Lecture 8: The Size Distribution of Cities

Economics 552

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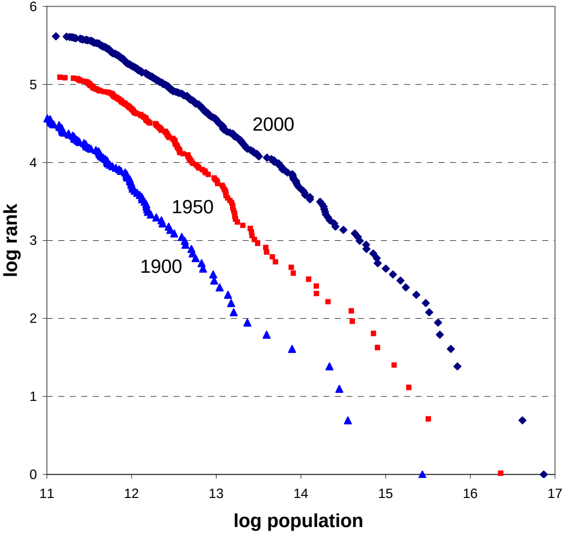
Week 8

Zipf's Law US



6
5
4
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log rank
2000
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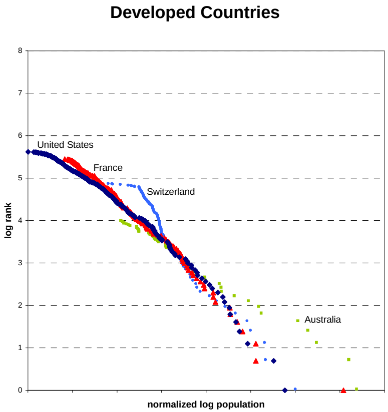
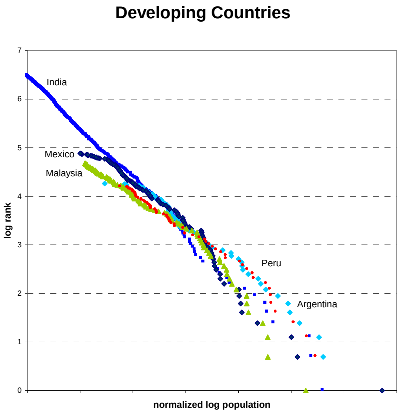
log population

Zipf's Law Across Countries





Soo (2005)

- Documents empirically facts that were known since Rosen and Resnick (1980) and first suggested by Auerbach (1913)
- Main empirical regularity is Zipf's Law
- That is, the size distribution of cities is well approximated by a Pareto distribution with coefficient one. So:

$$y = Ax^{-\alpha}$$

  or

$$\log y = \log A - \alpha \log x$$

  where x is a particular city size and y is the number of cities with population greater than x
- Zipf's Law says that $\alpha = 1$

Use Three Different Estimators

1. $\log y = \log A - \alpha \log x + \varepsilon$
2. $\log y = (\log A)' + \alpha' \log x + \beta' (\log x)^2 + \varepsilon$
3. Use also Hill (1975) estimator which is the maximum likelihood estimator under the null hypothesis of a power law

Results

Table 1
Results of OLS regression of Eqs. (2) and (3) and the Hill estimator, for the sample of cities, for latest year of each country

Country	Year	Cities	OLS				Hill
			α	α'	β'	log$A$	α
Algeria	1998	62	1.351**	− 2.3379	0.0408	18.7999**	1.3586*
Egypt	1996	127	0.9958	− 2.9116**	0.0781**	15.0635	1.0937
Ethiopia	1994	63	1.0653	− 4.3131**	0.1425**	14.2275	1.3341*
Kenya	1989	27	0.8169**	− 1.9487**	0.0486**	11.2945**	1.0060
Morocco	1994	59	0.8735**	− 1.0188	0.006	13.0697**	0.9295
Mozambique	1997	33	0.859**	1.0146**	− 0.0811**	12.1286**	0.8107
Nigeria	1991	139	1.0409**	− 0.9491	− 0.00375	15.9784**	1.0459
South Africa	1991	94	1.3595**	− 1.1031	0.01076	19.1221**	1.2679*
Sudan	1993	26	0.9085	− 0.2142	− 0.0283	13.0723*	1.0066
Tanzania	1988	32	1.01	− 1.8169	0.0348	13.6915	0.9089
Australia	1998	131	1.2279**	7.8935**	− 0.4055**	17.6039**	0.8012**
Argentina	1999	111	1.0437	2.9939**	− 0.1652**	16.1345**	0.9670
Brazil	2000	411	1.1341**	− 0.0963**	− 0.0418**	18.3681**	1.0607
Canada	1996	93	1.2445**	0.4273	− 0.0689	18.0872**	1.2526
Chile	1999	67	0.8669**	− 0.6516	− 0.00915	13.0195**	0.7908*
Colombia	1999	111	0.9024**	− 0.804	− 0.00404	14.0252**	0.9345
Cuba	1991	55	1.09	− 3.6859**	0.1093**	15.1299	1.3177
Dominican Republic	1993	23	0.8473	− 2.6376*	0.0749*	11.6874**	0.8029
Ecuador	1995	42	0.8083**	− 1.4086	0.0255	11.6871**	0.9015
Guatemala	1994	13	0.7287**	− 3.6578**	0.1249**	9.71255**	1.2074
Mexico	2000	162	0.9725	1.9514**	− 0.1172*	15.8281	0.8127**
Paraguay	1992	19	1.0137	− 1.9584	0.0415	13.1465	1.2571
USA	2000	667	1.3781**	− 1.9514**	0.0235**	21.3849**	0.9339
Venezuela	2000	91	1.0631*	− 0.7249	− 0.0139	15.8205**	1.4277**
Azerbaijan	1997	39	1.0347	− 5.2134**	0.1812**	13.6575	1.3605
Bangladesh	1991	79	1.0914	− 4.1878**	0.1274**	15.6311	1.3545*
China	1990	349	1.1811**	1.4338**	− 0.1008**	19.5678**	0.9616
India	1991	309	1.1876**	− 0.7453	− 0.0170**	19.3916**	1.2178**
Indonesia	1990	235	1.1348**	− 2.6325**	0.0610**	17.4209**	1.2334**
Iran	1996	119	1.0578**	− 1.5539	0.01985	16.2499**	1.0526
Israel	1997	55	1.0892*	1.4982**	− 0.1148**	14.8869**	1.0409
Japan	1995	221	1.3169**	− 0.6325	− 0.02655	20.6491**	1.2249**
Jordan	1994	34	0.8983**	− 2.4831**	0.0699**	12.0845**	1.0629
Kazakhstan	1999	33	0.9615	4.8618**	− 0.2444**	13.8818	0.8653
Kuwait	1995	28	1.719**	5.8975**	− 0.3547**	20.5508**	1.6859*
Malaysia	1991	52	0.8716*	2.8194**	− 0.1622**	12.6602**	0.8419
Nepal	2000	46	1.1870**	− 2.0959	0.0405	15.5832**	1.2591
Pakistan	1998	136	0.9623	− 2.4838**	0.0607**	15.0410**	1.0626
Philippines	2000	87	1.0804	3.4389**	− 0.1838**	16.4972**	0.8630
Saudi Arabia	1992	48	0.7824**	0.02426**	− 0.0333*	11.9143**	0.7302**
South Korea	1995	71	0.907**	− 0.3178	− 0.02251	14.5804**	0.6850**
Syria	1994	10	0.7442*	− 1.4709	0.02796	10.8967**	1.0862
Taiwan	1998	62	1.0587**	0.1482**	− 0.0487**	15.7536**	0.9294
Thailand	2000	97	1.1864**	− 4.9443**	0.1553**	16.6797	1.4184**
Turkey	1997	126	1.0536	− 2.6659**	0.0642**	16.1683	1.1850
Uzbekistan	1997	17	1.0488	− 8.9535**	0.3048**	14.7941	1.5111*
Vietnam	1989	54	0.9756**	− 1.4203	0.0184**	14.1331*	0.8028
Austria	1998	70	0.9876	− 3.9862**	0.1358**	13.0823	1.4226**
Belarus	1998	41	0.8435**	0.6492**	− 0.0639**	12.2363**	0.7503*
Belgium	2000	68	1.5895**	− 2.1862	0.02647	20.5048**	1.8348*
Bulgaria	1997	23	1.114	− 4.8424**	0.1531**	15.1382	1.2862
Croatia	2001	24	0.9207	− 1.7693	0.03769	12.0916**	0.9551
Czech Republic	2001	64	1.1684**	− 3.5189**	0.1029**	15.6961**	1.2669
Denmark	1999	58	1.3608**	− 2.7601**	0.06274*	17.5639**	1.3753*
Finland	1999	49	1.1924**	− 2.468**	0.0569**	15.6367**	1.3462
France	1999	104	1.4505**	− 4.1897**	0.1137**	20.2497**	1.6388**
Germany	1998	190	1.238**	− 0.3019**	− 0.0384**	18.6477**	1.2548**
Greece	1991	43	1.4133**	− 6.2019**	0.2036**	18.5979**	1.4804*
Hungary	1999	60	1.124**	− 4.0186**	0.1254**	15.1636	1.2789
Italy	1999	228	1.3808**	− 3.9073**	0.1064**	19.8143**	1.4967**
Netherlands	1999	97	1.4729**	− 0.4333	− 0.04491	20.0318**	1.4436**
Norway	1999	41	1.2704**	− 4.5945**	0.1481**	16.2593**	1.4026
Poland	1998	180	1.1833**	0.3931**	− 0.0679**	17.2931**	1.0908
Portugal	2001	70	1.382**	− 4.1362**	0.1241**	17.7945**	1.6703**
Romania	1997	70	1.1092*	− 0.05598	− 0.0445	15.9369**	1.0598
Russia	1999	165	1.1861**	1.2459*	− 0.0942*	18.9423**	1.0344
Slovakia	1998	42	1.3027**	− 4.4861**	0.1428**	16.5644**	1.4810*
Spain	1998	157	1.1859**	− 0.06586	− 0.04697	17.5737**	1.0969
Sweden	1998	120	1.4392**	− 1.2181	− 0.00991	19.1777**	1.2867**
Switzerland	1998	117	1.4366**	− 6.1258**	0.2229**	17.8549**	1.7386**
Ukraine	1998	103	1.0246	1.5787	− 0.1058**	15.7615**	1.0197
Yugoslavia	1999	60	1.1827*	− 2.2817	0.04839	15.8798**	1.1670
United Kingdom	1991	232	1.4014**	− 3.5503**	0.0894**	20.3123**	1.3983**

*Significant at 5%; **significant at 1%; for α, significantly different from 1; for α', significantly different from − 1; for β', significantly different from 0; for log$A$, significantly different from the log of the population of the largest city. α is defined as a positive value; to compare the coefficients of log$x$ in Eq. (2) and $(\log x)'$ in Eq. (3), we compare $-\alpha$ with α'.

Results

Table 2
Breaking down the results of OLS regressions (2) and (3) and the Hill estimator: statistical significance (5% level) in the latest available observation, for cities and urban agglomerations

Cities				Agglomerations			
Summary results: OLS estimates of α							
Continent	$\alpha<1$	$\alpha=1$	$\alpha>1$	Continent	$\alpha<1$	$\alpha=1$	$\alpha>1$
Africa	3	4	3	Africa	1	1	
N America		1	2	N America	2	1	
S America	4	4	2	S America	3	2	
Asia	5	8	10	Asia	3	2	
Europe	2	3	21	Europe	5	2	2
Oceania			1	Oceania	2		
Total	14	20	39	Total	16	8	2

Cities				Agglomerations			
Summary results: OLS estimates of β'							
Continent	$\beta'<0$	$\beta'=0$	$\beta'>0$	Continent	$\beta'<0$	$\beta'=0$	$\beta'>0$
Africa	1	6	3	Africa	1		1
N America		1	2	N America	2	1	
S America	3	4	3	S America		5	
Asia	11	5	8	Asia	2	2	1
Europe	4	7	14	Europe	3	4	2
Oceania	1			Oceania	1	1	
Total	20	23	30	Total	9	13	4

Cities				Agglomerations			
Summary results: OLS estimates of A (compared to largest city)							
Continent	Less than	Equal to	Greater than	Continent	Less than	Equal to	Greater than
Africa	3	4	3	Africa	1	1	
N America		1	2	N America	1	2	
S America	5	2	3	S America	5		
Asia	6	7	10	Asia	2	3	
Europe	2	3	21	Europe	5	3	1
Oceania			1	Oceania	2		
Total	16	17	40	Total	16	9	1

Cities				Agglomerations			
Summary results: Hill estimator for α							
Continent	$\alpha<1$	$\alpha=1$	$\alpha>1$	Continent	$\alpha<1$	$\alpha=1$	$\alpha>1$
Africa		7	3	Africa	1	1	
N America	1	1	1	N America	1	2	
S America	1	9		S America	1	4	
Asia	2	14	7	Asia		5	
Europe	1	12	13	Europe	1	8	
Oceania	1			Oceania	1	1	
Total	6	43	24	Total	5	21	

Close to One?

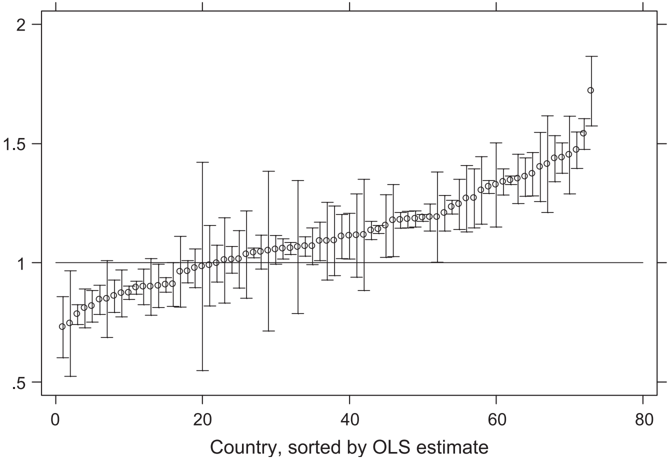


Fig. 1. Values of the OLS estimate of the Pareto exponent with the 95% confidence interval, for the full sample of 73 countries for the latest available period, sorted according to the Pareto exponent.

Agglomerations

Table 4
Results of OLS regression of Eqs. (2) and (3), and the Hill estimator, for the sample of urban agglomerations, for latest year of each country

Country	Year	AGG	OLS				Hill
			α	α'	β'	$\log A$	α
Morocco	1982	10	1.10466	− 14.207**	0.48473**	15.8475	1.5897
South Africa	1991	23	0.6275**	3.8188**	− 0.1747**	10.1609**	0.5058**
Australia	1998	21	0.5855**	0.9107	− 0.05806*	9.4412**	0.5087**
New Zealand	1999	26	0.7833**	− 0.8086	0.0011	10.8562**	0.7830
Argentina	1991	19	0.7025**	− 1.1177	0.01527	11.1267**	0.5229**
Brazil	2000	18	0.9904	− 1.1245	0.00444	16.5577	0.9737
Canada	1996	56	0.8345**	− 0.2635	− 0.0225	13.0979**	0.8273
Colombia	1993	16	0.8278**	− 0.2378	− 0.02141	12.9431**	1.0567
Ecuador	1990	43	0.9046	− 2.0169	0.0474	12.7637**	0.9573
Mexico	2000	38	0.9631	− 1.3863	0.01501	15.6724	0.8107
Peru	1993	65	0.8295**	− 1.5843	0.03171	12.3510**	0.8955
USA	2000	336	0.8847**	3.4992**	− 0.1669**	16.1013	0.5225**
Bangladesh	1991	43	0.8068**	− 2.9315**	0.08399**	12.1569**	0.9141
India	1991	178	0.9579**	0.1559**	− 0.0419**	16.2945	0.9001
Indonesia	1990	193	1.0001	− 1.1315	0.00532	15.8411	1.0384
Jordan	1994	10	0.6813**	0.2377	− 0.03703	9.7100**	0.7286
Malaysia	1991	71	0.9429	3.3355**	− 0.1872**	13.7914	0.8370
Austria	1998	34	0.7501**	− 0.6338	− 0.0051	10.6591**	0.6778**
Denmark	1999	27	0.8166**	− 3.7224**	0.1235**	11.2213**	1.0903
France	1999	114	1.02332	− 1.5263	0.02014	15.7905	1.0643
Germany	1996	144	0.8902**	0.5697**	− 0.0578**	14.6429**	0.8886
Greece	1991	15	0.6349**	− 3.987**	0.1324**	9.2190**	0.9499
Netherlands	1999	21	1.2301*	0.83	− 0.08044	17.5350**	0.9703
Norway	1999	19	0.8828*	− 1.7724	0.03853	11.7679**	0.9212
Switzerland	1998	48	0.9847	− 0.1671	− 0.0356**	13.7188	0.9557
United Kingdom	1991	151	1.0303*	− 0.9192	− 0.0045	16.0465	0.9438

AGG: number of urban agglomerations. *Significant at 5%; **significant at 1%; for α, significantly different from 1; for α', significantly different from − 1; for β', significantly different from 0; for $\log A$, significantly different from the log of the population of the largest city. α is defined as a positive value; to compare the coefficients of $\log x$ in Eq. (2) and $(\log x)'$ in Eq. (3), we compare $-\alpha$ with α'.

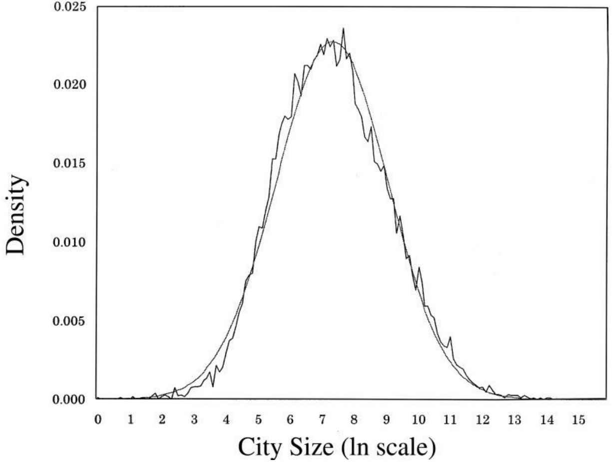
Relationship with Other Variables

Table 5
Panel estimation of Eq. (5) (dependent variable = OLS coefficient of α)

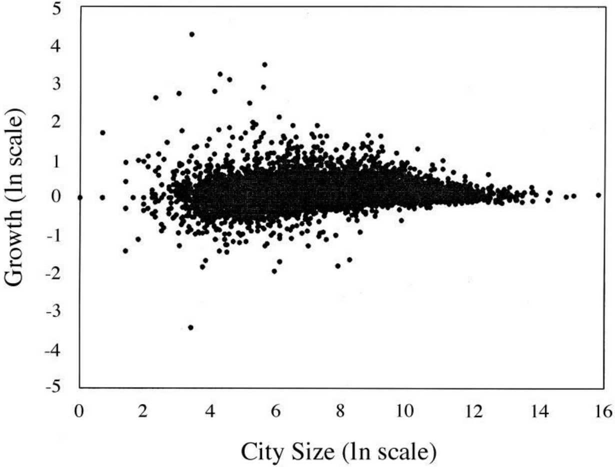
Dependent variable	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Transport cost	− 0.6151	− 0.2763	− 0.4064	− 0.8702	− 0.5014	− 0.6386
	(3.00)***	(1.13)	(1.36)	(3.48)***	(2.56)**	(2.31)**
Trade (% of GDP)	− 0.0928	0.0370	− 0.0240	− 0.0459	0.0532	− 0.0177
	(1.71)*	(0.51)	(0.30)	(0.89)	(0.81)	(0.25)
Nonagricultural economic activity	− 0.2411	− 1.0137	− 0.5644	− 0.6002	− 1.4002	− 0.7731
	(0.73)	(2.37)**	(1.69)*	(1.99)**	(3.37)***	(2.10)**
Scale economies	0.4467	0.4462	0.4057	0.4993	0.4756	0.4284
	(2.25)**	(2.14)**	(1.77)*	(2.30)**	(2.14)**	(1.75)*
GASTIL index of dictatorship	− 0.0375	− 0.0145	− 0.0369	− 0.0307	− 0.0028	− 0.0284
	(1.96)*	(1.32)	(1.97)**	(1.59)	(0.21)	(1.67)*
Total government expenditure	0.7837	0.8013	0.7500	1.0097	0.9598	0.9154
	(6.08)***	(6.30)***	(2.56)**	(6.74)***	(5.68)***	(2.90)***
Timing of independence	− 0.0596	− 0.0686	− 0.1429	− 0.0974	− 0.0984	− 0.1692
	(2.36)**	(2.82)***	(3.96)***	(3.80)***	(3.52)***	(4.75)***
War dummy	0.2211	0.1410	0.1474	0.2437	0.1425	0.1659
	(3.71)***	(3.03)***	(2.36)**	(4.42)***	(3.54)***	(3.05)***
ln(land area)		0.0066	0.0288		0.0097	0.0239
		(0.39)	(1.59)		(0.64)	(1.33)
ln(population)		0.0548	0.0100		0.0459	0.0032
		(3.50)***	(0.49)		(2.81)***	(0.16)
ln(GDP per capita)		0.0959	0.0585		0.1053	0.0467
		(4.45)***	(2.05)**		(4.23)***	(1.34)
Africa dummy			0.1306			0.0967
			(1.24)			(0.97)
Asia dummy			0.2069			0.1898
			(1.85)*			(1.92)*
North America dummy			− 0.0655			− 0.0184
			(0.59)			(0.16)
South America dummy			− 0.1304			− 0.1459
			(1.30)			(1.32)
Oceania dummy			− 0.0804			− 0.0375
			(1.02)			(0.50)
Constant	1.1638	− 0.1307	0.3961	1.4082	0.1885	0.8256
	(3.96)***	(0.24)	(0.69)	(5.69)***	(0.38)	(1.57)
R-squared	0.4702	0.5778	0.6587	0.5403	0.6254	0.7007
Observations	79	79	79	72	72	72
Countries	44	44	44	40	40	40

z statistics in parentheses. *Significant at 10%; **significant at 5%; ***significant at 1% OLS with panel-corrected standard errors results reported.

Eeckhout (2004)

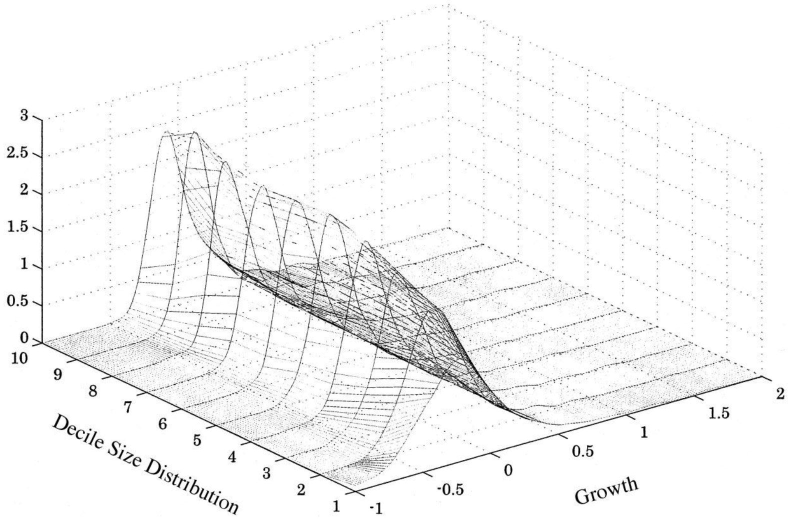


Gibrat's Law

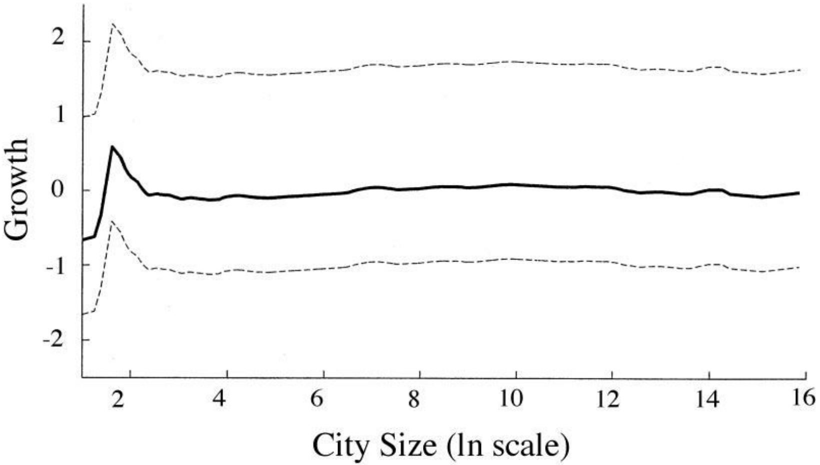


Growth (ln scale)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
2
4
6
8
10
12
14
16
City Size (ln scale)

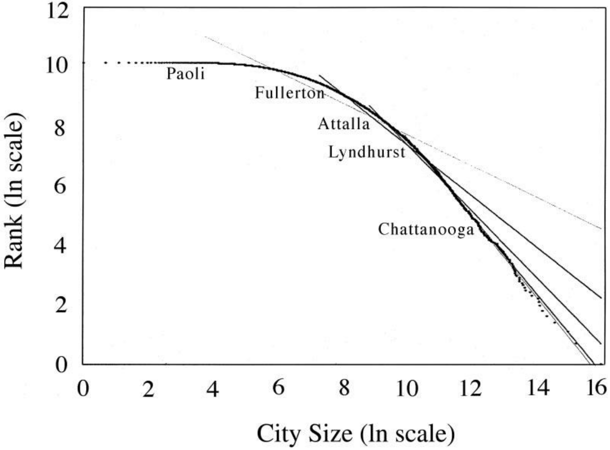
Another Look



Another Look



Right Tail Close to Pareto



A Simple Theory

- Let there be a set of locations (cities) $i \in I = \{1, ..., I\}$
- Each city has a continuum population of size $S_{i,t}$
- Total country-wide population is $S = \sum_I S_{i,t}$
- All individuals are infinitely lived and can perform exactly one job
- $A_{i,t}$ is the productivity of city i at time t with

$$A_{i,t} = A_{i,t-1} \left(1 + \sigma_{i,t}\right)$$

  where $\sigma_{i,t}$ is an exogneous productivity shock
- Denote by σ_t the vector of shock by all cities
- Shock is symmetric, iid, mean zero and $1 + \sigma_{i,t} > 0$
- No aggregate growth in productivity

A Simple Theory

- The marginal product of a worker is given by

$$y_{i,t} = A_{i,t} a_{+}\left(S_{i,t}\right)$$

- $a'_{+}\left(S_{i,t}\right) > 0$ is the positive external effect
- Denote the wage by $w_{i,t}$, then $w_{i,t} = y_{i,t}$ as firms are competitive
- Large cities have higher wages
- Workers have one unit of time and work $l_{i,t} \in [0,1]$
- Some work is lost because of commuting, so productive labor is

$$L_{i,t} = a_{-}\left(S_{i,t}\right) l_{i,t}$$

where $a_{-}\left(S_{i,t}\right) \in [0,1]$ and $a'_{-}\left(S_{i,t}\right) < 0$ is a negative external effect

Consumer Maximization

- Land in a city is fixed at H
- Price of land given by $p_{i,t}$ and an individuals consumption of land by $h_{i,t}$
- Consumers and firms are perfecty mobile
- Consumer solve

$$\begin{aligned} \max u\left(c_{i,t}, h_{i,t}, l_{i,t}; S_i\right) &= c_{i,t}^{\alpha}, h_{i,t}^{\beta}\left(1 - l_{i,t}\right)^{1-\alpha-\beta} \\ s.t.\ c_{i,t} + p_{i,t}h_{i,t} &\leq w_{i,t}L_{i,t} \end{aligned}$$

- Perfect mobility implies that

$$u^*\left(S_{i,t}\right) = U \text{ all } i, t$$

and so

$$A_{i,t}a_+\left(S_{i,t}\right)a_-\left(S_{i,t}\right)S_{i,t}^{-\frac{\beta}{\alpha}} \equiv A_{i,t}\Lambda\left(S_{i,t}\right)$$

is constant across cities

City Size

- This implies that

$$\begin{aligned} S_{i,t}\Lambda^{-1}\left(A_{i,t}\right) &= K \\ S_{i,t}\Lambda^{-1}\left(A_{i,t-1}\left(1+\sigma_{i,t}\right)\right) &= K \end{aligned}$$

- So $\Lambda' < 0$ implies that

$$\frac{dS_{i,t}}{d\sigma_{i,t}} > 0$$

- If Λ is a power function

$$\Lambda^{-1}\left(A_{i,t}\right) = \Lambda^{-1}\left(A_{i,t-1}\right)\Lambda^{-1}\left(1+\sigma_{i,t}\right)$$

- So

$$\begin{aligned} S_{i,t} &= \frac{K}{\Lambda^{-1}\left(A_{i,t-1}\right)\Lambda^{-1}\left(1+\sigma_{i,t}\right)} \\ &= \frac{K}{\Lambda^{-1}\left(1+\sigma_{i,t}\right)}S_{i,t-1} \\ &\equiv \left(1+\varepsilon_{i,t}\right)S_{i,t-1} \end{aligned}$$

Gibrat's Law and the Size Distribution

- Taking natural logarithms and letting, $\ln(1+\varepsilon_{i,t}) \approx \varepsilon_{i,t}$ for $\varepsilon_{i,t}$ small,

$$\ln S_{i,t} \approx \ln S_{i,t-1} + \varepsilon_{i,t}$$

  and so

$$\ln S_{i,T} \approx \ln S_{i,0} + \sum_{t=1}^{T} \varepsilon_{i,t}$$

- But then, since shocks, are iid the Central Limit Theorem implies that

$$\ln S_{i,T} \sim N$$

Rossi-Hansberg and Wright (2007)

- Most economic activity occurs in cities
  - 80% of the US population lives in cities; they earn 85% of personal income
- Aggregate economic activity is *urban* economic activity
- This creates a tension:
  - Urban agglomerations are evidence of increasing returns
  - It is difficult to find evidence of increasing returns at the aggregate level: Balanced Growth
- We argue that urban structure is the margin that eliminates local increasing returns to yield constant returns to scale in the aggregate
- Using this margin has strong implications on urban structure: Zipf's Law and its deviations

Key Issues

- This paper present an urban growth model that illustrates this mechanism using a particular specification that we can solve in closed form
- In the model cities arise endogenously: Trade-off between agglomeration forces, due to production externalities, and congestion forces, due to commuting costs
- Each city produces at an optimal scale given technology, productivity levels and the level of factors in the industry
- Given productivity levels and factor proportions industries behave as if using a linear technology by varying the number of cities
  - Constant returns to scale in the aggregate

Key Issues

- This mechanism has strong implications for the size distribution of cities once we include factor accumulation and productivity shocks
  - Our specification allows for exogenous and endogenous growth (via linearity in human capital accumulation)
- Scale independent city growth has been proven to generate Zipf's law (Gabaix (1999), Cordoba (2002))
- The model produces a scale independent city growth process for two polar cases
  - Fixed factors with permanent productivity shocks
  - AK model with temporary productivity shocks

Key Issues

- Diminishing returns to factor accumulation add persistence to the effect of transitory shocks
  - In general this implies scale dependent growth processes
- Urban structure exhibits some of the observed robust deviations
  - Growth process exhibits reversion to the mean
    - Not enough small cities and large cities are not ‘large enough’
  - Cross-country variation in the dispersion of city sizes
    - Model points to industry standard deviation as the key parameter

Urban Growth Model

- Households:
  - Order preferences over consumption according to

$$(1-\delta)E_0\left[\sum_{t=0}^{\infty}\delta^t N_t\left(\sum_{j=1}^{J}\theta_j \ln\left(C_{tj}/N_t\right)\right)\right]$$

  - And accumulate physical and human capital according to

$$\begin{aligned} K_{t+1j} &= K_{tj}^{\omega_j} X_{tj}^{1-\omega_j} \\ H_{t+1j} &= H_{tj}\left[B_j^0 + (1-u_{tj})B_j^1\right] \end{aligned}$$

- Households grow at rate g, and allocate their members across industries satisfying

$$\sum_j N_{tj} \leq N_t$$

Urban Growth Model

- Technology:
  - J industries in which a representative firm in city i produces using

$$A_{tj}^{i}\left(K_{tj}^{i}\right)^{\beta_j}\left(H_{tj}^{i}\right)^{\alpha_j}\left(u_{tj}^{i}N_{tj}^{i}\right)^{1-\alpha_j-\beta_j}$$

  - where total factor productivity differs by city and industry according to

$$A_{tj}^{i}=A_{tj}\left(H_{tj}^{i}\right)^{\gamma_j}\left(N_{tj}^{i}\right)^{\varepsilon_j}$$

  - Stochastic productivity A_{tj} is industry, but not city, specific
  - The production externality is urban in scope

Urban Growth Model

- Technology:
  - We identify different goods as different industries in the model
  - Most definitions of industries include a variety of goods in the same industry
  - Goods or industries in the model can be grouped according to technology
  - Within groups, industries have the same parameters, but face idiosyncratic productivity shocks
  - Across groups, all technological parameter may differ

The City Model

- Agents living in a circular city commute to work at the center.
- Commuting is costly, so rents are given by

$$R(z) = \tau \left(\bar{z} - z \right)$$

- Agents live in one unit of land, which implies city size

$$n = \bar{z}^2 \pi$$

- Total commuting costs are

$$TCC = \int_0^{\bar{z}} \tau z \left(2\pi z \right) dz = b n^{\frac{3}{2}}$$

City Developer Problem

$$\max_{\left\{\frac{N_{tj}}{\mu_{tj}},\frac{K_{tj}}{\mu_{tj}},\frac{H_{tj}}{\mu_{tj}},T_{tj},\tau^k_{tj},\tau^h_{tj}\right\}} \left[\frac{b}{2}\left(\frac{N_{tj}}{\mu_{tj}}\right)^{\frac{3}{2}} - T_{tj}\frac{N_{tj}}{\mu_{tj}} - \tau^k_{tj}\frac{R_{tj}}{P_{tj}}\frac{K_{tj}}{\mu_{tj}} - \tau^h_{tj}\frac{S_{tj}}{P_{tj}}\frac{H_{tj}}{\mu_{tj}}\right],$$

subject to

$$\begin{aligned}
\left(1-\tau^k_{tj}\right)R_{tj}/P_{tj} &= \beta_j Y_{tj}/K_{tj}, \\
\left(1-\tau^h_{tj}\right)S_{tj}/P_{tj} &= \alpha_j Y_{tj}/H_{tj}, \\
I_{tj} &= \left(1-\alpha_j-\beta_j\right)\frac{Y_{tj}}{N_{tj}} + T_{tj} - \frac{3b}{2}\left(\frac{N_{tj}}{\mu_{tj}}\right)^{1/2}.
\end{aligned}$$

Competition from other developers ensures that profits are zero, so

$$T_{tj} = \frac{b}{2}\left(\frac{N_{tj}}{\mu_{tj}}\right)^{\frac{1}{2}} - \tau^k_{tj}\frac{R_{tj}}{P_{tj}}\frac{K_{tj}}{N_{tj}} - \tau^h_{tj}\frac{S_{tj}}{P_{tj}}\frac{H_{tj}}{N_{tj}}.$$

Welfare Theorems

Proposition 1: There exists a unique Pareto efficient allocation for this economy.

Proposition 2: There exists a competitive equilibrium that attains the Pareto efficient allocation.

Proposition 3: Every competitive equilibrium in this economy is Pareto efficient.

- We use the social planner problem to solve for the unique equilibrium in this economy

Social Optimum

Choose state contingent sequences $\left\{C_{tj}, X_{tj}, N_{tj}, \mu_{tj}, u_{tj}, K_{tj}, H_{tj}\right\}_{t=0,j=1}^{\infty,J}$ so as to maximize

$$(1-\delta)E_0\left[\sum_{t=0}^{\infty}\delta^t N_t\left(\sum_{j=1}^{J}\theta_j \ln\left(C_{tj}/N_t\right)\right)\right]$$

subject to, for all t and j,

$$\begin{aligned}
C_{tj} + X_{tj} + b\left(\frac{N_{tj}}{\mu_{tj}}\right)^{\frac{3}{2}}\mu_{tj} &\leq A_{tj}K_{tj}^{\beta_j}H_{tj}^{\alpha_j+\gamma_j}N_{tj}^{1-\alpha_j-\beta_j+\varepsilon_j}u_{tj}^{1-\alpha_j-\beta_j}\mu_{tj}^{-\varepsilon_j-\gamma_j} \\
N_t &= \sum_{j=1}^{J} N_{tj}, \\
K_{t+1j} &= K_{tj}^{\omega_j}X_{tj}^{1-\omega_j}, \\
H_{t+1j} &= H_{tj}\left[B_j^0 + (1-u_{tj})B_j^1\right]
\end{aligned}$$

City Size

- The problem of choosing the number of cities is static. The first order condition implies

$$\frac{N_{tj}}{\mu_{tj}} = \left[\frac{2\left(\varepsilon_j + \gamma_j\right)}{b} \frac{Y_{tj}}{N_{tj}} \right]^2$$

  and so

$$TCC_{tj} \equiv b \left(\frac{N_{tj}}{\mu_{tj}} \right)^{\frac{3}{2}} \mu_{tj} = 2\left(\varepsilon_j + \gamma_j\right) Y_{tj}$$

- City size is determined by

$$\frac{d\left(Y_{tj}/N_{tj}\right)}{d\left(N_{tj}/\mu_{tj}\right)} = \frac{d\left(ACC\right)}{d(N_{tj}/\mu_{tj})}$$

- No positive production externalities $\left(d\left(Y_{tj}/N_{tj}\right)/d\left(N_{tj}/\mu_{tj}\right) \leq 0\right)$ implies no cities
- No commuting costs ($TCC = 0$) imply only one city

City Size

- City developers choose this city size and impose subsidies on employment and human capital, but not on physical capital
  - This is the result of production externalities on labor and human capital
- As is evident from the previous equations the number of cities in an industry is not restricted to be an integer
- As the externality is industry specific, cities specialize
  - This can be easily generalized if we specifiy externalities across well defined groups of industries

City Growth

- Imposing optimal city size results in constant returns to scale production function

$$F_j \hat{A}_{tj} H_{tj}^{\hat{\alpha}_j} K_{tj}^{\hat{\beta}_j} N_{tj}^{1-\hat{\alpha}_j-\hat{\beta}_j} u_{tj}^{\hat{\phi}_j} = Y_{tj} - TCC_{tj}$$

- Tests at the aggregate level will find constant returns even though the economy produces with increasing returns to scale technology
- Industry productivity is determined in part by

$$F_j = \left(1 - 2\left(\gamma_j + \varepsilon_j\right)\right) \left[\frac{2\left(\gamma_j + \varepsilon_j\right)}{b}\right]^{\frac{2\left(\gamma_j+\varepsilon_j\right)}{1-2\left(\gamma_j+\varepsilon_j\right)}}$$

  - Differences in the way production is organized in cities will be reflected in this term: A theory of differences in TFP

Differences in TFP

- Suppose cities are organized at a sub-optimal size, captured by a parameter $\kappa_j \neq 1$, such that

$$\frac{N_{tj}}{\mu_{tj}} = \kappa_j \left[\frac{2\left(\gamma_j + \varepsilon_j\right)}{b} \frac{Y_{tj}}{N_{tj}} \right]^2 .$$

- Output net of commuting costs would be given by the same equation with modified F_j given by

$$F_j = (1 - 2\left(\gamma_j + \varepsilon_j\right) \kappa_j^{1/2}) \left[\frac{2\left(\gamma_j + \varepsilon_j\right)}{b} \kappa_j^{1/2} \right]^{\frac{2\left(\gamma_j + \varepsilon_j\right)}{1 - 2\left(\gamma_j + \varepsilon_j\right)}} .$$

- This has a global optimum at $\kappa_j = 1$.
- Inefficiently organized cities (too small *or* too large), implies lower total factor productivity.

Urban Structure

- City size in industry j is given by

$$\frac{N_{tj}}{\mu_{tj}} = \left[\frac{2\left(\varepsilon_j + \gamma_j\right)}{b} \frac{Y_{tj}}{N_{tj}} \right]^2$$

- So city growth rates satisfy

$$\begin{aligned} \ln\left(\frac{N_{t+1j}}{\mu_{t+1j}}\right) - \ln\left(\frac{N_{tj}}{\mu_{tj}}\right) &= 2\left[\ln\left(A_{t+1j}\right) - \ln\left(A_{tj}\right)\right] - 2\left(\hat{\alpha}_j + \hat{\beta}_j\right) g_N \\ &\quad + 2\hat{\alpha}_j \ln\left(B_j^0 + (1 - u_j^*) B_j^1\right) \\ &\quad + 2\hat{\beta}_j \left[\ln\left(K_{t+1j}\right) - \ln\left(K_{tj}\right)\right] \end{aligned}$$

Urban Structure

- Or, solving for the dynamics of capital, in the long run

$$
\begin{aligned}
& \ln\left(\frac{N_{t+1j}}{\mu_{t+1j}}\right) - \ln\left(\frac{N_{tj}}{\mu_{tj}}\right) \\
= \quad & \frac{2\hat{\alpha}_j}{1-\hat{\beta}_j}\left[\ln\left(B_j^0 + (1-u_j^*)B_j^1\right) - g_N\right] \\
& +2\left[\ln\left(A_{t+1j}\right) - \ln\left(A_{tj}\right)\right] \\
& +2\left(1-\omega_j\right)\hat{\beta}_j\left[\ln(A_{tj}) - \sum_{s=1}^{\infty}\frac{\left(\omega_j + \left(1-\omega_j\right)\hat{\beta}_j\right)^{-s}}{\left(1-\left(\omega_j + \left(1-\omega_j\right)\hat{\beta}_j\right)\right)^{-1}}\ln(A_{t-sj})\right]
\end{aligned}
$$

Urban Structure

Proposition 4 (Exact Gibrat's Law and Zipf's Law): The growth process of city sizes satisfies Gibrat's Law, and therefore the invariant distribution for city sizes satisfies Zipf's Law, *if and only if* one of the following two conditions is satisfied:

1. (No physical capital) There is no physical capital $\left(\beta_j = \hat{\beta}_j = 0 \text{ or } \omega_j = 1\right)$ and productivity shocks are permanent;
2. (AK model) City production is linear in physical capital and there is no human capital $\left(\hat{\alpha}_j = 0, \hat{\beta}_j = 1\right)$, depreciation is 100% $\left(\omega_j = 0\right)$, and productivity shocks are temporary

Gibrat's Law and Zipf's Law

Proposition (Gabaix 1999): Suppose that city sizes S_t are determined by Gibrat's Law $S_{t+1}^i = \gamma_{t+1}^i S_t^i$, for some γ_t^i iid with distribution $f(\gamma)$. Then there exists an invariant distribution of city sizes satisfying Zipf's Law
Sketch of Proof: Normalize city sizes so that average size stays constant; then normalized growth rates satisfy $E[\gamma] = 1$. Then

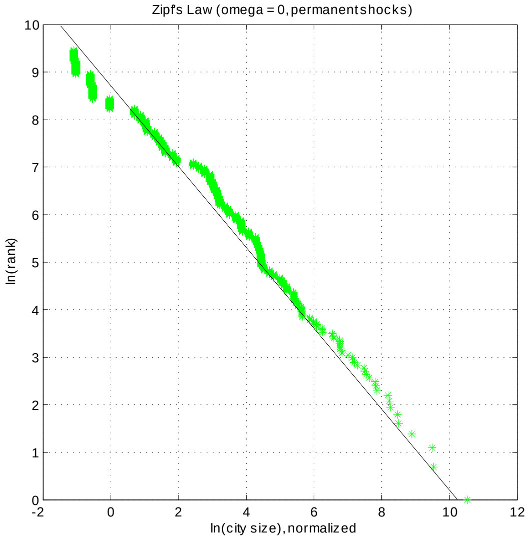
$$\begin{aligned} G_{t+1}(s) &= P(S_{t+1} > s) = P\left(\gamma_{t+1} S_t > s\right) \\ &= E\left[1_{S_t > s/\gamma_{t+1}}\right] = E\left[G_t\left(\frac{s}{\gamma_{t+1}}\right)\right] = \int_0^\infty G_t\left(\frac{s}{\gamma}\right) f(\gamma)\, d\gamma. \end{aligned}$$

If there exists an invariant distribution G, we must have

$$G(s) = \int_0^\infty G\left(\frac{s}{\gamma}\right) f(\gamma)\, d\gamma,$$

which is obviously satisfied by a distribution of the form $G(s) = a/s$.

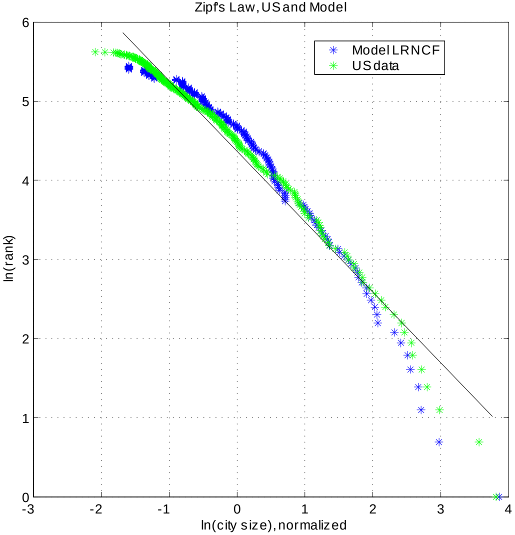
Exact Zipf's Law



Urban Structure

- The conditions placed on the model by the previous proposition are restrictive
- Reality surely lies between these two extremes: capital is one, but not the only, factor of production
- Between these two extremes, how close are the predictions of our model to observed urban structures?
- Recall that there are systematic deviations from Zipf's Law in the data

Deviations from Zipf's Law



Deviations from Zipf's Law

Proposition 5 (Concavity): The growth rate for cities exhibits (weak) reversion to the mean

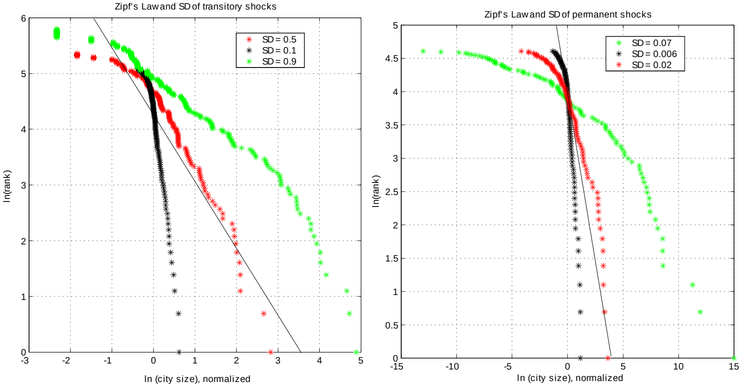
- That is, given a common distribution of all future shocks,
  - Small cities grow faster
    - Small past productivity shocks imply smaller capital stocks which increase the rate of return on capital given today's shock
  - Large cities grow more slowly
- In the data plots of log-rank against log-population are concave: small cities under-represented and big cities not 'big enough'

Deviations from Zipf's Law

Proposition 6: The standard deviation of city sizes increases with the standard deviation of industry shocks

- Given capital stocks, a larger standard deviation of shocks implies a larger standard deviation of city sizes and a larger standard deviation of investments, which in turn implies more disperse capital stocks
- Zipf's coefficients estimated to lie between 0.8 and 1.6, the coefficients are positively correlated with income (Soo 2005)
- This explains the positive correlation between Zipf's coefficient and income *if* high income countries experience less volatile shocks

The Effect of Volatility



Urban Accounting and Welfare, Desmet and Rossi-Hansberg (2013)

- Why do people live in particular cities? Agents can
  - be more productive (productivity advantages, high price of tradeables)
  - enjoy the city (amenities, geography)
  - frictions may be low (urban costs, taxes, infrastructure, other market frictions)
- We use a simple urban theory to calculate these components for the U.S. economy
  - "Wedge" analysis as in Chari, et al. (2007)
  - With and without externalities in productivity and amenities
- Wide set of counterfactual exercises that explain the relative importance of these characteristics for welfare

Introduction

- We find that eliminating differences in any of these characteristics leads to
  - Small changes in welfare
  - Large population reallocations
- Externalities have an overall small effect but lead to important city selection
- The effect of productivity and amenity shocks is substantially reduced by the urban structure
- Provide a simple methodology to compare urban systems across countries
  - Illustrate using the cases of the U.S. and China

The Literature

- Urban growth literature: (Gabaix, 1999a, b, Duranton, 2007, Rossi-Hansberg and Wright 2007, and Cordoba, 2008)
  - Take a stand on the one shock received by cities and calculate the resulting invariant distribution
- Au and Henderson (2006) study the cost of worker missallocation across cities in China
  - Large welfare gains of moving to optimum, focused on efficiency
- Several papers have emphasized a variety of city characteristics
  - Glaeser et al. (2001), Glaeser et al. (2005), Albouy (2008, 2009), and Rappaport (2008, 2009): city amenities and institutional frictions
  - Holmes and Stevens (2002, 2004), Holmes (2005), Duranton and Overman, (2008): efficiency in production
  - Davis and Weinstein (2002) and Bleakley and Lin (2010): geographic characteristics
- We use a GE theory with all three characteristics and study welfare

The Model

- Standard model of a system of cities with:
  - Elastic labor supply so that labor taxes create distortions
  - N_t identical agents choose where to live and work
  - Cities have idiosyncratic productivities and amenities
  - Mono-centric cities that require commuting infrastructures that city governments provide by levying labor taxes
  - City governments can be more or less efficient in the provision of the public infrastructure. We refer to this variation as a city's *excessive frictions*.
- Later add externalities in productivity and amenities

Technology

- Goods are produced in I mono-centric circular cities with sizes N_{it}
- Cities have a local level of productivity A_{it}. Production in a city i in period t is given by

$$Y_{it} = A_{it} K_{it}^{\theta} H_{it}^{1-\theta}$$

- The standard first order conditions of this problem are

$$\begin{aligned} w_{it} &= (1-\theta)\frac{Y_{it}}{H_{it}} = (1-\theta)\frac{y_{it}}{h_{it}} \\ r_t &= \theta \frac{Y_{it}}{K_{it}} = \theta \frac{y_{it}}{k_{it}} \end{aligned}$$

- Capital is freely mobile across locations so there is a national interest rate r_t
- We can then write down the "efficiency wedge" which is identical to the level of productivity, A_{it}, as

$$A_{it} = \frac{Y_{it}}{K_{it}^{\theta} H_{it}^{1-\theta}} = \frac{y_{it}}{k_{it}^{\theta} h_{it}^{1-\theta}}$$

Preferences

- Agents order consumption and hour sequences according to

$$\sum_{t=0}^{\infty} \beta^t \left[\log c_{it} + \psi \log\left(1 - h_{it}\right) + \gamma_i\right]$$

  where γ_i denotes the amenities associates with city i

- The problem of an agent with capital k_0 is therefore

$$\max_{\{i_t, c_{it}, h_{it}, k_{it}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left[\log c_{it} + \psi \log\left(1 - h_{it}\right) + \gamma_i\right]$$

  subject to

$$\begin{aligned} c_{it} + x_{it} &= r_t k_{it} + w_{it} h_{it} \left(1 - \tau_{it}\right) - R_{it} - T_{it} \\ k_{it+1} &= \left(1 - \delta\right) k_{it} + x_{it}, \end{aligned}$$

- In steady state $k_{it+1} = k_{it}$ and $x_{it} = \delta k_{it}$. Furthermore, we assume k_{it} is such that $r_t = \delta$ (capital is at the Golden Rule level)

The Labor Wedge

- The simplified budget constraint of the agent becomes

$$c_{it} = w_{it} h_{it} \left(1 - \tau_{it}\right) - R_{it} - T_{it}.$$

- The first order conditions of this problem are given by

$$\frac{1}{c_{it}} = \lambda_{it},$$

  and

$$\psi \frac{1}{1 - h_t} = w_{it} \left(1 - \tau_{it}\right) \lambda_{it},$$

- So the labor wedge τ is given by

$$\left(1 - \tau_{it}\right) = \frac{\psi}{\left(1 - \theta\right)} \frac{c_{it}}{1 - h_{it}} \frac{h_{it}}{y_{it}}$$

Commuting Costs and Land Rents

- Cities are mono-centric, all production happens at the center, and people live in surrounding areas characterized by their distance to the center, d
- Each agent lives on one unit of land and commutes from his home to work. Commuting is costly in terms of goods, $T(d) = \kappa d$
- We normalize the price of agricultural land to zero. Since land rents are continuous in equilibrium, $R(\bar{d}) = 0$.
- Since all agents in a city are identical,

$$R_{it}(d) + T(d) = T(\bar{d}_{it}) = \kappa \bar{d}_{it}$$

- Hence

$$R_{it}(d) + T(d) = \kappa \left(\frac{N_{it}}{\pi} \right)^{\frac{1}{2}} \text{ all } d$$

- Average land rents are equal to

$$AR_{it} = \frac{2\kappa}{3} \left(\frac{N_{it}}{\pi} \right)^{\frac{1}{2}}$$

Government Budget Constraint and Frictions

- The government levies a labor tax, τ_{it}, to pay for the transportation infrastructure
  - It requires κg_{it} workers per mile commuted to build and maintain urban infrastructure. So

$$G\left(h_{it}w_{it}, TC_{it}\right) = g_{it}h_{it}w_{it}\kappa TC_{it} = g_{it}h_{it}w_{it}\kappa\frac{2}{3}\pi^{-\frac{1}{2}}N_{it}^{\frac{3}{2}}$$

  - Hence, g_{it} is inversely related to the efficiency of the government in providing urban infrastructure
  - The government budget constraint is then given by

$$\tau_{it}h_{it}N_{it}w_{it} = g_{it}h_{it}w_{it}\kappa\frac{2}{3}\pi^{-\frac{1}{2}}N_{it}^{\frac{3}{2}}$$

which implies that the "labor wedge" can be written as

$$\tau_{it} = g_{it}\kappa\frac{2}{3}\left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}$$

Characterization of Equilibrium

- Labor market equilibrium satisfies $\sum_{i=1}^{I} N_{it} = N_t$ and all agents receive the same utility level $\bar{u}$
- So given $(A_{it}, \gamma_{it}, g_{it})$ we can calculate N_{it} all i
- In equilibrium
  - More productive cities are larger
  - Cities with larger amenities are larger
  - Larger cities have more frictions, but this tradeoff depends on how efficient local governments are in providing urban infrastructure
    - "Excess frictions" make cities smaller
- We explore these derivatives using data on U.S. cities and paying attention to the general equilibrium effects
  - The empirical results are consistent with the theory

Identifying City Characteristics

- Need to calculate the triplet $(A_{it}, \gamma_{it}, g_{it})$ from the data
- Obtain "efficiency wedge" from

$$A_{it} = \frac{y_{it}}{k_{it}^{\theta} h_{it}^{1-\theta}}$$

  - We can do this with or without capital data
- Calculate "labor wedge" from

$$(1 - \tau_{it}) = \frac{\psi}{(1-\theta)} \frac{c_{it}}{1 - h_{it}} \frac{h_{it}}{y_{it}}$$

- Then obtain $\ln g_{it}$ from

$$\ln \tau_{it} = \alpha + \frac{1}{2} \ln N_{it} + \ln g_{it}$$

- Use model to obtain γ_{it} so as to match size distribution of cities with $\bar{u} = 10$

Data

- Data for all MSA in the U.S. between 2005-2008
  - Cities with population greater than 50 000, consistently measured after 2003
- Consumption: No readily available data on consumption at MSA level
  - Use retail earnings and adjust using national averages
  - For housing consumptions use gross rents
- Capital: use U.S. sectoral capital stocks and allocate it to MSAs according to their shares in sectoral earnings
- Hours worked: use Current Population Survey but eliminate MSAs with less than 50 observations
- Housing rental prices: use American Community Survey

Parameters

- Let $\psi = 1.4841$ and $\theta = 0.3358$ as in McGrattan and Prescott (2009).
- Let $r = \delta = 0.02$ (assumptions on capital)
- Use

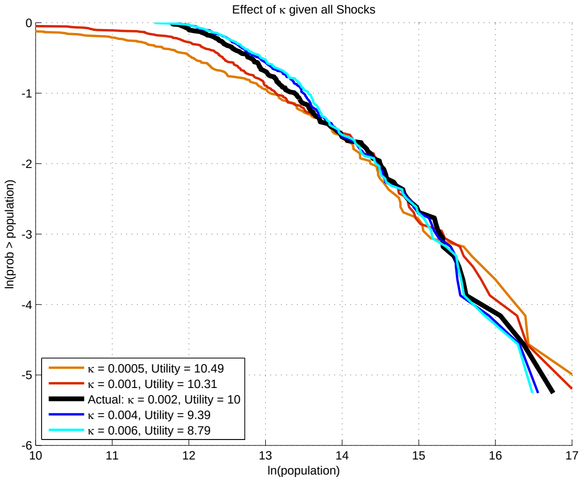
$$\ln \tau_{it} = \alpha + \frac{1}{2} \ln N_{it} + \varepsilon_{5it}$$

  then we can identify κ from the estimate of α as the model implies. We estimate $\kappa = 0.0017$

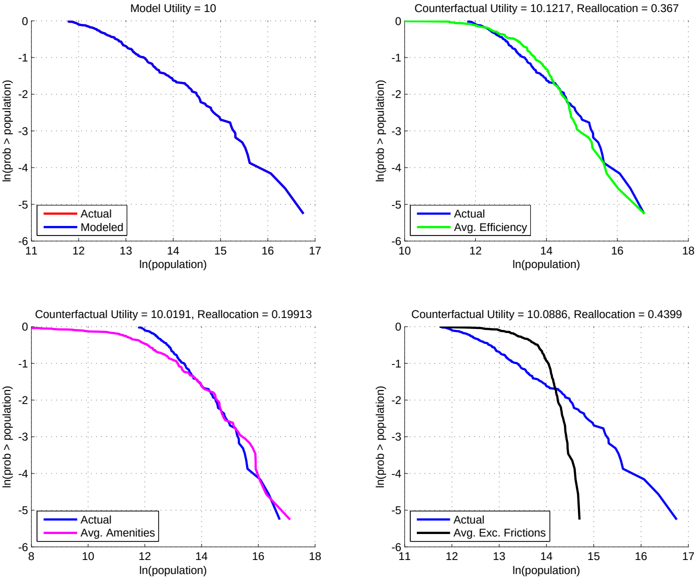
  - We use $\kappa = 0.002$ but do robustness checks with other values of κ

- If we eliminate all characteristics, welfare would increase by 3.26% and all cities would have 1 million 68 thousand people

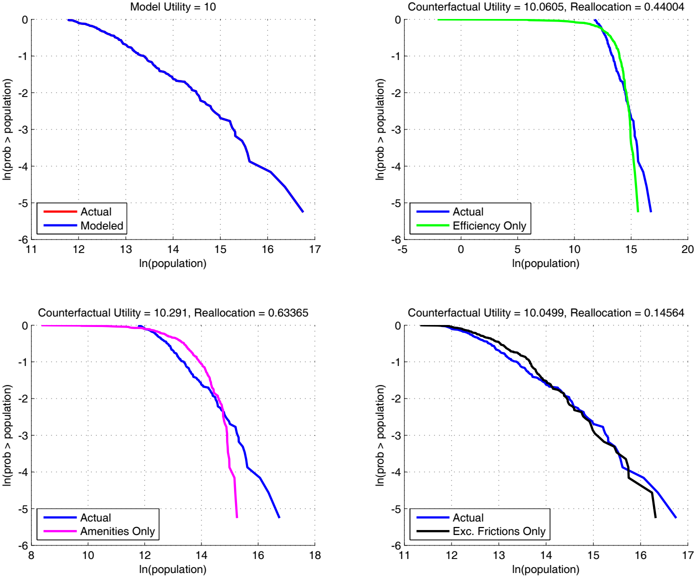
The Effect of Kappa



Counterfactuals Without One Shock



Counterfactuals With Only One Shock

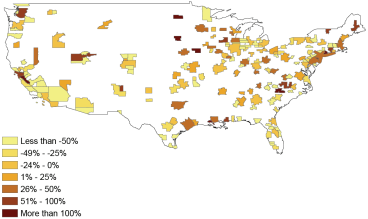


Reallocation

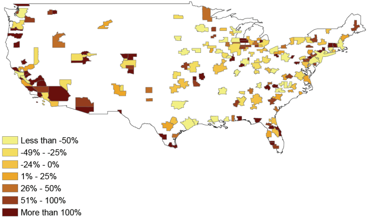
- Calculate reallocation following Davis and Haltiwanger (1992) by adding the number of new workers in expanding cities
  - Same efficiency: 37% reallocation and welfare gains of 1.2%
    Example: New York would lose 77% of its population
  - Same amenities: 20% reallocation and welfare gains of 0.2%
    Example: San Diego would lose 42% of its population
  - Same excessive frictions: 44% reallocation and welfare gains of 0.8%
    Example: Trenton would gain 326% of its population
- So very large reallocations, but small welfare gains
  - Reallocation in the U.S. economy amounts to around 2.1% over 5 years

Geographic Distribution

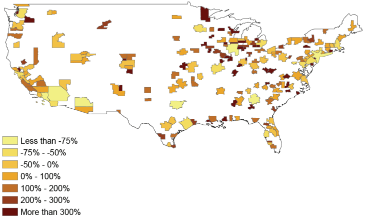
Without Differences in Amenities:



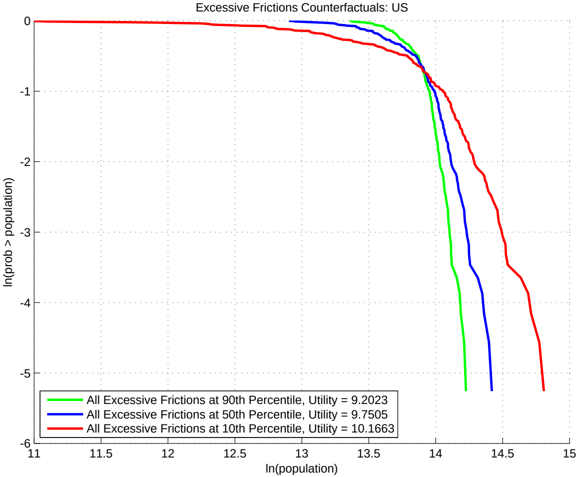
Without Differences in Efficiency:



Without Differences in Excessive Frictions:



Changing the Level of Excessive Frictions



- So overall cost of excessive frictions is significant in levels: Role for policy

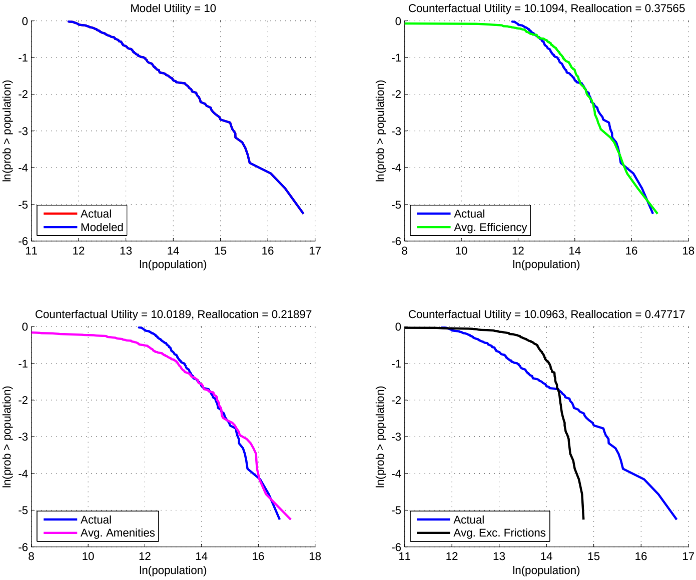
Adding Production Externalities

- Let

$$A_{it} = \tilde{A}_{it} N_{it}^{\omega}$$

  where $\tilde{A}_{it}$ is an exogenous characteristic and ω governs the elasticity of productivity with respect to size
- Fairly robust estimate of ω in the literature, so use $\omega = 0.02$

Counterfactuals with Production Externalities



Adding Externalities in Amenities

- Let

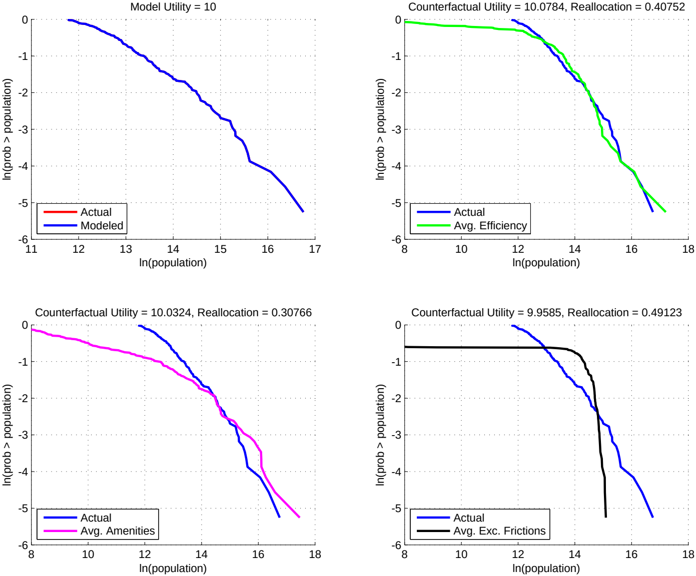
$$\gamma_{it} = \tilde{\gamma}_{it} N_{it}^{\zeta}$$

  where $\tilde{\gamma}_{it}$ is an exogenous characteristic and ζ governs the elasticity of productivity with respect to size

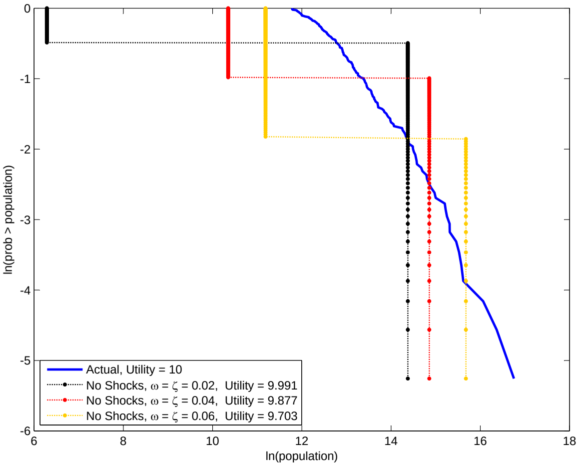
  - As in the case of production externalities we let $\zeta = 0.02$

- Reallocation and welfare changes very similar
- Less dispersion of city characteristics tends to decrease utility in the presence of externalities
- City selection effect is stronger

Counterfactuals Without One Shock and Both Externalities

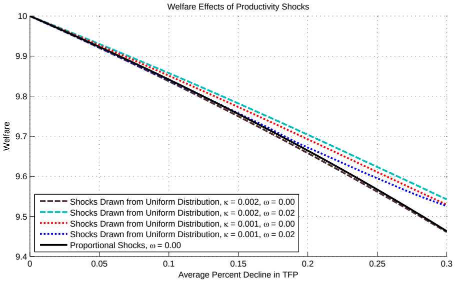


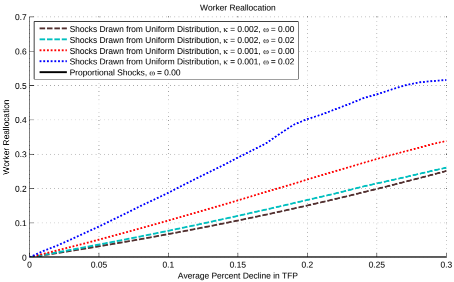
With Externalities but Only Average Characteristics



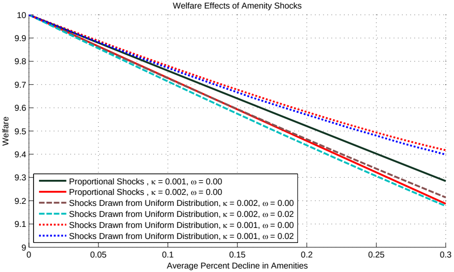
- For $\omega = 0.02$, 131 cities with only 613 agents and 61 with 3320745

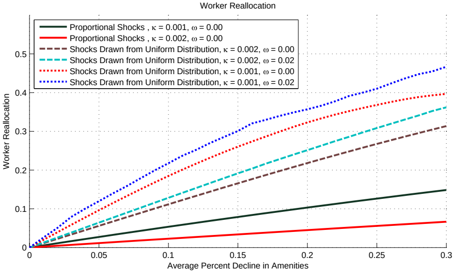
Steady State Impact of Shocks: Productivity





Steady State Impact of Shocks: Amenities

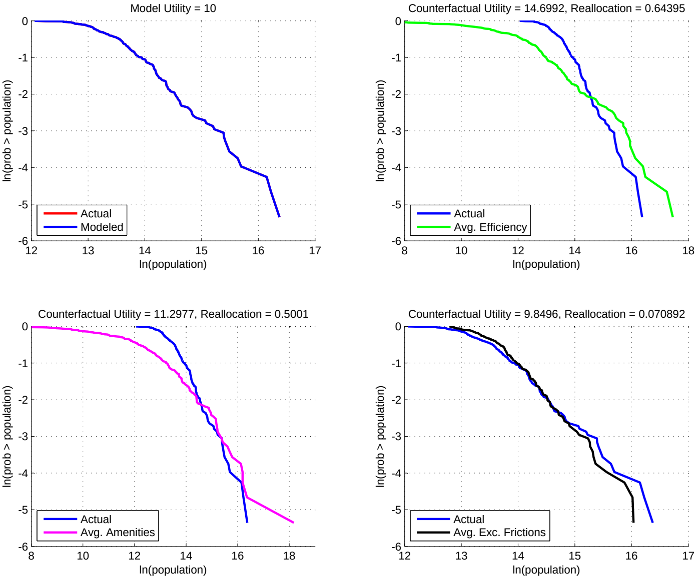




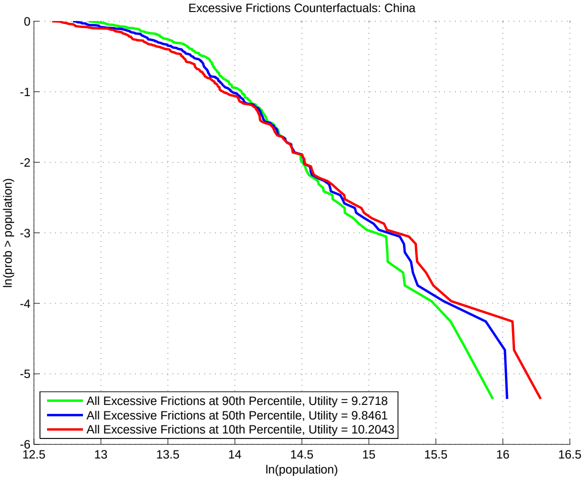
Steady State Impact of Shocks

- Shocks have small effects on welfare even without reallocation:
  - Agents can adjust their leisure as a result of the shock as well as the amount of capital
  - Agents obtain utility out of the amenities in the city and so consumption of goods is only one of the elements that determines an agent's utility
    - ★ Around 28% of an agent's utility.
  - Commuting costs and the distortions created to build the related public infrastructure go down with productivity and wages
- Effect of reallocation created through random shocks is again very small
  - Many cities are close substitutes so envelope is flat

Comparing with China



Comparing with China



Conclusions

- System of cities in U.S. such that large changes in city characteristics (or policy) have *small* effect on welfare but *large* effect on reallocation
- With externalities, city selection becomes an important part of reallocation
- Implies that the losses from lack of mobility are likely small
  - Small mobility costs would yield negative welfare effects
- More generally: Paper provides a simple GE methodology to compare urban systems
  - Identify main characteristics of cities
  - Understand the effect of shocks and policy
  - Assess magnitude of welfare gains at stake
    - Small in the US, but much larger in China