Are Chinese Cities Too Small? Discussion of Au and Henderson, ReStud 2006

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Today's Lecture

Today we will discuss Au and Henderson, ReStud 2006

However, before discussing their paper I will provide a quick background on "system of cities" models

This follows up on the discussion from last class (microfoundations of agglomeration) but adds some more detail (developers, sectors) that can be useful for understanding Au and Henderson (2006)

I will discuss a model from Duranton and Puga (2013): don't worry much about the equations and notation, but focus on the how sectors can affect optimal city size and how a central planner can overcome the inefficient equilibrium city size problem

System of Cities Models

Models following Henderson (AER 1974) seek to answer a series of related questions:

1. What explains the size of a city?
2. Why do cities have different sizes?
3. Why do cities have different industry specializations?
4. Is there an efficient (optimal) city size?
5. Can we reach the efficient size without coordinated city creation?
6. If instead we have city creation, how do private city developers compare to local governments?

Main Ideas

1. Effect of population size on output reflects tradeoff between agglomeration and congestion
2. Agglomeration occurs only *within* sectors (sector employment size), congestion occurs across sectors (total population)
3. Within sector agglomeration makes cities specialize in one sector
4. Different sectors may have different productivities, leads to different optimal and equilibrium population sizes
5. If agglomeration is concave in population and congestion is convex we get an optimal city size at positive population level
6. Cities can be too big because migrants don't consider externalities of location decision, stable point occurs when negative externality outweighs positive externality
7. Private developers and local governments can both coordinate city creation to reach optimal city size

Review: Basic Framework of Models

Have some form of agglomeration economies (IRS in population), often using CES production or utility

Also requires congestion costs; often these costs come from commuting as modeled with a simple version of the monocentric city model (fixed housing consumption)

Important details are 1) who gets land rent 2) are there trade costs

Classic paper is Henderson (AER 1974), somewhat simpler version with CES is presented in Duranton and Puga (Handbook Economic Growth, 2013)

The model in Henderson and Au (2006) is quite similar

DP (2013) paper also discusses interesting empirical implications of model

Industrial clusters in Guangdong

Selected specialised clusters in southern China

Town, *city*	Product	Town's claimed contribution
Ouhai, *Wenzhou*	Eyewear	90% of global-brand products (2016)
Jinjiang, *Quanzhou*	Zips	10% of global production (2011)
Chenghai, *Shantou*	Toys	30% of global production (2014)
Shiling, *Guangzhou*	Bags, suitcases	70% of European and US mass market (2013)
Gurao, *Shantou*	Bras	12% of China's production (2014)
Tangxia, *Dongguan*	Golf products	40% of global production (2011)

Sources: Chinese Academy of Social Sciences; State media; Government websites

*Places indicated may include multiple clusters

Economist.com

Who Creates Cities?

So far we have a model of productivity and specialization but no way to determine number of cities

Consider two alternative mechanisms: 1) self-organization 2) city-developers

We study equilibrium outcomes under these different mechanisms

Important detail: who earns land rent?

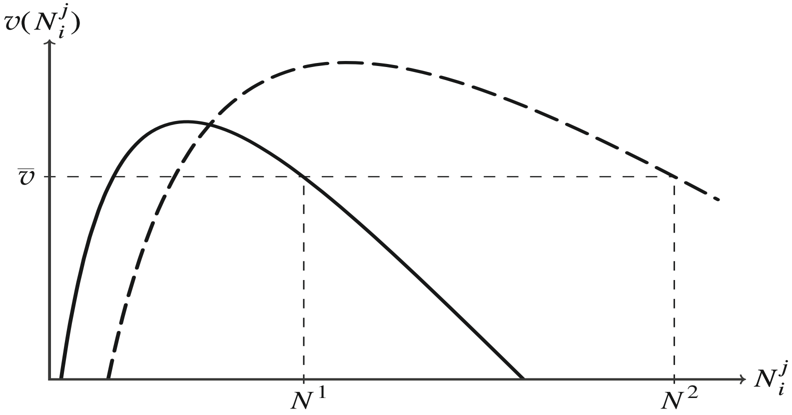
Equilibrium in Self-Organizing Cities

We assume land rents are divided among residents and then use numeraire consumption as a proxy for utility (fixed housing)

This yields the inverse U graph of utility against population: there will be an optimal city size but the stable size has too many people

In equilibrium all cities must offer same utility but cities with different specialities can have different populations

Self-organized City Has Too Many People



Panel (a)
Self-organization

Land Developer

Using the notation from DP 2013, we can think about the land developer (P^j price of final good in sector j, N_i is pop of city i,γ is elasticity of commuting costs w.r.t distance)

Land developers create new cities and collect all land rents, $R_i = P^j * \tau * N_i^{\gamma+1}$; to attract migrants to a new city they can offer a payment of T_i

Land developer profit equation is thus:

$$\max_{T_i, N_i} \Pi_i = P^j \tau N_i^{1+\gamma} - T_i N_i \tag{5.43}$$

However, migrants will not come to a new city unless they receive (at least) the same utility $\bar{c}$—wages minus housing plus commuting costs ($w(N_i) - P(0)$—as other cities

$$P^j \beta^j N_i^{\sigma^j} + T_i - P^j \frac{1+\gamma}{\gamma} \tau N_i^{\gamma} = \bar{c} \tag{5.44}$$

Land Developer's Problem

Minimum utility $\bar{c}$ gives required transfer T_i:

$T_i = \bar{c} + P^j \left[\frac{1+\gamma}{\gamma} \tau N_i^{\gamma} - \beta^j N_i^{\sigma} \right]$

Then (unconstrained) profit maximization problem is:

$$\max_{N_i} \Pi_i = P^j \beta^j N_i^{1+\sigma^j} - P^j \frac{\tau}{\gamma} N_i^{1+\gamma} - \bar{c} N_i \qquad (5.45)$$

DP point out that this equation shows land developers acting like owners of a "factory town": revenue is $P^j Y_i^j = P^j \beta^j N_i^{1+\sigma^j}$ and labor costs are $P^j \frac{\tau}{\gamma} N_i^{1+\gamma} + \bar{c} N_i$

Solving for the FOC gives (in DP $\bar{v} = \bar{c}$):

$$\bar{v} = \bar{c} = P^j \left((1+\sigma^j) \beta^j N_i^{\sigma^j} - \frac{1+\gamma}{\gamma} \tau N_i^{\gamma} \right) \qquad (5.46)$$

Land Developer Internalizes Externality

Put FOC into profit to get maximized profits:

$$\Pi_i = P^j \tau N_i^{1+\gamma} - \sigma^j P^j \beta^j N_i^{1+\sigma^j} \tag{5.47}$$

Then from 5.43 we know $T_i N_i = \sigma^j P^j \beta^j N_i^{1+\sigma^j}$, or

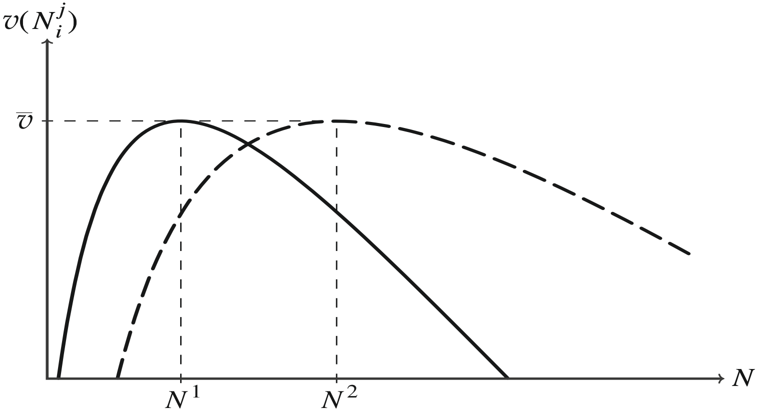
$$T_i = \sigma^j P^j \beta^j N_i^{\sigma^j} \tag{5.48}$$

Finally, with free entry $\Pi_i = 0$ in 5.47, which yields:

$$N_i = \left(\beta^j \frac{\sigma^j}{\tau} \right)^{\frac{1}{\gamma - \sigma^j}} \tag{5.49}$$

This is exactly the utility maximizing population!

Land Developers Can Choose Optimal Size



Panel (b)
Land developers

Free Entry and Equal Utility

Why do all sectors produce at efficient output level?

If not, additional developers could enter and make positive profits by producing at more efficient city size

If some sectors are more productive than others (higher β^j) or have greater agglomeration benefits (higher σ^j) won't land developers offer higher utility to residents?

Process: sectors with higher utility will have additional entry, entry increases production of product j, P^j declines, and thus transfers to workers must decline

Implications

1. Improvements in transportation technology (lower γ or τ) will increase city size
2. City size also increases with productivity gains (higher β^j) or stronger agglomeration forces (higher σ^j)
3. In decentralized equilibrium cities will be too large
4. Possibility of using policy to improve welfare
5. Lots of ongoing work: search "Henry George Theorem" and optimal city size

Au and Henderson: Motivation

The authors want to estimate the inverted U of population against utility (proxied with valued added per capita).

Why do the authors choose China to study this question?

China has two advantages: 1) GDP at the city (prefecture) level 2) migration restrictions which may cause some cities to be to the left of the peak

What data do we need?

What do we estimate?

What are the challenges?

Outline of Au and Henderson

This is a fairly difficult and complicated paper

Model: they take the basic System of Cities model but add 1) trade costs 2) geography (market potential) 3) CES consumers of final good

Empirics: estimate a structural model and thus forced to reconcile data with model variables (difficult)

Identification: authors note that estimating relationship between inputs and outputs of production function has many endogeneity problems, must instrument for *all* variables

Additional issues of non-linearity and functional form

There are lots of details to this paper, I will try to emphasize the main ideas

Production

Authors start with a model where each city specializes in one *type* of good; can be many symmetrically differentiated final good producers of this type

Uses Cobb-Douglas production function with embedded CES:

$$\tilde{y} = y - c_y = A(\cdot)k_y^{\alpha} l_y^{\beta} \left(\int_{s_x} x(i)^{\rho} di \right)^{\gamma/\rho} - c_y \quad (1)$$

$\alpha + \beta + \gamma = 1$, and $0 < \rho < 1$

Term c_y represents fixed cost of entry in terms of output–what is point of this?

Intermediate suppliers have usual IRS production function (shown as conditional factor demand):

$$l_x = f_x + c_x X \quad (3)$$

Agglomeration Economies: Three Sources

First, as city *effective* labor size L increases, TFP (productivity) increases

$$A(\cdot) = AL^{\epsilon} \tag{2}$$

Microfoundations include spillovers, search, matching economies

Second, sharing economies through CES production (number varieties $s_x$increases with city size)

Can see IRS effect by rewriting production function with symmetric intermediates: $y = A(\cdot) k_y^{\alpha} l_y^{\beta} (x s_x)^{\gamma} s_x^{\gamma(1-\rho)/\rho}$

Third, home-market effect: larger home markets will minimize trade costs (will discuss in greater detail when we read Krugman 1991)

Aggregate Demand for Final Good

Consumer utility:

$$U = \left(\int y(i)^{(\sigma_y - 1)/\sigma_y} di \right)^{\sigma_y/(\sigma_y - 1)} \quad (4)$$

From above we can derive aggregate demand (how?) as:

$$p_{y,j} = MP_j^{1/\sigma_j} (y - c_y)^{-1/\sigma_j} \quad (5)$$

$$MP_j = \sum_{\nu} \frac{E_\nu I_\nu}{\tau_{j\nu}^{\sigma_y - 1}}, \text{ where } I = \left[\sum_u s_{y,u} (p_{y,u} \tau_{\nu u})^{1-\sigma_y} \right]^{-1} \quad (6)$$

Market Potential

$$MP_j = \sum_{\nu} \frac{E_{\nu} I_{\nu}}{\tau_{j\nu}^{\sigma_y - 1}}, \text{ where } I = \left[\sum_{u} s_{y,u} (p_{y,u} \tau_{\nu u})^{1-\sigma_y} \right]^{-1} \qquad (6)$$

In above equation authors incorporate demand from all locations with positive trade costs

The I_{ν} term is a price index, takes into account trade costs

Implication: larger markets can consume own good with lower price (net of transporation costs); also, cities near large markets can export their goods at a lower net price

Urban Costs: Commuting

Assume commuting costs measured in time; time cost at location b is tb

Then if lot size is fixed at $h = 1$, city is circular, and population is N the radius (fringe) of city is $\pi^{-1/2}N^{1/2}$

Can define effective labor as population's total time minus time spent commuting:

$$L = N - (2/3\pi^{-1/2}t)N^{3/2} \tag{7}$$

Also try specifications allowing for congestion: commuting costs increase with city size $L = N - (2/3\pi^{-1/2}t)N^{z}$, where $z > 3/2$

Net Output per Worker

Given setup can solve for net output per worker as function of:

Parameters σ_y (consumer subst. elasticity), α (capital share), β (labor share),ϵ (labor agglomeration), γ (intermediate share), ρ (producer subst. elasticity), and A (TFP)

Costs: f_x (intermediate fixed cost), c_x (variable cost), r (cost of capital), t (time commuting cost) as part of a_0, τ (trade cost), c_y (final good fixed cost)

Maximizing this gives optimal city size N^*; note that σ is not part of expression for N^* (equation 9)

Total Value Added

Authors note that they can't estimate net output per worker because they don't have capital rents r

Instead they measure "total value-added", $p\tilde{y}s_y$:

$$VA = Q_3 MP^{1/\sigma_y} AK^{\alpha}(N - \alpha_0 N^{3/2})^{\epsilon+\beta+\gamma/\rho} \tag{10}$$

Holding constant the capital stock per worker, K/N, eq 10) is maximized at N^*

Manufacturing to Service Ratio

Value added in y sector: $p_y(y - c_y)s_y$

Value added in x sector: $p_x s_x X$

Can show that ratio of these is:

$$MS = \frac{p_y(y - c_y)s_y}{p_x s_x X} = \frac{1-\gamma}{\gamma} \tag{A3}$$

Will use this to estimate intermediates share γ_g in different sectors

Note that they assume elasticity is constant across sectors; in other models differences in elasticity partly explain different city sizes for different sectors

Extend Model to Multiple Cities

First expand consumer utility function to incorporate taste heterogeneity

Consumers consume g varieties of composite goods with Cobb-Douglas top level utility function

$$U = \Pi_g \left(\int y_g(i)^{(\sigma_g - 1)/\sigma_g} di \right)^{\mu_g \sigma_g (\sigma_g - 1)} \quad \text{(4a)}$$

Assume elasticities don't vary by product, $\sigma_g = \sigma_y$

Main point is just to allow different consumption weights μ_g in different cities

Empirical Specification

Make usual assumption that agglomeration occurs within sector but congestion costs are across sectors

Then every city will specialize to some degree; this specialization is solely measured in MS ratio

Authors note that in China, and other countries, bigger cities have a smaller MS ratio (more employment in services compared to manufacturing)

Use this idea to define urban hierarchy in China

Then log VA for a given city is:

$$\ln VA = \ln Q_3 + 1/\sigma_y \ln MP + \ln A + \alpha \ln K$$
$$+ (1 - \alpha + \epsilon) * \ln(N - \alpha_0 N^{3/2}) + \frac{1-\rho}{\rho(1+MS)} \ln(N - \alpha_0 N^{3/2}) \tag{10a}$$

Data

Data for 225 prefectural cities for 2 years: 1990 and 1997

- MS defined as ratio of VA in 2nd to VA in 3rd sector
- Value Added is basically output minus input costs but without capital, GDP includes government taxes and subsidies
- Use proportion of population with high school education and cumulative foreign direct investment (FDI) divided by population as measure of TFP (A)
- To measure MP use GDP as measure of expenditure E_ν
- Uses measure of rail transport costs in China to back out τ
- Have no data on prices by city and so assume all prices $p_y = 1$ in price index I_ν =1

Identification

$$\ln VA = \ln Q_3 + 1/\sigma_y \ln MP + \ln A + \alpha \ln K + (1 - \alpha + \epsilon) * \ln(N - \alpha_0 N^{3/2}) + \frac{1-\rho}{\rho(1+MS)} \ln(N - \alpha_0 N^{3/2}) \tag{10a}$$

Authors argue that *all* 1997 variables could be endogenous

As instruments they use historical characteristics (1990 values), arguing that central planning in 1980's determined 1990 values and is uncorrelated with 1997 city shocks

Do you agree that these are good instruments?

Why do authors use non-linear least squares and IV?

Further identification: instrumenting for labor force

Use a migration model (from Au and Henderson, JDE 2006) to argue that amenities can predict city populations using rural populations within same municipality

Urban amenities include: library books, doctors, telephones, and roads, divided by city population

Therefore use urban amenities in 1990 plus rural municipality population in 1990 (assumed exogenous) to predict 1997 urban population

Discussion of Estimates

- High capital share in production $\alpha = 0.43$–note that this is consistent with other estimates for China
- Writing production as $y = A(\cdot)k_y^{\alpha} l_y^{\beta}(xs_x)^{\gamma} s_x^{\gamma(1-\rho)/\rho}$ gives $\gamma(1-\rho)/\rho$ as elasticity of number of intermediates in production (sharing agglomeration). They estimate this value at 0.18 and note it's quite high and must be an important force in explaining Chinese city size
- Estimate for matching/search agglomeration is low: $\epsilon = 0.33$
- Estimate of a_0 gives commuting costs equal to 25% of labor force–very high. These estimates actually decrease when they allow congestion to vary with city size, implying more efficiency in commuting in larger cities (surprising result)

Urban Productivity Results

TABLE 2

Results for urban productivity (S.E. in parentheses)

	IV estimation structural model	Ordinary non-linear least squares structural model
a for capital	0·428** (0·0846)	0·417** (0·0442)
$(1-\alpha+\varepsilon)$	0·605** (0·182)	0·576** (0·874)
$(1-\rho)/\rho$	0·425** (0·187)	0·143* (0·0779)
$-a_0(=2/3\pi^{-1/2}t)$	−0·0347** (0·00494)	−0·00833 (0·0228)
% High-school education	0·000473 (0·00432)	0·00432 (0·00313)
FDI per worker	0·0793** (0·0272)	0·0727** (0·0166)
$1/\sigma_y$	0·650** (0·0987)	0·536** (0·0790)
E_R/σ_y	1·46 (2·91)	4·45** (2·01)
Constant	0·182 (1·13)	1·38* (0·741)
N	205	205
R^2	0·914	0·923
χ^2-test statistics from specification test (critical value)	14·8 (16·9)	

Optimal Population Calculation

Find that cities with lowest MS (most advanced) have optimal population of 1.4 million people

Does this imply that Shanghai, Beijing, Guangzhou, Chongqing, Tianjin way oversized?

Main point is that most cities are undersized: given MS they should be bigger

Estimates of Optimal Population

TABLE 3

Urban agglomeration: city employment at the peak to net output per worker

MS	0·6	1·0	1·4	1·7	2·0	2·5	3·0	4·0
Peak point in thousands	1441	1174	1019	926	849	744	663	544
Lower* 95% confidence interval	977	749	552	411	283	99		
Upper 95% confidence interval	1905	1598	1486	1441	1414	1390	1376	1360

*A blank indicates a negative lower bound.

Discussion of Size Results

- "Enormous agglomeration economies": moving from 100,000 to 1.27 million for MS=1 raises real output by 83%
- Agglomeration benefits are concave: increase very quickly with population at first but then level out. Moving from 635,000 to 1.27 million only increases real output by 14%
- Agglomeration benefits accumulate quickly in small cities (high MS) compared to large cities (point of Figure 1)
- Asymmetric around peak size: being too big lowers output less than being equally too small; past the peak curve declines slowly
- Large potential benefits: "What is clear is that free migration would result in large increases in city sizes and productivity gains."

Agglomeration Benefits Estimation

TABLE 6

Agglomeration benefits (MS = 1)

	Employment in thousands										
	20	50	100	320	635	950	1270	1590	1900	2490	3000
Per cent gain in net output per worker of moving to peak size $N^* = 1270$	133	103	83	40	14	2·9	0	2·3	8·0	26	46
Current city size as a per cent of peak size	1·6	3·9	7·9	25	50	75	0	125	150	196	236

Inverted U Estimate

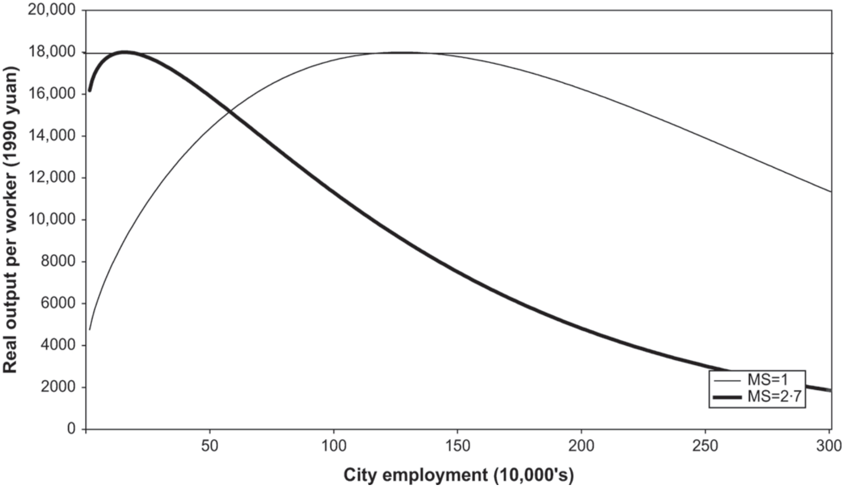


FIGURE 1

The inverted U for cities

Flexible Form Estimates

TABLE 4

Flexible functional form specifications

	IV estimation	IV estimation
	Generalized Leontief	Regular Taylor series (terms in square brackets)
$\ln(K/N)$	0·362** (0·0916)	0·363** (0·0897)
$N^{0\cdot5}\,[N]$	0·366** (0·116)	0·0102** (0·00230)
$N\ [N^2]$	−0·00805** (0·00254)	−0·0000140** (0·00000394)
$N^{0\cdot5} \times \mathrm{MS}^{0\cdot5}\,[N \times \mathrm{MS}]$	−0·184** (0·0872)	−0·00474** (0·00199)
$\mathrm{MS}^{0\cdot5}\,[\mathrm{MS}]$	0·218 (1·93)	−0·128 (0·278)
$\mathrm{MS}\,[\mathrm{MS}^2]$	0·206 (0·615)	0·0508 (0·0521)
% High-school education	0·00142 (0·00491)	0·00209 (0·00452)
FDI per worker	0·0683** (0·0286)	0·0652** (0·0291)
$\ln(\mathrm{MP}_{j,\mathrm{domestic}})$: $\{1/\sigma_y\}$	0·680** (0·117)	0·746** (0·109)
$(\mathrm{MP}_{j,\mathrm{domestic}}(Ad^{0\cdot82}_{j,\mathrm{coast}}))^{-1}$: $\{E_R/\sigma_y\}$	3·94 (3·16)	3·94 (3·28)
Constant	0·00576 (1·35)	0·593 (1·01)
N	205	205
R^2	0·550	0·530
χ^2-test statistics from specification test (critical value)	10·8 (16·9)	10·3 (16·9)

Implications for China

- From Table 4 estimates: 51% of 205 cities in sample are too small
- Depending on estimates, 1%, 6%, or 3% of cities are too *large*–Shanghai?
- Able to estimate welfare as loss net real output from being below peak
- Estimates imply large welfare losses for significant number of cities; relaxing migration barriers would lead to huge increases in real wages for rural migrants

Next class: Ellison and Glaeser, JPE 1997

Next class we turn to measuring industry concentration, as predicted by agglomeration models