The Global Leapfrogging of Urban Growth

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July 2023

The 21st Conference on Research on Economic Theory and Econometrics

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Motivation: Increasing Number and Size of Cities

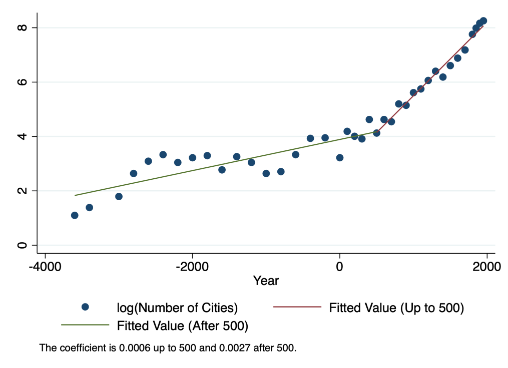


Figure 1: The number of cities in logarithm worldwide

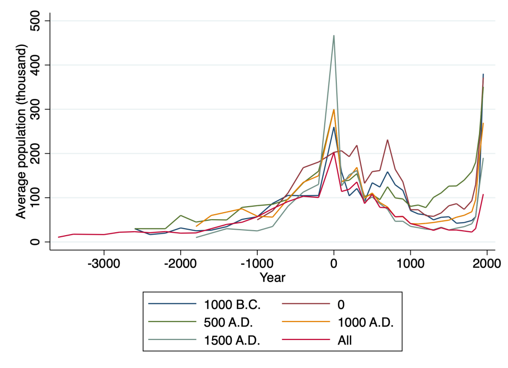
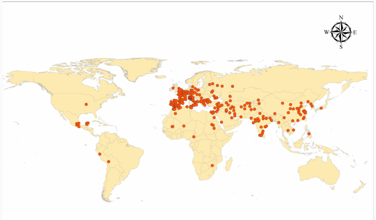


Figure 2: The average size of cities worldwide

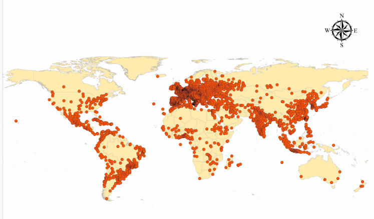
Motivation: Cities Were Widely Established

(a) 2000 B.C.

(b) 0



(c) 1000 A.D.



(d) 1950 A.D.

Research Question

- National growth **leapfrogs,** first Mesopotamia and China, then Egypt, Greece and Rome, back to China and India, back to Europe, the Western Offshoots, like North America, Australia, back to Europe, then on to Japan, Korea and China. Africa and South America lag behind.

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- Urban growth leaps from a city to other cities.
- Are geographical characteristics, temperature, or urban interactions the driving forces?
- How have these influences varied across different epochs and continents?

Literature Review

Overview

- Geographical characteristics and temperature alone do not provide a satisfactory explanation for urban growth.
  - In most cases, the coefficients related to these factors are statistically insignificant for urban population growth and emergence of cities.
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  - There exists a strong relationship between a city's growth rate and those of its neighboring cities.
- The lifespan of a city also contributes to explaining urban growth and emergence.

Data & Definitions

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    - Data Sources:
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    - An expanded dataset by Buringh (2021), focusing on European cities from 700 A.D. to 1900 A.D. It builds on the work of Bairoch (1988).
  - Methodology in merging datasets:
    - Cities from different datasets were harmonized based on their geographic coordinates and names.
    - Following the methodology of Bosker and Buringh (2017), we excluded observations with populations under 5,000 to maintain consistency in the dataset.

Definition of Epochs

Our study spans from 3700 B.C. to 1950 A.D. We segment entire span into six distinct epochs for nuanced analysis and “homogeneity”:

- **Preclassical Epoch**: 3700 BCE– 500 BCE, mainly centered on Europe.
- **Classical Hellenic and Roman Epoch**: 500 B.C. to 300 A.D., marked by the zenith of Athens and the founding of New Rome, Constantinople.
- **Byzantine to Charlemagne Epoch**: 300 AD– 800 AD, Roughly, Beginning of Byzantine Era to Charlemagne’s coronation as the Holy Roman Emperor; also includes developments in Asia and the Great Arab conquests post-600 AD.

...continue

- **Charlemagne to Black Death Epoch**: 800 AD – 1400 AD, Charlemagne's Coronation to Black Death in Europe; notably beginning of Ming Dynasty in China.
- **Black Death to Modern Era Epoch**: 1400 AD – 1800 AD. Spanning Sung Dynasty, China, and Zheng He's expeditions starting in 1405 AD.
- **Modern Era Epoch**: 1800 A.D. to 1950 A.D., after onset and spread of the Industrial Revolution.

Urban Growth across Continents: Populations

$$pten_{it}^{wd} = a_i + \beta_1 ptens_{it}^{eu} + \beta_2 pten_{it}^{af} + \beta_3 pten_{it}^{na} + \beta_4 pten_{it}^{sa} + \beta_5 pten_{it}^{as} + \beta_6 pten_{it}^{oc} + \delta_t + \epsilon_{it}, \quad (1)$$

- $pten_{it}^{wd}$: decile rank of city i in **global population distribution** at time t.
- RHS variables: $pten_{it}^{X}$ population decile rank of city i at time t within continent X.
- $pten_{it}^{X} = 0$, if city i not in continent X.
- δ_t: fixed time effect.
- a_i : city fixed effect.

Urban Growth across Continents: Populations

- Urbanization varying dramatically across continents over epochs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	ALL	up to -500	-500 to 300	300 to 800	800 to 1400	1400 to 1800	After 1800
$tenths^{eu}$	0.861***	0.374***	0.639***	0.361***	0.666***	0.805***	0.882***
	(0.006)	(0.123)	(0.137)	(0.081)	(0.010)	(0.006)	(0.006)
$tenths^{as}$	0.550***	0.992***	0.888***	0.792***	0.409***	0.312***	0.628***
	(0.016)	(0.019)	(0.034)	(0.036)	(0.021)	(0.019)	(0.022)
$tenths^{na}$	0.807***	1.130***	0.203***	0.123	0.351***	0.717***	1.039***
	(0.035)	(0.175)	(0.043)	(0.120)	(0.054)	(0.053)	(0.045)
$tenths^{sa}$	0.830***				0.273***	0.729***	0.852***
	(0.016)				(0.027)	(0.051)	(0.014)
$tenths^{af}$	0.540***	0.332***	0.118***	0.616***	0.443***	0.303***	0.647***
	(0.028)	(0.107)	(0.043)	(0.118)	(0.036)	(0.021)	(0.031)
$tenths^{oc}$	0.153***						0.090**
	(0.042)						(0.036)
Constant	1.207***	0.672***	1.473***	2.071***	2.330***	1.578***	0.873***
	(0.032)	(0.084)	(0.217)	(0.172)	(0.050)	(0.035)	(0.036)
Observations	18,073	233	241	395	2,034	4,250	9,343
R-squared	0.939	0.942	0.937	0.918	0.971	0.978	0.971
N	3,668	59	64	120	560	1,382	3,342

Urban Growth across Continents: Growth Rates

$$gten_{it}^{wd} = a_i + \beta_1 gtens_{it}^{eu} + \beta_2 gten_{it}^{af} + \beta_3 gten_{it}^{na} + \beta_4 gten_{it}^{sa} + \beta_5 gten_{it}^{as} + \beta_6 gten_{it}^{oc} + \delta_t + \epsilon_{it}, \tag{2}$$

- Here, $gten_{it}^{wd}$ represents the decile rank of city i in terms of growth rate at time t globally.
- On the right-hand side, $gten_{it}^{X}$ denotes the decile rank of city i in terms of growth rate at time t within the continent X.
- For cities not located in continent X, $gten_{it}^{X}$ is set to 0.

Urban Growth across Continents: Growth Rates

- Urban growth rates varying dramatically across continents over epochs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	ALL	up to -500	-500 to 300	300 to 800	800 to 1400	1400 to 1800	After 1800
$tenths^{eu}$	0.938***	1.033***	0.907***	1.062***	0.980***	0.957***	0.916***
	(0.002)	(0.109)	(0.078)	(0.194)	(0.010)	(0.004)	(0.003)
$tenths^{as}$	0.938***	0.969***	0.978***	0.943***	0.812***	1.024***	0.918***
	(0.008)	(0.022)	(0.015)	(0.015)	(0.024)	(0.018)	(0.018)
$tenths^{na}$	0.967***	0.667**		0.849***	0.629***	0.497**	1.018***
	(0.033)	(0.322)		(0.181)	(0.133)	(0.204)	(0.028)
$tenths^{sa}$	1.122***				0.645**	1.110***	1.125***
	(0.023)				(0.266)	(0.099)	(0.025)
$tenths^{af}$	0.882***	1.011***	0.863***	0.883***	0.714***	0.935***	0.970***
	(0.021)	(0.045)	(0.069)	(0.156)	(0.051)	(0.044)	(0.039)
$tenths^{oc}$	1.947***						1.946***
	(0.557)						(0.556)
Constant	0.333***	0.529***	0.467***	0.316**	0.549***	0.212***	0.377***
	(0.014)	(0.101)	(0.097)	(0.126)	(0.055)	(0.028)	(0.021)
Observations	13,384	148	156	265	1,422	2,984	7,670
R-squared	0.937	0.887	0.926	0.915	0.902	0.965	0.950

Emergence

Emergence of Cities

- Geographic characteristics significantly impact global urban growth; technological advancements enable human settlement in previously inhospitable areas.

[1] Our methodology, while simpler than the one utilized by Bosker and Buringh (2017), makes the analysis manageable by significantly reducing the number of observations.

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- We assume that all city locations up to 1950 AD indicate potential city sites[1]. We designate a value of 100 to $city_{it}$[2] If a city has been established by time t, and 0 otherwise.

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Geographical Characteristics (City Emergence)

$$p(city_{it}|city_{it-1} = 0) = \alpha_i + X\beta + f(x_i, y_i) + \delta_t + \epsilon_{it}, \quad (3)$$

- α_i represents random effect
- X is a vector of both time-variant and time-invariant geographic characteristics that includes proximity to a river within 10 km, proximity to an ocean within 10 km, roughness, elevation, and temperature
- $f(x_i, y_i)$ denotes a cubic function with respect to longitude x_i and latitude y_i
- δ_t is time fixed effect

Geographical Characteristics (City Emergence)

- The influence of geographical characteristics varies across epochs.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	ALL	up to -500	-500 to 300	300 to 800	800 to 1400	1400 to 1800	After 1800
river	0.104	0.035	0.048	1.214***	0.397	-5.505***	2.910*
	(0.097)	(0.044)	(0.115)	(0.235)	(1.035)	(1.476)	(1.704)
ocean	0.121	-0.020	0.467***	0.522***	-1.179	-0.861	-0.146
	(0.097)	(0.040)	(0.138)	(0.197)	(0.902)	(1.389)	(1.527)
roughness	0.002	-0.003***	-0.004***	-0.005*	0.029**	0.104***	0.029
	(0.001)	(0.001)	(0.002)	(0.003)	(0.012)	(0.020)	(0.021)
elevation (100m)	0.005	0.015***	0.059***	0.114***	-0.178***	-0.356**	-1.116***
	(0.011)	(0.005)	(0.015)	(0.027)	(0.065)	(0.150)	(0.147)
temperature	0.009	0.025***	0.034***	0.078***	0.102**	-0.153	-1.044***
	(0.008)	(0.004)	(0.010)	(0.016)	(0.046)	(0.101)	(0.108)
Constant	48.904***				3.303***	26.259***	
	(1.452)				(1.169)	(2.414)	
Observations	154,010	67,336	28,685	22,241	19,463	11,163	5,122
N	4,827	4,827	4,822	4,809	4,109	3,959	2,513

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- Some research exploring earlier periods confirms network effects on urban growth (Beltran Tapia et al., 2021, Bosker and Buringh, 2017, Cuberes et al., 2021, Rauch, 2014).
- Using Özak (2010)'s travel time dataset, superior to the commonly used great circle distances, we define a city's neighboring area as a 16-hour walking range, approximately 50-100 kilometers.

Urban Network Effects (City Emergence)

$$p(city_{it}|city_{it-1} = 0) = a_i + D_{t-1}\beta + \delta_t + \epsilon_{it}, \tag{4}$$

- D_{t-1} is a vector consisting of four dummy variables. Define NC_{it-1} as the count of neighboring cities for city seed i at time $t-1$.
  - D_{1t-1} is 1 if $NC_{it-1} = 1$, and 0 otherwise.
  - D_{2t-1} is 1 if $2 \leq NC_{it-1} < 5$, and 0 otherwise.
  - D_{3t-1} is 1 if $5 \leq NC_{it-1} < 11$, and 0 otherwise.
  - D_{4t-1} is 1 if $NC_{it-1} \geq 11$, and 0 otherwise.
- a_i represents the city fixed effect.
- δ_t denotes the time fixed effect.

Urban Network Effects (City Emergence)

- Network effects vary across epochs, with the optimal number of neighboring cities influencing city emergence differing by epoch.

Neighboring Cities (NC_{it-1})	(1) ALL	(2) up to -500	(3) -500 to 300	(4) 300 to 800	(5) 800 to 1400	(6) 1400 to 1800	(7) After 1800
$NC_{it-1} = 1$	1.292***	2.875***	0.236	-0.665	2.161***	1.008	14.118***
	(0.439)	(1.073)	(0.339)	(0.615)	(0.750)	(1.694)	(3.597)
$2 \leq NC_{it-1} < 5$	3.561***	8.502**	-0.197	-0.101	1.281	4.962*	22.540***
	(0.871)	(4.062)	(0.457)	(1.968)	(0.920)	(3.012)	(4.318)
$5 \leq NC_{it-1} < 11$	-4.038*	20.158***			0.404	19.344***	-18.655**
	(2.083)	(7.714)			(1.387)	(5.009)	(8.282)
$11 \leq NC_{it-1}$	-15.099***				-0.898	37.280***	-53.249***
	(3.091)				(0.686)	(9.149)	(12.608)
Constant	3.165***	0.117***	0.400***	0.986***	1.506***	5.728***	25.514***
	(0.026)	(0.008)	(0.015)	(0.034)	(0.094)	(0.321)	(1.437)
Observations	154,034	67,350	28,684	22,210	18,943	9,859	4,336
R-squared	0.259	0.109	0.350	0.282	0.303	0.377	0.520
N	4,828	4,828	4,816	4,776	3,589	2,655	1,727

Population Growth

Influence of Geographical Characteristics on Population Growth

$$\log\left(\frac{\text{population}_{it}}{\text{population}_{it-1}}\right) = \alpha_i + \delta \log(\text{population}_{it-1}) + X\beta + f(x_i, y_i) + \delta_t + \epsilon_{it}$$

- The left-hand side represents the population growth rate.
- α_i, X, $f(x_i, y_i)$, and δ_t retain their previous definitions.

Simplified, we obtain:

$$\log(\text{population}_{it}) = \alpha_i + (\delta + 1) \log(\text{population}_{it-1}) + X\beta + f(x_i, y_i) + \delta_t + \epsilon_{it}$$

Influence of Geographical Characteristics on Population Growth

- Geographical characteristics exert a strong and significant influence on urban growth, particularly in the final two epochs.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	ALL	up to -500	-500 to 300	300 to 800	800 to 1400	1400 to 1800	After 1800
river	0.098***	0.053	-0.138*	0.047	0.041	0.050**	0.112***
	(0.020)	(0.121)	(0.076)	(0.083)	(0.027)	(0.022)	(0.024)
ocean	0.189***	-0.414*	-0.074	-0.056	0.045	0.078***	0.217***
	(0.020)	(0.247)	(0.097)	(0.085)	(0.030)	(0.024)	(0.023)
roughness	-0.003***	0.000	-0.004**	-0.001	-0.001**	-0.001*	-0.003***
	(0.000)	(0.003)	(0.002)	(0.001)	(0.000)	(0.000)	(0.000)
elevation (100m)	0.006***	-0.007	-0.009	0.004	0.005	-0.009**	0.007**
	(0.002)	(0.016)	(0.008)	(0.007)	(0.004)	(0.004)	(0.003)
temperature	-0.012***	-0.014	0.008	-0.006	-0.000	-0.010***	-0.017***
	(0.002)	(0.018)	(0.007)	(0.008)	(0.004)	(0.004)	(0.002)
Constant	1.219***	1.304		1.537***		1.108***	1.418***
	(0.267)	(0.800)		(0.333)		(0.135)	(0.069)
Observations	14,080	168	175	311	1,610	3,471	8,345
N	3,646	58	68	126	564	1,441	3,435

Urban Network Effects (Population Growth)

$$log(\text{population}_{it}) = a_i + (\delta + 1)log(\text{population}_{it-1}) + D_{t-1}\beta + \delta_t + \epsilon_{it}, \tag{5}$$

- D_{t-1} is a vector consisting of four dummy variables. Define NC_{it-1} as the count of neighboring cities for city seed i at time $t-1$.
  - D_{1t-1} is 1 if $NC_{it-1} = 1$, and 0 otherwise.
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  - D_{3t-1} is 1 if $5 \leq NC_{it-1} < 11$, and 0 otherwise.
  - D_{4t-1} is 1 if $NC_{it-1} \geq 11$, and 0 otherwise.
- a_i represents the city fixed effect.
- δ_t denotes the time fixed effect.

Urban Network Effects (Population Growth)

Network effects have become significantly prominent in the recent two periods

	(1) ALL	(2) up to -500	(3) -500 to 300	(4) 300 to 800	(5) 800 to 1400	(6) 1400 to 1800	(7) After 1800
log(population$_{it-1}$)	0.645***	0.196**	0.137	0.455***	0.464***	0.368***	0.367***
	(0.013)	(0.079)	(0.154)	(0.058)	(0.044)	(0.034)	(0.016)
Neighboring Cities (NC_i)							
$NC_i == 1$	0.091***	0.235*	-0.257**	0.409	-0.013	0.075	0.133***
	(0.028)	(0.125)	(0.115)	(0.257)	(0.068)	(0.056)	(0.049)
$2 <= NC_i < 5$	0.150***	-0.060	0.102	0.047	0.078	0.166***	0.136**
	(0.032)	(0.119)	(0.253)	(0.123)	(0.080)	(0.062)	(0.061)
$5 <= NC_i < 10$	0.242***	-0.061			0.177*	0.211***	0.167**
	(0.037)	(0.232)			(0.098)	(0.066)	(0.081)
$10 <= NC_i$	0.365***				0.266	0.268***	0.278***
	(0.043)				(0.211)	(0.073)	(0.088)
Constant	1.178***	2.604***	4.202***	2.336***	1.713***	1.711***	2.118***
	(0.042)	(0.240)	(0.739)	(0.257)	(0.140)	(0.098)	(0.066)
Observations	13,384	148	156	265	1,422	2,984	7,670
R-squared	0.8959	0.8436	0.8237	0.8259	0.8846	0.9214	0.9286
N	2,946	38	49	80	376	953	2,758

Life spam

Life Spam

- In our previous analysis, we focused on the influence of geographic characteristics and urban networks on urban growth.
- Another important factor is a city's history. Looking back, we find that countries with a long history have hosted relatively larger cities.
- However, have older cities maintained their large sizes? Additionally, does this effect vary across continents?

We investigate the influence of a city's history on its population and growth rate. We specify two alternative models:

$$\log(\text{population}_{it}) = \alpha_i + \beta_1 \text{age}_{it} + f(x_i, y_i) + \delta_t + \epsilon_i \tag{6}$$

and

$$\log(\text{population}_{it}) = \alpha_i + \gamma \log(\text{population}_{it-1}) + \beta_2 \text{age}_{it} + f(x_i, y_i) + \delta_t + \epsilon_i, \tag{7}$$

where age_{it} is the age of city i at time t, and α_i is random effect.

Life Spam

- Over time, the impact of a city's age on its size and population growth becomes increasingly stronger.

	ALL	up to -500	-500 to 300	300 to 800	800 to 1400	1400 to 1800	After 1800
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	panel A: City Size						
age(100 yr)	0.071***	0.001	0.021**	0.032***	0.061***	0.080***	0.074***
	(0.005)	(0.011)	(0.010)	(0.008)	(0.008)	(0.006)	(0.005)
Observations	19,083	270	299	541	2,278	5,377	10,318
Number of City	4,678	96	122	266	804	2,509	4,317
	Panel B: Population Growth						
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
log(population$_{it-1}$)	0.778***	0.717***	0.774***	0.616***	0.811***	0.763***	0.780***
	(0.008)	(0.060)	(0.075)	(0.044)	(0.020)	(0.017)	(0.011)
age(100 yr)	0.007***	-0.007	-0.003	0.011***	0.001	0.008***	0.011***
	(0.001)	(0.008)	(0.006)	(0.004)	(0.002)	(0.002)	(0.002)
Observations	14,085	168	175	311	1,610	3,473	8,348
Number of City	3,647	58	68	126	564	1,442	3,436

Conclusion

Conclusion

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