The Wealth Of Cities: Agglomeration Economies and Spatial Equilibrium in the US

Spatial Economics Reading Group, MIT

Glaeser and Gottlieb, JEL (2009)   Presentation by Joaquin Blaum

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Main issues in Urban Economics

- Much research has focused on cross-country differences in wealth and growth. Yet, within-country differences in income and productivity are also substantial:
  - Avg. per capita income in San Francisco in 2007: 60,000 dollars
  - Avg. per capita income in Brownsville, Texas in 2007: $<$20,000 dollars
- Also: big differences in population density across space, within countries:
  - 68% of Americans occupy only 1.8% of the land of the country
- Central question in urban economics: Why do cities exist?
- This requires answering: Why are dense areas so much more productive?
- Central theoretical tool: **spatial equilibrium model**
  - treats city income, population density and housing prices as endogenous
  - assumes that welfare is equalized across space

This paper

- Long survey of recent research on urban economics
- Sketch **Spatial Equilibrium model** (Rosen (1979), Roback (1982)). Writen to guide interpretation of empirical work.
    - Study how productivity, housing supply and amenities determine city population, wages and prices.
    - Application: rise of Sunbelt cities
- **Agglomeration economies and existence of cities**.
    - Why do cities exist?
        - Innate advantages vs. agglomeration economies
        - amenities vs. housing supply vs. *productivity*
    - Add agglomeration in productivity to spatial eq. model
    - Estimation of agglomeration economies: the IV approach in light of the model
    - What causes agglomeration economies?

Metropolitan Income Heterogeinity

- Gaps between poor and rich areas within the US can be of up to 100%
- Productivity is strongly correlated with city size (see Figure 1)
- Are these productivity differences temporary?
- On the one hand, there has been some convergence since 1960s. (Initially) Poorer cities have tended to grow faster. However, initially richer areas did not exhibit subsequent higher population growth.
- Incomes are converging, but not because people are disproportionaly moving to high wage areas
- On the other hand, over 30 years rich places have stayed rich and poor places have stayed poor. The correlation between log income per capita in 1970 and income per capita in 2000 is 0.77. (Figure 2)
- This continuing income disparity motivates the notion of a **spatial equilibrium**, where differences in per capita income and prices can persist for many decades.

Spatial Equilibrium Model, overview

- Fundamental assumption: **free migration of workers**. Over 40% of Americans change homes and around 20% change counties every 5 years.
- Exogenous variables: differences across space in productivity, amenities, and the construction sector.
- Endogenous variables: area population, wages and (home) prices.
- The core indredients:
    1. Workers are indifferent between locations $\rightarrow$ labor supply
    2. Firms are indifferent about hiring more workers$\rightarrow$ labor demand
    3. Builders are indifferent about supplying more housing$\rightarrow$housing supply

Spatial Equilibrium Model, overview (continued)

- Implication: welfare levels are equalized across space. High incomes are off-set by negative urban attributes (high prices, low amenities)
- **Issue**: evidence shows that migration reacts slowly to local shocks. This does not imply, however, that the spatial equlibrium holds only over long periods. As long as housing prices react quickly, welfare can be constantly equalized.
- Empirical question: do housing costs move enough to equalize utility levels across space? Glaeser and Gyourko (2007) can't reject that welfare levels are equalized across space (due to measurement problems, as there is too much housing price volatility relative to volatility in local incomes)

Spatial Equilibrium Framework

- There are a number of cities (indexed by i), 2 sectors (traded and non-traded goods) and 2 factors (labor and capital)
  - Capital is a compound of two types of capital: traded and non-traded capital.
  - Labor is mobile across sectors and cities.Traded capital is mobile across sectors and cities. Non-traded capital is city and sector specific.
- **Traded sector**

$$A_t^i F\left(K_T, K_N, L\right) = A_t^i K_{TN}^{\alpha\gamma} K_{TT}^{\alpha(1-\gamma)} L_T^{1-\alpha}$$

  where A_t^i is city-specific productivity, K_{TT} is traded capital (with nationwide, exogenous price r_T) and K_{TN} is non-traded capital (which is sector and city specific, with local, endogenous price r_N)
- There is a fixed stock of non-traded capital of $\bar{K}_{TN}$ in each city.
- Firm FOCs wrt L_T and K_T imply

$$\varphi A_t^i \bar{K}_{TN}^{\alpha\gamma} L_T^{-\alpha\gamma} = W^{1-\alpha(1-\gamma)} \text{ , where } \varphi \text{ is some constant}$$

- Higher city wages reflect either: higher productivity or fewer workers.

- **Non-traded sector** (housing):

$$H_t^i F_N\left(Z_N, K_{NT}, L_N\right) = H_t^i \bar{Z}_N^{\mu\eta} K_{NT}^{\mu(1-\eta)} L_N^{(1-\mu)}$$

  where Z_N is non-traded capital specific to the non-traded sector (land).
- FOCs wrt K_{NT} and L_N imply that output in N is

$$\left(\left(P_t^i\right)^{1-\eta\mu} H_t^i W^{\mu-1}\right)^{\frac{1}{\mu\eta}} \bar{Z}_N$$

- **Preferences**:

$$U\left(G_T, G_N, \theta_t^i\right) = \theta_t^i G_T^{\beta} G_N^{1-\beta}$$

  where G_T is consumption of traded goods, G_N is consumption of non-traded goods (housing), and θ_t^i represents local amenities.
- Indirect utility function:

$$V\left(W_t^i, P_t^i, \theta_t^i\right) = c\theta_t^i W_t^i \left(P_t^i\right)^{\beta-1}$$

  where W_t^i is income, and P_t^i is the relative price of non-traded goods, and $c \equiv \beta^{\beta}\left(1-\beta\right)^{(1-\beta)}$ is a constant. (Budget constraint: $G_T + P_t^i G_N = W_t^i$)

- Static model: utility is constant across space
- Dynamic model: lifetime utility is equalized across space. But, if migration is sufficiently cheap, also utility flows are equalized.
- Thus, high income levels are offset by high price prices

$$V_W\left(W_t^i, P_t^i, \theta_t^i\right) dW_t^i + V_P\left(W_t^i, P_t^i, \theta_t^i\right) dP_t^i = 0 \Leftrightarrow dW_t^i = -\frac{V_P}{V_W} dP_t^i$$

- **Definition**. Given $\left\{\theta_t^i, A_t^i, H_t^i\right\}$, and $\bar{Z}_N, \bar{K}_N$ and N (total labor in the country), a spatial equilibrium is $\left\{N_t^i, W_t^i, P_t^i\right\}$ such that
  1. $L_{Tt}^i\left(W_t^i\right) + L_{Nt}^i\left(W_t^i, P_t^i\right) = N_t^i$ (city labor market)
  2. $\left(P_t^{i(1-\eta\mu)} H_t^i W_t^{i(\mu-1)}\right)^{\frac{1}{\mu\eta}} \bar{Z}_N = (1-\beta) W_t^i / P_t^i$ (housing market)
  3. $V\left(W_t^i, P_t^i, \theta_t^i\right) = c\theta_t^i W_t^i \left(P_t^i\right)^{\beta-1} = U_t$, $\forall i$ (workers mobility)
  4. $\sum_i N_i = N$ (aggregate labor clearing condition)

Solution to the model

$$
\begin{aligned}
\log\left(N_t^i\right) &= \kappa_N + \lambda_A^N \log\left(A_t^i \bar{K}_N^{\alpha\gamma}\right) + \lambda_H^N \log\left(H_t^i \bar{Z}_N^{\mu\eta}\right) + \lambda_\theta^N \log\left(\theta_t^i\right) \quad (1)\\
\log\left(W_t^i\right) &= \kappa_W + \lambda_A^W \log\left(A_t^i \bar{K}_N^{\alpha\gamma}\right) + \lambda_H^W \log\left(H_t^i \bar{Z}_N^{\mu\eta}\right) + \lambda_\theta^W \log\left(\theta_t^i\right) \quad (2)\\
\log\left(P_t^i\right) &= \kappa_P + \lambda_A^P \log\left(A_t^i \bar{K}_N^{\alpha\gamma}\right) + \lambda_H^P \log\left(H_t^i \bar{Z}_N^{\mu\eta}\right) + \lambda_\theta^P \log\left(\theta_t^i\right) \quad (3)
\end{aligned}
$$

- Comparative Statics:
  - An increase in A_t^i increases N_i^t, W_t^i and P_t^i
  - An increase in H_t^i increases N_t^i and decreases W_t^i and P_t^i
  - An increase in θ_t^i increases N_i^t and decreases W_t^i and P_t^i
- Consider an exogenous variable X_t^i that affects productivity in both sectors, as well as amenities:

$$
\frac{\partial}{\partial X_t^i} \log\left(A_t^i \bar{K}_N^{\alpha\gamma}\right) = \delta_A, \frac{\partial}{\partial X_t^i} \log\left(H_t^i \bar{Z}_N^{\mu\eta}\right) = \delta_H, \frac{\partial}{\partial X_t^i} \log\left(\theta_t^i\right) = \delta_\theta
$$

- Let $\hat{b}_N$, $\hat{b}_W$ and $\hat{b}_P$ be coefficients from regressions of population, wages and prices on X_t^i. Then, linear combinations of $\hat{b}_N$, $\hat{b}_W$ and $\hat{b}_P$ will provide unbiased estimates of δ_A, δ_H and δ_θ.

$$\begin{aligned}
\hat{b}_N &\approx \frac{\partial}{\partial X_t^i} \log\left(N_t^i\right) = \lambda_A^N \delta_A + \lambda_H^N \delta_H + \lambda_\theta^N \delta_\theta \\
\hat{b}_W &\approx \frac{\partial}{\partial X_t^i} \log\left(W_t^i\right) = \lambda_A^W \delta_A + \lambda_H^W \delta_H + \lambda_\theta^W \delta_\theta \\
\hat{b}_P &\approx \frac{\partial}{\partial X_t^i} \log\left(P_t^i\right) = \lambda_A^P \delta_A + \lambda_H^P \delta_H + \lambda_\theta^P \delta_\theta
\end{aligned}$$

- Thus:

$$\begin{aligned}
\delta_\theta &= (1-\beta)\,\hat{b}_P - \hat{b}_W \\
\delta_A &= \alpha\gamma\hat{b}_N + (1-\alpha(1-\gamma))\,\hat{b}_W \\
\delta_H &= \mu\eta\hat{b}_N + (1-\mu+\mu\eta)\,\hat{b}_W - \hat{b}_P
\end{aligned}$$

- Parameters: housing exp. $1-\beta = 0.3$, capital share $\alpha = 1/3$, share of non-traded capital $\alpha\gamma = 0.1$

Dynamic model

First differencing equations (1),(2) and (3)

$$
\begin{aligned}
\log\left(N_{t+1}^i / N_t^i\right) &= \kappa_{\Delta N} + \lambda_A^N \log\left(A_{t+1}^i / A_t^i\right) + \lambda_H^N \log\left(H_{t+1}^i / H_t^i\right) + \lambda_\theta^N \log \\
\log\left(W_{t+1}^i / W_t^i\right) &= \kappa_{\Delta W} + \lambda_A^W \log\left(A_{t+1}^i / A_t^i\right) + \lambda_H^W \log\left(H_{t+1}^i / H_t^i\right) + \lambda_\theta^W \\
\log\left(P_{t+1}^i / P_t^i\right) &= \kappa_{\Delta P} + \lambda_A^P \log\left(A_{t+1}^i / A_t^i\right) + \lambda_H^P \log\left(H_{t+1}^i / H_t^i\right) + \lambda_\theta^P \log
\end{aligned}
$$

$$
\frac{\partial}{\partial X_t^i} \log\left(\frac{A_{t+1}^i}{A_t^i}\right) = \Delta_A, \frac{\partial}{\partial X_t^i} \log\left(\frac{H_{t+1}^i}{H_t^i}\right) = \Delta_H, \frac{\partial}{\partial X_t^i} \log\left(\frac{\theta_{t+1}^i}{\theta_t^i}\right) = \Delta_\theta
$$

$\hat{b}_{\Delta N}, \hat{b}_{\Delta W}, \hat{b}_{\Delta P}$ are estimated coefficients from population change, income change and non-traded goods price change regressions

$$
\begin{aligned}
\Delta_\theta &= (1-\beta)\,\hat{b}_{\Delta P} - \hat{b}_{\Delta W} \\
\Delta_A &= \alpha\gamma\hat{b}_{\Delta N} + (1-\alpha(1-\gamma))\,\hat{b}_{\Delta W} \\
\Delta_H &= un\hat{b}_{\Delta N} + (1-u+un)\,\hat{b}_{\Delta W} - \hat{b}_{\Delta P}
\end{aligned}
$$

Application: The Rise of Sunbelt Cities, I

- One the most striking trends in regional economics in last 50 years
- Fastest growing metropolitan areas of last 6 years: Atlanta, Dallas, Houston, Phoenix.
- January temperature positively correlates with metropolitan area population, and its growth rate:

$$\begin{aligned}\log(\text{Pop. } 2000) &= \underset{(0.2)}{12.2} + \underset{(0.005)}{0.017} * \text{Avg Jan Temp} \\ \log(\text{Pop. } 2000/\text{Pop. } 1990) &= \underset{(0.14)}{0.016} + \underset{(0.0004)}{0.003} * \text{Avg Jan Temp}\end{aligned}$$

- Different hypothesis:
  - Capital accumulation and structural transformation in South. Also: improvements in Southern political institutions. In model, increases in productivity variables (particularly non-traded). Barro and Sala-i-Martin 91, Caselli and Coleman 01.
  - Improvement in consumption amenities in the South. Technological changes (such as AC) that are complements to warmth.
  - Local policies that support construction of housing (Glaeser and Tobio, 2007).

Application: The Rise of Sunbelt Cities, II

- Use connection between Jan temperature and wage and price growth.
- Regressing log-population, log-wages and log-house value on Jan temperatures we obtain $\hat{b}_N = 0.017$, $\hat{b}_W = -0.19$ and $\hat{b}_P = 0.60$. These are cross-sectional wage regressions using microdata from the 2000 Census. See Table 3
- Using the above procedure,

$$\delta_A = \alpha\gamma\hat{b}_N + (1 - \alpha(1-\gamma))\hat{b}_W = -0.14$$

- Warmer places are less productive: 0.14% per degree of Jan temp.
- Amenities:

$$\delta_\theta = (1-\beta)\hat{b}_P - \hat{b}_W = 0.37$$

  which means warmer places have higher amenity values. People will sacrifice 0.37% of their real wage $(W_t^i P_i^{t(\beta-1)})$ per degree Fahrenheit.
- Housing supply:

$$\delta_H = \mu\eta\hat{b}_N + (1-\mu+\mu\eta)\hat{b}_W - \hat{b}_P = -0.7487$$

Application: The Rise of Sunbelt Cities, III

- Now focus on positive correlation between Jan temperatures and growth in city size during 1990s. Why did warmer places experience higher population growth?
- Regressions yield $\hat{b}_{\Delta P} = -0.43$ (warmer places experience lower growth in housing prices), and $\hat{b}_{\Delta W} \approx 0$ (warmer places do not feature higher wage growth) –> real wage has been improving in warmer places
- This suggests that amenities are actually falling in warmer places during this period: $\Delta_\theta = (1-\beta)\,\hat{b}_{\Delta P} - \hat{b}_{\Delta W} < 0$.
- Using coefficients from the three regressions: $\Delta_A < 0$. Over the 90s, Jan temperature was not associated with rising productivity.
- However, we get $\Delta_H > 0$. The rise of Sunbelt cities in the 90s is related to abundant housing supply.

Agglomeration Economies and the Existence of Cities

- Why do we see such a remarkable clustering of human activity in a small number of urban areas?
- Previous spatial eq. model: cities may form because some places have *innate* advantages in productivity, housing supply or amenities.
- Or it may be because clusters of people *endogenously* increase productivity, housing supply or amenities (agglomeration effects)
- Example: Los Angeles. In its early history, prosperous retirees came to enjoy the climate (an innate amenity). Also: restaurants and theather endogenously emerged with the influx of population.
- But: if cities were driven by amenities, then real wages should be lower in big urban areas. This is not true. People require a wage premium to locate in big cities.
- Can cities be driven by innate advantage in supplying housing, or because density makes it easier to build? No. It is more expensive to build vertically than horizontally. Housing supply is more expensive in bigger areas.

Cities and Productivity

- Then: cities exist because they are in areas with high productivity, either innate or endogenously generated by agglomeration effects. Supported by strong correlation between city size and productivity.
- Typical innate productivity advantage: (i) waterways; everyone of the 20 largest American cities in 1900 was on a major waterway, (ii) proximity to natural resources (Pittsburgh and coal mines)
- Decline in shipping costs over 20th century: access to water systems and raw materials is less valuable. Places farther from rivers have grown more quickly.

Agglomeration in Productivity

- Agglomeration economies are simply *reductions in transport costs of goods, people and ideas.*
  - costs of moving goods (suppliers and customers locating near each other)
  - costs of moving people (more efficient labor markets)
  - costs of transmitting ideas (cities facilitate the flow of knowledge)
- Now, suppose productivity is also function of city size: $A_i^t = a_t^i \left(N_t^i\right)^{\omega}$
- Solution to the model is still given by equations (1),(2) and (3), but the $\lambda's$ are now different functions of the underlying parameters. See Table 2.
- Some effects are magnified:
  - Positive relation between amenities/housing supply/productivity an population is stronger; Because initial increase in N_t^i (from basic model) now increases A_t^i which furhter increases N_t^i.
- Some effects can be reversed: An increase in θ^i or H^i has the usual negative effect on prices and wages, plus a new positive effect: $\uparrow N^i \rightarrow \uparrow A^i \rightarrow \uparrow W^i, \uparrow P^i$

Estimating Agglomeration

- Estimate ω (true treatment effect of population on productivity). Simple regression:

$$\log GMP \text{ per capita } = \underset{(0.01)}{0.13} * \log(\text{population}) + \underset{(0.1)}{8.8}$$

- Doesn't work (N is endogenous) Some areas may be more populated precisely because they are intrinsically more productive
- **IV approach** (Ciccone and Hall (1996), and Combes et al. (2009)): Instrument population with a variable that is correlated with H_t^i or θ_t^i but not with A_t^i
- The spatial model with agglomeration effects tells us how to interpret the *IV* coefficients.
- **Problem**: no *IV* estimate can yield an unbiased estimator of ω:
  - If the IV is only correlated with A_t^i, then *IV* will estimate $\lambda_A^W / \lambda_A^N = \mu\eta(1-\beta) / (\beta + \mu(1-\beta)(1-\lambda))$
  - If the IV is only correlated with H_t^i (or only with θ_t^i) then *IV* will estimate $\lambda_H^W / \lambda_H^N = (\omega - \alpha\gamma) / (1 - \alpha + \alpha\gamma) = \lambda_\theta^W / \lambda_\theta^N$

IV Estimation

- Consider variable Z^i which is correlated with H^i but orthogonal to A^i and θ^i
- Recall model

$$\begin{aligned}
\log\left(W_t^i\right) &= \kappa_W + \lambda_A^W \log\left(A_t^i \bar{K}_N^{\alpha\gamma}\right) + \lambda_H^W \log\left(H_t^i \bar{Z}_N^{\mu\eta}\right) + \lambda_\theta^W \log\left(\theta_t^i\right) \\
\log\left(N_t^i\right) &= \kappa_N + \lambda_A^N \log\left(A_t^i \bar{K}_N^{\alpha\gamma}\right) + \lambda_H^N \log\left(H_t^i \bar{Z}_N^{\mu\eta}\right) + \lambda_\theta^N \log\left(\theta_t^i\right)
\end{aligned}$$

- Main regression

$$\log W_t^i = \text{constant} + \beta \log N_t^i$$

- 1st Stage: obtain estimator of λ_H^N; get predicted values $\hat{\lambda}_H^N Z^i$
- 2nd Stage: obtain estimator of β which will satisfies

$$\beta \lambda_H^N = \lambda_H^W$$

- Regressions (Table 4) of the form:

$$\log W_t^i = \text{constant} + \beta \log N_t^i$$

- OLS gives $\hat{\beta} = 0.04$
- Some IV's that have been used:
  - population in 1880 for population today (Ciccone and Hall); $\hat{\beta} = 0.08$; problem, might be correlated with productivity
  - weather variables (Jan and July temperatures, precipitation, longitude and latitude; similar to Rosenthal and Strange(2003) and Combes(2009)); $\hat{\beta} = 0.04$. If these reflect amenities (or housing supply) and *are orthogonal to productivity* then $(\omega - \alpha\gamma) / (1 - \alpha + \alpha\gamma) = 0.04$. Thus, under $\alpha\gamma = 0.1$, and $1 - \alpha + \alpha\gamma = 0.76$, $\hat{\omega} = 0.13$.
  - not clear whether any instrument will be orthogonal to productivity...
- Can do the same procedures for a log housing price regression.
- Existence of industrial clusters also suggests agglomeration economies; but this could be due to heterogeneity in natural advantages across space.

Causes of Agglomeration

- Agglomeration economies are simply reductions in transport costs for either (i) goods, (ii) people and/or (iii) ideas:

1. Goods.

- Krugman (91) is a model of this
- Many examples of industries locating in cities to reduce transport costs.
- To be either close to suppliers (Pittsburgh, coal) or customers (NYC, garment manufacturing, printing and publishing)
- Evidence of input-output linkages for industrial location. Head and Mayer (2004): location of Japanese affiliates in Europe is correlated with pre-existing market demand
- Also: cross-industry co-location patterns. Ellison, Glaeser and Kerr (2007) find tendency of manufacturing firms to locate near suppliers or buyers.
- But: high transport cost industries locate away from urban areas (Figure 7)

2. Access to workers and dense labor markets
   - If firms (and workers) are subject to shocks (or quality of match is uncertain), then a dense labor market facilitates the reallocation process.
   - Not much evidence documenting labor market pooling. Diamond and Simon (1990) show that workers in more specialized cities, who face greater employment risk, are compensated with higher wages. Ellison, Glaeser and Kerr(2007): industries locate near industries that use the same type of workers.
3. Cities and Ideas
   - Ideas move imperfectly across space
   - Key empirical evidence: Jaffe, Trajtenberg and Henderson (1993): patents are more likely to cite previous patents that are geographically proximate.
   - Saxenian (1994): communication of new ideas across firms in social settings in Silicon Valley.
   - Duranton and Puga (1998): cities are "nurseries" for new ideas. Model in which mature industries flee cities for lower production costs.

- Transmission of ideas facilitates human capital acquisition by workers
- Evidence for the role of cities as disseminators of knowledge:
- Rauch (1993): positive relation between wages and avg human capital in the area. Problem: areas with higher human capital may be more productive for other unobserved reasons
- Moretti (2004) looks at plant level production functions and finds that productivity rises with area level human capital
- Also: positive relation between initial levels of human capital in cities and population growth. Glaeser, Scheinkman and Shleifer (1995).
- Large body of research is compatible with the hypothesis that cities thrive because they facilitate the spread of knowledge.

Policy

- Should the Government subsidize movement of people or firms from rich, dense areas to poor, less populated ones?
- Not clear. Even if agglomeration economies exists, moving people will reduce the productivity in one area and increase it in another. We dont know if the winning area will gain more than what the losing area loses.
- No concensus over the functional form of agglomeration economies.
- Likewise: the existence of human capital externalities provides little guidance about whether skilled workers should be pushed into already skilled areas, or dispersed throughout the country. We dont know the functional form of these externalities..