.000 (0.015)		–0.023 (0.009)***	–0.028 (0.009)***
Log average annual precipitation (1961–90)		–0.097 (0.018)***	–0.071 (0.025)***		–0.097 (0.019)***	–0.087 (0.021)***
Share of workers in manufacturing at t-10		–0.032 (0.060)	–0.023 (0.059)	0.327 (0.091)***	0.014 (0.063)	–0.042 (0.055)
Share of workers in professional services at t-10		–0.113 (0.090)	–0.095 (0.087)	–0.851 (0.144)***	–0.048 (0.102)	0.029 (0.077)
Share of workers in trade at t-10		0.276 (0.151)*	0.122 (0.154)	–0.393 (0.164)**	0.181 (0.154)	0.200 (0.149)
Unemployment rate at t-10					–0.043 (0.200)	
Share of high school dropouts (age 25+) at t-10					–0.163 (0.060)***	
Log colleges per capita in 1940						0.033 (0.007)***
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	No	Yes	No	No	Yes	Yes
State fixed effects	No	No	Yes	No	No	No
City fixed effects	No	No	No	Yes	No	No
Observations	2160	2160	2160	2169	2160	2070
R squared	0.11	0.26	0.36	0.8	0.27	0.26

Note: Robust standard errors in parentheses
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

Identification

1. Controlling directly for multiple city characteristics
   - Including climate amenities strengthens the effect
   - The educated tend to live in colder, damper cities
2. Including metropolitan-area fixed effects
   - Similar coefficients, less precisely estimated
   - Striking significance considering that education is hugely persistent
3. Measuring education by the number of colleges per capita in 1940
   - Directly instead of IV because orthogonality is less than guaranteed
4. Timing: do skilled people flock to fast-growing cities?
   - The unskilled move to declining cities with cheap housing
   - Little evidence of skill sorting among cities with positive growth

Colleges in 1940 and Human Capital in 2000



Share with bachelor's degree in 2000 = 0.207 + 1.816 × colleges per 1,000 population in 1940.
(0.006) (0.337)

R squared: 0.085, N: 313.

Reverse Causation

	Δshare bachelor's degree					
	Cities			*Metropolitan statistical area*		
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Spline growth for declining areas	0.058 (0.014)***	0.055 (0.016)***	–0.311 (0.203)	0.121 (0.024)***	0.087 (0.020)***	1.249 (1.996)
Spline growth for growing areas	0.011 (0.005)**	–0.005 (0.006)	0.057 (0.065)	0.010 (0.007)	0.022 (0.007)***	–0.155 (0.103)
Log of population at t-10		0.000 (0.001)	–0.001 (0.001)		0.007 (0.001)***	0.006 (0.001)***
Share of workers in manufacturing at t-10		–0.048 (0.013)***	–0.063 (0.017)***		0.023 (0.011)**	–0.079 (0.031)**
Share of workers in professional services at t-10		0.074 (0.021)***	0.069 (0.023)***		0.138 (0.016)***	0.060 (0.051)
Share of workers in trade at t-10		–0.081 (0.037)**	–0.086 (0.045)*		0.033 (0.034)	–0.038 (0.054)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
IV for growth (weather instruments)	No	No	Yes	No	No	Yes
Observations	2709	2169	2160	954	954	918
R squared	0.11	0.15		0.22	0.42	

Note: Robust standard errors in parentheses.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

The Connection Between Skills and Growth

1. Productivity drives the connection between skills and growth
   - Education level predicts future growth in ▸ housing prices and ▸ nominal income
   - Real wages are not declining and may be rising with skill ▸ Table
2. Effects on cities within metropolitan areas ▸ Table
   - The prevalence of high-school dropouts predicts local decline
   - Evidence of consumption disamenities if the MSA is the labor market
3. Human capital matters controlling for patents per capita ▸ Table
   - Skills spillovers seem to go beyond R&D spillovers
4. Support for the reinvention hypothesis
   - Negative cross-effect of skills and warmth or immigration ▸ Table
   - Skilled cities shifted out of manufacturing more quickly ▸ Table

Education and Median Home Value Growth

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Δlog(MSA median house value)						
Share with bachelor's degree (age 25+) at t-10	0.185 (0.083)**	1.166 (0.186)***	2.324 (0.237)***	2.258 (0.518)***	0.902 (0.220)***	
Log median house value at t-10		–0.417 (0.036)***	–0.71 (0.041)***	–1.183 (0.060)***	–0.422 (0.035)***	–0.333 (0.036)***
Unemployment rate at t-10					–0.881 (0.344)**	
Share of high school dropouts (age 25+) at t-10					–0.053 (0.109)	
Log colleges per capita in 1940						0.032 (0.012)***
Panel B: Δlog(city median house value)						
Share with bachelor's degree (age 25+) at t-10	0.226 (0.045)***	1.619 (0.116)***	2.25 (0.118)***	1.869 (0.222)***	1.097 (0.151)***	
Log median house value at t-10		–0.376 (0.024)***	–0.602 (0.029)***	–1.096 (0.026)***	–0.41 (0.025)***	–0.169 (0.017)***
Unemployment rate at t-10					–1.483 (0.279)***	
Share of high school dropouts (age 25+) at t-10					–0.377 (0.083)***	
Log colleges per capita in 1940						–0.002 (0.008)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	No	Yes	No	No	Yes	Yes
State fixed effects	No	No	Yes	No	No	No
MSA fixed effects	No	No	No	Yes	No	No
Other variables in table 2	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

▸ Individual Data ▸ Back

Education and Average Income Growth

	(1)	(2)	(3)	(4)	(5)	(6)
Panel C: Δlog(average MSA family income)						
Share with bachelor's degree (age 25+) at t-10	0.191 (0.029)***	0.761 (0.082)***	0.849 (0.090)***	1.769 (0.171)***	0.59 (0.090)***	
Log average family income at t-10		–0.291 (0.029)***	–0.359 (0.036)***	–1.155 (0.043)***	–0.336 (0.030)***	–0.143 (0.025)***
Unemployment rate at t-10					–0.307 (0.161)*	
Share of high school dropouts (age 25+) at t-10					–0.186 (0.054)***	
Log colleges per capita in 1940						0.019 (0.004)***
Panel D: Δlog(average city family income)						
Share with bachelor's degree (age 25+) at t-10	0.275 (0.020)***	0.632 (0.052)***	0.671 (0.056)***	1.624 (0.094)***	0.434 (0.057)***	
Log average family income at t-10		–0.135 (0.016)***	–0.167 (0.020)***	–1.091 (0.031)***	–0.231 (0.020)***	0.042 (0.009)***
Unemployment rate at t-10					–0.709 (0.118)***	
Share of high school dropouts (age 25+) at t-10					–0.313 (0.041)***	
Log colleges per capita in 1940						0.015 (0.003)***
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	No	Yes	No	No	Yes	Yes
State fixed effects	No	No	Yes	No	No	No
MSA fixed effects	No	No	No	Yes	No	No
Other variables in table 2	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

Individual Data | Back

Education and Individual Income and Home Value Growth

	Log IPUMS wage	*Log IPUMS house value*
	(1)	*(2)*
Share with bachelor's degree	0.527	0.389
at t-10*1980 dummy	(0.459)	(1.550)
Share with bachelor's degree	0.738	2.205
at t-10*1990 dummy	(0.347)**	(1.087)**
Share with bachelor's degree	0.785	1.698
at t-10*2000 dummy	(0.271)***	(0.855)**
MSA fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	1026867	1222890
R squared	0.33	0.64
Average growth in education effect per decade	0.26	0.57

Note: Robust standard errors clustered by MSA-year in parentheses.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

Wage regressions include year and MSA fixed effects, controls for age, age squared, education dummies interacted with year, race, Hispanic ethnicity, marital status, and veteran status. Observations include males over 21 years old with complete observations.

Value regressions include year and MSA fixed effects, controls for number of rooms and bedrooms, quality of plumbing and kitchen facilities, and age of the building. The results use a 50 percent random sample of the IPUMS data for all single units with the relevant information.

Back

Human Capital and Real Wage Growth

	Δlog(average wage/ Accra prices)		Δlog(average manufacturing wage/Accra prices)		Δlog(IPUMS adjusted wage/ Accra prices)	
	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Share with bachelor's degree (age 25+) at t-10	0.78 (0.217)***	1.78 (0.239)***	–0.003 (0.178)	0.213 (0.297)	0.045 (0.088)	0.057 (0.144)
Log of population at t-10		–0.03 (0.011)***		–0.018 (0.010)*		–0.018 (0.005)***
Log average heating degree days (1961–90)		–0.033 (0.024)		0.028 (0.024)		0.011 (0.007)
Log average annual precipitation (1961–90)		–0.03 (0.029)		0.024 (0.040)		0.031 (0.014)**
Share of workers in manufacturing at t-10		–0.029 (0.212)		0.188 (0.182)		–0.069 (0.080)
Share of workers in professional services at t-10		–1.362 (0.318)***		0.203 (0.389)		–0.08 (0.177)
Share of workers in trade at t-10		2.063 (0.505)***		0.505 (0.476)		0.262 (0.371)
Decade fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	No	No	No	No	No	No
Observations	238	234	135	135	130	129
R squared	0.11	0.37	0.06	0.22	0.58	0.64

Note: Robust standard errors in parentheses. We use Boston in 1990 as baseline, the evolution of Urban CPI and of relative prices from Accra to calculate prices by MSA and year.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

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Minor Civil Divisions Within a Metropolitan Area

	Δlog(population)		Δlog(median value)	
	(1)	(2)	(3)	(4)
Share with bachelor's degree (age 25+) at t-10	0.179 (0.031)***		0.49 (0.035)***	
Share of high school dropouts (age 25+) at t-10		–0.274 (0.028)***		–0.079 (0.025)***
Log of population at t-10	–0.03 (0.002)***	–0.029 (0.002)***	–0.019 (0.001)***	–0.019 (0.001)***
Share of workers in manufacturing at t-10	–0.12 (0.045)***	–0.068 –0.045	–0.099 (0.026)***	–0.105 (0.027)***
Share of workers in professional services at t-10	–0.512 (0.059)***	–0.518 (0.053)***	–0.264 (0.041)***	0.033 –0.034
Share of workers in trade at t-10	–0.245 (0.080)***	–0.363 (0.082)***	–0.143 (0.049)***	–0.249 (0.051)***
Log median value at t-10			–0.111 (0.012)***	–0.019 (0.011)*
Decade fixed effects	Yes	Yes	Yes	Yes
MSA-year fixed effects	Yes	Yes	Yes	Yes
Observations	13752	13752	13645	13645
Minor civil divisions	4584	4584	4584	4584
R squared	0.24	0.25	0.59	0.59

Note: Robust standard errors in parentheses.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

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Human Capital, Patents, and Growth

	Log patents per worker	*Δlog(population)*	
	(1)	*(2)*	*(3)*
Share with bachelor's degree (age 25+) at t-10	9.135 (0.903)***		0.781 (0.119)***
Log patents per worker at t-10		0.02 (0.006)***	0.003 (0.006)
Log of population at t-10	0.156 (0.040)***	0.001 (0.005)	–0.011 (0.005)**
Log average heating degree days (1961–90)	–0.208 (0.080)***	–0.026 (0.010)**	–0.037 (0.010)***
Log average annual precipitation (1961–90)	–0.014 (0.107)	–0.038 (0.017)**	–0.05 (0.018)***
Share of workers in manufacturing at t-10	5.894 (0.740)***	–0.226 (0.109)**	–0.047 (0.122)
Share of workers in professional services at t-10	–0.485 (1.341)	–0.213 (0.157)	–0.756 (0.162)***
Share of workers in trade at t-10	1.832 (2.367)	–0.229 (0.287)	0.232 (0.297)
Region fixed effects	Yes	Yes	Yes
Observations	304	304	304
R squared	0.56	0.38	0.46

Note: Robust standard errors in parentheses.
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

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The Reinvention Hypothesis

	Δlog (population) (1)	Δlog(wage) (2)	Δlog(house value) (3)	Δlog (population) (4)	Δlog(wage) (5)	Δlog(house value) (6)
Share with bachelor's degree (age 25+) at t-10	0.945 (0.138)***	2.541 (0.230)***	1.264 (0.209)***	0.999 (0.135)***	2.203 (0.226)***	1.046 (0.204)***
Temperature * share with bachelor's degree at t-10	–0.396 (0.112)***	–0.284 (0.137)**	–0.121 (0.133)			
Log of population at t-10	–0.013 (0.004)***	0.424 (0.051)***	0.04 (0.007)***	–0.013 (0.004)***	0.442 (0.052)***	0.038 (0.007)***
Log average heating degree days (1961–90)	–0.143 (0.022)***	–0.075 (0.026)***	–0.06 (0.023)***	–0.093 (0.011)***	–0.052 (0.014)***	–0.021 (0.014)
Log average annual precipitation (1961–90)	–0.027 (0.015)*	–0.015 (0.018)	0.063 (0.017)***	–0.026 (0.016)*	–0.031 (0.019)*	0.078 (0.020)***
Share of workers in manufacturing at t-10	–0.128 (0.087)	–0.151 (0.115)	0.138 (0.114)	–0.145 (0.082)*	–0.185 (0.109)*	0.074 (0.112)
Share of workers in professional services at t-10	–0.295 (0.145)**	–1.266 (0.207)***	–0.139 (0.178)	–0.456 (0.143)***	–1.267 (0.210)***	–0.198 (0.180)
Share of workers in trade at t-10	–0.004 (0.257)	0.088 (0.336)	0.119 (0.307)	–0.05 (0.252)	0.078 (0.333)	0.103 (0.304)
Log average wage receipts per worker at t-10		–0.403 (0.047)***			–0.417 (0.048)***	
Log median house value at t-10			–0.414 (0.036)***			–0.466 (0.042)***
Share immigrant at t-10 * share with bachelor's degree t-10				–5.751 (1.201)***	2.376 (1.897)	3.433 (2.142)
Share immigrant at t-10				0.704 (0.268)***	–0.901 (0.352)**	–0.031 (0.409)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	918	918	918	918	918	918
R squared	0.52	0.72	0.75	0.54	0.72	0.76

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Education and the Shift Out of Manufacturing

	Share manufacturing (1940–2000)		*Δlog(population) (1940–2000)*
Share with bachelor's degree in 1940	–0.011 (0.006)*	Share with bachelor's degree in 1940	0.094 (0.017)***
Share in manufacturing in 1940	–0.547 (0.084)***	Log(population) in 1940	–0.139 (0.028)***
January mean temperature	–0.002 (0.0008)**	January mean temperature	0.032 (0.002)***
Share manufacturing 1940 * share with bachelor's degree in 1940	–0.048 (0.018)**	Log average annual precipitation	–0.309 (0.058)***
January mean temperature * share with bachelor's degree in 1940	0.0003 (0.0001)*	Share in manufacturing in 1940	0.046 (0.29)
Log employment in 1940	–0.004 (0.003)	Constant	2.227 (0.371)***
Constant	0.222 (0.050)***		
Observations	293	Observations	293
R squared	0.78	R squared	0.58

Note: Standard errors in parentheses. Panel A: Temperature = 9.27 – log(heating degree days); 9.27 corresponds to the city with max(log heating degree days).
*Significant at 10 percent level. **Significant at 5 percent level. ***Significant at 1 percent level.

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