Income Heterogeneity, Transportation, and City Structure

Urban Economics: Week 2

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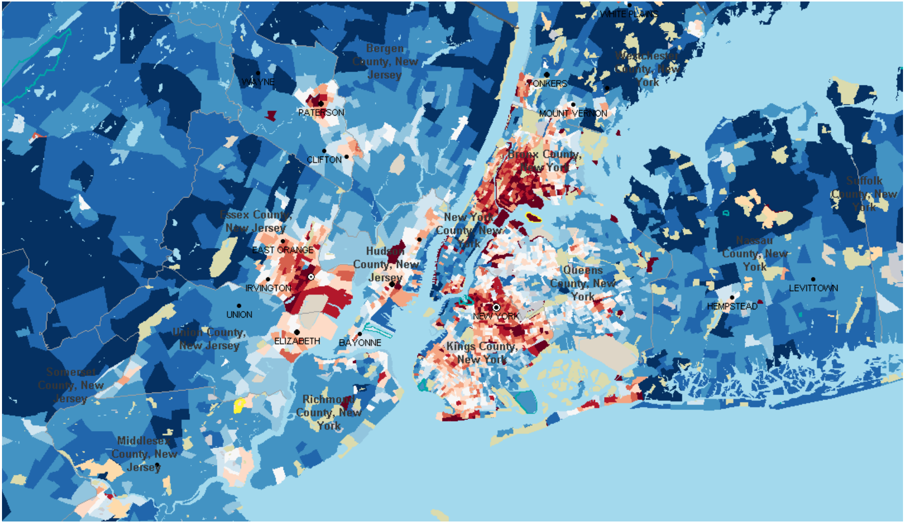
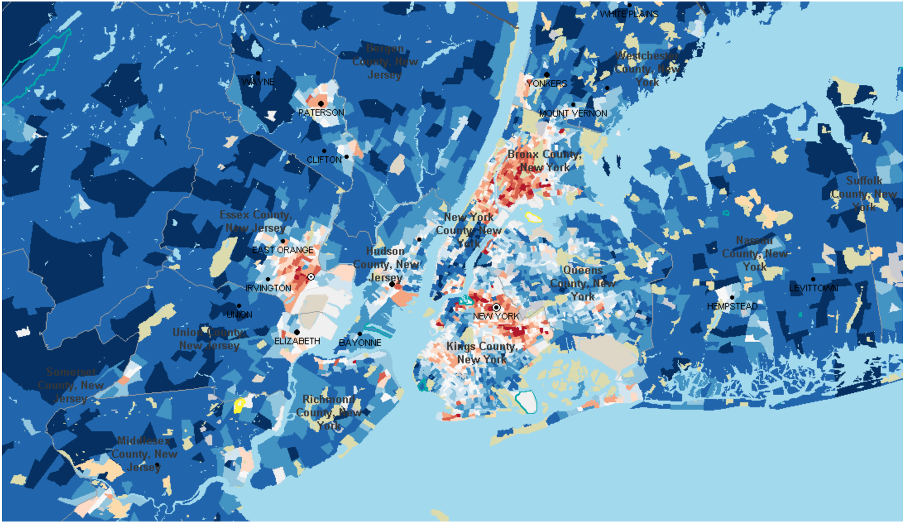
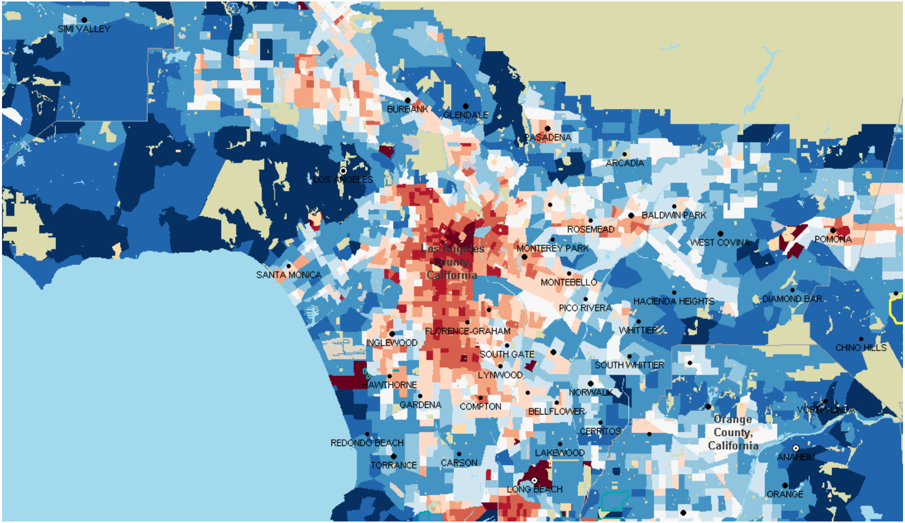
Median Household Income in New York



% Living in Poverty in New York



Median Household Income in Los Angeles



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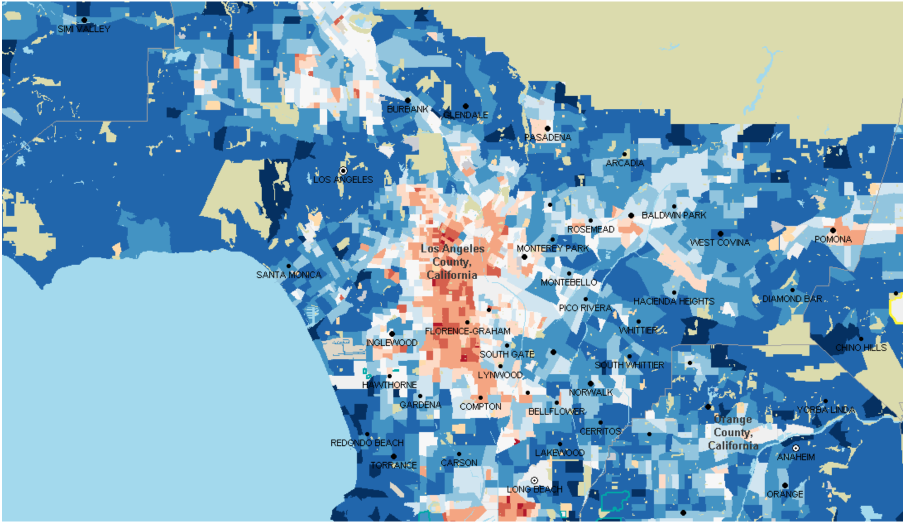
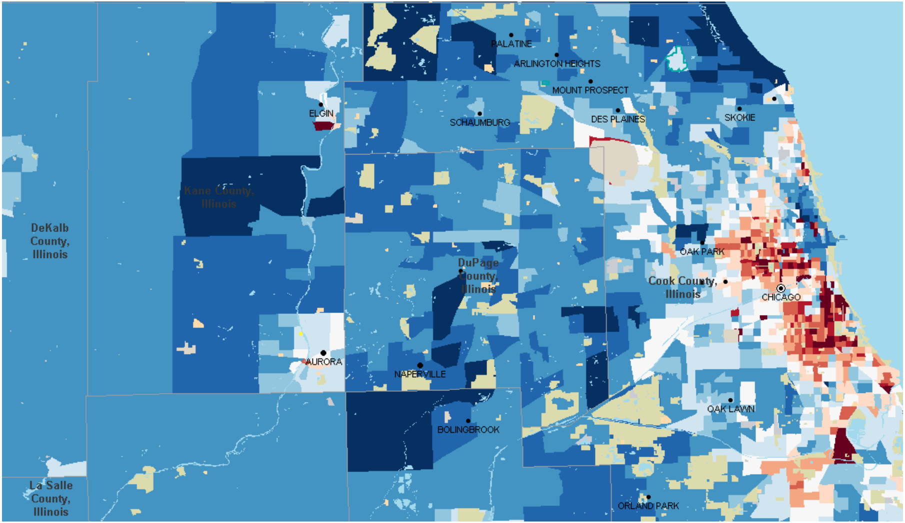
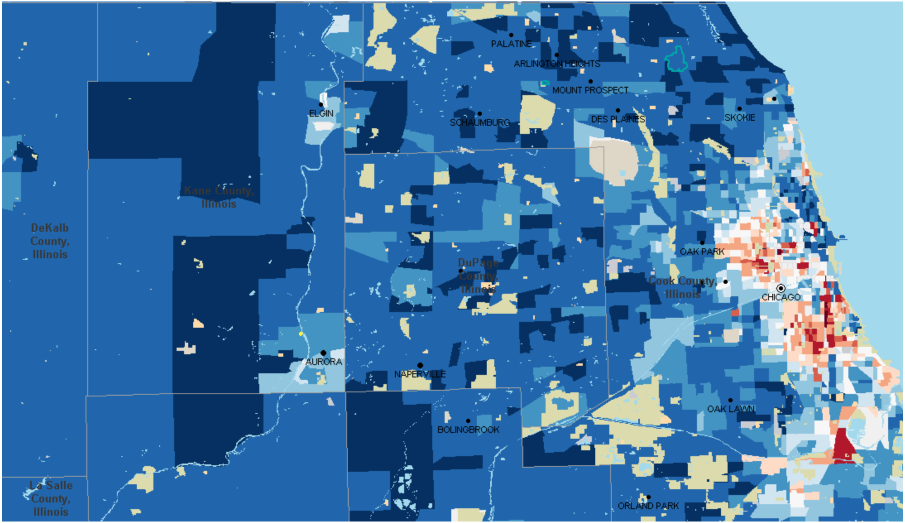


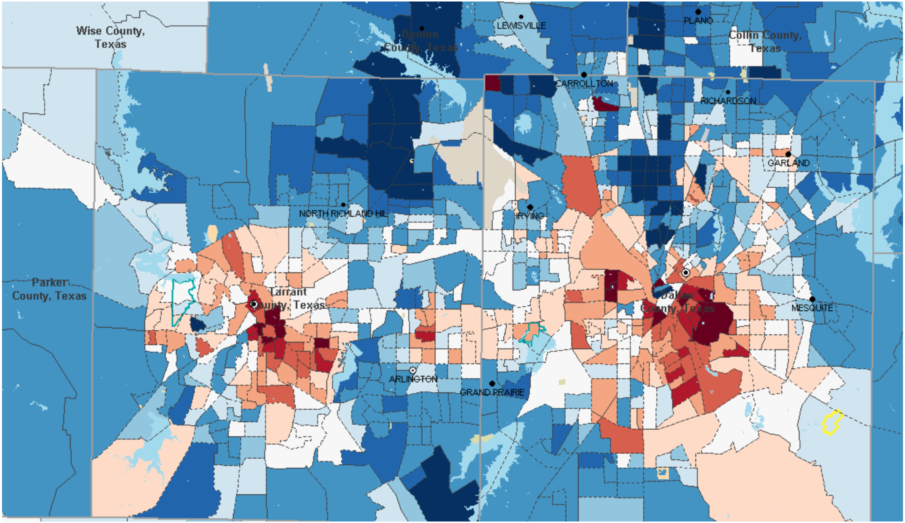
Median Household Income in Chicago



% Living in Poverty in Chicago



Median Household Income in Dallas – Fort Worth



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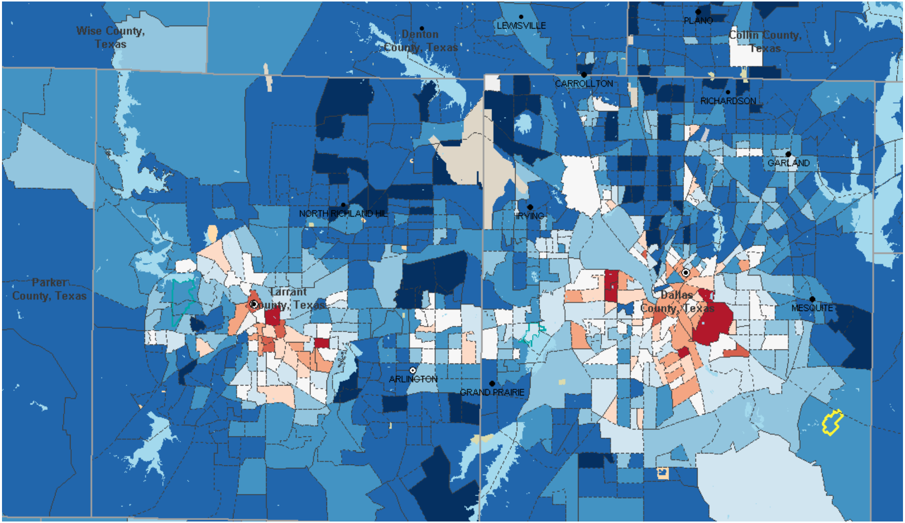


Basic Intuition

- Heterogeneous agents have heterogeneous bid rents
- Housing is efficiently allocated to the residents with the highest bid rent at any distance d
- Residents with the steepest bid rent live closer to the center
- Suppose an agent with income y has
  1. Commuting costs $dt(y)$
  2. An *exogenous* consumption of housing $h(y)$
- The bid rent has

$$\frac{\partial p}{\partial d} = -\frac{t}{h} \Rightarrow \frac{\partial^2 p}{\partial d \partial y} = \frac{t}{hy}\left(\frac{yh'}{h} - \frac{yt'}{t}\right)$$

- The rich live in the suburbs if h is more income-elastic than t

The Bid Rent in an Open City

- The bid rent p is defined by $\max_h u(w - td - ph, h) = \underline{u}$
- By the envelope theorem

$$\frac{\partial p}{\partial d} = -\frac{t}{h} < 0,\ \frac{\partial p}{\partial t} = -\frac{d}{h},\ \frac{\partial p}{\partial w} = \frac{1}{h} > 0, \text{ and } \frac{\partial p}{\partial \underline{u}} = -\frac{1}{hu_c} < 0$$

- The first-order condition is $u_h - pu_c = 0$
- The second-order condition is $s = -\left(u_{hh} - 2pu_{ch} + p^2 u_{cc}\right) > 0$
- The implicit-function theorem and the derivatives of p imply

$$\frac{\partial h}{\partial d} = \frac{tu_c}{hs} > 0,\ \frac{\partial h}{\partial t} = \frac{du_c}{hs} > 0,\ \frac{\partial h}{\partial w} = -\frac{u_c}{hs} < 0$$

and

$$\frac{\partial h}{\partial \underline{u}} = \frac{1}{hs} + \frac{u_{ch} - pu_{cc}}{su_c}$$

which is positive if (but not only if) housing is a normal good

Comparative Statics for Real Income

- A change in w and $\underline{u}$ proportional to the unit vector $\Delta = (\Delta_w, \Delta_{\underline{u}})$
- The directional derivative of the bid rent p is

$$\frac{\partial p}{\partial \Delta} = \frac{1}{h}\left(\Delta_w - \frac{\Delta_{\underline{u}}}{u_c}\right)$$

- The directional derivative of its slope $\partial p/\partial d = -t/h$ is

$$\frac{\partial^2 p}{\partial d \partial \Delta} = \frac{t}{h^2}\left(\frac{\partial h}{\partial w}\Delta_w + \frac{\partial h}{\partial \underline{u}}\Delta_{\underline{u}}\right) = \frac{t}{h^2}\left(\frac{u_{ch} - p u_{cc}}{s u_c}\Delta_{\underline{u}} - \frac{u_c}{s}\frac{\partial p}{\partial \Delta}\right)$$

  such that

$$\frac{\partial p}{\partial \Delta} = 0 \Rightarrow \frac{\partial^2 p}{\partial d \partial \Delta} = \frac{u_{ch} - p u_{cc}}{s}\frac{t\Delta_{\underline{u}}}{h^2 u_c}$$

  which is positive if and only if housing is a normal good
- Then there is a distance d_Δ such that

$$\frac{\partial p}{\partial \Delta} \lesseqgtr 0 \Leftrightarrow d \lesseqgtr d_\Delta$$

Sorting by Income

If agents with $(w_i, \underline{u}_i) \neq (w_j, \underline{u}_j)$ live in the same city

1. The rich have higher wages and higher utility: $w_i < w_j \Leftrightarrow \underline{u}_i < \underline{u}_j$
2. If $(w_i, \underline{u}_i) < (w_j, \underline{u}_j)$ and housing is a normal good, there is a distance $d_{ij} \in [0, \bar{d}]$ such that the poor live in $[0, d_{ij}]$ and the rich in $[d_{ij}, \bar{d}]$

- When housing is a normal good the rich consume more of it
- Heavy consumers of housing prefer to live where it is cheaper
- The rich have big houses in the suburbs, the poor small ones in the city center
- The sorting would be reversed if house size were an inferior good
    - A theoretical curiosity

Heterogeneous Commuting Costs

- Since commuting costs are largely opportunity costs of time, t is likely to rise with w.
- Consider changes proportional to the unit vector $\Delta = (\Delta_t, \Delta_w, \Delta_{\underline{u}})$
- The directional derivative of the bid rent is

$$\frac{\partial p}{\partial \Delta} = \frac{1}{h}\left(\Delta_w - d\Delta_t - \frac{\Delta_{\underline{u}}}{u_c}\right)$$

so that

$$\frac{\partial p}{\partial \Delta} = 0 \Rightarrow \frac{\partial^2 p}{\partial d \partial \Delta} = \frac{t}{h}\left(\frac{u_{ch} - pu_{cc}}{s}\frac{\Delta_{\underline{u}}}{hu_c} - \frac{\Delta_t}{t}\right)$$

- In equilibrium there is monotonic sorting if the last term has an unambiguous sign

Income Elasticities

- The income elasticity of housing demand for utility $u(c,h)$ is

$$\eta_{h,y} = \frac{u_{ch} - pu_{cc}}{s} \frac{y}{h}$$

- Define income net of commuting costs by $y = w - td$
  1. Its directional derivative with respect to Δ is

$$\frac{\partial y}{\partial \Delta} = \Delta_w - d\Delta_t$$

  2. The elasticity of t to y for changes proportional to Δ is

$$\eta_{t,y} = \frac{\Delta_t}{t} \frac{y}{\partial y / \partial \Delta}$$

- We can rewrite

$$\frac{\partial p}{\partial \Delta} = 0 \Rightarrow \frac{\partial^2 p}{\partial d \partial \Delta} = \frac{t}{hy} \left(\eta_{h,y} - \eta_{t,y} \right) \frac{\Delta_{\underline{u}}}{u_c}$$

Sorting in an Open City

- If $\eta_{h,y} > \eta_{t,y}$ the rich live in the suburbs and the poor in the center
- If $\eta_{h,y} < \eta_{t,y}$ the rich live in the center and the poor in the suburbs
- If commuting has linear cash and time costs

$$t = \underline{t} + \tau w$$

then $\Delta_t = \tau \Delta_w$ and

$$\eta_{t,y} = 1 - \frac{\underline{t}}{(1 - \tau d)(\underline{t} + \tau w)} \in [0, 1]$$

- If $u(c, h)$ is Cobb-Douglas and $\underline{t} > 0$ then $\eta_{h,y} = 1 > \eta_{t,y}$
- In practice $\eta_{t,y} < 1$ is persuasive, but $\eta_{h,y} \geq 1$ less so
- Housing expenditure is a roughly constant share of income, but quality is a factor in addition to size and location

Alternative Transportation Technologies

- Two transportation technologies: cars a and public transport b
- Transport costs

$$t_m(d) = T_m + (t_m + \tau_m w) d$$

- The car is faster but more expensive

$$T_a > T_b,\ t_a > t_b, \text{ and } \tau_a < \tau_b$$

- An agent with wage

$$w > \frac{t_a - t_b}{\tau_b - \tau_a}$$

prefers the car iff he lives at a distance greater than

$$d_{ab}(w) = \frac{T_a - T_b}{t_b + \tau_b w - t_a - \tau_a w}$$

Transport Choice and the Bid Rent

- The cost of commuting is

$$t(d,w) = \min_{m\in\{a,b\}} T_m + (t_m + \tau_m w)\, d = \begin{cases} T_b + (t_b + \tau_b w)\, d & \text{if} \quad d \leq d_{ab}(w) \\ T_a + (t_a + \tau_a w)\, d & \text{if} \quad d \geq d_{ab}(w) \end{cases}$$

- The bid rent $p(d, w, \underline{u})$ is defined by

$$\max_{h\geq 0} u(w - t(d,w) - ph, h) = \underline{u}$$

- Its gradient is

$$\frac{\partial p}{\partial d} = \begin{cases} -\frac{t_b + \tau_b w}{h} & \text{if} \quad d < d_{ab}(w) \\ -\frac{t_a + \tau_a w}{h} & \text{if} \quad d > d_{ab}(w) \end{cases}$$

with a convex kink at $d_{ab}(w)$

Sorting by Income

- The poor i and the rich j live in the same city
- There is a threshold d_{ij} separating them
- Around the threshold, either group $g \in \{i, j\}$ consumes housing h_g and chooses a transportation technology $g \in \{a, b\}$
- The rich live on the suburban side of the threshold iff

$$\frac{t_i + \tau_i w_i}{h_i(d_{ij})} > \frac{t_j + \tau_j w_j}{h_j(d_{ij})}$$

- If the arc elasticity of housing consumption is low, this does not hold when both groups use the same technology, whether car or public transport
- But it may hold if the rich use a and the poor b

Transportation Choice and Non-Monotonic Sorting

Without fixed costs ($T_a = 0$) sorting is monotonic:

1. Rich in the center and poor in the suburbs using the same technology
2. Poor in the center using b, rich in the suburbs using a

Fixed costs $T_a > 0$ can induce multiple concentric rings

1. The area closest to the center is inhabited by the rich using b
2. A middle ring is inhabited by the poor using b
3. The suburbs are inhabited by the rich using a
4. The fringes of the city can be inhabited by the poor using a

- New York City has a bagel of poverty around the rich center
  - But how many rich city dwellers don't own a car?

Exogenous Amenities

- The utility function $u(c, h, a)$ includes local amenities a
  1. Natural amenities: hills, bodies of water, etc.
  2. Historical amenities: buildings, monuments, etc.
- The bid rent p is defined by $\max_h u(w - t(d) - ph, h, a) = \underline{u}$
  - First-order condition $u_h - pu_c = 0$
  - Second-order condition $s = -\left(u_{hh} - 2pu_{ch} + p^2 u_{cc}\right) > 0$
- By the envelope theorem

$$\frac{\partial p}{\partial a} = \frac{u_a}{hu_c} > 0$$

- If amenities vary with distance according to $a(d)$, then

$$p'(d) = \frac{1}{h(d)}\left[\frac{u_a}{u_c} a'(d) - t'(d)\right]$$

Amenities and Housing Consumption

- By the implicit-function theorem

$$\frac{\partial h}{\partial a} = -u_a \left(\frac{1}{sh} + \frac{u_{ch} - pu_{cc}}{su_c} \right) + \frac{u_{ah} - pu_{ac}}{s}$$
$$= -u_a \frac{\partial h}{\partial \underline{u}} + \frac{u_h}{s} \left(\frac{u_{ah}}{u_h} - \frac{u_{ac}}{u_c} \right)$$

- The sign of the last term is ambiguous
  - Amenities might be strong complements to house size
  - Amenities might be substitutes to non-housing consumption
- Most likely $\partial h / \partial a < 0$: in high-amenity areas people have smaller houses and pay higher prices per square metre.
- An empirical pitfall when trying to estimate the value of amenities
  1. Using housing expenditure is not enough
  2. Using median housing values is not enough

Amenities and Income Heterogeneity

- Suppose that $t(d) = td$ and that $a(d)$ is monotonic
- Rich and poor with $(t_i, w_i, \underline{u}_i) < (t_j, w_j, \underline{u}_j)$
- A boundary at d_{ij} separates the two groups
- The rich live on the suburban side iff at d_{ij}

$$\frac{t_i}{h_i(d_{ij})} - \frac{t_j}{h_j(d_{ij})} > \left[\frac{\partial p_i}{\partial a}(d_{ij}) - \frac{\partial p_j}{\partial a}(d_{ij})\right] a'(d_{ij})$$

- Take the standard perspective that $t_i / h_i > t_j / h_j$
  - The arc elasticity of transport cost is smaller than that of housing
  - Possibly because of endogenous transport mode
- If $a'(d) \approx 0$ the usual logic makes the rich live in the suburbs

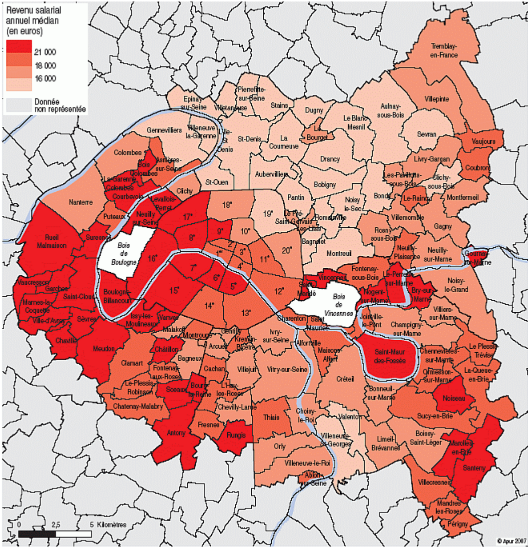
Why Is Central Paris Rich?

1. Amenities decline rapidly with distance from the center: $a'(d) \ll 0$
   - Historical amenities are concentrated in the center
   - The historical residents of the city liked natural amenities
2. The rich have a higher marginal willingness to pay for amenities: $\partial p_i / \partial a < \partial p_j / \partial a$

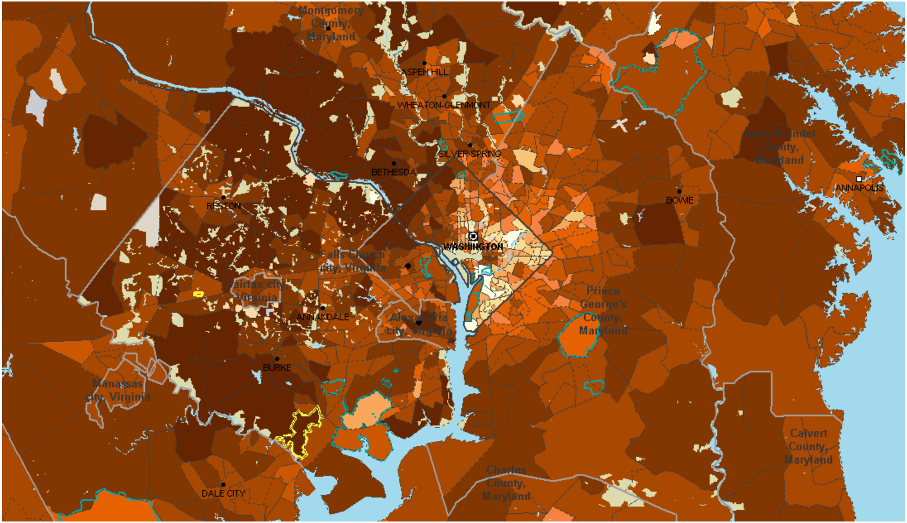
- The latter property is neither obvious nor trivial because h adjusts
  1. If h were fixed, u_a / u_c would unambiguously increase with income
  2. Presumably u_a / u_c increases with income even when h does
  3. But does u_a / u_c increase faster than h?
- The assumption in terms of arc elasticities

$$\frac{\partial \log (u_a / u_c)}{\partial \log y} > \frac{\partial \log h}{\partial \log y} > \frac{\partial \log t}{\partial \log y}$$

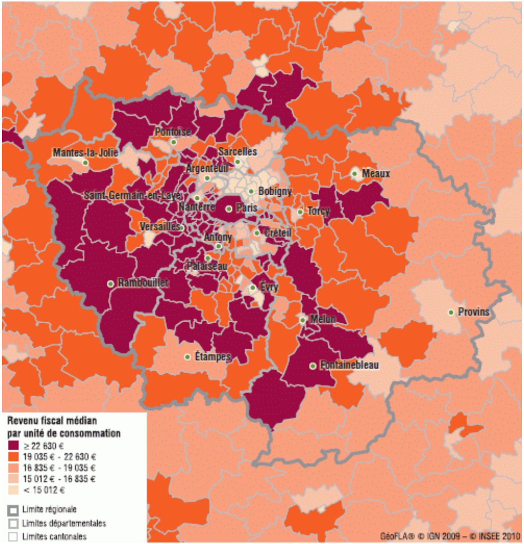
Median Household Income in Paris



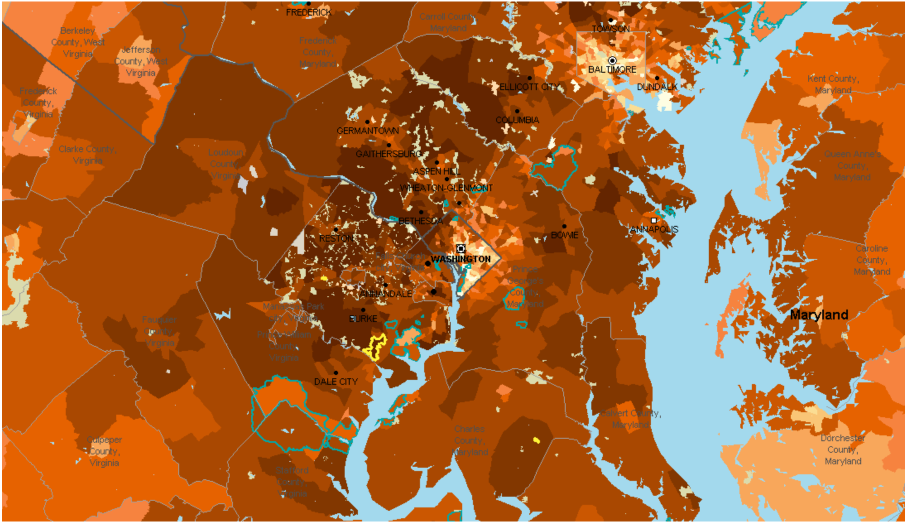
Median Household Income in Washington, D.C.



Median Household Income in Île-de-France



Median Household Income around Washington – Baltimore



Endogenous Amenities

- Residents' wealth brings amenities to a neighborhood
  - Nicer buildings, better public services, less petty criminality
- Some amenities may be such only for the rich
  - Prestigious addresses, upscale shops, proximity to the rich

Endogenous segregation:

1. The rich like living with the rich, the poor with the poor
   - Consumption goods appropriate to their income
   - Neighborliness, class loyalty
   - *Pares autem vetere proverbio cum paribus facillime congregantur*
2. Everyone likes wealth-induced amenities, but the rich have a higher willingness to pay
   - Complementarity between private consumption and amenities
   - Decreasing marginal utility of income
3. Everyone likes living with the poor, but the poor more so
   - Social networks substitute for market goods
   - Seemingly less realistic than 1 and 2

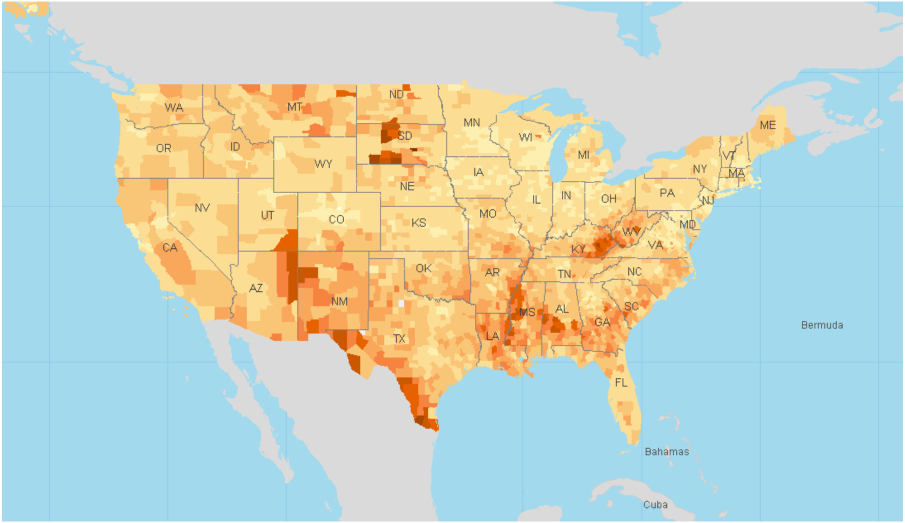
Multiple Equilibria

Endogenous amenities may create multiple equilibria

1. The rich live in the suburbs
   - The bid-rent gradient is relatively flat
   - Prices underestimate the value of proximity to the CBD
2. The rich live in the center
   - The bid-rent gradient is extremely steep

- Neighborhood spillovers alone explain segregation but not its pattern
- Is "white flight" $(2 \to 1)$ easier than gentrification $(1 \to 2)$?
  - First movers always lose proximity to the rich
  - Early gentrification means moving close to the poor
  - Early suburbanization can mean having few neighbors
- If poverty has a worse impact in urban centers, 2 is more efficient
  - Then property developers have market incentives to achieve 1

Poverty in the United States

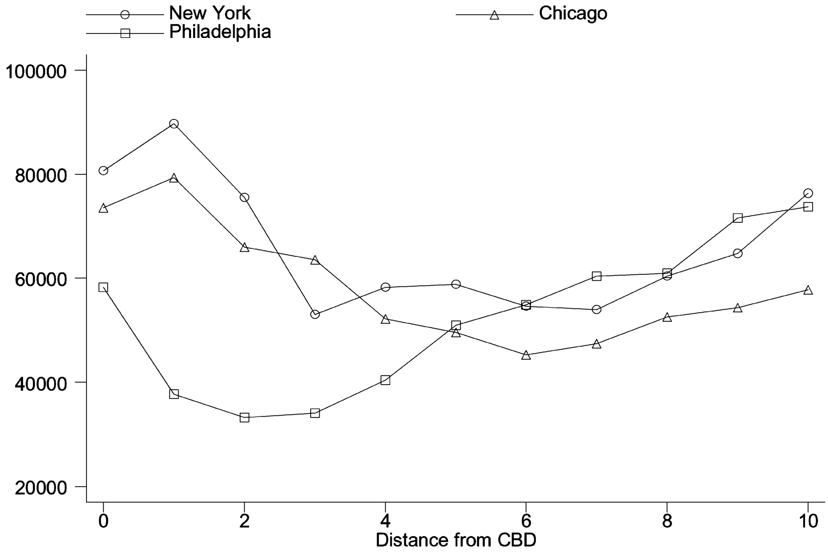


Poverty in U.S. Cities and Suburbs

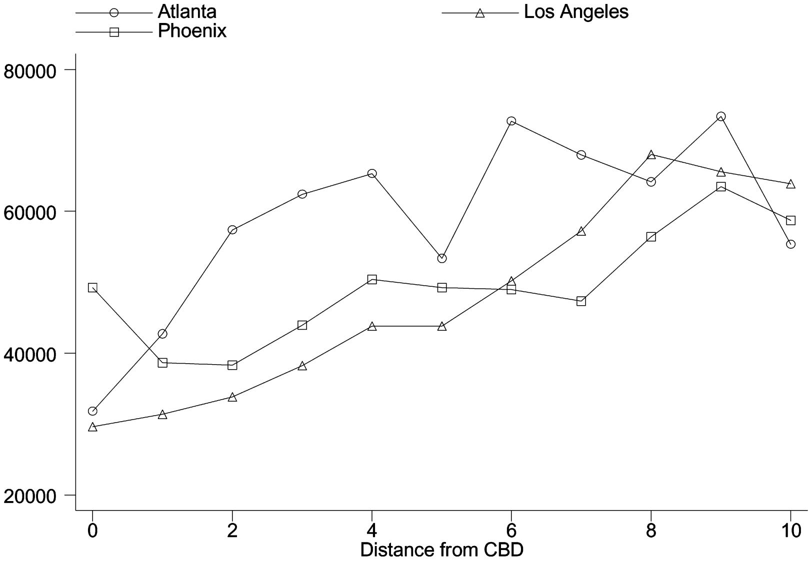
Row		Center city resident	Suburban resident	Metropolitan area resident center city status unknown	Non-metro area resident
1	All	0.1990	0.0753	0.1195	0.1290
2	Northeast	0.2089	0.0599	0.1184	0.0914
3	Midwest	0.1984	0.0565	0.0988	0.1036
4	South	0.1865	0.0744	0.1282	0.1546
5	West	0.1895	0.1031	0.1247	0.1403
6	Changed house in the last 5 years	0.2166	0.0974	0.1453	0.1626
7	Changed house within the same MSA in the last 5 years	0.2186	0.0941	0.1399	
8	Changed house and MSA in the last 5 years	0.2130	0.1004	0.1519	
9	Stayed in same house for the last 5 years	0.1695	0.0538	0.0846	0.0947
10	Blacks	0.2768	0.1364	0.2375	0.2863
11	Non-blacks	0.1677	0.0690	0.1013	0.1142
12	Age 18–39	0.1911	0.0814	0.1300	0.1478
13	Age 40–65	0.1395	0.0494	0.0752	0.0849
14	Not in the labor force	0.2724	0.1180	0.1728	0.1852
15	In the labor force	0.1030	0.0403	0.0663	0.0748
16	Male	0.1835	0.0682	0.1092	0.1149
17	MSA's percent black is 10% or less	0.1821	0.0857	0.1234	

Note. This table reports sample means based on micro data from the 2000 IPUMS 1% sample.

The Income Gradient in Older U.S. Cities



The Income Gradient in Newer U.S. Cities



Why Do the Urban Poor Live in the Inner City in the U.S.?

- Within U.S. metropolitan areas, the poor live closer to the center
  1. In 2000, the poverty rate within 10 miles of the CBD is 14.5%
  2. For people living 10 to 25 miles of the CBD it is 8.3%
- This is a spatial equilibrium phenomenon
  - It is true for newcomers as much as for long-time residents
- It is hugely correlated with race, but it is present within races too
- It is particularly true in the older U.S. cities
  - Strongest in the Northeast, weakest in the West
- Concentrated poverty is quite natural; but why in the center?

Estimating the Income Elasticity of Demand for Land

Glaeser, Kahn, and Rappaport (2008)

- Actual data on lot size for single-family homes

1. Price is not observed
   - If AMM is right the coefficient is biased upward as the rich face lower prices
   - Minimum lot size regulation would also induce an upward bias
2. Current income is a noisy measure of permanent income
   - Attenuation bias: instrument income with education
3. Having a single family home by itself means consuming more land
   - Impute the land demand for an apartment of known floor area

$\Rightarrow$ Estimated range: $\eta_{h,y} \in [0.25, 0.55] \ll 1$

The Income Elasticity of Demand for Space

	Log of land per household					Log(Age of Unit)	
	Single detached OLS (1)	Single detached OLS (2)	Single detached IV (3)	Apartment and single detached OLS (4)	Apartment and single detached IV (5)	OLS (6)	IV (7)
Log of household income	0.0807	0.0783	0.2570	0.3442	0.5484	−0.0514	−0.2283
	(0.0075)	(0.0078)	(0.0263)	(0.0944)	(0.0294)	(0.0382)	(0.0121)
Constant	8.3144	7.8943	5.5720	4.5643	0.5608	4.1780	6.2523
	(0.0809)	(0.0934)	(0.3304)	(0.1005)	(0.3871)	(0.0382)	(0.1615)
Demographic controls included	no	yes	yes	no	yes	no	no
MSA fixed effects included	yes	yes	yes	yes	yes	yes	yes
Observations	13,081	13,081	13,081	21,154	21154	24,076	24,076
Adjusted R-squared	0.0960	0.1060		0.1560		0.1292	

Notes. Numbers in parentheses are standard errors. The dependent variable in columns (1)–(3) is the log of lot size for people who live in single detached dwellings. For apartment dwellers the dependent variable is the log of (unit's interior square footage $*$ 1.5/(floors in their building)). In columns (2), (3), and (5) the demographic controls include the head of household's age, race, number of people in the household and whether children are present. In columns (3), (5) and (7), head of household's education is used as an instrumental variable for income. The data source is the 2003 American Housing Survey. The unit of analysis is a household.

- The last two columns are our brief encounter with "filtering"

A Brief Aside: Filtering

- The housing stock as a cause (rather than a consequence) of location

1. High-quality new housing is built for the rich
   - The rich leave the old city center for the new suburbs
2. Housing deteriorates over time and is handed down to the poor
   - The location of the poor lags that of the rich
3. The oldest housing is eventually redeveloped
   - Gentrification brings the rich back to the center
     Bruckner and Rosenthal (2009)

- Empirically, very new and very old houses are the most valued

Travel Times by Mode and Location

Reasonable parameter estimates support LeRoy and Sonstelie (1983)

- Those earning $10/h use public transport, those earning $20/h a car

	Travel time to work (minutes)			
	Walking (1)	Car (2)	Bus (3)	Subway (4)
Intercept	4.0731	5.6182	22.1610	18.4106
	(0.3170)	(0.1055)	(1.3015)	(1.9547)
Miles to work	10.2305	1.5881	2.9472	3.3228
	(0.3585)	(0.0180)	(0.2580)	(0.3132)
Observations	899	14,792	602	352
Adjusted R-squared	0.5680	0.3570	0.4161	0.2507

Notes. The unit of analysis is a person. The data source is the 2001 National Household Transportation Survey. In column (1), the sample is the set of commuters who live within 3 miles from work. MSA fixed effects are included in each specification. In columns (2)–(4), the sample includes all workers who live within 10 miles of where they work. Numbers in parentheses are standard errors.

The Effects of Public Transportation

- The location of rail and subway lines predicts the location of the poor
  - It reduces significantly the explanatory power of raw distance
- In cities with little public transport the rich live closer to the center
- Within 3 miles of the CBD in older cities with a subway
  1. Income falls with distance from the CBD
  2. The correlation between income and public transport usage is 0.26
  3. The correlation between income and walking to work is 0.162

$\Rightarrow$ Cities built before the car fit the three-mode pattern to this day

The Defining Characteristics of Sprawl

1. Decentralization
   - Employment is no longer concentrated in the CBD
   - Associated decentralization of population
2. Low density
   - We have models of polycentric cities
   - But sprawl replaces the dense CBD with diffuse employment

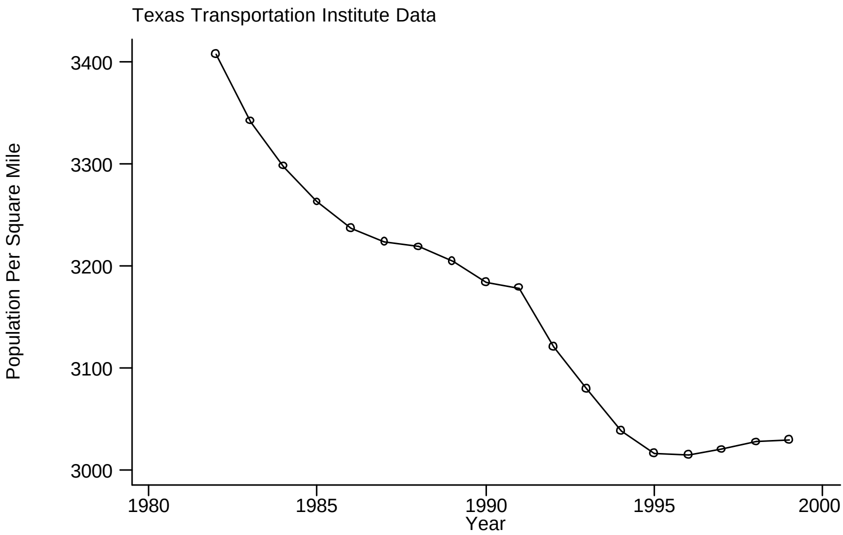
- Both can be measured in many ways
  - All are correlated, but sometimes very weakly
  - The ranking of cities varies according to the measure

Sprawling U.S. Cities

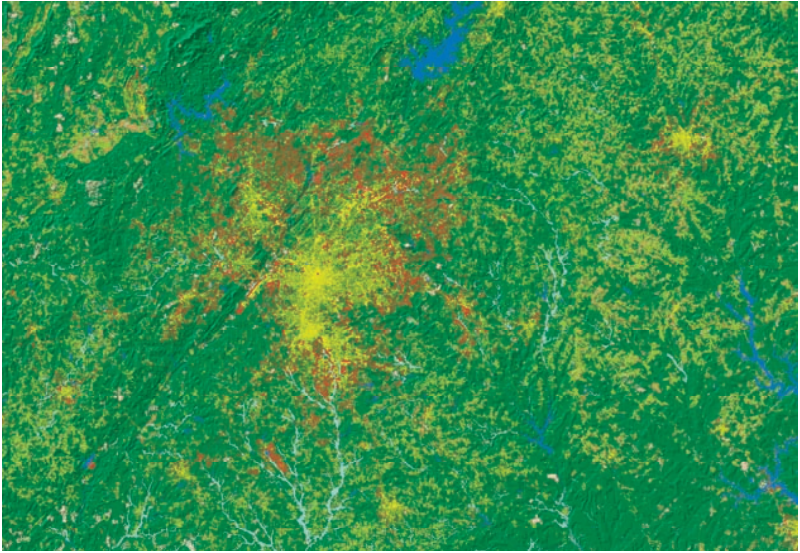
MSA Measure for 150 Major MSAs	mean	s.d	10th Percentile	90th Percentile
Percentage of Population Within Inner 3 Mile Ring	18.26	10.82	5.78	32.9
Percentage of Population Within Inner 5 Mile Ring	34.72	15.71	17.54	55.94
Percentage of Population Within Inner 10 Mile Ring	63.95	16.51	40.17	86.13
Percentage of Employment Within Inner 3 Mile Ring	25.71	12.33	10.94	43.76
Percentage of Employment Within Inner 5 Mile Ring	42.59	18.09	19.29	66.67
Percentage of Employment Within Inner 10 Mile Ring	70.18	18.53	43.1	91.5
MSA Average Population Density	2952	3969	917	4971
MSA Average Employment Density	3900	9867	624	6519
Overall MSA Population Density	1008	1782	230	2031
Median Person's Distance in Miles from CBD	7.88	2.97	4.55	11.72
Median Worker's Distance in Miles from CBD	6.93	3.27	3.54	12.05

Average Population Density and Average Employment Density are defined as the weighted average of
of zip code density where the weight is the zip code's share of total MSA activity.
Inner Rings refer to distance from the Central Business District.
Median Distance is the location such that 50Percentage of economic activity in the MSA is beyond that distance.

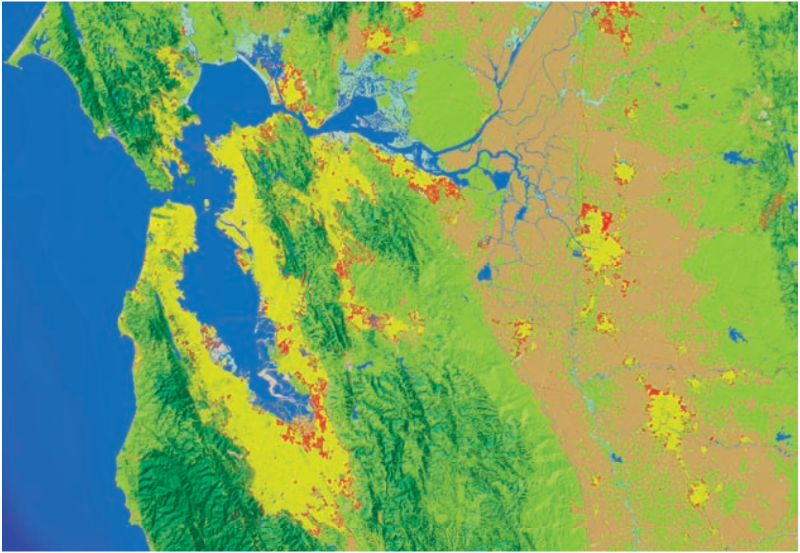
The Evolution of Urban Population Density in the U.S.



Atlanta: The Epitome of Sprawl

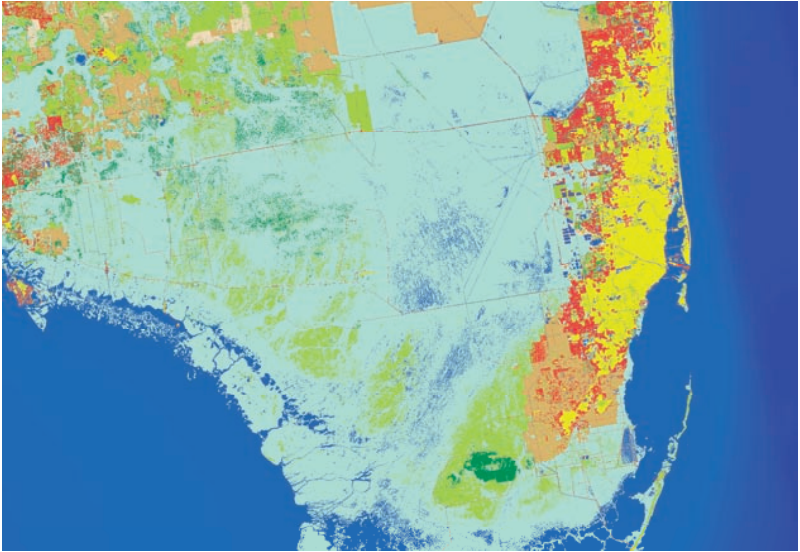


San Francisco: A Compact City

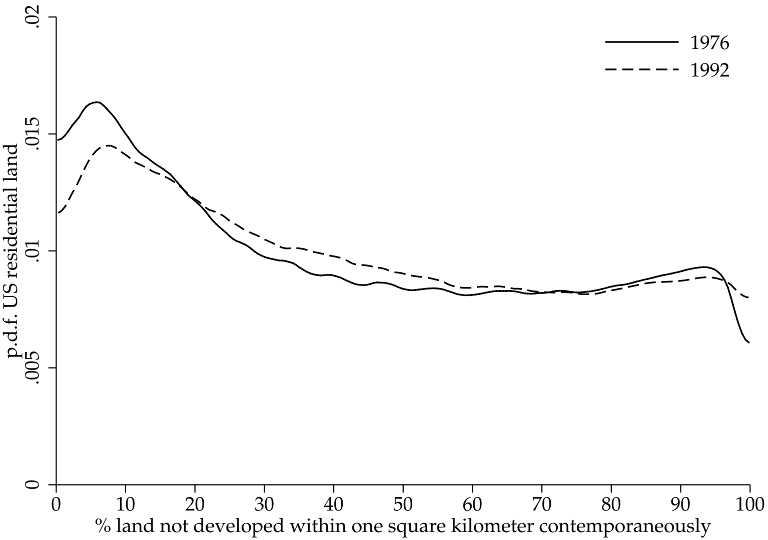


Boston: Compact Core, Scattered Development

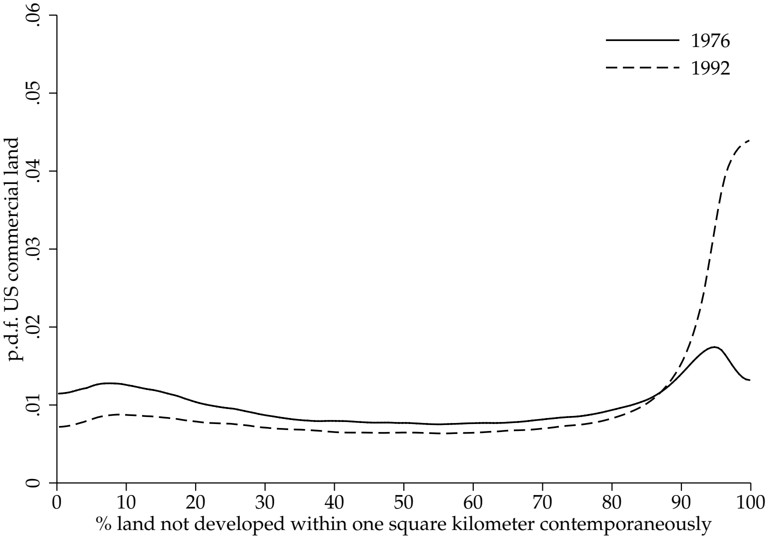
Miami: Contiguous Growth



Residential sprawl in the U.S., 1976–1992



Employment Sprawl in the U.S., 1976–1992



Theories of Sprawl

In a monocentric city, sprawl can result from

1. Lower transport costs
2. Lower opportunity cost of land
3. An increased desire or subsidy for large houses

▷ Greater demand for the city makes it bigger but denser

A polycentric city is more decentralized for

1. Lower costs of creating a new employment subcenter
2. Smaller productivity advantage of proximity to the center
3. Greater demand for the city: e.g., better climate

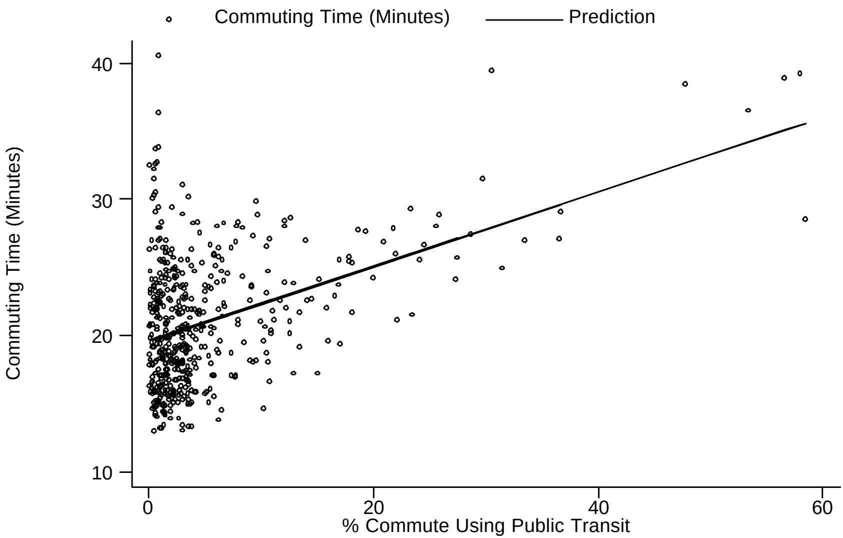
Non-contiguous development is more likely if

1. City growth is slower
2. City growth is more uncertain

Transport Technology Shapes Urban Form

1. Old ports: New York
   - Goods are shipped on waterways
   - People walk around the city
   - High density city
2. Railroads and streetcars: Chicago
   - Large capital investments
   - Hub and spoke network
   - High density center
3. Cars and Trucks: Los Angeles
   - Point to point transportation
   - Manufacturing can decentralize
   - Cars not only enable but require lower densities

Cars and Commute Times across U.S. Cities



Transportation Modes and Sprawl in the U.S.

Variable	Whole Sample	Sprawled MSAs	Centralized MSAs	Centralized MSA in Northeast
Percentage of Trips by Private Vehicle	86.34	91.55	81.82	72.54
Percentage of Trips Walked	7.39	4.65	10.19	17.53
Percentage of 1 mile or shorter trips by private vehicle	68.47	77.6	62.27	51.07
Percentage of Shopping Trips by Private Vehicle	87.06	92.93	81.8	72.25
Percentage Went Out to Eat by Private Vehicle	84	90.36	77.95	69.16
Average Trip Time in Minutes	**Whole Sample**	**Sprawled MSAs**	**Centralized MSAs**	**Centralized MSA in Northeast**
All Trips	16.76	16.48	17	17.72
1 mile or shorter trips by private vehicle	4.7	4.52	4.85	4.86
Shopping Trips	12.07	12.29	11.87	11.75
Eating Trips	13.25	13.5	13.02	13.18
Non-Car Trips	19	17.2	19.93	21.15
Walking Trips	10.59	9.68	11.01	10.67
Bus Trips				35.57
Subway Trips				39.04

The data source is the 1995 National Personal Transportation Survey Day Trip File.
The unit of analysis is a trip. The NPTS Sample covers 46 MSAs.
Centralized MSAs are those above the median of the Smart Growth Index of Ewing, Pendall and Chen (2002).
Sprawled MSAs have an index score below this median.

International Evidence on Transportation and Density

	Log of Urban Density			Vehicles Per-Capita			Log of Gasoline Price Regime
Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
vehicles per-capita	-0.0047 (0.0006)		-0.0075 (0.0010)	-0.0052 (0.0013)			
gasoline price regime		0.0134 (0.0016)			-1.7861 (0.2547)	-2.1069 (0.4545)	
real GDP per-capita	0.0001 (0.0006)	-0.0002 (0.0000)	0.0002 (0.0000)	0.0001 (0.0001)	0.0445 (0.0019)	0.0436 (0.0025)	0.0000 (0.0000)
French Legal Origin Dummy							0.5592 (0.1772)
constant	9.1510 (0.1358)	8.4910 (0.1709)	8.9717 (0.1642)	9.0864 (0.1775)	64.2527 (27.2768)	95.7327 (44.3699)	4.2110 (0.1536)
observations	70	70	70	62	70	62	62
R2	0.776	0.7902			0.8907		0.1632
Estimation	OLS	OLS	IV	IV	OLS	IV	OLS

The Data source is the Ingram and Liu (1999) International Data set. The time trend is suppressed.
In regression (3), the gasoline price regime is used as an instrument for vehicles per-capita.
In regression (4), legal origin dummies are used as an instrument for vehicles per-capita.
In regression (6), legal origin dummies are used as an instrument for gas price regime.
Vehicles per 1000 has a mean of 294 and a standard deviation of 207.4.
Gasoline price regime has a mean of 70.2 and a standard deviation of 33.14.
real GDP per-capita has a mean of 8297 and a standard deviation of 4331.

The cities in the sample include: Adelaide, Amsterdam, Bandung, Bangkok, Brisbane, Brussels, Chicago, Copenhagen, Denver, Detroit, Frankfurt, Guangzhou, Hamburg, Hong Kong Jakata, Los Angeles, London, Manila, Melbourne, Munich, NYC, Osaka, Paris, Perth Phoenix, San Francisco, Seoul, Singapore, Stockholm, Surabaya, Sydney, Tokyo, Toronto, Vienna and West Berlin.

Other Causes of Sprawl

1. Rising incomes lead to higher demand for land
   - Complementary to car ownership
   - Sprawl is not greater in richer U.S. cities
2. White flight
   - Sprawl is modestly correlated with inner-city poverty in the U.S.
3. U.S. government subsidies
   1. Federal highway spending
   2. Low (sub-Pigovian) gasoline taxation
   3. Mortgage interest deduction
4. Local government policy
   1. Tiebout competition
   2. Rich people fleeing redistribution
   3. Zoning and building restrictions

Which Cities Have More Sprawl?

	Regression results				Summary statistics	
	(1)	(2)	(3)	(4)	Mean	St. dev.
Centralized-sector employment 1977	-1.270 (0.517)**	-1.194 (0.526)**	-0.922 (0.599)	-0.462 (0.489)	22.65	1.14
Streetcar passengers per capita 1902	-1.723 (0.507)***	-1.918 (0.553)***	-1.762 (0.520)***	-1.822 (0.535)***	21.53	62.54
Mean decennial % population growth 1920-70	-6.072 (1.854)***	-5.528 (1.839)***	-6.241 (2.187)***	-4.686 (1.367)***	24.54	22.42
Std. dev. decennial % population growth 1920-70	3.169 (1.315)**	3.208 (1.210)***	3.419 (1.424)**	2.482 (1.005)**	15.72	23.42
% of urban fringe overlaying aquifers	1.222 (0.473)***	1.090 (0.507)**	0.945 (0.539)*	1.720 (0.484)***	30.43	37.96
Elevation range in urban fringe (m.)	-1.609 (0.946)*	-1.166 (1.023)	0.914 (1.117)	-1.731 (0.815)**	542.43	737.02
Terrain ruggedness index in urban fringe (m.)	1.252 (0.746)*	1.267 (0.746)*	1.108 (0.767)	2.195 (0.741)***	8.84	10.10
Mean cooling degree-days	-6.512 (1.562)***	-5.415 (1.657)***	-6.440 (2.359)***	-6.157 (1.564)***	1348.43	923.13
Mean heating degree-days	-4.986 (1.341)***	-4.768 (1.381)***	-3.051 (2.632)	-6.966 (1.360)***	4580.79	2235.66
% of urban fringe incorporated 1980	-1.363 (0.455)***	-1.558 (0.451)***	-1.708 (0.464)***	-1.629 (0.422)***	5.21	5.05
Intergov. transfers as % of local revenues 1967	1.075 (0.633)*	1.070 (0.682)	1.136 (0.679)*	2.206 (0.596)***	37.17	10.65
Bars and restaurants per thousand people		0.176 (0.783)			1.51	0.41
Major road density in urban fringe (m./ha.)		-0.179 (0.698)			0.87	0.36
% population growth 1970-90		-1.916 (0.910)**			35.29	45.46
Herfindahl index of incorporated place sizes		-0.274 (0.652)			0.32	0.26
Latitude			-2.083 (2.731)		37.57	5.22
Longitude			-5.221 (2.700)*		−91.18	13.52
Census division fixed effects			1.000			
Constant	111.375 (11.503)***	108.895 (11.870)***	90.467 (21.441)***	75.050 (10.907)***		
Observations	275	275	275	275		
R^2	0.405	0.418	0.469	0.404		

Notes: The dependent variable in columns (1), (2) and (3) is our sprawl index for 1976–92 development, which has mean 64.51 and standard deviation 10.90. The dependent variable in column (4) is our sprawl index for 1992 development, which has mean 46.54 and standard deviation 10.82. The regressions are run for all 275 metropolitan areas in the conterminous United States. Coefficients give the impact on the index of a one standard deviation increase in the corresponding variable. Numbers in brackets report heteroscedastic-consistent standard errors. $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

Highways and Suburbanization

Baum-Snow (2007): the interstate highway system

1. Authorized in 1944, grid planned in 1947
2. Designed to link distant hubs, not to shorten local commutes

$\Rightarrow$ The 1947 plan is a plausibly exogenous source of identification

- Actual construction and its timing was endogenous

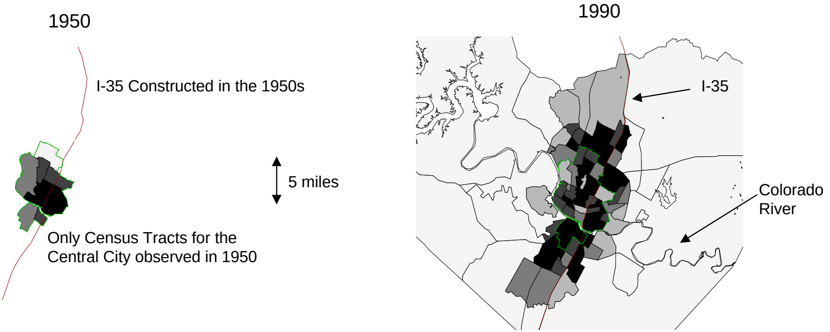
Highway construction shapes city growth

1. The metropolitan area spreads out along new highways
2. Central city population declines with the number of radial highways
   - Each highway ray reduces central city population by .09 log points
   - The highway system overall turned growth from $+8\%$ to -17%

▷ The effects are stronger for cities in a featureless space

- Borders and bodies of water exogenously restrict sprawl

Development Patterns in Austin, TX



Note: Each shaded region is a separate census tract.

Spatial Distribution of Metropolitan Area Population

Panel A: 1970 and 1990 Cross-Sections

Sample		Log Population Density 1970	1990
Large MSAs in 1950	**Distance to CBD**	-0.132	-0.114
		(0.001)**	(0.001)**
	Distance to Highway	-0.014	-0.019
(36,250 tracts, 139 MSAs)		(0.002)**	(0.002)**
Large MSAs in 1950 With	**Distance to CBD**	-0.134	-0.117
Central Cities at least		(0.002)**	(0.001)**
20 Miles from a Coast or Border	**Distance to Highway**	-0.055	-0.054
(17,336 tracts, 100 MSAs)		(0.003)**	(0.003)**

Panel B: Evolution Between 1970 and 1990

Sample		ΔLog Population Density
Large MSAs in 1950	**Distance to CBD**	0.021
		(0.000)**
	ΔDistance to Highway	-0.015
(36,250 tracts, 139 MSAs)		(0.002)**
Large MSAs in 1950 With	**Distance to CBD**	0.021
Central Cities at least		(0.001)**
20 Miles from a Coast or Border	**ΔDistance to Highway**	-0.008
(17,336 tracts, 100 MSAs)		(0.003)**

Determinants of Central City Population Growth

Large MSAs in 1950

	Change in Log Population in Constant Geography Central Cities					
	OLS3	**IV1**	**IV2**	**IV3**	**IV4**	**IV5**
Change in Number	-0.059	-0.030	-0.106	-0.123	-0.114	-0.101
of Rays	(0.014)**	(0.022)	(0.032)**	(0.029)**	(0.026)**	(0.046)*
1950 Central City Radius	0.080		0.111	0.113	0.106	0.125
	(0.014)**		(0.023)**	(0.023)**	(0.023)**	(0.021)**
Change in Simulated	0.084			0.048	-6.247	-0.137
Log Income	(0.378)			(0.417)	(6.174)	(0.480)
Change in Log of MSA	0.363			0.424	0.374	0.405
Population	(0.082)**			(0.094)**	(0.079)**	(0.108)**
Change in Gini Coeff					-23.416	
of Simulated Income					(23.266)	
Log 1950 MSA Population						-0.062
						(0.062)
Constant	-0.640	-0.203	-0.359	-0.588	4.580	-0.611
	(0.260)*	(0.078)*	(0.076)**	(0.281)*	(5.091)	(0.265)*
Observations	139	139	139	139	139	139
R-squared	0.39	0.00	0.01	0.30	0.33	0.37

Notes: In columns IV1-IV5, the number of rays in the 1947 plan instruments for the change in the number of rays. Standard errors are clustered by state of the MSA central city. Standard errors are in parentheses. ** indicates significant at the 1% level, * indicates significant at 5% level. Summary statistics are in the Appendix Table. First stage results are in Table II.

Advantages and Disadvantages of the Car

The benefits that motivate sprawl

1. Larger homes
2. Shorter commutes

Negative externalities of car driving

1. Traffic congestion
    - Not so much if employment is decentralized
    - Commutes are shorter in cities with greater sprawl
    - But there isn't only the commute to work
        - ★ The average American spends 161 min/d in a car
2. Pollution
    - Greenhouse gases and local smog
    - Improvements over time despite increases in sprawl
    - Unsustainable on a world scale

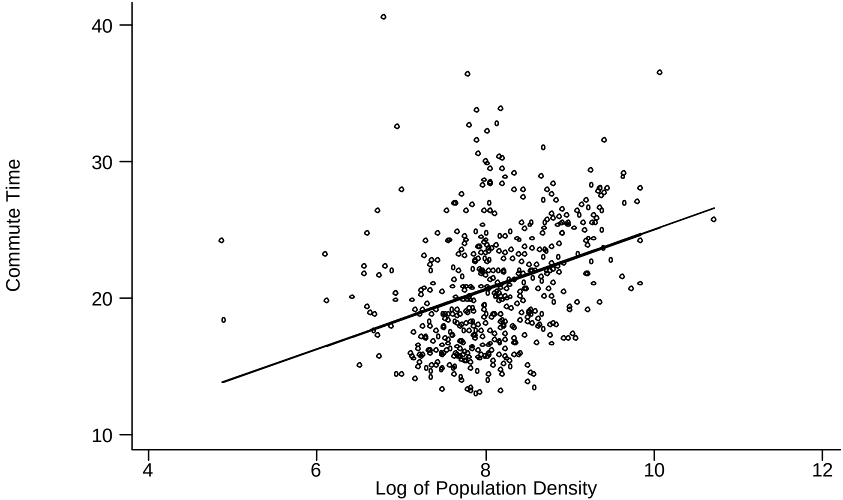
▷ Both externalities can and should be priced: somewhere they are

Urban and Suburban Housing Consumption

Housing Measure Means by Cell	Major MSAs Center City	Major MSAs Suburb	Entire AHS Sample Center City	Entire AHS Sample Suburb
Unit square feet	1755.30	2139.71	1726.96	1964.42
Unit square feet per person	496.34	570.21	485.42	539.12
Bedrooms	2.56	3.03	2.68	3.00
Bathrooms	1.32	1.61	1.41	1.64
% Living in a Single Family House	0.35	0.70	0.51	0.69
House price	165029.20	196013.30	144321.60	175868.90
House Price per unit square foot	142.19	104.00	96.55	92.87
Annual rent	8432.23	9668.27	7935.59	9074.82
Year built	1947.80	1958.61	1953.47	1961.64

Data Source is the 1999 American Housing Survey. The sample includes households where there are at least three people living in the unit and household income is greater than $10,000.
The Major MSAs include: Atlanta, Boston, Chicago, Dallas, Detroit, Houston, Los Angeles, NYC, Philadelphia, San Francisco and Washington D.C.

Density and Commuting Time



1990 Cross-City Relationship Between Commuting Time and Density

The Fundamental Law of Road Congestion

Vehicle-km travelled increase proportionally to highway km built

- Endogeneity problem: demand for travel induces road building
- Duranton and Turner (2011): historical IV strategy
  1. 1947 interstate highway plan
  2. Railroad km in the metropolitan area in 1898
  3. Roads and exploration routes, 1835–1850
  - ▷ Exogeneity relies on appropriate controls: e.g., population
- Increased provision of bus services does not relieve congestion
- All margins of utilization react to highway construction
  1. Long-haul trucking increases: $19 - 29\%$
  2. Driving by existing residents increases: $9 - 39\%$
  3. Population increases: $5 - 21\%$
  4. Traffic is diverted from other roads: $0 - 10\%$

Congestion as a Function of Road Provision

	[1]	[2]	[3]	[4]	[5]
Panel A (TSLS). Dependent variable: ln VKT for interstate highways, entire MSAs.					
Instruments: ln 1835 exploration routes, ln 1898 railroads, and ln 1947 planned interstates					
ln(IH lane km)	1.32[a]	0.92[a]	1.03[a]	1.01[a]	1.04[a]
	(0.04)	(0.10)	(0.11)	(0.12)	(0.13)
ln(population)		0.40[a]	0.30[a]	0.34[a]	0.23[c]
		(0.07)	(0.09)	(0.10)	(0.12)
Geography			Y	Y	Y
Census divisions			Y	Y	Y
Socio-econ. charac.				Y	Y
Past populations					Y
Overidentification p-value	0.60	0.11	0.26	0.24	0.29
First stage Statistic	42.8	16.5	11.8	11.5	8.84

Other Consequences of Sprawl

Changes in agglomeration economies

- Productivity could fall as density decreases
- What is the required density?
  - Walking in New York or Tokyo
  - Driving around Los Angeles or Silicon Valley

Social impact of sprawl

1. Income-based segregation increases
2. Racial segregation seems to decrease

▷ The poor may well be the losers