The Internal Geography of Cities

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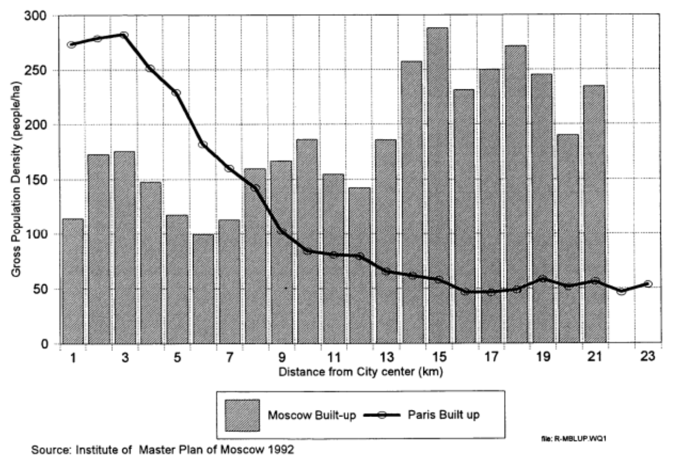
The internal geography of cities

- Now we consider a microscale
- Two types of decisions:
  - residential location (our focus)
  - firm location (e.g. microagglomeration literature)
- The internal geography of cities determines how agglomeration benefits translate into welfare
- Canonical model: the Alonso-Muth-Mills model
  - monocentric city: all employment is downtown
  - in contrast to polycentric city models (e.g. Lucas and Rossi-Hansberg ECMA 2002)

Key incentive: land markets!

Figure: Density in Paris and Moscow (Bertaud and Renaud JUE 1999)

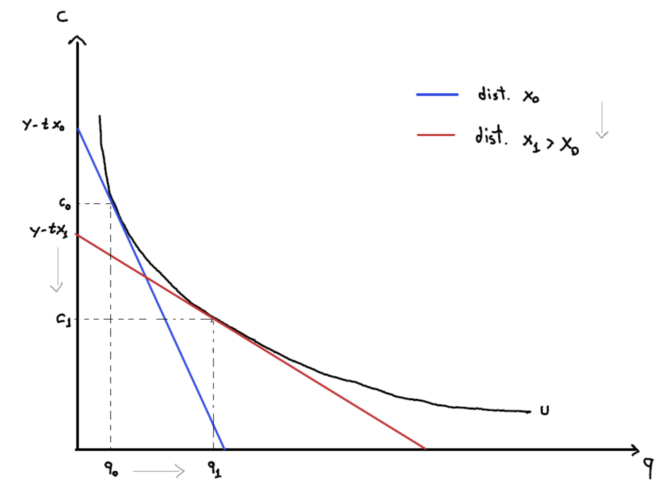


The monocentric city model: demand side

- Each resident commutes to the CBD:
  - t: monetary commuting cost per unit of distance
  - tx: total commuting cost if living x away from the CBD
  - y: income earned in the CBD
- Utility is $v(c, q)$, where c is non-housing consumption and q is housing space
  - consumption good is numeraire, $p(x)$ is price of housing space
  - identical workers, so same utility u

The worker problem is a Hicksian demand

$$u = \max_q v(y - tx - p(x)q, q)$$



The worker problem is a Hicksian demand

- Solving for the FOC, we have a two variable, two equation system:

$$\frac{v_q\big(y - tx - p(x)q(x), q(x)\big)}{v_c\big(y - tx - p(x)q(x), q(x)\big)} = p(x)$$
$$v\big(y - tx - p(x)q(x), q(x)\big) = u$$

- Housing demand implies that housing prices fall and housing consumption increases with distance:

$$p'(x) = -\frac{t}{q(x)} < 0, \quad q'(x) = -\frac{v_c}{pv_{cc} - 2pv_{qc} + v_{qq}} \frac{t}{q(x)} = \eta p'(x) > 0$$

where $\eta < 0$ is the Hicksian elasticity of housing

The monocentric city model: supply side

- Housing is produced under CRS using inelastic land L and perfectly elastic capital N

$$\max p(x)H(K,L) - iK - r(x)L$$

- Let $k = \frac{N}{L}$ be the capital-land ratio, so profit maximization is

$$\max p(x)h(k) - ik - r(x)$$

  where $h(k) = H(k,1)$
- Competitive real estate development, so zero profits
- Let r_0 be the outside value of land (e.g. agriculture)

Housing supply

- Profit maximization and zero profits yield

$$p(x)h'(k(x)) = i$$
$$p(x)h(k(x)) - ik(x) = r(x)$$

- Totally differencing and using the demand-driven slope of $p(x)$ leads to:

$$k'(x) = \frac{1}{p(x)} \frac{h'}{h''} \frac{t}{q(x)} < 0$$
$$r'(x) = -h(k(x)) \frac{t}{q(x)} < 0$$

Closing the model: open city model

- Open city: u is exogenous, there is free-entry of workers
- The city extends up to $\bar{x}$ where $r(\bar{x}) = r_0$
  - this fixes conditions for $r(\bar{x})$ and $k(\bar{x})$
  - it also fixes $p(\bar{x})$ and $m(\bar{x})$
  - differential equations determine the entire shape of these variables
- The total population is:

$$P = \int_0^{\bar{x}} \frac{h(k(x))}{q(x)} L(x) dx$$

Cities in Bad Shape:
Urban Geometry in India

Harari

American Economic Review

2020

Urban shape 1

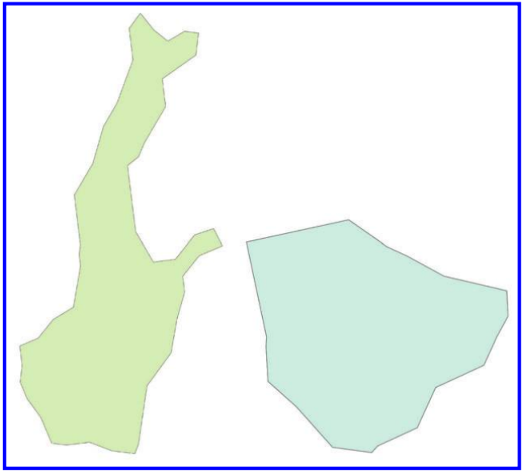
Urban shape 2

Urban shape 3

Motivation

- An important advantage of cities is to allow meetings between people
  - more and better meetings at larger cities
- But cities also have characteristics that may make such meetings difficult
  - congestion
  - transit and road infrastructure
  - large distances, which is a result of city area and **shape**
- Well-studied in architecture and urban studies, but not much in economics
  - causal effects of urban shape
- But how relevant could be such costs?
  - faster population growth + more willingness to pay for more compact city shapes

Comparison of city shapes in India



Shape metric	Kolkata	Kolkata Normalized	Bangalore	Bangalore Normalized
Disconnection, km	20.4	1.2	16	0.94
Remoteness, km	14.8	0.87	11.8	0.69
Spin, km^2	287.1	0.99	9.4	0.55
Range, km	65.2	3.83	44.5	2.62

Data: measuring city shapes and areas

- 350 cities in India
- US Army Service Maps for 1950: georeferenced footprints
- DMSP/OLS Nightime Lights, from 1992-2010
- City: contiguous area of pixels with nightlights above 35 (out of 64)
- Measure of city shape (disconnection index): linear distance between any two randomly drawn points within the city area
    - highly correlated with area (and population), so it is important to control for area

Example: Mumbai (1950–2010)

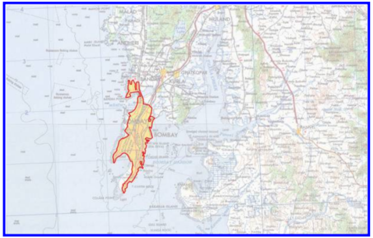


Figure 2. US Army India Topographic Maps

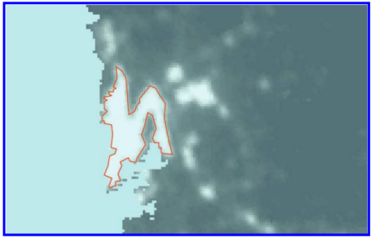


Figure 3. DMS/OLS Night-Time Lights, Year 1992

Other data

- City population: censuses from 1871 to 2011
- Wages: Annual Survey of Industries (1990, 2010)
- Rents: National Sample Survey (2005-6, 2007-8), Human Development Survey (2005, 2012)
- Undevelopable land: if within water (MODIS Raster Water Mask) and if slope greater than 15% (ASTER DEM)

Summary Statistics

	Observations	Mean	Median	SD	Min	Max
Panel A. 1950, 1992–2010						
Area, km^2	5,028	73.15	24.14	191.93	0.43	3,986
Shape, km	5,028	3.58	2.60	3.29	0.35	38.21
Potential shape, km	5,028	3.16	2.65	1.88	0.42	20.03
City population	1,135	480,626	133,229	1,546,857	5,822	22,085,130

	1950	2010	2010–1950
Panel B. Long difference			
Area, km^2	3.743	118.0	114.2
	(7.22)	(304.15)	(298.64)
Shape, km	1.012	4.714	3.703
	(0.71)	(4.24)	(3.81)
Potential shape, km	1.376	3.985	2.608
	(0.99)	(2.30)	(1.78)
City population	106,807	657,420	550,614
	(325,337)	(1,968,436)	(1,703,455)

Notes: Panel A reports descriptive statistics from the 351 cities in the main estimation sample, in all years for which data is available. City area, shape, and potential shape are observable in years 1950 and 1992–2010. City population is available for census years 1951, 1991, 2001, and 2011. Panel B reports variable averages for the 351 cities in the main estimation sample for years 1950, 2010, and for the long difference 2010–1950. For city population, 1950 and 2010 correspond to census years 1951 and 2011, respectively. Standard deviations in parentheses.

Econometric specification

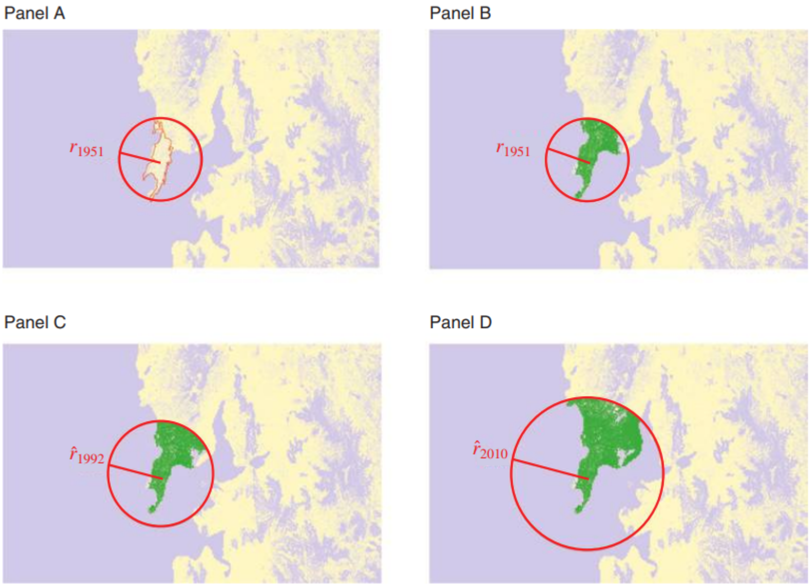
$$y_{c,t} = \alpha S_{c,t} + \beta log(area_{c,t}) + \eta_{c,t}$$

- Sources of bias to OLS estimates:
  1. Shape and area are endogenous to population growth, and faster growing cities often end up with worse shapes
  2. Better urban planning and policies may result in both faster city growth and better shapes
- It is thus important to construct two IVs

Instrumental variable strategy

- The IVs are constructed based only on physical restrictions and pre 1951 growth:
  1. Log-linearly project the 1871-1951 population of city c to obtain projected population $\hat{pop}_{c,t}$ for $t \in \{1992, ..., 2010\}$. This is the IV for city area
  2. Pooling the panel of cities and estimating a regression of log area on log predicted population, log 1950 population density, and year fixed effects
  3. Compute the radius of that the city would be if a circle (best shape) as $\hat{r}_{c,t} = \sqrt{\frac{\hat{area}_{c,t}}{\pi}}$
  4. Create IV for shape with the area of the circle that is developable (see figure below)

IV construction example



First stage

	Long difference, 2010–1950		Panel 1950, 1992–2010	
	Δ Shape, km (1)	Δ log area (2)	Shape, km (3)	log area (4)
Δ Potential shape, km	1.941 (0.249)	0.232 (0.0488)		
Δ log projected population	−2.226 (0.484)	0.0467 (0.131)		
Potential shape, km			1.503 (0.241)	0.185 (0.0495)
log projected population			−1.354 (0.278)	0.213 (0.122)
Observations	351	351	5,028	5,028
AP *F*-statistic shape	27.51	27.51	78.36	78.36
AP *F*-statistic area	9.14	9.14	13.60	13.60
KP *F*-statistic	12.86	12.86	15.97	15.97
City fixed effects			Y	Y
Year fixed effects			Y	Y

Notes: This table reports OLS estimates of the first-stage relationship between city shape and area, and the instruments discussed in Section IV. Each observation is a city in columns 1 and 2 and a city-year in columns 3 and 4. The dependent variables are the 2010–1950 long differences in city shape, in km, in column 1, and city area, in squared km, in column 2; and levels of city shape and city area in columns 3 and 4. The regressors are the shape of the potential footprint and log projected historic population, in long differences in columns 1 and 2, and in levels in columns 3 and 4. Shape is defined as the average distance between two points in the city. Columns 3 and 4 include

Strong and negative impacts on population growth

	Δ log population, 2011−1951	
	IV	OLS
	(1)	(2)
Δ Shape, km	−0.0964	0.0222
	(0.0439)	(0.00721)
Δ log area	0.851	0.213
	(0.238)	(0.0338)
Observations	351	351
AP *F*-statistic shape	27.51	
AP *F*-statistic area	9.14	
KP *F*-statistic	12.86	

Notes: This table reports estimates of the impact of city shape on population. Each observation is a city. The dependent variable is the 2011−1951 long difference in log city population. The regressors are the 2010−1950 long differences in city shape, in km, and log city area. Estimation is by IV in column 1 and OLS in column 2. AP and KP *F*-statistics are the Angrist-Pischke and Kleibergen-Paap *F*-statistics respectively and are reported in column 1. Robust standard errors in parentheses.

Cities with bad shape have higher nominal wages...

	Δ log rent 2010−1990					
	All		Only districts with one city		Only top city per district	
	IV	OLS	IV	OLS	IV	OLS
Sample:	(1)	(2)	(3)	(4)	(5)	(6)
Δ Shape, km	0.0364	0.0336	0.0728	0.0466	0.0562	0.0349
	(0.0354)	(0.0132)	(0.0470)	(0.0154)	(0.0293)	(0.0150)
Δ log area	−1.057	−0.0787	0.0542	−0.0371	−0.418	−0.0668
	(0.944)	(0.0833)	(0.368)	(0.130)	(0.435)	(0.101)
Observations	183	183	80	80	145	145
AP *F*-statistic shape	13.86		10.21		10.4	
AP *F*-statistic area	1.94		3.76		3.10	
KP *F*-statistic	1.67		1.76		2.28	
Average yearly wage, 1992	72	72	72	72	72	72
Average yearly wage, 2010	187	187	193	193	187	187

Notes: This table reports estimates of the impact of city shape on wages. Each observation is a city. The dependent variable is the 2010−1990 long difference in the log urban average yearly wage in the city's district. The regressors are the 2010−1992 long differences in city shape, in km, and log city area. Estimation is by IV in odd columns and OLS in even columns. In columns 3 and 4 the sample is restricted to districts with only one city. In columns 5 and 6 the sample is restricted to the top cities in their respective districts. AP and KP *F*-statistics are the Angrist-Pischke and Kleibergen-Paap *F*-statistics respectively. Average yearly wages are in thousand 2018 rupees. Robust standard errors in parentheses.

...and lower rents

Sample:	Δ log rent 2008–2006					
	All		Only districts with one city		Only top city per district	
	IV (1)	OLS (2)	IV (3)	OLS (4)	IV (5)	OLS (6)
Δ Shape, km	−0.606	0.000310	−0.486	−0.0172	−0.697	0.0145
	(0.521)	(0.0472)	(0.310)	(0.0675)	(0.648)	(0.0476)
Δ log area	−2.367	−0.0101	−1.245	−0.101	−1.955	−0.0594
	(2.145)	(0.0902)	(1.044)	(0.108)	(2.094)	(0.0970)
Observations	262	262	134	134	215	215
AP *F*-statistic shape	9.60		14.77		5.11	
AP *F*-statistic area	3.00		6.12		2.80	
KP *F*-statistic	1.67		2.93		1.20	
Average yearly rent per m^2, 2006	703	703	705	705	700	700
Implied willingness to pay	−0.133		−0.151		−0.168	
$0.16 \cdot \beta_{\text{Rents}} - \beta_{\text{Wages}}$	(0.082)		(0.072)		(0.107)	
	[0.104]		[0.037]		[0.115]	

Notes: This table reports estimates of the impact of city shape on housing rents. Each observation is a city. The dependent variable is the 2008–2006 long difference in the log urban average of housing rent per square meter in the city's district. The regressors are the 2008–2006 long differences in city shape, in km, and log city area. Estimation is by IV in odd columns and OLS in even columns. In columns 3 and 4 the sample is restricted to districts with only one city. In columns 5 and 6 the sample is restricted to the top cities in their respective districts. AP and KP *F*-statistics are the Angrist-Pischke and Kleibergen-Paap *F*-statistics respectively. Average yearly rents are

What is this compensating differential for the bad shape?

- In spatial equilibrium, workers in all cities will have the same utility $\rightarrow$ same "real wage"
- The WTP for a marginal improvement in city shape is

$$HousingShare \times ElastRents - ElastWage$$

- Using a calibrated $\alpha = 0.16$, the impact is thus $0.16 \times (-0.606) - 0.0364 = -0.133$

But there seems to be no impact for firms

- Assuming now a free entry (zero profit) condition
- Let $\beta = 0.4$ be the labor share and $\gamma = 0.3$ be the tradable capital share (Glaeser 2008)
- The impact on firms will be?

$$(1-\beta-\gamma)\mathit{ElastPop} - (1-\gamma)\mathit{ElastWage} = -0.029 + 0.025 = -0.004$$

- Firm productivity does not seem to depend much on shape (perhaps because they can choose their location within the city)