ECON G6905
Topics in Trade

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Spring 2025, Week 5

Columbia University
in the City of New York

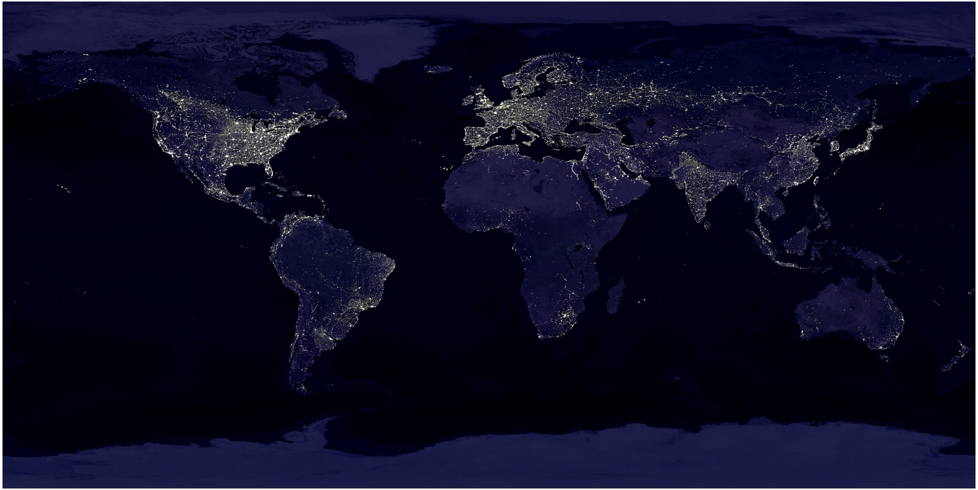


Image from NOAA

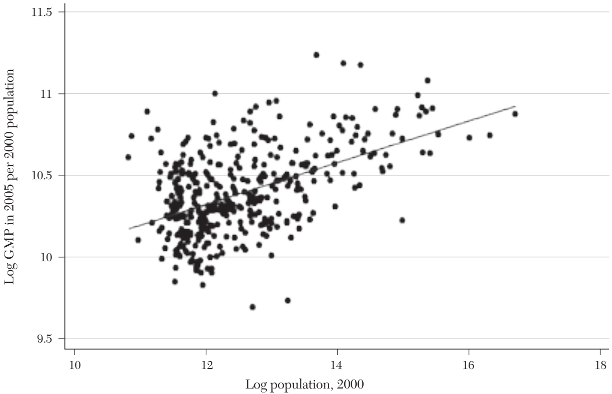
(Defense Meteorological Program Operational Linescan System)

Donaldson & Storeygard, "The View from Above: Applications of Satellite Data in Economics", *JEP*, 2016

Image from NASA

Today: Agglomeration economies

Gross metropolitan product per capita rises with metro population:



Lucas (1988) on local external economies: “What can people be paying Manhattan or downtown Chicago rents **for**, if not being near other people?”

Today's agenda

- Spatial equilibrium in the Rosen-Roback framework
- Spatial equilibrium and the marginal resident
- Evidence of agglomeration economies
- Spatial equilibrium with increasing returns (Henderson 1974)
- Developing-economy cities
- What is a city?

Spatial equilibrium

Fundamentally, spatial equilibrium is a no-arbitrage condition. Glaeser and Gottlieb (*JEL* 2009):

> *The high mobility of labor leads urban economists to assume a spatial equilibrium, where elevated New York incomes do not imply that New Yorkers are better off. Instead, welfare levels are equalized across space and high incomes are offset by negative urban attributes such as high prices or low amenities.*

- The benchmark model of spatial equilibrium is dubbed the "Rosen-Roback" model, due to the theory of equalizing differences (Sherwin Rosen 1974, 1979) applied to cities for both workers and firms (Jennifer Roback 1982)
- I borrow my exposition of Rosen-Roback model from Owen Zidar's slides

Rosen-Roback framework

Goals

- How does change in amenity s alter local prices (wages, rents)?
- Infer the value of amenities

Markets

- Labor: price w, quantity N
- Land: price r, quantity $L = L^w + L^p$ used by workers and producers
- Goods: price $p = 1$, quantity X [no trade of consequence]

Agents

- Workers (homogeneous, perfectly mobile)
- Firm (perfectly competitive, constant returns to scale)

Indifference conditions

- Workers have same indirect utility in all locations
- Firm has zero profit (i.e., unit costs equal 1)

Workers: Preferences and budget constraint

Utility is $u(x, l^c, s)$

- x is consumption of private good
- l^c is consumption of land
- s is amenity

Budget constraint is $x + rl^c - w - I = 0$

- I is non-labor income that is independent of location
- w is labor income (note: no hours margin)

Indirect utility is

$$V(w, r, s) = \max_{x, l^c} u(x, l^c, s) \text{ s.t. } x + rl^c - w - I = 0$$

Let $\lambda = \lambda(w, r, s)$ be the marginal utility of a dollar of income, then

$$V_w = \lambda > 0 \qquad V_r = -\lambda l^c < 0 \qquad \implies V_r = -V_w l^c$$

Example: Cobb-Douglas preferences

Utility is Cobb Douglas over goods and land with an amenity shifter:

$$u(x, l^c, s) = s^{\theta_W} x^{\gamma} (l^c)^{1-\gamma}$$

- Then $x = \gamma \left(\frac{w+I}{1}\right)$ and $l^c = (1-\gamma)\left(\frac{w+I}{r}\right)$
- Let $\Gamma \equiv \gamma^{\gamma}(1-\gamma)^{(1-\gamma)}$ so that indirect utility is

$$V(w, r, s) = \underbrace{\Gamma}_{\text{constant}} \underbrace{s^{\theta_W}}_{\text{amenities}} \underbrace{1^{-\gamma} r^{-(1-\gamma)}}_{\text{prices}} \underbrace{(w+I)}_{\text{income}}$$

- MU of income is $\lambda(w, r, s)$

$$V_w = \lambda = \Gamma s^{\theta_W} r^{-(1-\gamma)}$$

$$V_r = -\lambda l^c = -\Gamma s^{\theta_W} r^{-(1-\gamma)} (1-\gamma) \left(\frac{w+I}{r}\right)$$

$$\Rightarrow V_r = -V_w l^c$$

Firms: Unit cost function

CRS production with cost function $C(X, w, r, s)$

- X is output
- Unit cost $c(w, r, s) = \frac{C(X,w,r,s)}{X}$
- L^p is total amount of land used by firms
- N is total employment

From Shepard's Lemma, we have

$$c_w = N/X > 0$$
$$c_r = L^p/X > 0$$

Example: Cobb-Douglas production

Suppose the production function is

$$X = f(N, L^p) = s^{\theta_F} N^{\alpha} L^{1-\alpha}$$

Let $\mathcal{A} \equiv \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$. Then the cost function is

$$C(X, w, r, s) = X(s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A} \implies c(w, r, s) = (s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A}$$

Then

$$C_w(X, w, r, s) = \alpha \frac{\left(X(s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A}\right)}{w} = N$$

$$C_r(X, w, r, s) = (1-\alpha) \frac{\left(X(s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A}\right)}{r} = L^p$$

Dividing both sides by X gives:

$$c_w = N/X > 0 \qquad c_r = L^p/X > 0$$

Model recap

Workers parameters: s, θ_W, γ, I

- s is level of amenities
- θ_W is value of s for utility
- γ is goods share of expenditure
- $1 - \gamma$ is land share
- I is non-labor income

Firm Parameters: s, θ_F, α

- s is level of amenities
- θ_F is value of s for productivity
- α is output elasticity of labor
- $1 - \alpha$ is output elasticity of land

Endogenous outcomes:

- Labor: price w, quantity N
- Land: price r, quantities L^w, L^p for workers and production
- Goods: price $p = 1$, quantity X

Equilibrium concept: Two key indifference conditions

In equilibrium, workers and firms are indifferent across cities with different levels of s and endogenously varying wages $w(s)$ and rents $r(s)$:

$$c(w(s), r(s), s) = 1 \tag{1}$$

$$V(w(s), r(s), s) = V^0 \tag{2}$$

where V^0 is the equilibrium level of indirect utility.

Specifically, in our example:

Given $s, \theta_W, \theta_F, \gamma, I, \alpha$, equilibrium is defined by local prices and quantities $\{w, r, N, L^w, L^p, X\}$ such that (1) and (2) hold and land markets clear.

N.B. We will mainly be focusing on prices: $w(s)$ and $r(s)$.

Solving for effect of amenity changes on prices

- Differentiate (1) and (2) with respect to s and rearrange, we have:

$$\begin{bmatrix} c_w & c_r \\ V_w & V_r \end{bmatrix} \begin{bmatrix} w'(s) \\ r'(s) \end{bmatrix} = \begin{bmatrix} -c_s \\ -V_s \end{bmatrix}$$

- Solving for $w'(s), r'(s)$, we have

$$w'(s) = \frac{V_r c_s - c_r V_s}{c_r V_w - c_w V_r}$$
$$r'(s) = \frac{V_s c_w - c_s V_w}{c_r V_w - c_w V_r}$$

- Note we can rewrite

$$c_r V_w - c_w V_r = \lambda L^p / X + \lambda l^c N / X = \lambda L / X = V_w L / X$$

Aside: example values for matrix elements

$$
\begin{aligned}
c_w &= \alpha \frac{(s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A}}{w} \\
c_r &= (1-\alpha) \frac{(s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A}}{r} \\
c_s &= \theta_F \frac{(s^{\theta_F})^{-1} w^{\alpha} r^{1-\alpha} \mathcal{A}}{s} \\
V_w &= s^{\theta_W} 1^{-\gamma} r^{-(1-\gamma)} \Gamma \\
V_r &= -s^{\theta_W} 1^{-\gamma} r^{-(1-\gamma)} \Gamma (1-\gamma) \left(\frac{w+I}{r} \right) \\
V_s &= \theta_W \frac{\left(s^{\theta_W} 1^{-\gamma} r^{-(1-\gamma)} \Gamma \left(w + I \right) \right)}{s}
\end{aligned}
$$

Effect of amenity changes on prices

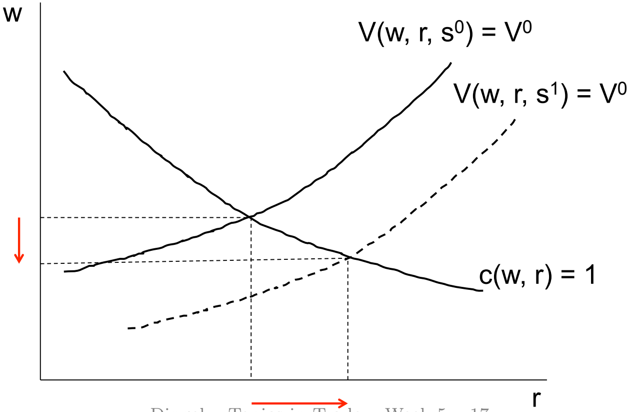
- Price changes

$$w'(s) = \frac{(V_r c_s - c_r V_s)X}{\lambda L}$$
$$r'(s) = \frac{(V_s c_w - c_s V_w)X}{\lambda L}$$

- Special cases of interest:
    1. Amenity only valued by consumers: $\theta_F = 0 \Rightarrow c_s = 0$
    2. Amenity only has productivity effect: $\theta_W = 0 \Rightarrow V_s = 0$
    3. Firms use no land $1 - \gamma = 0$ and amenity is non-productive $\theta_F = 0$: $c(w(s)) = 1$, $c_r = c_s = 0$

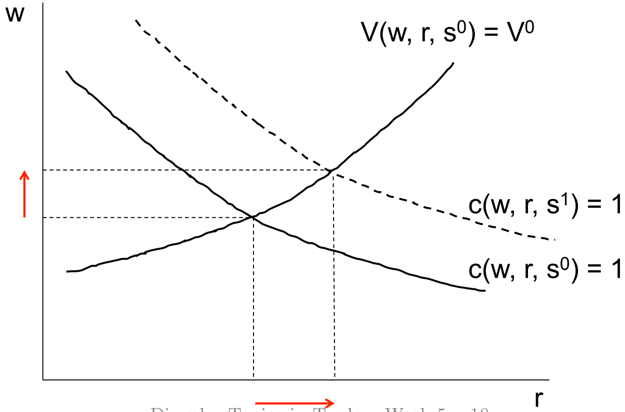
1. Amenity only valued by consumers: $\theta_F = 0 \Rightarrow c_s = 0$

- When $c_s = 0$, higher $s \Rightarrow$ higher r, lower w
- Workers are willing to pay more in land rents and receive less in wages to have access to higher levels of amenities



2. Amenity only valued by firms: $\theta_W = 0 \Rightarrow V_s = 0$

- When $V_s = 0$, higher $s \Rightarrow$ higher r and higher w
- Firms are willing to pay more in land rents and wages to access higher productivity due to amenities



3. Firms don't use land nor value amenity

- Firms don't use land ($\alpha = 1$) nor value amenity ($\theta_F = 0$)
- Only production input is labor and firms are indifferent across locations, so wages must be the same across cities: $c(w(s)) = 1$

- Since $c_r = c_s = 0$,

$$w'(s) = 0$$

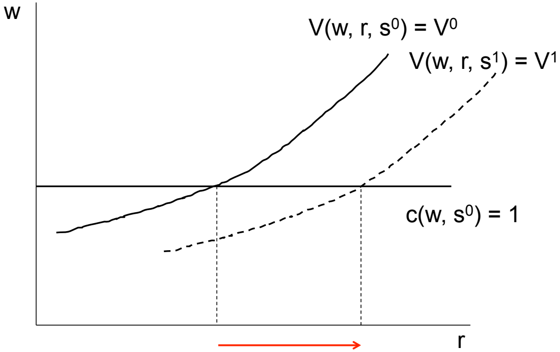
$$r'(s) = \frac{V_s c_w}{-c_w V_r} = \frac{V_s}{l^c V_w}, \text{ since } V_r = -l^c V_w$$

- So the rise in total cost of land for a worker living in a city with higher s is

$$l^c r'(s) = \frac{V_s}{V_w}$$

3. Firms don't use land nor value amenity

- $\frac{V_s}{V_w}$ = marginal WTP for a change in s so the marginal value of a change in the amenity is "fully capitalized" in rents



$\frac{V_s}{V_w} = \theta_W \frac{(w+I)}{s}$ is increasing in income, decreasing in level of amenities

Valuing consumer amenities

- General case: Start from equal-utility condition $V_0 = V(w(s), r(s), s)$

$$0 = V_w w'(s) + V_r r'(s) + V_s$$

$$\frac{V_s}{V_w} = l^c r'(s) - w'(s) \tag{3}$$

- WTP for amenity is extra land cost for consumers plus lower wages
- Zero-profit condition:

$$c_w w'(s) + c_r r'(s) + c_s = 0 \tag{4}$$

- When $c_s = 0$, $w'(s) = \frac{-c_r}{c_w} r'(s) = \frac{-L^p}{N} r'(s)$
- Combine (3) and (4) to get the WTP of the N people in a given city:

$$N \frac{V_s}{V_w} = N l^c r'(s) + L^p r'(s) = L r'(s)$$

Aggregate WTP is how the total value of all land changes as s changes

Inferring and valuing amenities

Cobb-Douglas preferences:

$V_0 = \Gamma s^{\theta_W} r^{-(1-\gamma)}(w + I)$ implies

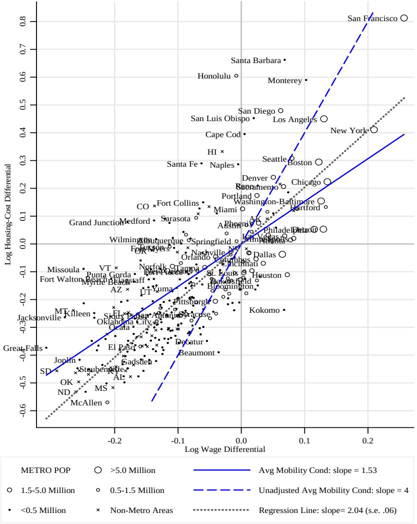
$s^{\theta_W} = \frac{V_0}{\Gamma}\frac{r^{1-\gamma}}{w+I}$

More generally,

$\hat{s}_j^{\theta_W} \approx s_y \hat{p}_j - s_w(1-\tau')\hat{w}_j$ where p are all local prices and τ' is the marginal tax rate, s_y and s_w are national shares (my bad notation), and $\hat{x}_j = \frac{\mathrm{d}x_j}{x}$ are local deviations

Albouy (2012) "Are Big Cities Bad Places to Live?" and Albouy (2016) "What are cities worth? Land rents, local productivity, and the total value of amenities"

Figure 1: Housing Costs versus Wage Levels across Metro Areas, 2000



What's an amenity?

Urban economists use the word "amenity" in two imperfectly aligned ways (blog post)

1. Amenities are place-specific services/flows that are not explicitly transacted and hence do not appear in the budget constraint
2. Amenities are place-specific residuals because the researcher lacks expenditure/price data

Traditional view (Diamond and Tolley 1982):

- Clean air, lack of severe snow storms, and sunny days (Roback 1982)

Recent literature on "consumption amenities"

- Restaurants and retail (variety-adjusted price indices)

If an amenity is a non-tradable with crummy price data, then housing is an amenity in some empirical settings

Endogenous amenities

Thus far, s was an exogenous characteristic of a location.

- Sunshine doesn't respond to population composition
- Crime rates, school quality, and variety of restaurants are endogenous
- Endogenous amenities mean endogeneity problems
- See Milena Almagro's UEA summer school lecture

Spatial equilibrium and the marginal resident

Thus far, local labor supply is perfectly elastic (all workers are indifferent at V_0)

- No notion of welfare or spatial inequality for workers
- All workers adjust to shocks similarly
- Incidence of shocks/amenities is on land prices

The concept of spatial equilibrium is a no-arbitrage condition: the marginal resident must be indifferent

- Moretti (2011) and Diamond (2016): discrete-choice problem with idiosyncratic preferences so there are inframarginal residents
- Inferring and valuing amenities with heterogeneous individuals is harder

Evidence of agglomeration economies

People are concentrated. Are industries concentrated? Yes.

- Ellison and Glaeser (1997) "dartboard approach" to address internal vs external economies
- Duranton and Overman (2005) for continuous space

Identify agglomeration channels empirically

- Estimate directly (faces peer-effects problem)
- Infer from observed spatial equilibrium
- Test for multiple equilibria
- Greenstone, Hornbeck, Moretti (2010) use "million-dollar plants" to estimate agglomeration economies (cf Patrick 2016)
- Combes and Gobillon - "The Empirics of Agglomeration Economies" (*Handbook* 2015)
- Lin and Rauch - "What future for history dependence in spatial economics?"

Bleakley and Lin 2012: Portage and Path Dependence

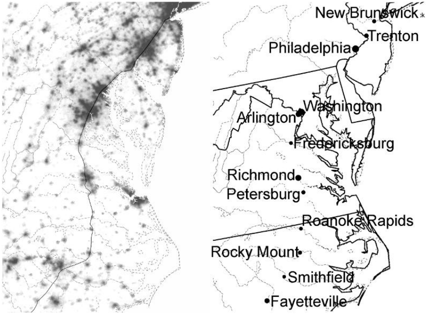


FIGURE IV
Fall-Line Cities from North Carolina to New Jersey

The map in the left panel shows the contemporary distribution of economic activity across the southeastern United States measured by the 2003 nighttime lights layer from NationalAtlas.gov. The nighttime lights are used to present a nearly continuous measure of present-day economic activity at a high spatial frequency. The fall line (solid) is digitized from *Physical Divisions of the United States*, produced by the U.S. Geological Survey. Major rivers (dashed gray) are from NationalAtlas.gov, based on data produced by the U.S. Geological Survey. Contemporary fall-line cities are labeled in the right panel.

Table 1: Proximity to Historical Portage Site and Contemporary Population Density

	(1) Basic	(2) Other spatial controls	(3)
Specifications:		State fixed effects	Distance from various features
Explanatory variables:			
Panel A: Census Tracts, 2000, N = 21452			
Dummy for proximity	1.113	1.009	1.118
to portage site	(0.340)***	(0.321)***	(0.243)***
Distance to portage	−0.617	−0.653	−0.721
site, natural logs	(0.134)***	(0.128)***	(0.118)***
Panel B: Nighttime Lights, 1996–97, N = 65000			
Dummy for proximity	0.504	0.445	0.490
to portage site	(0.144)***	(0.127)***	(0.161)***
Distance to portage	−0.188	−0.159	−0.151
site, natural logs	(0.065)***	(0.065)**	(0.090)

TABLE II
UPSTREAM WATERSHED AND CONTEMPORARY POPULATION DENSITY

	(1) Basic	(2) Other spatial controls	(3)	(4) Water power	(5)
Specifications:		State fixed effects	Distance from various features		
Explanatory variables:					
Panel A: Census Tracts, 2000, N = 21452					
Portage site times	0.467	0.467	0.500	0.496	0.452
upstream watershed	(0.175)**	(0.164)***	(0.114)***	(0.173)***	(0.177)**
Binary indicator	1.096	1.000	1.111	1.099	1.056
for portage site	(0.348)***	(0.326)***	(0.219)***	(0.350)***	(0.364)***
Portage site times				−1.812	
horsepower/100k				(1.235)	
Portage site times					0.110
I(horsepower > 2000)					(0.311)

Davis & Weinstein: "Bones, Bombs, and Breakpoints"

Does a temporary shock have permanent effects? After the Allied bombing in WWII, most cities returned to their rank in the distribution of city sizes within about 15 years

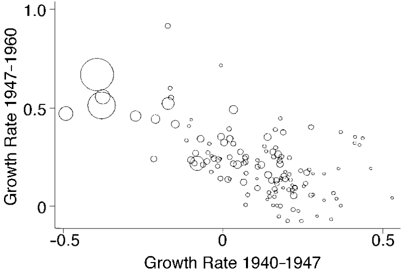


FIGURE 1. EFFECTS OF BOMBING ON CITIES WITH MORE THAN 30,000 INHABITANTS

Note: The figure presents data for cities with positive casualty rates only.

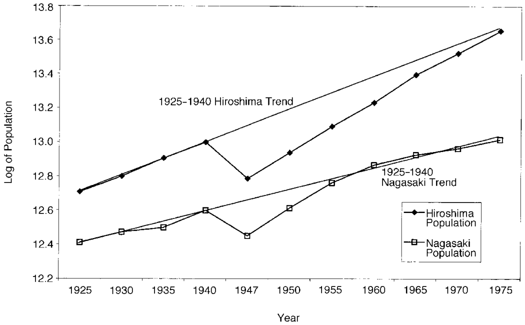


FIGURE 2. POPULATION GROWTH

Also, Miguel and Roland (*JDE* 2011): "even the most intense bombing in human history did not generate local poverty traps in Vietnam"

When and where does history matter?

Lin and Rauch (2022):

- "with a few important exceptions, major temporary shocks do not appear to permanently affect the fortunes of cities or large regions"
- "there is perhaps more evidence of history dependence in the location and scale of city-industries and even more evidence of history dependence in neighborhood sorting and segregation"
- "What factors might distinguish city-industries or neighborhoods from regions in making history dependence and multiplicity more empirically relevant? These factors may provide guidance on when history matters, and when it does not."

(Homogeneous) agglomeration: Henderson (1974)

"The Sizes and Types of Cities" addresses basic, fundamental questions about a system of cities in general equilibrium

- Why do cities exist?
- Are cities too large or too small?
- Why do cities of different sizes exist?

(Homogeneous) agglomeration: Henderson (1974)

"The Sizes and Types of Cities" addresses basic, fundamental questions about a system of cities in general equilibrium

- Why do cities exist? "because there are technological economies of scale in production or consumption"
- Are cities too large or too small? a stability argument says that cities tend to be too large
- Why do cities of different sizes exist? "because cities of different types specialize in the production of different traded goods"

Henderson (1974) environment

- Factors: land L, labor N, capital K
- Tradables production (external economies a la Chipman)

$$X_1^{1-\rho_1} = L_1^{\alpha_1} K_1^{\beta_1} N_1^{\gamma_1} \qquad \alpha_1 + \beta_1 + \gamma_1 = 1, \rho_1 \in (0,1)$$

- Housing production

$$X_3 = L_3^{\alpha_3} K_3^{\beta_3} N_3^{\gamma_3} \qquad \alpha_3 + \beta_3 + \gamma_3 = 1,$$

- Land sites produced by labor

$$L = N_0^{1/(1-z)} \qquad z < 0, z'(N) < 0$$

- Clear factor markets with prices p_N, p_K, p_L

$$N_0 + N_1 + N_3 = N, \quad K_1 + K_3 = K, \quad L_1 + L_3 = L$$

- Cobb-Douglas preferences ($U = x_1^a x_2^b x_3^c$) with income y, import of good 2, and prices q deliver indirect utility

Capitalists and workers

Different (stark) assumptions about capital ownership:

- each laborer owns equal capital stock (Assumption A)
- capital owners live outside of cities (Assumption B)

Utility components for labor income and capital income

$$U_N \propto p_N q_1^{-a} q_2^{-b} q_3^{-c}$$

$$U_K \propto \bar{p}_K \frac{\bar{K}}{\bar{N}} q_1^{-a} q_2^{-b} q_3^{-c}$$

Solving for optimal and equilibrium city sizes

- Optimum: maximize $U_N + U_K$, given the determination of U_N, U_K, and p_K through simultaneous location and investment of labor and capital in cities in the economy
- Equilibrium: atomistic choices of capital owners, firms, and laborers

Utility and factor prices

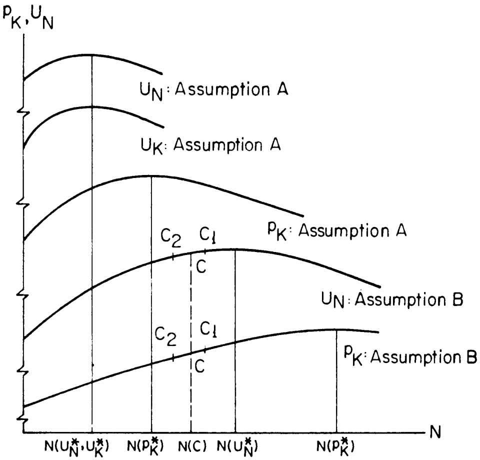


FIGURE 1. UTILITY AND CAPITAL RENTAL PATHS UNDER ASSUMPTIONS A AND B

- $\alpha_1 > \rho_1$ (site intensity vs IRS) is sufficient for both p_K and U_N to exhibit interior maxima
- p_K curve has peak to right of U_N and U_K peak because U_K is p_K deflated by q_3^{-c}
- Assumption B curves peak to right of Assumption A curves because capitalist income doesn't bid up housing prices
- Why isn't "two identical cities at point C" stable?

Optimal city size

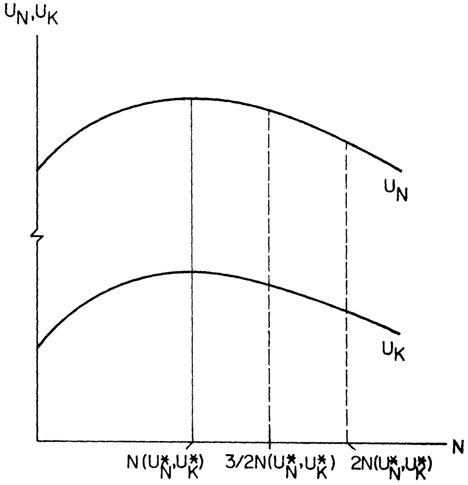


FIGURE 2. OPTIMUM CITY SIZE: ASSUMPTION A

- For Assumption A, maximize the vertical sum of U_N and U_K
- Planner has total population N and faces integer constraint
- Start second city when N is twice $N(U_N^*, U_K^*)$
  (Starting second city earlier is not a stable optimum)
- Figure 3 is more complicated due to Assumption B and the worker vs capitalist disagreement on optimal city size

Equilibrium city size

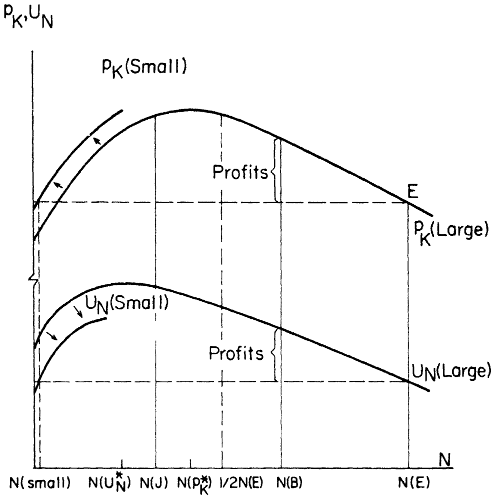


FIGURE 4. EQUILIBRIUM CITY SIZE

- Why is N(small) a bit of a fudge?
- Atomistic equilibrium with particular dynamics is at $N(E)$, way past both peaks
- City corporation attains optimal city sizes under Assumption B
- City corporation achieves $N(J)$ under Assumption A

BDRN (2014): "there is a coordination failure in city formation so that any population size between optimal city size and grossly oversized cities – leaving their residents with zero consumption – can occur in equilibrium."

Henderson (1974) on heterogeneous cities

- "Our second type of city specializes in the production of another type of traded good, say, X_2."
- "Different types of cities differ in size because production parameters, in particular α_i and ρ_i, differ between the traded goods of each type of city."
- "Although utility levels will be equalized between cities, wage rates and housing prices will vary with city type and size."

Developing-economy cities

- World Bank projects 2.7 billion more urban residents in developing economies by 2050
- Cities still require agglomeration and dispersion forces, but the technologies and conditions might differ
- Gollin, Jedwab, Vollrath "Urbanization with and without Industrialization" (2016) on 'consumption cities' in resource exporters
- Jedwab, Loungani, Yezer: cities in rich countries are tall and sprawl; in poor countries they crowd
- Typically, urban wages are much higher than rural wages
- Gollin, Kirchberg, Lagakos (2021): observed private consumption and amenities are higher in urban areas of 20 SSA countries (they avoid using prices)
- Henderson and Turner (2020): higher incidence of lifestyle diseases, poorer child health outcomes and greater exposure to crime
- See Bryan, Glaeser, Tsivanidis (2019) "Cities in the Developing World"

What is a city?

- Municipality versus county versus metropolitan area versus commuting zone
- An integrated labor market defined by commuting ties? (c.f. Monte et al 2018)
- What to do absent commuting flows? (Dingel, Miscio, Davis 2021)
- Discretization vs continuous linkages (Duranton and Overman 2005)
- Know the modifiable areal unit problem (MAUP)
- (Related: Are agglomeration economies about size or density?)

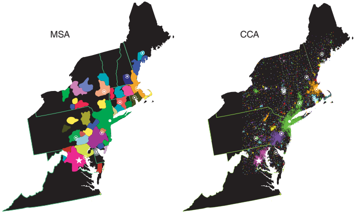


FIGURE 6. COMPARISON BETWEEN THE MSAS AND THE CCA CLUSTERS

Notes: Panel A shows the MSAs for the northeastern US. For example, New York county (Manhattan) with a population larger than 50,000 is a center of an MSA. Jersey City belongs to the same MSA since a large number of its population commute to Manhattan, setting economic and social ties between the two regions. Panel B shows the CCA clusters for the northeastern US for $\ell = 5$ km. Each cluster or MSA is plotted with a different grayscale. For instance, the MSA centered in New York City is composed of several clusters. The white concentric circles correspond to the location of the state capitals in the considered region. The star denotes Washington, DC, and the white full circle corresponds to New York City.

Data on lights at night

- Defense Meteorological Satellite Program-Operational Linescan System (DMSP-OLS) for 1992-2011 versus Visible Infrared Imaging Radiometer Suite (VIIRS) for 2011 onwards
- Lights are more useful for predicting GDP in cross section than time series (Chen and Nordhaus 2019 on both DMSP and VIIRS)
- Chen and Nordhaus (2019): high-resolution VIIRS lights better predict MSA GDP than state GDP (urban vs rural; lights do not explain value-added GDP in agriculture and forestry)
- Gibson, Kim, Li (2024): "these GDP-luminosity elasticities vary especially by spatial scale and metro status, and also by period and remote sensing source. The elasticities mainly capture extensive margins of luminosity."

Next week

- Up next: Quantitative spatial models
- Read Krugman (1991) before class so I can cover quickly