Agglomeration Economies in Transition
Measuring the Sources of Agglomeration Economies*

Urban Economics: Week 7

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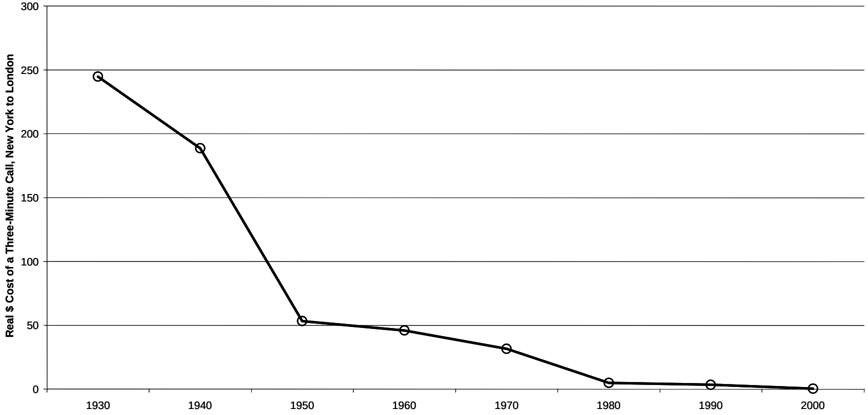
Secular Decline in Communication Costs



Source: IMF World Economic Outlook 1997

Telecommunications and Cities

- Will improvements in information technology make cities obsolete?
- Probably, if telecommunication eliminates face-to-face interactions
- But are the two forms of information transmission substitutes?

1. Substitutability at the interaction level
   - We can meet or we can phone / fax / e-mail / chat
2. Complementarity at the relationship level
   - We can interact with more people thanks to phones, computers, etc.

- Overall complementarity is possible and plausible
  1. The increase in the number of relationships is the dominant effect
  2. All relationships require some face-to-face interactions

Production

1. Each agent learns the value R of an individual project
   - Idiosyncratic draw from the cumulative distribution $H(R)$
2. He can pursue the project alone or discard it to form a partnership
3. The productivity α of the partnership is revealed
   - Idiosyncratic draw from the cumulative distribution $\Phi(\alpha)$
4. Investment i in developing the partnership yields $\alpha f(i)$
   - Well-behaved production function with $f'(i) > 0 > f''(i)$ for all $i > 0$

Investment in a partnership consists of time devoted to interactions

- Electronic communication yields $i = \beta_P t$
- Face-to-face meetings yield $i = \beta_F (t - t_F)$ for $t > t_F$
- Face-to-face mettings are preferable for high-intensity relationships

$$\beta_F > \beta_P \text{ but } t_F > 0$$

Optimal Interactions

- Linear cost of time c
- Optimal time investment if electronic communication is chosen

$$t_P^*(\alpha) = \arg\max_{t \geq 0} \{\alpha f(\beta_P t) - ct\} = \frac{1}{\beta_P} i_P^*(\alpha)$$

for optimal intensity

$$i_P^*(\alpha) = f'^{-1}\left(\frac{c}{\alpha \beta_P}\right)$$

- Optimal time investment if face-to-face meetings are chosen

$$t_F^*(\alpha) = \arg\max_{t \geq t_F} \{\alpha f(\beta_F(t - t_F)) - ct\} = t_F + \frac{1}{\beta_F} i_F^*(\alpha)$$

for optimal intensity

$$i_F^*(\alpha) = f'^{-1}\left(\frac{c}{\alpha \beta_F}\right)$$

Technology Comparison

- Face-to-face meetings induce greater intensity

$$i_F^* (\alpha) > i_P^* (\alpha)$$

- Maximal return if electronic communication is chosen

$$R_P^* (\alpha) = \alpha f \left(i_P^* (\alpha) \right) - \frac{c}{\beta_P} i_P^* (\alpha)$$

- Maximal return if face-to-face meetings are chosen

$$R_F^* (\alpha) = \alpha f \left(i_F^* (\alpha) \right) - \frac{c}{\beta_F} i_F^* (\alpha) - ct_f$$

- Single crossing condition

$$R_P^{*\prime} (\alpha) = f \left(i_P^* (\alpha) \right) < R_F^{*\prime} (\alpha) = f \left(i_F^* (\alpha) \right)$$

Technology Selection

- A relationship is worth investing in with electronic communication if

$$\alpha > \underline{\alpha} = \frac{c}{\beta_P f'(0)}$$

  - $\underline{\alpha} = 0$ if we impose the Inada condition $f'(0) = \infty$
- Assume that $R_F^*(\underline{\alpha}) < 0$
  - True if but not only if $f'(0) = \infty$
- A relationship is worth investing in with face-to-face meetings if

$$\alpha > \alpha^* : R_F^*(\alpha^*) = R_P^*(\alpha^*)$$

1. Inframarginal relationships are abandoned: $\alpha \leq \underline{\alpha}$
2. Low-value relationships are pursued electronically: $\alpha \in (\underline{\alpha}, \alpha^*]$
3. High-value relationships are pursued face to face: $\alpha > \alpha^*$

Substitutability

- The efficiency of information technology is captured by β_P
- Differentiating

$$\alpha^* f\left(i_P^*\left(\alpha^*\right)\right) - \frac{c}{\beta_P} i_P^*\left(\alpha^*\right) = \alpha^* f\left(i_F^*\left(\alpha^*\right)\right) - \frac{c}{\beta_F} i_F^*\left(\alpha^*\right) - c t_f$$

by the envelope theorem

$$\frac{\partial \alpha^*}{\partial \beta_P} = \frac{c}{\beta_P^2} \frac{i_P^*\left(\alpha^*\right)}{f\left(i_F^*\left(\alpha^*\right)\right) - f\left(i_P^*\left(\alpha^*\right)\right)} > 0$$

and by the definition of α^* we can also rewrite

$$\frac{\partial \alpha^*}{\partial \beta_P} = \frac{\alpha^*}{\beta_P} \frac{t_P^*\left(\alpha^*\right)}{t_F^*\left(\alpha^*\right) - t_P^*\left(\alpha^*\right)} > 0$$

- As communication technology improves, fewer relationships involve face-to-face meetings

Complementarity

- The expected value of a partnership is

$$R^* = \int_{\underline{\alpha}}^{\alpha^*} R_P^*(\alpha)\, d\Phi(\alpha) + \int_{\alpha^*}^{\infty} R_F^*(\alpha)\, d\Phi(\alpha)$$

- Differentiating and recalling the definitions of $\underline{\alpha}$ and α^*

$$\frac{\partial R^*}{\partial \beta_P} = \int_{\underline{\alpha}}^{\alpha^*} \frac{\partial R_P^*(\alpha)}{\partial \beta_P} d\Phi(\alpha)$$

  and by the envelope theorem

$$\frac{\partial R^*}{\partial \beta_P} = \frac{c}{\beta_P^2} \int_{\underline{\alpha}}^{\alpha^*} i_P^*(\alpha)\, d\Phi(\alpha) = \frac{c}{\beta_P} \int_{\underline{\alpha}}^{\alpha^*} t_P^*(\alpha)\, d\Phi(\alpha) > 0$$

- As communication technology improves, more people, $H(R^*)$, choose to form partnerships
  - Active partnerships, $[1 - \Phi(\underline{\alpha})]\, H(R^*)$, may increase even more

Ambiguous Overall Effect on Face-to-Face Partnerships

- The number of partnerships using face-to-face interactions is

$$n_F = H\left(R^*\right)\left[1 - \Phi\left(\alpha^*\right)\right]$$

- Differentiating

$$\frac{\partial n_F}{\partial \beta_P} = h\left(R^*\right)\left[1 - \Phi\left(\alpha^*\right)\right]\frac{\partial R^*}{\partial \beta_P} - H\left(R^*\right)\phi\left(\alpha^*\right)\frac{\partial \alpha^*}{\partial \beta_P}$$

which is positive if and only if

$$\frac{h\left(R^*\right)}{H\left(R^*\right)} c \int_{\underline{\alpha}}^{\alpha^*} t_P^*\left(\alpha\right) d\Phi\left(\alpha\right) > \frac{\phi\left(\alpha^*\right)}{1 - \Phi\left(\alpha^*\right)} \frac{\alpha^* t_P^*\left(\alpha^*\right)}{t_F^*\left(\alpha^*\right) - t_P^*\left(\alpha^*\right)}$$

- Face-to-face relationships grow if
  1. More people are on the margin between individual and joint projects
  2. Fewer relationships are on the margin between electronic and face-to-face interaction

Ambiguous Overall Effect on Face-to-Face Meetings

- The amount of time spent in face-to-face interactions is

$$T_F = H(R^*) \int_{\alpha^*}^{\infty} t_F^*(\alpha)\, d\Phi(\alpha)$$

- Differentiating

$$\frac{\partial T_F}{\partial \beta_P} = h(R^*) \int_{\alpha^*}^{\infty} t_F^*(\alpha)\, d\Phi(\alpha) \frac{\partial R^*}{\partial \beta_P} - H(R^*)\, t_F^*(\alpha^*)\, \phi(\alpha^*) \frac{\partial \alpha^*}{\partial \beta_P}$$

which is positive if and only if

$$\frac{h(R^*)}{H(R^*)} c \int_{\underline{\alpha}}^{\alpha^*} t_P^*(\alpha)\, d\Phi(\alpha) > \frac{t_F^*(\alpha^*)\, \phi(\alpha^*)}{\int_{\alpha^*}^{\infty} t_F^*(\alpha)\, d\Phi(\alpha)} \frac{\alpha^* t_P^*(\alpha^*)}{t_F^*(\alpha^*) - t_P^*(\alpha^*)}$$

- Face-to-face meetings grow if
  1. More people are on the margin between individual and joint projects
  2. Fewer meetings are on the margin between electronic and face-to-face interaction

Location Choice

- Ex ante, individuals choose to live in the city or in the hinterland
- The cost of living in the city is $kN/2$
  - Linear city with population N and linear commuting costs
- The city reduces the fixed cost of face-to-face meetings: $t_F^C < t_F^H$

1. Marginal productivity $\underline{\alpha}$ and optimal intensities $i_P^* (\alpha^*)$ and $i_F^* (\alpha^*)$ are constant across space
2. Urban relationships are more likely to be face-to-face: $\alpha_C^* < \alpha_H^*$

$$\frac{\partial \alpha^*}{\partial t_F} = \frac{c}{f\left(i_F^*\left(\alpha^*\right)\right) - f\left(i_P^*\left(\alpha^*\right)\right)} = \frac{\alpha^*}{t_F^*\left(\alpha^*\right) - t_P^*\left(\alpha^*\right)} > 0$$

3. Urban residents are more likely to pursue relationships: $R_C^* > R_H^*$

$$\frac{\partial R^*}{\partial t_F} = \int_{\alpha^*}^{\infty} R_F^*\left(\alpha\right) d\Phi\left(\alpha\right) = -c\left[1 - \Phi\left(\alpha^*\right)\right] < 0$$

Spatial Equilibrium

- Spatial equilibrium condition

$$H\left(R_C^*\right)R_C^* + \int_{R_C^*}^{\infty} RdH\left(R\right) - \frac{k}{2}N = H\left(R_H^*\right)R_H^* + \int_{R_H^*}^{\infty} RdH\left(R\right)$$

- Equilibrium city size

$$N = \frac{2}{k}\left[H\left(R_C^*\right)R_C^* + \int_{R_C^*}^{\infty} RdH\left(R\right) - H\left(R_H^*\right)R_H^* - \int_{R_H^*}^{\infty} RdH\left(R\right)\right]$$

- Differentiating

$$\frac{\partial N}{\partial \beta_P} = \frac{2}{k}\left[H\left(R_C^*\right)\frac{\partial R_C^*}{\partial \beta_P} - H\left(R_H^*\right)\frac{\partial R_H^*}{\partial \beta_P}\right]$$
$$= \frac{2c}{k\beta_P}\left[H\left(R_C^*\right)\int_{\underline{\alpha}}^{\alpha_C^*} t_P^*\left(\alpha\right)d\Phi\left(\alpha\right) - H\left(R_H^*\right)\int_{\underline{\alpha}}^{\alpha_H^*} t_P^*\left(\alpha\right)d\Phi\left(\alpha\right)\right]$$

IT and Urbanization

- As communication technology improves, the city grows if more time is spent on electronic communication in the city than in the hinterland
- A sufficient condition is

$$\frac{\partial}{\partial t_F} H\left(R^*\right) \int_{\underline{\alpha}}^{\alpha^*} t_P^*\left(\alpha\right) d\Phi\left(\alpha\right) < 0 \text{ for } t_F \in \left(t_F^C, t_F^H\right)$$

which coincides with

$$\frac{h\left(R^*\right)}{H\left(R^*\right)} c \int_{\underline{\alpha}}^{\alpha^*} t_P^*\left(\alpha\right) d\Phi\left(\alpha\right) > \frac{\phi\left(\alpha^*\right)}{1-\Phi\left(\alpha^*\right)} \frac{\alpha^* t_P^*\left(\alpha^*\right)}{t_F^*\left(\alpha^*\right) - t_P^*\left(\alpha^*\right)}$$

- If communication technology is a complement to face-to-face meetings, then it is a complement to the city
- Moreover $\partial N/\partial t_F^C < 0$, $\partial N/\partial t_F^H > 0$, $\partial N/\partial \beta_F > 0$

Suggestive Evidence of Complementarity

Complementarity between IT and face-to-face interaction

1. Most telephone calls are between people who are physically close
2. Business travel has grown faster than GDP since 1970
3. Coauthorship in economics has become more common since 1960
    - So have articles with coauthors from the same university or city

Complementarity between IT and cities

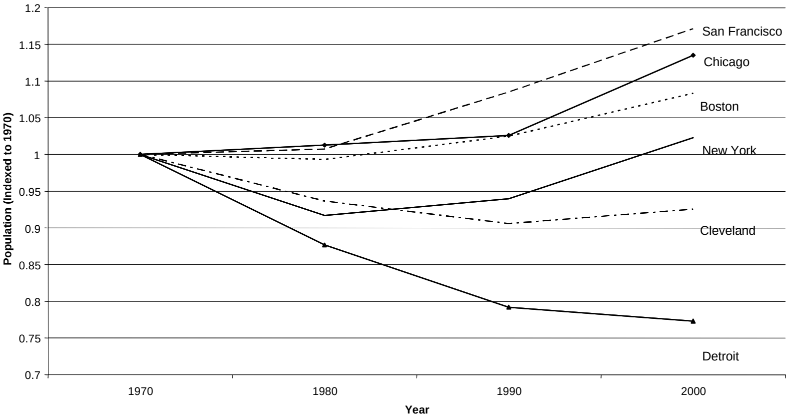
1. Telephone usage is greater in cities
    - Phone usage and urbanization in Japan and the U.S.
    - Phone ownership and urbanization across countries, controlling for GDP
2. No break in U.S. urbanization growth when the telephone appears

- No conclusive evidence from internet usage

Urban Diversity and Improvements in IT

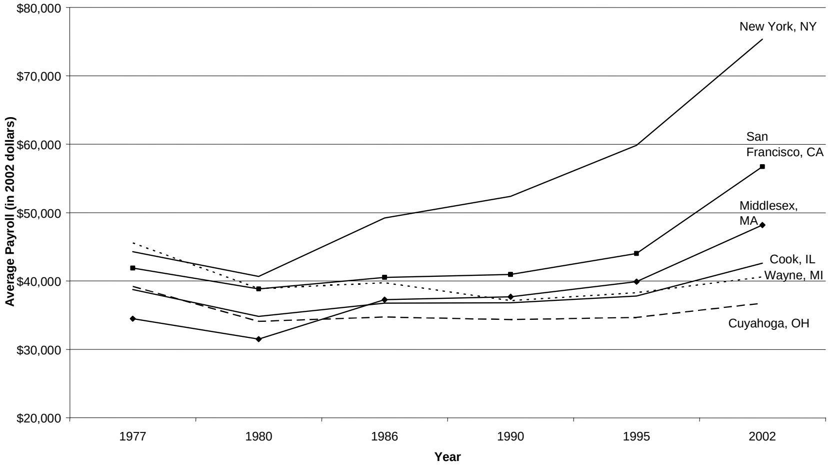
1. Revolution in communication technology
   - Fax machines, cell phones, internet, wi-fi, etc.
   - Improvements in competition as well as technology
2. Increasing distance between headquarters and operations
   - Kim (1999), Henderson and Ono (2007)
   - Rise of multi-national firms (Markusen, 1995)
3. Heterogeneity in growth trends across older U.S. cities
   - In 1975 Cleveland, Detroit, New York and Boston were all in trouble
   - The first two are still troubled; the second two are now very successful
4. Successful older and colder cities increasingly specialize in idea-oriented industries rather than manufacturing
   - High human capital industries centralize (Glaeser and Kahn, 2001)

Population Growth Across Cities, 1970-2000



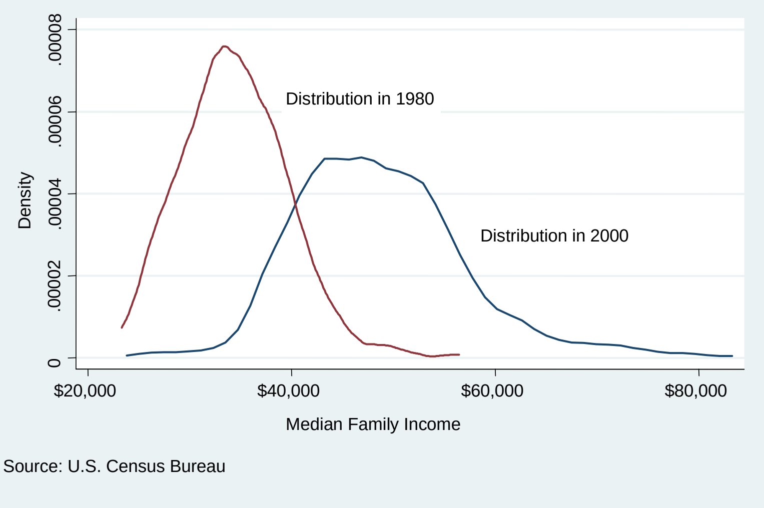
Source: U.S. Census Bureau, indexed to 1970

Trends in Earnings per Worker Across Cities, 1977-2002



Source: County Business Patterns

Distribution of Median Family Income Across Cities



Main Industry Groups by Share of Total City Payroll

	1977		2002	
	Top Industries	% Total Annual Payroll	Top Industries	% Total Annual Payroll
Chicago (Cook County)	Manufacturing	36.03%	Finance & insurance	14.00%
	Retail Trade	10.62%	Professional, scientific & technical services	12.72%
	Wholesale Trade	10.35%	Health care and social assistance	11.03%
	Finance, Insurance, and Real Estate	9.37%	Manufacturing	11.01%
	Transportation and Other Public Utilities	8.41%	Wholesale trade	6.77%
Cleveland (Cuyahoga County)	Manufacturing	44.07%	Manufacturing	15.94%
	Wholesale Trade	9.92%	Health care and social assistance	15.01%
	Retail Trade	9.52%	Finance & insurance	10.44%
	Transportation and Other Public Utilities	8.77%	Professional, scientific & technical services	9.40%
	Health and Social Services	6.70%	Wholesale trade	8.27%
Boston (Middlesex County)	Manufacturing	39.26%	Professional, scientific & technical services	18.85%
	Retail Trade	10.89%	Manufacturing	12.92%
	Wholesale Trade	9.31%	Information	8.91%
	Educational Services	7.24%	Wholesale trade	8.30%
	Health and Social Services	6.77%	Health care and social assistance	8.23%
New York (New York County)	Finance, Insurance, and Real Estate	22.96%	Finance & insurance	39.50%
	Manufacturing	19.85%	Professional, scientific & technical services	14.25%
	Wholesale Trade	11.18%	Information	7.91%
	Business Services Incl. Legal Services and Computer Services	10.68%	Management of companies & enterprises	6.70%
	Transportation and Other Public Utilities	9.77%	Health care and social assistance	5.91%
San Francisco (San Francisco County)	Transportation and Other Public Utilities	23.37%	Finance & insurance	23.07%
	Finance, Insurance, and Real Estate	17.14%	Professional, scientific & technical services	21.26%
	Manufacturing	11.85%	Information	8.40%
	Construction	10.16%	Health care and social assistance	7.89%
	Retail Trade	8.27%	Management of companies & enterprises	4.86%
Detroit (Wayne County)	Manufacturing	55.22%	Manufacturing	20.46%
	Retail Trade	8.83%	Health care and social assistance	11.66%
	Transportation and Other Public Utilities	7.17%	Management of companies & enterprises	8.56%
	Health and Social Services	6.86%	Professional, scientific & technical services	6.17%
	Wholesale Trade	6.61%	Transportation & warehousing	6.01%

Source: County Business Patterns

The Death of Distance

1. Cities have a comparative advantage in connecting people
   - Within the idea-producing sector
   - Between the idea- and the goods-producing sector
2. Improving communication technology erodes the city's advantage
   - Goods production is on the margin, as idea producers use less space
3. Manufacturing moves out of the city
   - Cheaper production in the hinterland or in China
   - Decreasing need for ports or rail hubs
   - Aggregate productivity increases.
4. As the world becomes flatter, cities thrive through innovation
   - Lower cost since more resources are available
   - Higher return since demand increases

Demand

- Three sectors: traditional, advanced, and innovation
- The traditional sector produces the numeraire Z
  - Constant returns to scale and perfect competition
- The advanced sector produces the Dixit-Stiglitz composite good

$$Y = \left[\int_0^n x(j)^\alpha \, dj \right]^{\frac{1}{\alpha}} \text{ with } \alpha \in (0,1)$$

- Homothetic aggregate demand is described by the budget share

$$\beta(p_Y) = \frac{p_Y Y}{p_Y Y + Z} \text{ with } \beta'(p_Y) \leq 0$$

- E.g., constant elasticity of substitution $\sigma \geq 1$

$$U = (1-\zeta)^{\frac{1}{\sigma}} Y^{\frac{\sigma-1}{\sigma}} + \zeta^{\frac{1}{\sigma}} Z^{\frac{\sigma-1}{\sigma}} \Rightarrow \beta(p_Y) = \left[p_Y^{\sigma-1} \zeta (1-\zeta) + 1 \right]^{-1}$$

Monopolistic Competition

- Monopolistic competition among advanced good producers
- Constant unit cost c_x
- Monopoly pricing

$$p_x = \frac{1}{\alpha} c_x$$

- Monopoly profits

$$\pi = (1 - \alpha) \, p_x \frac{X}{n}$$

  - X denotes the total output of differentiated varieties
- Price index for advanced goods

$$p_Y = n^{-\frac{1-\alpha}{\alpha}} p_x$$

Spillovers in Innovation

- An innovator's productivity depends on an external effect S
- Spillovers depend on the number of active innovators. In the city

$$S_U = \left(L_n^U + \eta L_n^R\right)^\delta$$

  - $\delta \geq 0$ measures external economies of scale
  - L_n^U is the number of innovators in the city
  - L_n^R is the number of innovators outside of the city
  - $\eta \in (0,1)$ is an inverse measure of the benefits of proximity

- Outside of the city there are no benefits from proximity

$$S_R = \left[\eta \left(L_n^U + L_n^R\right)\right]^\delta$$

- It is efficient for all innovators to congregate in the city: $L_n = L_n^U$

Heterogeneous Innovators

- Each urban innovator creates measure aS_U of varieties
- Creativity a is idiosyncratic, with a Pareto distribution

$$F(a) = 1 - \left(\frac{a}{\underline{a}}\right)^{-\theta} \text{ and } f(a) = \theta \underline{a}^{\theta} a^{-\theta-1}$$

- All individuals have the same output in manufacturing
- Perfect sorting into innovation: the marginal innovator has creativity t
  - Decreasing returns to innovation
  - Income inequality
- Employment in innovation as a function of marginal creativity

$$L_n = 1 - F(t) = \left(\frac{t}{\underline{a}}\right)^{-\theta}$$

- Knowledge spillovers

$$S_U = L_n^{\delta} = \left(\frac{t}{\underline{a}}\right)^{-\delta\theta}$$

Innovation

- Total amount of innovation as a function of marginal creativity

$$n = S_U \int_t^{\infty} af(a)\, da = \underline{a}^{(1+\delta)\theta} \frac{\theta}{\theta - 1} t^{1-(1+\delta)\theta}$$

- Employment in innovation

$$L_n = \left(\frac{n}{\mathbb{E}a} \right)^{\frac{\theta}{(1+\delta)\theta - 1}}$$

- Output of the marginal innovator

$$tS_U = \frac{\theta - 1}{\theta} \left[\left(\mathbb{E}a \right)^{\theta} n^{\delta\theta - 1} \right]^{\frac{1}{(1+\delta)\theta - 1}}$$

- Revenue of the marginal innovator: $\pi t S_U$

Production

- The city is endowed with labor-saving urban infrastructure
  - Its fixed cost F is not too large and defrayed with real-estate taxes
- The unit labor requirement of the advanced sector is

$$\psi_x S_U^{-\mu} \text{ in the city or } \psi_x \left(1+\tau_x\right) S_R^{-\mu} \text{ in the hinterland}$$

  - $\mu \in [0,1]$ measures knowledge spillovers for manufacturing
- The unit labor requirement of the traditional sector is

$$\psi_Z \text{ in the city or } \psi_Z \left(1+\tau_Z\right) \text{ in the hinterland}$$

  - Normalize units of labor so $\psi_Z \left(1+\tau_Z\right) = 1$
- A rural innovator's output is $aS_R / \left(1+\tau_n\right)$
- The value of urban infrastructure is ranked across sectors

$$\tau_n \geq \tau_x \geq \tau_Z \geq 0$$

Real Estate

- Each worker needs one unit of real estate for a residence
- Real estate is used in every sector with a Leontief technology
  - Each worker in sector $s \in \{Z, x, n\}$ requires κ_s units of land
- Real estate intensity is ranked across sectors

$$\kappa_n \leq \kappa_x \leq \kappa_Z \leq 0$$

- The city is endowed with a fixed amount K of real estate
  - $K < 1 + \kappa_n$ ensures scarcity
  - The price of real estate in the city is w_K
- Real estate is not a scarce resource in the hinterland
  - $K_R > 1 + \kappa_Z$
  - The price of real estate in the hinterland is zero

Spatial Equilibrium

- Let there be advanced manufacturing in both locations
  - All traditional manufacturing is in the hinterland
  - All innovation is in the city
- The wage in the hinterland is normalized to one
  - Unit cost in the hinterland: $c_x^R = \psi_x (1 + \tau_x) \left(\eta^\delta S_U\right)^{-\mu}$
- Spatial equilibrium for workers implies the urban wage $w_U = 1 + w_K$
  - Unit cost in the city: $c_x^U = \psi_x [1 + (1 + \kappa_x) w_K] S_U^{-\mu}$
- Spatial equilibrium for advanced manufacturers implies

$$w_K = \frac{(1 + \tau_x) \eta^{-\delta\mu} - 1}{1 + \kappa_x}$$

- Free entry of (urban) innovators implies $\pi t S_U - w_K \kappa_n = w_U$

Market Clearing

- Total production of advanced goods

$$X = \frac{L_n^{\delta\mu}}{\psi_x}\left(L_U + \frac{\eta^{\delta\mu}}{1+\tau_x}L_R\right)$$

- Labor market clearing

$$L_n + L_U + L_R + Z = 1$$

- Real estate market clearing

$$(1+\kappa_n)\,L_n + (1+\kappa_x)\,L_U = K$$

- We can solve explicitly for prices p_x and p_Y, quantities n, X, Y and Z, and employment L_U and L_R as a function of the number of (urban) innovators L_n

Communication Costs

- Transport and information technology are summarized by

$$\Delta \equiv (1+\tau_x)\,\eta^{-\delta\mu} - 1 > 0$$

  - For $\tau_x > 0$, manufacturers benefit from urban infrastructure
  - For $\eta < 1$ and $\mu > 0$, they benefit from innovation spillovers
- Technological improvement is measured by a decline in Δ
- The relevant impact is the one on manufacturing, the marginal sector
  - τ_n may also decline, and η certainly affects innovation
  - The productivity of innovation in the hinterland is off-equilibrium
  - Productivity in manufacturing determines spatial equilibrium

Equilibrium

- Equilibrium condition

$$L_n = \frac{(\theta - 1)(1 - \alpha)\beta(p_Y)}{\theta - (1 - \alpha)\beta(p_Y)} \frac{1 + \kappa_x + \Delta K}{1 + \kappa_x + (1 + \kappa_n)\Delta}$$

- Stability condition

$$\frac{\alpha[\theta - (1 - \alpha)\beta(p_Y)]}{(1 - \alpha)[(1 + \delta)\theta - 1] + \alpha\delta\theta\mu} > -\frac{p_Y \beta'(p_Y)}{\beta(p_Y)}$$

  - Innovation reduces p_Y and thus (weakly) increases $\beta(p_Y)$
  - Decreasing returns to innovation for heterogeneous creativity (low θ)
  - Increasing returns to innovation from greater variety (low α)
  - Increasing returns to innovation from knowledge spillovers (high δ, μ)

Declining Communication Costs

1. Manufacturing leaves the city
    - Increase in aggregate productivity: p_Y falls and all real incomes rise
    - Output of Y increases while output of and employment in Z decline
    - Output and employment in urban manufacturing decline
2. The value of the city for advanced manufacturers declines
    - Real estate values in the city decline
    - Nominal wages for production workers in the city falls
3. Innovation expands as manufacturing frees up real estate
    - Innovation and employment in its production increase
    - The total population of the city increases
4. Income inequality in the city increases

A Purely Innovative City

- Let urban real estate K be sufficiently scarce
- At a threshold $\underline{\Delta} > 0$ the city fully specializes in innovation
  - No innovation in the hinterland if its disadvantage is high enough

If Δ declines below $\underline{\Delta}$

1. Manufacturing productivity continues to rise
   - p_Y falls and all real incomes rise
   - Aggregate output of Y increases
2. City size is limited by scarcity of real estate
   - Innovation and employment in its production are constant
   - The total population of the city is constant
3. Returns to innovation increase if demand for Y is elastic
   - Employment in Y increases while employment in (output of) Z declines
   - The value of urban real estate increases

Two Cities

- Two cities with $K_1 = K_2 = K$
- It is efficient for all innovators to be in one city
  - The symmetric equilibrium is unstable
- Let the innovative city host both innovation and manufacturing
  - The manufacturing city is fully specialized in manufacturing
- As Δ declines, in the innovative city
  1. The innovative sector grows
  2. The manufacturing sector shrinks
  3. Total population grows
  4. Average real income grows, relative to the manufacturing city
- When the value of urban infrastructure τ_x falls, property values in the manufacturing city fall relative to the innovative city

Human Capital Intensity as a Proxy for Innovation

- Innovation in the model is a broader concept than formal R&D
  - Including finance, consulting, internet commerce, etc.
  - Sorting into innovation by human capital
- Private-sector occupations of skilled workers ▸ Table

1. Spillovers from specialization in knowledge sectors ▸ Figure
2. Specialization in knowledge sectors predicts growth
   - Greater income growth throughout the U.S. ▸ Figure
   - Greater population growth for older and colder cities ▸ Table
3. Specialization in knowledge sectors has increased ▸ Figure
   - The increase is correlated with income growth ▸ Figure
4. Specialization in knowledge sectors predicts rising inequality ▸ Figure
   - Some predictive power in a multivariate setting ▸ Table

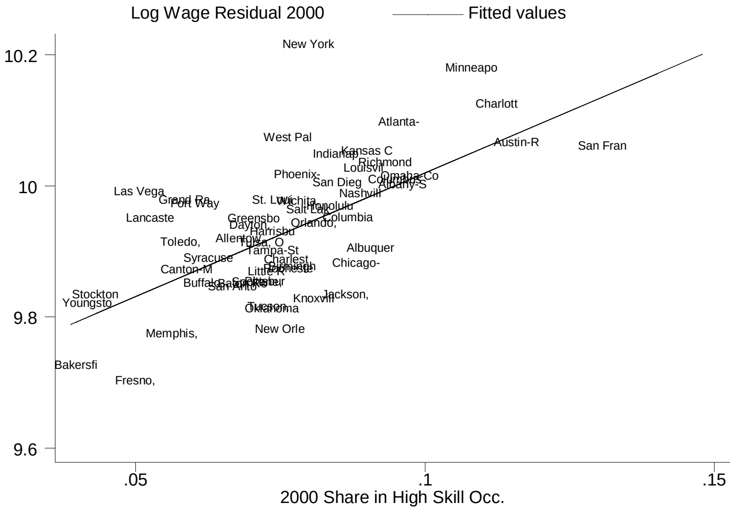
Main Occupations of Skilled Workers, 1970

1	Physicians
2	Dentists
3	Lawyers
4	Physicists and astronomers
5	Veterinarians
6	Geologists
7	Chemical engineers
8	Optometrists
9	Petroleum, mining, and geological engineers
10	Other health and therapy occupations
11	Chemists
12	Architects
13	Economists, market researchers, and survey researchers
14	Pharmacists
15	Clergy and religious workers
16	Metallurgical and materials engineers, variously phrased
17	Aerospace engineers
18	Electrical engineers
19	Civil engineers
20	Mechanical engineers

Source: The Integrated Public Use Microdata Series

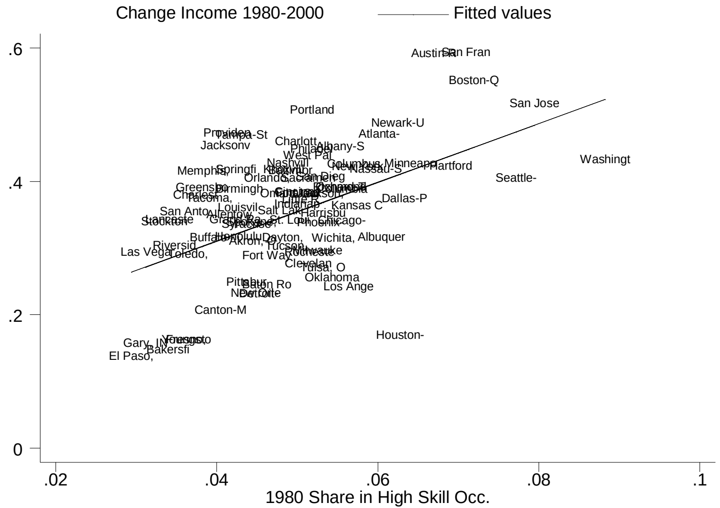
Back

Employment in Knowledge Sectors and Spillovers



Back

Specialization in Knowledge Sectors and Income Growth



Back

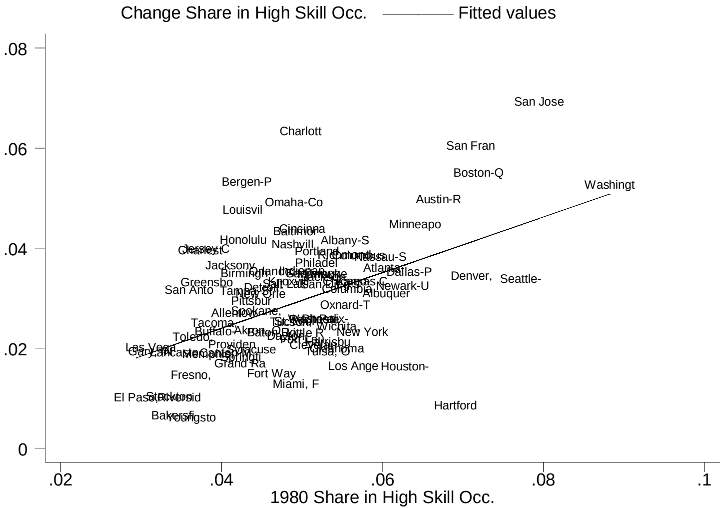
Specialization in Knowledge Sectors and City Growth

	(1)	(2)	(3)	(4)	(5)	(6)
	Change in Log Income			Change in Log Population		
Share of Workers in High Skill Occupations in 1980	5.757 (0.943)	6.684 (1.076)	3.839 (1.698)	1.437 (2.129)	6.071 (1.941)	0.564 (3.494)
Log Income 1980	-0.266 (0.101)	-0.351 (0.108)	-0.278 (0.101)	-0.21 (0.228)	-0.216 (0.195)	-0.254 (0.189)
Log Population 1980	-0.007 (0.013)	-0.003 (0.012)	-0.005 (0.013)	-0.013 (0.029)	-0.046 (0.022)	-0.044 (0.021)
Share of Population with BA in 1980			0.676 (0.499)			2.084 (1.117)
Northeast Dummy	0.062 (0.026)	0.054 (0.019)	0.054 (0.026)	-0.029 (0.058)	-0.04 (0.033)	-0.063 (0.035)
South Dummy	0.016 (0.026)		0.006 (0.027)	0.203 (0.059)		
West Dummy	0.008 (0.025)		-0.011 (0.028)	0.316 (0.056)		
Constant	2.941 (1.031)	3.729 (1.123)	3.026 (1.027)	2.431 (2.327)	2.73 (2.027)	3.045 (1.96)
R-squared	0.4173	0.6999	0.4309	0.4425	0.2631	0.338

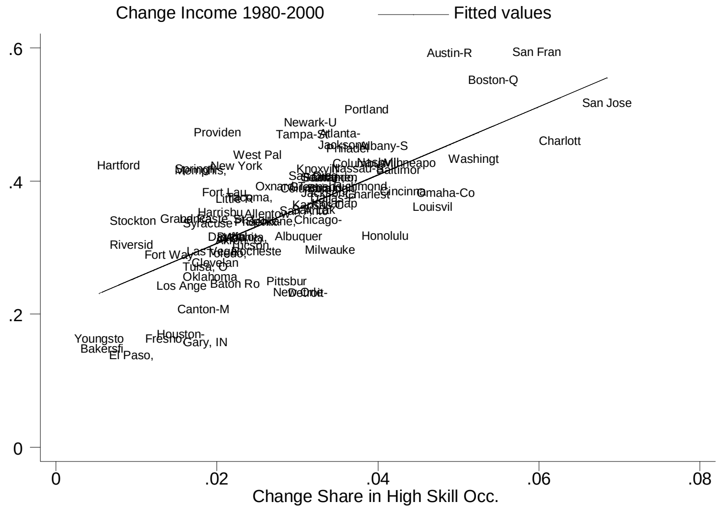
Source: U.S. Census Bureau and the Integrated Public Use Microdata Series

Back

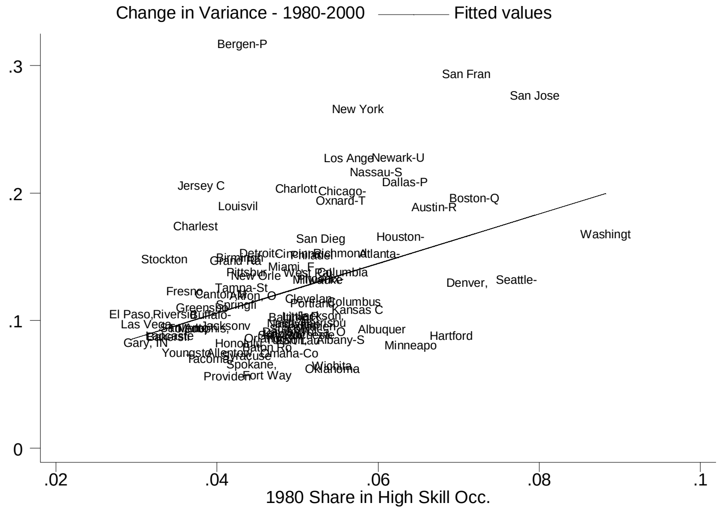
Increasing Specialization in Knowledge Sectors



Increasing Specialization in Knowledge Sectors and Growth



Specialization in Knowledge Sectors and Inequality



▸ Back

Specialization in Knowledge Sectors and Inequality

	(1)	(2)	(3)	(4)
	Change in Variance of Log Income		Change in 90/10 Income Ratio	
Share of Workers in High Skill Occupations in 1980	1.158 (0.516)	1.224 (0.941)	1.088 (0.947)	1.351 (1.729)
Variance of Log Income 1980 or 90/10 Income Ratio 1980	-0.139 (0.206)	-0.14 (0.207)	-0.455 (0.157)	-0.458 (0.159)
Log Income 1980	0.05 (0.055)	0.051 (0.056)	0.077 (0.101)	0.079 (0.103)
Log Population 1980	0.03 (0.008)	0.03 (0.008)	0.054 (0.013)	0.053 (0.014)
Share of Population with BA in 1980		-0.023 (0.276)		-0.093 (0.509)
Northeast Dummy	0.015 (0.014)	0.015 (0.014)	0.01 (0.025)	0.011 (0.026)
South Dummy	0.033 (0.016)	0.033 (0.017)	0.069 (0.030)	0.07 (0.032)
West Dummy	0.039 (0.015)	0.038 (0.017)	0.098 (0.028)	0.01 (0.032)
Constant	-0.859 (0.564)	-0.862 (0.569)	-0.842 (1.04)	-0.852 (1.05)
R-squared	0.412	0.412	0.346	0.347

Source: U.S. Census Bureau and the Integrated Public Use Microdata Series

Back

Changes in the Specialization of U.S. Cities

The diminishing sectoral specialisation and increasing functional specialisation of US cities

Local population[a]	Sectoral specialisation[b]			Functional specialisation in management against production[c] (%)			
	1977	1987	1997	1950	1970	1980	1990
5,000,000–19,397,717	0.377	0.376	0.374	+10.2	+22.1	+30.8	+39.0
1,500,000–4,999,999	0.366	0.360	0.362	+0.3	+11.0	+21.6	+25.7
500,000–1,499,999	0.397	0.390	0.382	−10.9	−7.8	−5.0	−2.1
250,000–499,999	0.409	0.389	0.376	−9.2	−9.5	−10.9	−14.2
75,000–249,999	0.467	0.442	0.410	−2.1	−7.9	−12.7	−20.7
67–75,000	0.693	0.683	0.641	−4.0	−31.7	−40.4	−49.5

Source. Authors' calculations based on data from County Business Patterns (sectoral specialisation) and Decennial Census of Population and Housing (functional specialisation).

[a] The units of analysis are Metro Areas plus those counties not included in any Metro Area. This covers the entire continental US. For Metro Areas, county-level data has been aggregated into Metropolitan Statistical Area/Consolidated Metropolitan Statistical Area outside New England and into New England County Metropolitan Area in New England using 2000 definitions. Individual Metro and Non-metro Areas have been allocated to the same population class for the entire table on the basis of population data from the Decennial Census of 2000.

[b] Mean value for each population class of a Gini index comparing the local and national distributions of employment shares across 2-digit SIC manufacturing sectors. If s_h and $\bar{s}_h$ are respectively the local and national shares of employment in sector h, the Gini specialisation index is $\frac{1}{2}\sum_h |s_h - \bar{s}_h|$. Its value is close to one if a city is fully specialised in a sector that is very small at the national level and is equal to zero if local employment is dispersed across sectors in the same way as national employment.

[c] Percentage difference from the national average in the number of executives and managers per production worker (occupied in precision production, fabrication, or assembly).

A Theory of Urban Specialization

Motivating Facts

1. Decreasing concentration of city employment by manufacturing sector
2. Increasing share of non-production employees in city employment
3. Separation of management and production within each firm

Driving Forces

1. Co-locating headquarters and production reduces management costs
   - This benefit declines as communication technology improves
2. Localization economies for headquarters from all sectors
   - All headquarters use non-tradable differentiated business services
3. Localization economies for production plants in the same sector
   - Production uses sector-specific non-tradable differentiated inputs
4. Congestion limits city size

The Duranton-Puga Model

Duranton and Puga (2005) is much like Duranton and Puga (2001)

1. Consumers have Cobb-Douglas demand for final goods from m sectors
2. Final goods from each sector
   - Produced with constant returns to scale and perfect competition
   - Cobb-Douglas aggregate of headquarter and production services
3. Headquarter services
   - Cobb-Douglas aggregate of labor and business services
   - Iceberg cost $\rho > 1$ of shipping headquarter services to a production plant
4. Production and business services
   - Dixit-Stiglitz aggregates of non-tradable differentiated varieties
   - Increasing returns and monopolistic competition with free entry

- Congestion
  - Linear city, fixed land requirement per worker, linear commute time

Spatial Equilibrium

- Perfectly mobile workers
- A continuum of perfectly competitive land developers
  - City formation maximizes the total wage bill in the city
  - The Henry George Theorem applies

Three types of cities can exist in equilibrium

1. Full specialization in headquarters and business services
2. Full specialization in production and its inputs for a single sector
3. Specialization in headquarters and production for a single sector

Intuition

1. Stand-alone stages seek separate cost-minimizing locations
2. Production plants from different sectors never co-locate
3. All firms in the same city prefer either integration or separation

Declining Communication Costs

1. If $\rho > \hat{\rho}$ all firms are integrated and cities specialize by sector
2. If $1 < \rho < \hat{\rho}$ all firms separate headquarters and production
    - Some cities specialize in headquarter and business services
    - Some cities specialize in production and in a single industry

- Headquarter cities are larger if localization economies are stronger for business services than for manufacturing intermediates
    - Cities hosting integrated firms have intermediate size
- Increasing localization economies for headquarters might also raise $\hat{\rho}$ and therefore trigger the transition on their own
    - If localization economies are much stronger for business services than for manufacturing intermediates to begin with

Theoretical Sources of Agglomeration Economies

- Location-specific advantages
  - A confound rather than a source of agglomeration economies

1. Market access and backward linkages
2. Input sharing and forward linkages
3. Labor markets
   - Pooling: Diamond and Simon (1990)
   - Matching: Costa and Kahn (2000)
4. Knowledge spillovers
   - Ideas and patents: Audretsch and Feldman (1996)
   - Human capital: Rauch (1993), Moretti (2004)
5. Consumer externalities
   - Glaeser, Kolko, and Saiz (2001)
6. Rent-seeking
   - Primate city: Ades and Glaeser (1995)

The Scope of Agglomeration Economies

All production-based sources of agglomeration economies can operate

1. At the industry level: localization economies
   - Potential to understimate by defining the industry too broadly
2. Beyond the industry level: in particular, co-localization economies
   - Industries that share suppliers, workers, ideas ...
3. At the aggregate level: urbanization economies
4. Beyond the aggregate level: gains from diversity

Further distinctions

- Geographic scope
- Temporal scope
- Industrial organization

Decomposing Geographic Concentration

Costs y_{li} of inputs $l = 1, ..., L$ in each location $i = 1, ..., N$

1. Direct approach: for each industry j, regress the employment share

$$s_{ji} = \sum_{l=1}^{L} \beta_{lj} y_{li} + u_{ji}$$

   - Across states, more resources than locations: $L \gg N$

2. Pooled estimation across sectors:

$$s_{ji} = \delta_j \sum_{l=1}^{L} \beta_l y_{li} z_{lj} + u_{ji}$$

   - δ_j is an industry-specific cost-sensitivity
   - z_{lj} is the intensity with which industry j uses input l

- Factor costs y_{li} and factor shares z_{lj} are presumably endogenous
   - Ellison and Glaeser (1999) is silent on this problem

Ellison and Glaeser (1997) to Ellison and Glaeser (1999)

- The original index of geographic concentration

$$\gamma_j \equiv \frac{G_j - H_j}{1 - H_j} \text{ for } G_j = \frac{\sum_{i=1}^{N} (s_{ji} - x_i)^2}{1 - \sum_{i=1}^{N} x_i^2}$$

  - Comparison to states' share of aggregate employment, x_i
  - Control for industrial concentration with plant-level Herfindahl index H_j
- Observed natural advantages yield a predicted share $\hat{s}_{ji}$
- Geographic concentration beyond observed natural advantage

$$\tilde{\gamma}_j \equiv \frac{\tilde{G}_j - H_j}{1 - H_j} \text{ for } \tilde{G}_j = \frac{\sum_{i=1}^{N} (s_{ji} - \hat{s}_{ji})^2}{1 - \sum_{i=1}^{N} \hat{s}_{ji}^2}$$

- Cannot distinguish spillovers and *unobserved* natural advantages

The Logit Model of Firm Location

- Plant k in industry j chooses location $v_{kj} = i$ to maximize profits

$$\log \pi_{kji} = \log \bar{\pi}_{ji} + g_{ji}\left(v_{1j}, \ldots, v_{(k-1)j}\right) + \varepsilon_{kji}$$

- In 1997, x_i was the only observable predictor of $\bar{\pi}_{ji}$ for all j
- Instead in 1999 input costs are additional predictors

$$\log \bar{\pi}_{ji} = \alpha_0 \log n_i + \alpha_1 \log x_i - \delta_j \sum_{l=1}^{L} \beta_l y_{li} z_{lj} + \eta_{ji}$$

  - n_i is the state's share of total U.S. population

- The state-industry shock η_{ji} is well behaved

  1. It has a χ^2 distribution
  2. It does not shift averages: $\mathbb{E}\left(e^{\eta_{ji}}\right) = 1$
  3. Its variance is parametrized by γ^{na}

Expected Employment Shares

- Observed input costs yield the prediction

$$\mathbb{E}\left(s_{ji}\right)=\frac{n_i^{\alpha_0}x_i^{\alpha_1}\exp\left(-\delta_j\sum_{l=1}^{L}\beta_l y_{li}z_{lj}\right)}{\sum_{h=1}^{N}n_h^{\alpha_0}x_h^{\alpha_1}\exp\left(-\delta_j\sum_{l=1}^{L}\beta_l y_{lh}z_{lj}\right)}$$

- This could be estimated by maximum likelihood
  - In fact, you could do ML for the conditional logit model at the plant level
- Ellison and Glaeser (1999) choose nonlinear least squares
- Standardized variables on the right-hand side

Natural Advantages and State-Industry Employment

A. State variable × industry variable	Coefficient (t statistic)		
(a) Electricity price × electricity use	0.170 (17.62)	(i) Average mfg wage × import competition	0.036 (3.10)
(b) Natural gas price × natural gas use	0.117 (6.91)	(j) Percentage without HS degree × percentage unskilled	0.157 (7.38)
(c) Coal price × coal use	0.119 (4.55)	(k) Unionization percentage × percentage precision products	0.100 (12.17)
(d) Percentage farmland × agricultural inputs	0.026 (2.58)	(l) Percentage with B.A. or more × percentage executive/professional	0.170 (12.70)
(e) Per capita cattle × livestock inputs	0.053 (5.08)	(m) Coast dummy × heavy exports	−0.031 (−2.20)
(f) Percentage timberland × lumber inputs	0.152 (11.98)	(n) Coast dummy × heavy imports	0.017 (0.92)
(g) Average mfg wage × wages/value added	0.059 (4.11)	(o) Population density × percentage to consumers	0.043 (3.68)
(h) Average mfg wage × exports/output	−0.014 (−1.28)	(p) (Income share − mfg share) × percentage to consumers	0.025 (4.49)

Do Natural Advantages Explain Agglomeration?

- Compare geographic concentration γ_j with residual concentration $\tilde{\gamma}_j$

Model	Mean $\tilde{\gamma}$	Percentage of industries with $\tilde{\gamma}$ in range				
		<0.0	0.00–0.02	0.02–0.05	0.05–0.10	>0.1
A	0.051	2.8	39.9	29.2	15.3	12.8
B	0.048	3.9	39.9	30.1	13.7	12.4
C	0.045	3.1	42.9	29.4	13.5	11.1
D	0.041	4.4	42.9	29.8	13.3	9.6

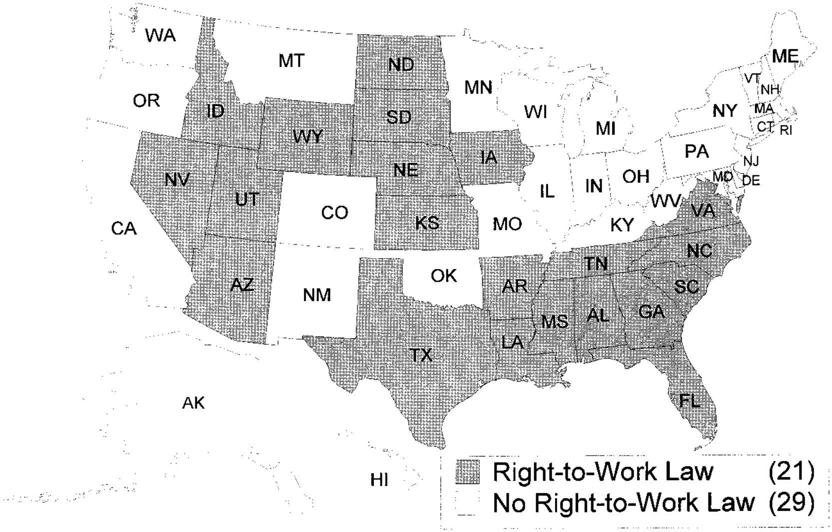
Notes: Models A–D are different models of natural advantage: (A) no cost variables; (B) cost interactions introduced; (C) cost interactions plus dummies for two-digit industries; (D) cost interactions plus dummies for three-digit industries.

- 20% of concentration is explained by observed "natural advantages"
  - Ellison and Glaeser conjecture 50% is explained by all first-nature forces
- Industry localization, but nothing on overall urbanization economies

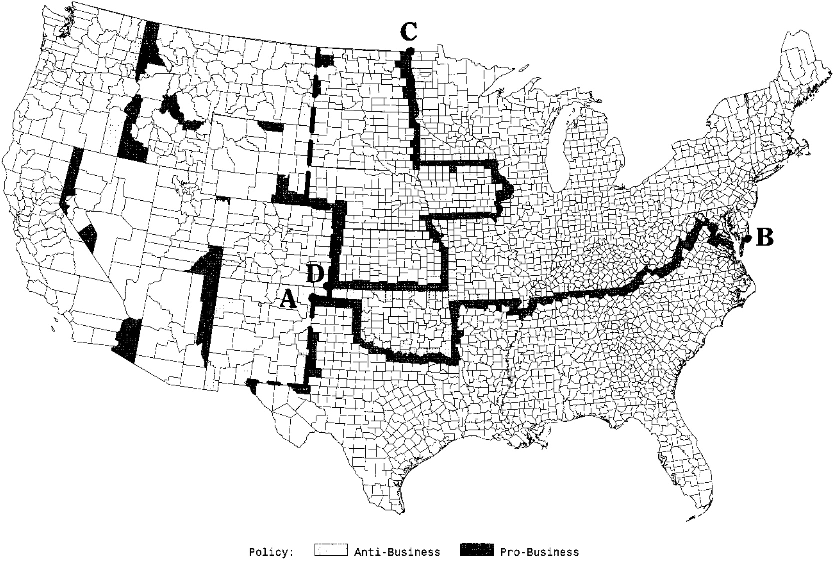
Border Effects

- Ellison and Glaeser (1999) cannot do anything about endogeneity
- Holmes (1999) looks at state labor laws
  - Right-to-work laws forbid requiring all workers in a plant to join a union
  - More attractive for manufacturing than other sectors
- "Natural advantage" in the same manner as low wages
- Far from exogenous at the state level
  - Rise of the sun belt: trucking, air conditioning, politics, ...
- Only state policies vary discontinuously across state borders
  - Even politics is more continuous, because so are voters' attitudes
  - Policy package, not right-to-work laws per se

Geography of Right-to-Work Laws



Counties within 25 Miles of the Policy Border



Discontinuity at the Policy Border

MANUFACTURING EMPLOYMENT SHARES AND GROWTH RATES: CROSS-COUNTY AVERAGES BY DISTANCE FROM BORDER AND SIDE OF BORDER

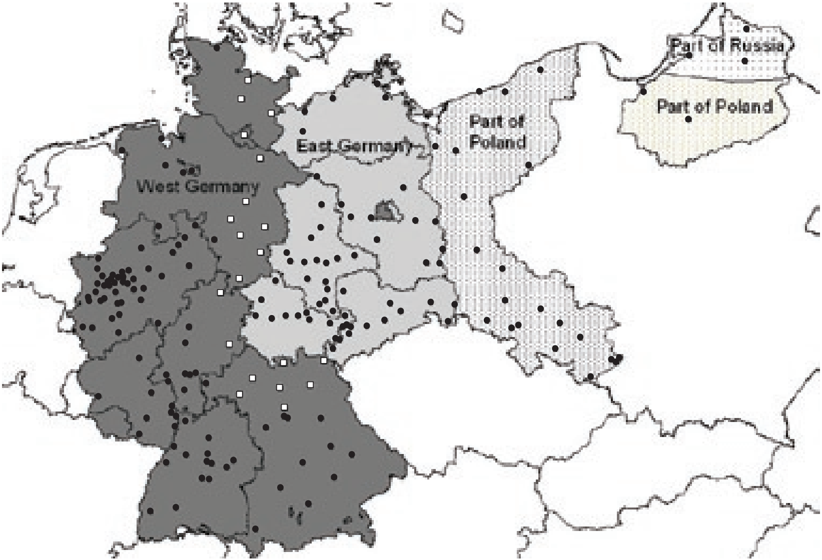
Miles from Border	Coal Region Included: Share of 1992 Total (1)	Coal Region Included: Growth Rate, 1947–92 (2)	Coal Region Excluded: Share of 1992 Total (3)	Coal Region Excluded: Growth Rate, 1947–92 (4)
	A. Antibusiness Side of Border			
75–100	25.9	67.5	25.0	68.2
50–75	23.1	62.7	25.0	80.9
25–50	23.2	82.0	24.7	88.8
0–25	21.0	62.4	22.1	77.2
	B. Probusiness Side of Border			
0–25	28.6	100.7	27.9	104.2
25–50	26.7	89.1	25.5	88.3
50–75	26.7	92.9	24.5	90.1
75–100	25.4	91.8	23.1	93.5

The Cost of Remoteness

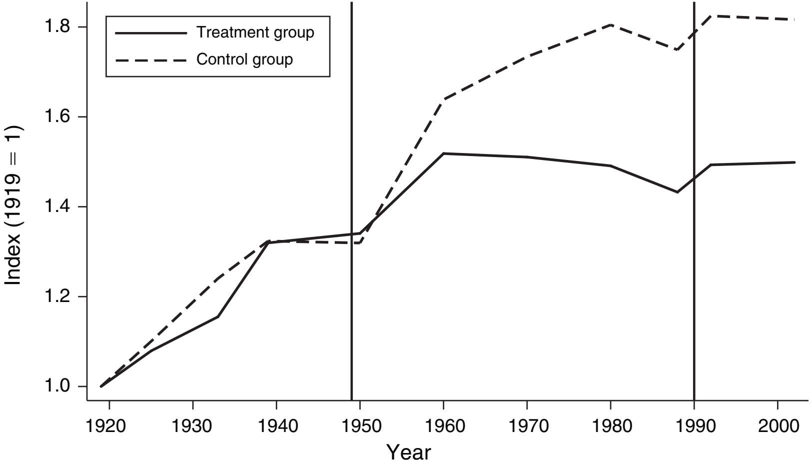
- New Economic Geography: a large home market attracts producers
- Is there more employment where there are more consumers?
- Identification problem: production workers are consumers too
- Redding and Sturm (2008) study the East-West German border
- Division in 1949 and reunification in 1990 are exogenous shocks to market access for 20 West German cities within 75 km of the border
- Baseline empirical specification

$$Popgrowth_{ct} = \beta Border_c + \gamma \left(Border_c \times Division_t \right) + d_t + \varepsilon_{ct}$$

Division of Germany After World War II



Evolution of Treatment and Control City Population



Impact of Division

	Population growth				
	(1)	(2)	(3)	(4)	(5)
Border × division	−0.746*** (0.182)			−1.097*** (0.260)	−0.384 (0.252)
Border × year 1950–60		−1.249*** (0.348)			
Border × year 1960–70		−0.699** (0.283)			
Border × year 1970–80		−0.640* (0.355)			
Border × year 1980–88		−0.397*** (0.147)			
Border	0.129 (0.139)	0.129 (0.139)		0.233 (0.215)	−0.009 (0.148)
Year effects	Yes	Yes	Yes	Yes	Yes
City sample	All cities	All cities	All cities	Small cities	Large cities
Observations	833	833	833	420	413
R^2	0.21	0.21	0.21	0.23	0.30

Notes: Data are a panel of 119 West German cities. The left-hand-side variable is the annualized rate of growth of city-population, expressed as a percentage. Population growth rates are for 1919–1925, 1925–1933, 1933–1939, 1950–1960, 1960–1970, 1970–1980, and 1980–1988. Border is a dummy which is zero unless a city lies within 75 kilometers of the East-West German border, in which case it takes the value one. Division is a dummy which is zero, except for the

Geographic Scope of Market Access

	Population growth				
	(1)	(2)	(3)	(4)	(5)
Border 0–25km × division			−0.702*** (0.257)		
Border 25–50km × division			−0.783*** (0.189)		
Border 50–75km × division			−0.620* (0.374)		
Border 75–100km × division			0.399 (0.341)		
Border 0–25km			−0.110 (0.185)		
Border 25–50km			0.144 (0.170)		
Border 50–75km			0.289 (0.272)		
Border 75–100km			−0.299* (0.160)		
Border	0.129 (0.139)	0.129 (0.139)		0.233 (0.215)	−0.009 (0.148)
Year effects	Yes	Yes	Yes	Yes	Yes
City sample	All cities	All cities	All cities	Small cities	Large cities
Observations	833	833	833	420	413
R^2	0.21	0.21	0.21	0.23	0.30

Robustness of the Market Access Treatment

1. Treatment cities could have specialized in declining industries
   - Match city pairs by industry breakdown
2. Treatment cities could has suffered differently from the war
   - Control for rubble per capita, share of housing destroyed, refugees
3. Increasing integration with the West could help control cities
   - Control for a Western border dummy
4. Treatment cities could have been more threatened in the Cold War
   - Control for the presumed Warsaw Pact attack route

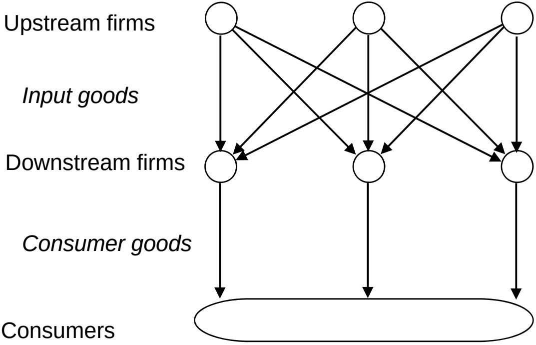
The Fall of the Iron Curtain

- Redding and Sturm (2008) do not find much after 1990
- Brülhart, Carrère, and Trionfetti (2010) look at Austria
- Opening of Czech, Hungarian, Slovakian, and Slovenian borders
- Significant positive effect on both employment and wage growth
  - 2,305 municipalities within 25 km of the borders
  - Social security data on all working-age Austrians
  - Time and municipality fixed effects for growth rates
  - Nonparametric estimation of the geographic scope

Outsourcing in Industry Clusters

Theory: localization promotes vertical disintegration

- Outsourcing is more attractive when there are more potential suppliers
- Supplier density increases with industry agglomeration



Localization and Vertical Disintegration

- Vertical disintegration: purchased-inputs intensity
  - Value of purchased inputs relative to total sales
  - Not made available by the Census at the plant level
  - Use the finest geographic disaggregation available for each industry
- Density of employment in the same industry
  - Employment measured at the plant level
  - For each plant, compute employment in other plants within 50 miles
    - By county rather than a true circle, due to data availability
  - Aggregate from the plant to the area level, weighing by employment
- The Longitudinal Business Database now provides the plant-level data
  - It remains confidential, so you need to be authorized to use it

Descriptive Results

TABLE 2.—PURCHASED-INPUTS INTENSITY FOR LOCALIZED INDUSTRIES

	Four-Digit Industry	Center	Center Share of Employees (%)	Purchased-Inputs Intensity (%)	
				Center	Rest of U.S.
2371	Fur Goods	New York	77	71	60
2084	Wines, Brandy, Brandy Spirits	California	78	58	54
2252	Hosiery, n.e.c.	North Carolina	66	**52**	**52**
3533	Oil Field Machinery	Texas	66	47	42
2251	Women's Hosiery Except Socks	North Carolina	62	53	40
2273	Carpets and Rugs	Georgia	62	73	62
2429	Special Product Sawmills, n.e.c.	Washington	59	59	55
3961	Costume Jewelry	Rhode Island	54	40	36
2895	Carbon Black	Texas	39	56	53
2874	Phosphatic Fertilizers	Florida	54	**68**	**70**
2061	Raw Cane Sugar	Hawaii	32	**46**	**71**
2281	Yarn Spinning Mills	North Carolina	49	**58**	**61**
2034	Dehydrated Fruits	California	59	57	41
2083	Malt	Wisconsin	43	69	69
2221	Weaving Mills, Synthetics	South Carolina	41	57	55
2284	Thread Mills	North Carolina	46	65	60
2282	Throwing and Winding Mills	North Carolina	40	79	68
2257	Circular Knit Fabric Mills	North Carolina	44	65	57
2262	Finishing Plants Synthetics	South Carolina	39	76	70
2044	Rice Milling	Arkansas	29	85	61
2022	Cheese, Natural and Processed	Wisconsin	35	83	78
2512	Upholstered Household Furn.	North Carolina	34	51	50
3711	Motor Vehicles and Car Bodies	Michigan	37	74	73
2261	Finishing Plants, Cotton	North Carolina	19	**57**	**57**
3743	Railroad Equipment	Pennsylvania	39	**42**	**56**
2258	Lace and Warp Knit Fabric Mills	North Carolina	33	60	59
	Mean Values			59.6	56.6

Regression Results

TABLE 3.—PURCHASED-INPUTS INTENSITY AND NEIGHBORING EMPLOYMENT COEFFICIENT ESTIMATES FOR REGRESSION MODELS (NEIGHBORING EMPLOYMENT IN 1,000S)

Estimated Coefficients for Linear and Cubic Models

	Own-Industry			Related-Industry			Other-Manufacturing			
Model	Level (1,000)	Level Squared	Level Cubed	Level (1,000)	Level Squared	Level Cubed	Level (1,000)	Level Squared	Level Cubed	R^2
1	0.04	—	—	—	—	—	—	—	—	0.001
	(0.01)									
2	0.04	—	—	0.000	—	—	—	—	—	0.001
	(0.02)			(0.003)						
3	0.05	—	—	0.009	—	—	−0.0013	—	—	0.002
	(0.02)			(0.004)			(0.0004)			
4	0.35	−0.013	0.00012	−0.054	0.0009	−3.0E-6	0.0025	−1.4E-5	1.0E-8	0.006
	(0.07)	(0.003)	(0.00004)	(0.023)	(0.0003)	(1.2E-6)	(0.0032)	(0.7E-5)	(0.4E-8)	

Estimated Coefficients for Size-Class Model

	Own-Industry					Related-Industry					Other-Manufacturing					
Model	0–0.5	0.5–2.5	2.5–10	10–25	25+	0–2.5	2.5–10	10–25	25–100	100+	0–10	10–25	25–100	100–500	500+	R^2
5	x	0.6	0.2	1.4	2.0	—	—	—	—	—	—	—	—	—	—	0.003
		(0.2)	(0.3)	(0.4)	(0.6)											
6	x	1.2	1.4	3.1	3.7	x	0.8	0.8	0.1	1.0	x	1.8	0.9	−0.2	−1.0	0.009
		(0.3)	(0.4)	(0.6)	(0.8)		(0.4)	(0.5)	(0.6)	(0.7)		(0.9)	(0.6)	(0.7)	(0.7)	

Interpreting Holmes's (1999) Findings

- Link between localization and vertical disintegration
  - Correlation without proof of causality
- Is this a source of localization economies?
  - The theory suggests that localization helps outsourcing
  - No reason why localization would hinder vertical integration
  - Yet, no direct evidence of localization economies
- A problematic measure of vertical integration
  - The opposite of value added over revenues
  - Clusters could specialize in higher-quality varieties
- Systematic differences across industries in the same chain
  - Car parts plants are heavily concentrated in Michigan
  - Car assembly plants are spread throughout the U.S.
  - PII is mechanically higher for downstream assembly plants

Evidence from Coagglomeration Patterns

- Ellison, Glaeser, and Kerr (2010): lastest instalment in the industry-concentration series
- Coagglomeration index from Ellison and Glaeser (1997)

$$\gamma_{ij} = \frac{\sum_{c=1}^{N} \left(s_{ic} - x_c\right) \left(s_{jc} - x_c\right)}{1 - \sum_{c=1}^{N} x_c^2}$$

  - Plant-level Herfindahl indices do not matter for coagglomeration
  - Compute the index at the state, MSA, and county level
- Approximation to Duranton and Overman's (2005) measure
  - Plant location is approximated by county in U.S. Census data
  - Replace populations with random sub-samples to save computing power

Highest Pairwise Coagglomerations

Rank	Industry 1	Industry 2	Coagglomeration
Panel A. EG index using 1987 state total employments			
1	Broadwoven mills, cotton (221)	Yarn and thread mills (228)	0.207
2	Knitting mills (225)	Yarn and thread mills (228)	0.187
3	Broadwoven mills, fiber (222)	Textile finishing (226)	0.178
4	Broadwoven mills, cotton (221)	Broadwoven mills, fiber (222)	0.171
5	Broadwoven mills, fiber (222)	Yarn and thread mills (228)	0.164
6	Handbags (317)	Photographic equipment (386)	0.155
7	Broadwoven mills, wool (223)	Carpets and rugs (227)	0.149
8	Carpets and rugs (227)	Yarn and thread mills (228)	0.142
9	Photographic equipment (386)	Jewelry, silverware, plated ware (391)	0.139
10	Textile finishing (226)	Yarn and thread mills (228)	0.138
11	Broadwoven mills, cotton (221)	Textile finishing (226)	0.137
12	Broadwoven mills, cotton (221)	Carpets and rugs (227)	0.137
13	Broadwoven mills, cotton (221)	Knitting mills (225)	0.136
14	Carpets and rugs (227)	Pulp mills (261)	0.110
15	Jewelry, silverware, plated ware (391)	Costume jewelry and notions (396)	0.107
Panel B. DO index using 1997 firm employments, 250 mi. threshold			
1	Broadwoven mills, fiber (222)	Yarn and thread mills (228)	0.283
2	Carpets and rugs (227)	Yarn and thread mills (228)	0.262
3	Broadwoven mills, fiber (222)	Carpets and rugs (227)	0.226
4	Broadwoven mills, cotton (221)	Yarn and thread mills (228)	0.219
5	Broadwoven mills, cotton (221)	Carpets and rugs (227)	0.218

Why Do Firms Agglomerate?

Goods: Proximity to customers and suppliers

- Share of i's inputs that come from j: $Input_{i \leftarrow j}$
- Share of i's output sold to j: $Output_{i \rightarrow j}$
- Define $InputOutput_{ij} = \max\left\{Input_{i \leftarrow j}, Output_{i \rightarrow j}\right\}$

People: Labor market pooling

- Correlation between the shares of i's and j's employment in each occupation: $LaborCorrelation_{ij}$

Ideas: Intellectual or technology spillovers

- i's benefits from j's R&D spending: $TechIn_{i \leftarrow j}$
- i's R&D spending benefiting j: $TechOut_{i \rightarrow j}$
- Define $Tech_{ij} = \max\left\{TechIn_{i \leftarrow j}, TechOut_{i \rightarrow j}\right\}$
  - Share of i's patents citing j's: $PatentIn_{i \leftarrow j}$
  - Share of i's patents cited by j's: $PatentOut_{i \rightarrow j}$
  - Define $Patent_{ij} = \max\left\{PatentIn_{i \leftarrow j}, PatentOut_{i \rightarrow j}\right\}$

Why Do Firms Agglomerate?

Confound: Natural advantages

- Natural advantages as in Ellison and Glaeser (1999)
- Predicted coagglomeration:

$$Coagg_{ij}^{NA} = \frac{\sum_{c=1}^{N} \left(\hat{s}_{ic} - x_c\right)\left(\hat{s}_{jc} - x_c\right)}{1 - \sum_{c=1}^{N} x_c^2}$$

- Bottom line
  - All sources of agglomeration matter
  - Natural advantages are the single most important force
  - Agglomeration economies matter more than natural advantages
  - Technology spillovers (as measured) are weakest

OLS Multivariate Specification

	EG coaggl. index with state total emp.				DO coaggl. index, 250 mi.			
	Base estimation	Exclude natural advantages	Separate input & output	Exclude pairs in same SIC2	Base estimation	Exclude natural advantages	Separate input & output	Exclude pairs in same SIC2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Natural advantages	0.163		0.162	0.172	0.251		0.252	0.253
[DV specific]	(0.017)		(0.017)	(0.016)	(0.012)		(0.012)	(0.013)
Labor correlation	0.118	0.146	0.114	0.085	0.069	0.098	0.066	0.029
	(0.011)	(0.012)	(0.011)	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)
Input-output	0.146	0.149		0.110	0.162	0.150		0.177
	(0.032)	(0.032)		(0.022)	(0.035)	(0.035)		(0.032)
Input			0.106				0.097	
			(0.029)				(0.029)	
Output			0.093				0.107	
			(0.039)				(0.038)	
Technology flows	0.096	0.112	0.079	0.046	0.076	0.075	0.065	0.033
Scherer R&D	(0.035)	(0.035)	(0.035)	(0.019)	(0.033)	(0.034)	(0.032)	(0.020)
R^2	0.103	0.077	0.110	0.059	0.113	0.051	0.117	0.102
Observations	7,381	7,381	7,381	7,000	7,381	7,381	7,381	7,000

Notes: See Table 3. Regressions of pairwise coagglomeration on determinants of industrial co-location. Columns 4 and 8 exclude SIC3 pairwise combinations within the same SIC2. Online Appendix Table 6 provides additional robustness checks. Variables are transformed to have unit standard deviation for interpretation. Bootstrapped standard errors are reported in parentheses.

Identification Problems

- Co-location could cause industrial relationships rather than viceversa
  - Industries that happen to be close share inputs, workers, and technology
- The right-hand side variables are endogenous
  - Controlling for observed natural advantages is not enough

1. Instrument with UK industry linkages
   - Insufficient UK data to instrument for technology spillovers
   - What if coagglomeration patterns are similar in the two countries?
2. Instrument with industry linkages of specific US plants
   - Plants in industry i located where industry j is rare
   - No plant-level data on technology spillovers
   - What if technology evolves at the industry rather than plant level?

IV Specifications

	EG coaggl. index with state total emp.			DO coaggl. index, 250 mi.		
	Base OLS	UK IV	US spatial IV	Base OLS	UK IV	US spatial IV
	(1)	(2)	(3)	(4)	(5)	(6)
Natural advantages	0.173	0.173	0.171	0.254	0.210	0.233
[DV specific]	(0.016)	(0.019)	(0.016)	(0.013)	(0.016)	(0.012)
Labor correlation	0.083	0.079	0.091	0.027	0.501	0.248
	(0.012)	(0.060)	(0.023)	(0.012)	(0.060)	(0.023)
Input-output	0.122	0.191	0.185	0.186	0.164	0.213
	(0.023)	(0.048)	(0.036)	(0.031)	(0.054)	(0.049)
Observations	7,000	7,000	7,000	7,000	7,000	7,000

Notes: See Table 3. OLS and IV regressions of pairwise coagglomeration on determinants of industrial co-location. All estimations exclude SIC3 pairwise combinations within the same SIC2. Online Appendix Tables 7 and 8 report first stages and additional robustness checks. Variables are transformed to have unit standard deviation for interpretation. Bootstrapped standard errors are reported in parentheses.