# Agglomeration Economies and Spatial Equilibrium: Discussion of Glaeser and Gottlieb, JEL 2009

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# Administration

Midterm:

- replacing undergrad style midterm with referee report on new papers (unpublished or recently accepted) covering topics from class
- should be more helpful for student research as well as prepare you for writing referee reports in your career
- I will send out a document with details on what I want in the referee report
- I will also give a list of papers (one student per paper); students are also welcome to choose their own paper to review but must get my approval

For 5/23: outline due for research idea

6/13 (?): research proposal presentation

# How do we price negative effect of pollution?

Most cost-benefit analyses of “bads”, like pollution, need some measure for negative effect of pollution

In order to evaluate policy we usually calculate a marginal willingness to pay; this can be compared to cost of implementing some pollution reduction policy

So, if you wanted to quantify the negative effect of pollution on Beijing, how would you do it?

What would you try to measure? How would you report your results?

What method would you use to identify this effect? What data would you use?

# Glaeser Gottlieb 2009: Introduction

Paper starts out by noting that while research on economic growth tends to focus on cross-country differences, differences *within* countries are also quite large

In US, productivity in most productive cities is more than three times productivity in lowest cities

Further, population is very concentrated: 68% of Americans live in 1.8% of land (we've seen this stat before)

Authors use classic spatial equilibrium model (Rosen-Roback) to explain how to empirically study these issues

Three key equilibrium conditions: 1) workers indifferent between locations 2) firms indifferent about hiring more workers 3) builders indifferent about building more housing supply

After describing model they show several empirical applications

# Productivity and City Size

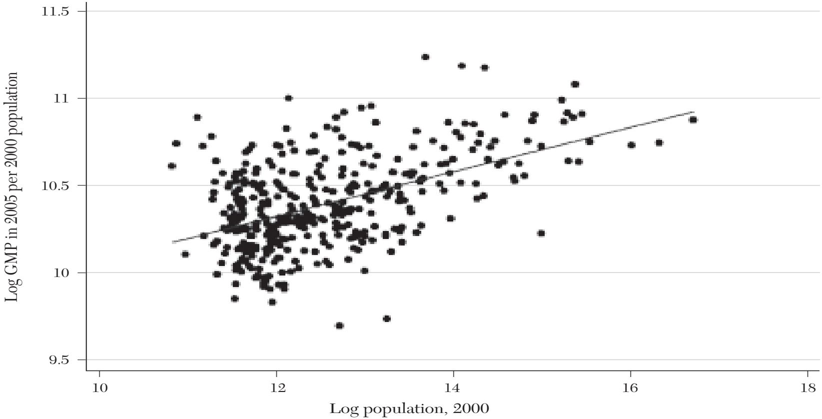



*Figure 1.* Productivity and City Size

*Notes:* Units of observation are Metropolitan Statistical Areas under the 2006 definitions. Population is from the Census, as described in the Data Appendix. Gross Metropolitan Product is from the Bureau of Economic Analysis.

The regression line is $\log \textit{GMP per capita} = 0.13\ [0.01] \times \log \textit{population} + 8.8\ [0.1]$.
$R^2 = 0.25$ and $N = 363$.

# Persistence of Productivity

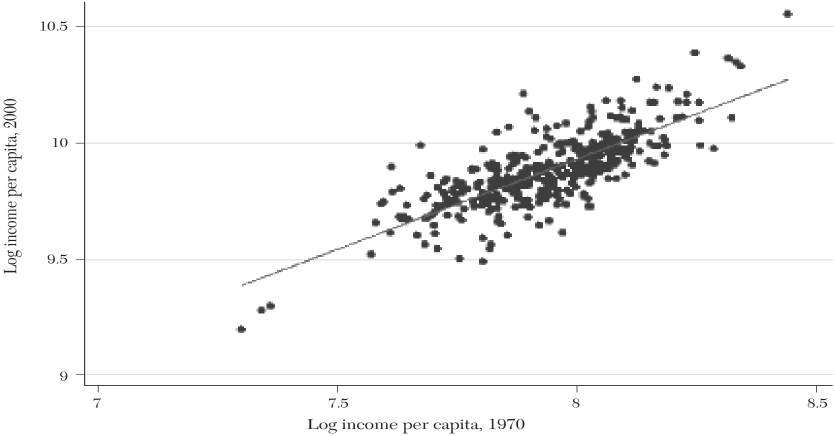



*Figure 2.* Income Over Time

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

The regression line is $\textit{Income 2000} = 0.77\ [0.03] \times \textit{Income 1970} + 3.75\ [0.26]$.
$R^2 = 0.60$ and $N = 363$.

# Roback JPE 1982

Intuition of Roback model much simpler in original paper

Has nice graphical representation of equilibrium

One of the main points is that we cannot measure the value of some city amenity from house prices alone because wages will also change

First review original model and then move to GG 2009

# Workers

Identical workers with cost-less migration, each supplies one unit of labor

Different cities have different *exogenous* amenities (ex: warm climate, natural beauty, clean air), denoted $s$

Worker utility is function of $s$, consumption of composite commodity $X$ (numeraire, paid with wage $w$), and consumption of land $l^c$ (rented at $r$)

Free migration ensures spatial equilibrium condition of equal utility:

$$V(w, r; s) = k \quad (2)$$

Assume amenity increases utility: $V_s > 0$

# Firms

Firms produce $X$ with CRS production function $X = f(l^p, N; s)$, where $N$ is number of workers and $l^p$ is land used in production

In equilibrium the unit cost (CRS) must equal price of $X$ (assumed to be 1); if not firms could relocate to more profitable cities, which would increase factor prices (land, labor) in those cities until equilibrium is reached

$$C(w, r; s) = 1 \tag{3}$$

Let $C_w = N/X$ and $C_r = l^p/X$; the amenity may be unproductive $C_s < 0$ or productive $C_s > 0$

An amenity that is positive for consumers (clean air) may be unproductive for firms (clean air regulation may require expensive non-polluting technology)

# Equilibrium

Can use equations 2) and 3) to determine wages $w$ and rent $r$

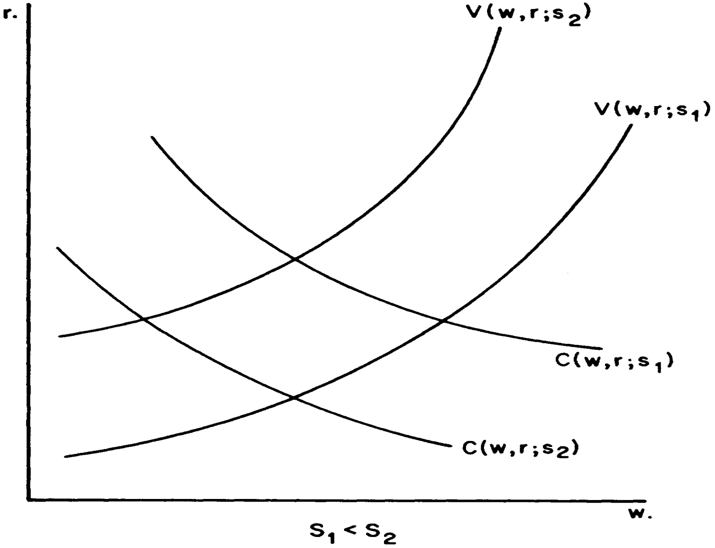
Easiest way is to graph isocost curves ($C = 1$) and indifference curves ($V = k$) in wage $w$ and rent $r$ space

Can vary amount of amenity $s$ to see effect on curves and solve for equilibrium levels of $w$ and $r$

In following figure $s$ is unproductive for firms but a positive amenity for consumers; factor prices must be lower in places with higher $s$ so that $C = 1$ but higher in places with greater $s$ so that $V = k$

Key results: increase in unproductive $s$ leads to lower wages but effect on rent is unclear; if $s$ is productive would find ambiguous effect on wages but certain increase in rent $r$

# Equilibrium in Roback Model



# Roback's Extensions

Roback then extends the basic model by introducing a non-tradable goods (housing) sector

This sector also competes for land use; incorporating this sector allows author to derive effect of change in $s$ on utility as function of house price changes *and* wages

Glaeser and Gottlieb extend this set-up even further and look more deeply at empirical implications

# City Production

City-level production function with two types of capital: 1) tradable $K_T$ with national exogenous price $\gamma_t$ and 2) non-tradable $K_N$ (ex: land) with local endogenous price $\gamma_N$

Assume that amount of non-traded capital is fixed at stock $\bar{K_N}$, then:

$$F() = A_t^i \bar{K_N}^{\alpha\gamma} K_T^{\alpha(1-\gamma)} L^{1-\alpha} \qquad \text{(GG1)}$$

Taking FOC w.r.t. $L$ and $K_T$ (assume some price of output) gives (inverse) demand for labor:

$$\phi A_t^i \bar{K_N}^{\alpha\gamma} L^{-\alpha\gamma} = W^{1-\alpha(1-\gamma)} \qquad \text{(GG2)}$$

The term $\phi$ includes price of output, price of traded capital, and other constants

# Worker Utility 1

Workers get utility from 1) traded goods $G_T$ 2) non-traded goods $G_N$ and 3) amenities $\theta_t^i$

Can write this as indirect utility function like $V(w, r; s)$, with $Y_t^i$ as income (wage), $P_t^i$ as price of non-traded good (housing), and amenities:

$$V(Y_t^i, P_t^i, \theta_t^i) \tag{GG3}$$

Authors note that spatial equilibrium condition implies constant utility: $V(Y_t^i, P_t^i, \theta_t^i) = U_t$

Then holding $\theta$ fixed and taking the total differential we have $dV = V_y dY + V_p dP = 0$, or

$$\frac{dY}{dP} = -\frac{V_P}{V_Y} \tag{1}$$

An increase in housing prices is associated with higher income, or higher incomes are offset by higher housing prices

# Worker Utility 2

Authors assume Cobb-Douglas utility with amenity multiplier: $U = \theta^i_t G_T^{\beta} G_N^{1-\beta}$

Then, optimizing and plugging demand equations back into utility function gives indirect utility ($\omega$ is constant):

$$V = \omega \theta^i_t W^i_t (P^i_t)^{\beta - 1} \quad \text{(GG4)}$$

Setting this equal to country utility $U_t$ we can solve for wage and take logs:

$$log(W^i_t) = log(U_t) + (1-\beta) log(P^i_t) - log(\theta^i_t) \quad \text{(GG5)}$$

# Housing Prices vs Income

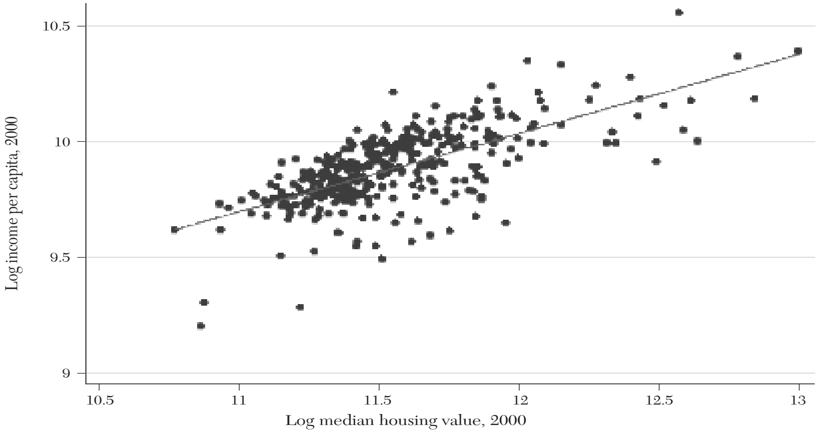



*Figure 3.* Housing Prices and Income

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

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

# Production of Non-Tradable Sector

Again, assume there is labor $L$ and tradable and non-tradable capital in production of $H$

Tradable capital is same as in city production of tradable good, $K_T$

Non-tradable capital (land) is different: $Z_N$, fixed at $\bar{Z}_N$

$$H = H_t^i \bar{Z}_N^{\mu\eta} K_T^{\mu(1-\eta)} L^{1-\mu} tag GG6 \tag{2}$$

Note: I think equation at top of p993 has type (should be $K_T$, not $K_N$)

Term $H_t^i$ is non-tradable productivity multiplier

# Output of Non-Tradable Sector (Housing)

Then with price $P_t^i$ profit maximization gives output as:

$$\left((P_t^i)^{1-\mu\eta} H_t^i W^{(\mu-1)}\right)^{1/\mu\eta} \bar{Z}_N \tag{GG7}$$

Can also solve for labor demand from this non-tradable sector, which authors note is $(1-\mu)(1-\beta) * N_t^i$, where $N_t^i$ is city population

This part is generally unclear but population can be determined by labor demand for two sectors

# Equilibrium

Authors do not clearly write equilibrium equations; however, given text we can write this as:

$$L^i_{Tt}(W^i_t) + L^i_{Nt}(W^i_t, P^i_t) = N^i_t \tag{1}$$

$$\left((P^i_t)^{1-\mu\eta} H^i_t W^{(\mu-1)}\right)^{1/\mu\eta} \bar{Z}_N = (1-\beta) W^i_t / P^i_t \tag{2}$$

$$V(W^i_t, P^i_t, \theta^i_t) = \omega \theta^i_t W^i_t (P^i_t)^{\beta-1} = U_t, \forall i \tag{3}$$

$$\sum_i N^i_t = N_t \tag{4}$$

Note: slides from Joaquin Blaum (MIT presentation) were very useful in corroborating above equations and I mostly use his notation

# Equilibrium Solution

$$log(N_t^i) = \kappa_N + \lambda_A^N log(A_t^i \bar{K_N}^{\alpha\gamma}) + \lambda_H^N log(H_t^i \bar{Z_N}^{\mu\eta}) + \lambda_\theta^N log(\theta_t^i)$$
$$log(W_t^i) = \kappa_W + \lambda_A^W log(A_t^i \bar{K_N}^{\alpha\gamma}) + \lambda_H^W log(H_t^i \bar{Z_N}^{\mu\eta}) + \lambda_\theta^W log(\theta_t^i)$$
$$log(P_t^i) = \kappa_P + \lambda_A^P log(A_t^i \bar{K_N}^{\alpha\gamma}) + \lambda_H^P log(H_t^i \bar{Z_N}^{\mu\eta} + \lambda_\theta^P log(\theta_t^i)$$

Following table shows how parameters from model feed into $\lambda$'s and can be used for comparative statics

- Increase in productivity increases population, wages, house prices
- Increase in housing construction productivity increases population, decreases wages and house prices
- Increase in amenities increases population but decreases wages and house prices

# Parameter Table

TABLE 2
ESTIMATING PARAMETERS

| Equation parameters | Value of parameters in the baseline model | Value of parameters with agglomeration economies |
|---|---|---|
| $\lambda_A^N$ | $\frac{\beta+\mu(1-\beta)(1-\eta)}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{\beta+\mu(1-\beta)(1-\lambda)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_H^N$ | $\frac{(1-\alpha+\alpha\gamma)(1-\beta)}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{(1-\alpha+\alpha\gamma)(1-\beta)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_\theta^N$ | $\frac{1-\alpha+\alpha\gamma}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{1-\alpha+\alpha\gamma}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_A^W$ | $\frac{\mu\eta(1-\beta)}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{\mu\eta(1-\beta)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_H^W$ | $\frac{-\alpha\gamma(1-\beta)}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{-(1-\beta)(\alpha\gamma-\omega)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_\theta^W$ | $\frac{-\alpha\gamma}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{-(\alpha\gamma-\omega)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_A^P$ | $\frac{\mu\eta}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{\mu\eta}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_H^P$ | $\frac{-\alpha\gamma}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{-(\alpha\gamma-\omega)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |
| $\lambda_\theta^P$ | $\frac{(1-\alpha)\mu\eta-(1-\mu)\alpha\gamma}{((1-\alpha)\eta+\alpha\gamma)\mu(1-\beta)+\alpha\beta\gamma}$. | $\frac{(1-\alpha+\omega)\eta\mu-(1-\mu)(\alpha\gamma-\omega)}{(1-\alpha+\omega)(1-\beta)\eta\mu+(\mu+\beta-\mu\beta)(\alpha\gamma-\omega)}$ |

# How to use this in estimation

Researchers often try to estimate effect of some variable ($X_t^i$) on productivity in traded sector, non-traded sector, or amenities

$$\frac{\partial log(A_t^i \bar{K_N}^{\alpha\gamma})}{\partial X_t^i} = \delta_A \tag{3}$$

$$\frac{\partial log(H_t^i \bar{Z_N}^{\mu\eta})}{\partial X_t^i} = \delta_H \tag{4}$$

$$\frac{\partial log(\theta_t^i)}{\partial X_t^i} = \delta_\theta \tag{5}$$

This effect can be inferred by running regressions of population, wages, and prices on variable $X_t^i$

# Inferring Effects

$$\hat{b}_N = E[N_t^i | X_t^i] = \lambda_A^N \delta_A + \lambda_H^N \delta_H + \lambda_\theta^N \delta_\theta \quad (6)$$

$$\hat{b}_W = E[W_t^i | X_t^i] = \lambda_A^W \delta_A + \lambda_H^W \delta_H + \lambda_\theta^W \delta_\theta \quad (7)$$

$$\hat{b}_P = E[P_t^i | X_t^i] = \lambda_A^P \delta_A + \lambda_H^P \delta_H + \lambda_\theta^P \delta_\theta \quad (8)$$

Or:

$$\delta_\theta = (1 - \beta)\hat{b}_P - \hat{b}_W \quad (9)$$

$$\delta_A = \alpha\gamma\hat{b}_N + (1 - \alpha(1 - \gamma))\hat{b}_W \quad (10)$$

$$\delta_H = \mu\eta\hat{b}_N + (1 - \mu_\mu\eta)\hat{b}_W - \hat{b}_P \quad (11)$$

Ex: to understand effect of crime on utility $\partial log(\theta_t^i)/\partial X_t^i = \delta_\theta$ we use estimates of house prices and wages on (exogenous) crime, plus need estimate of share of household expenditure on housing $(1 - \beta)$ from literature

Important: notice that this cannot be inferred solely from change in house prices, must also look at change in wages

# Rise of the "Sunbelt"

In US, fastest growing areas have warm climates

These areas, in the south and west of US, are known as the "sunbelt"

Why has population growth shifted to sunbelt?

1. Has productivity increased in South?
2. Have political institutions become more efficient (and less corrupt)?
3. Has advent of air conditioning made South more comfortable (amenities)?
4. Are people attracted to cheap housing, made possible by pro-building policies?

# Population Growth and Climate

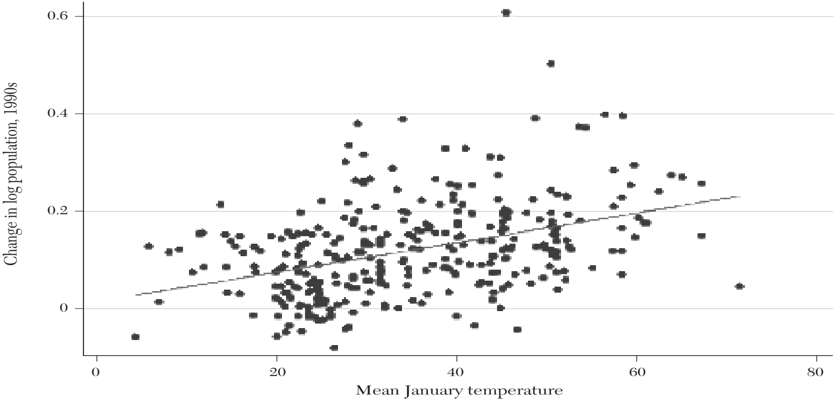



*Figure 4.* Population Growth and Temperature

*Notes:* Units of observation are Metropolitan Statistical Areas under the 1999 definitions, using Primary Metropolitan Statistical Areas rather than Consolidated Metropolitan Statistical Areas where applicable and New England County Metropolitan Areas where applicable. Population data are from the Census, as described in the Data Appendix. Mean January temperature is from the City and County Data Book, 1994.

The regression line is *Population growth* $= 0.0030$ [0.0004] $\times$ *Temperature* $+ 0.02$ [0.01]. $R^2 = 0.16$ and $N = 316$.

# Explaining the sunbelt 1

Authors run regressions of population, wages, and house values on temperature with controls

Combine coefficients using model to look at effect of temperature on amenities, productivity, housing construction productivity

Find

- Effect of temperature on productivity: $-0.14$
- Effect of temperature on amenities: $+0.59$–people are willing to give up 0.59% of real wages for an additional degree F.
- Effect of temperature on wages: $-0.52$

# Sunbelt Regressions

TABLE 3
SPATIAL EQUILIBRIUM

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent variable | Log wage | Log house value | Log real wage | Log wage | Log house value | Log real wage |
| *Year:* | 2000 | 2000 | 2000 | 1990, 2000 | 1990, 2000 | 1990, 2000 |
| Mean January temperature | −0.19 | 0.60 | −0.33 | | | |
| | [0.06] | [0.31] | [0.10] | | | |
| Mean January temperature × year 2000 | | | | −0.001 | −0.43 | 0.19 |
| | | | | [0.05] | [0.11] | [0.03] |
| Year 2000 dummy | | | | 0.25 | 0.62 | 0.06 |
| | | | | [0.02] | [0.06] | [0.02] |
| Individual controls | Yes | — | Yes | Yes | — | Yes |
| Housing controls | — | Yes | — | — | Yes | — |
| MSA fixed effects | — | — | — | Yes | Yes | Yes |
| $N$ | 1,590,467 | 2,341,976 | 1,590,467 | 2,950,850 | 4,245,315 | 2,950,850 |
| $R^2$ | 0.29 | 0.36 | 0.21 | 0.27 | 0.60 | 0.26 |

*Notes:* Individual-level data are from the Census Public Use Microdata Sample, as described in the Data Appendix. Metropolitan-area population is from the Census, as also described in the Data Appendix. Mean January temperature is from the City and County Data Book, 1994, and is measured in hundreds of degrees Fahrenheit. Real wage is controlled for with median house value, also from the Census as described in the Data Appendix. Individual controls include age and education. Location characteristics follow Metropolitan Statistical Areas under the 1999 definitions, using Primary Metropolitan Statistical Areas rather than Consolidated Metropolitan Statistical Areas where applicable and New England County Metropolitan Areas where applicable. Standard errors are clustered by metropolitan area.

# Explaining the sunbelt 2

Repeat exercise but look at growth instead of levels

Find that in 1990's temperature not correlated with *increases* in productivity or amenities but is correlated with increasing housing supply

Conclude that over longer period, rise of Sunbelt due to both increases in productivity and housing supply but *not* amenities

Emphasize that most expensive US cities had large housing price increases with very little population growth

Authors argue that more attention should be paid to housing supply as a driver of population growth

# House Values and City Growth

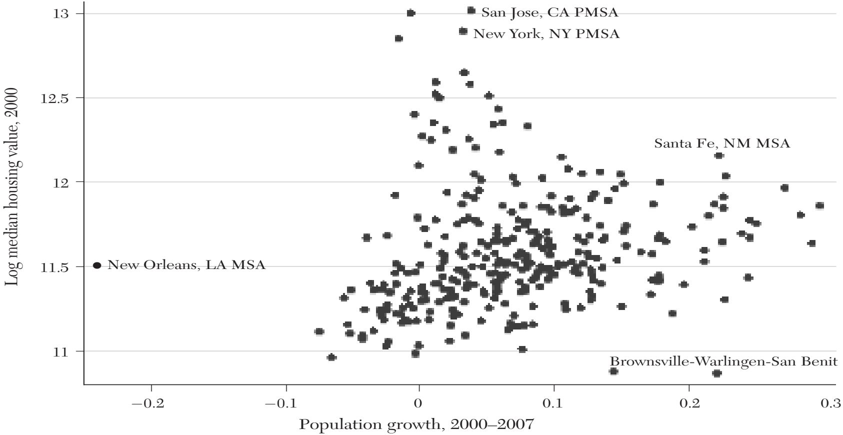



*Figure 5.* House Values and City Growth

*Notes:* Units of observation are Metropolitan Statistical Areas under the 1999 definitions, using Primary Metropolitan Statistical Areas rather than Consolidated Metropolitan Statistical Areas where applicable and New England County Metropolitan Areas where applicable. Data are from the Census, as described in the Data Appendix.

# Agglomeration

Authors extend model by allowing productivity to be a function of population, similar to earlier papers in our class

This can strengthen some effects but also reverse others, depending on parameters

Example: increase in amenities increases population but that may now increase productivity, possibly increasing wages

# Final Note: Estimation of Agglomeration

Typically we estimate agglomeration economies by regressing log income on log population or log density

Spatial equilibrium model shows that population is an outcome and thus must be endogenous: some omitted variable increasing productivity must increase population

Most papers try to instrument for population with a historical variable which may be exogenous to current unobservable productivity shocks

In context of GG model, this means either correlated with $H_t^i$ or $\theta_t^i$

Problem is that neither gives true treatment effect of population on productivity because will depend on other parameters (share of production associated with nontraded capital, or share of production associated with labor plus nontraded capital)