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WP-AD 2010-05

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Ivie

Working papers Working papers Working papers

Edita / Published by: Instituto Valenciano de Investigaciones Económicas, S.A.

Depósito Legal / Legal Deposit no.: V-1081-2010

Impreso en España (febrero 2010) / Printed in Spain (February 2010)

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Sequential city growth: empirical evidence*

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Abstract

Using two comprehensive datasets on population of cities (1800-2000) and metropolitan areas (1960-2000) for a large set of countries, I present three new empirical facts about the evolution of city growth. First, the distribution of cities growth rates is skewed to the right in most countries and decades. Second, within a country, the average rank of each decade's fastest growing cities tends to increase over time. Finally, this rank grows faster in periods of rapid growth in urban population. These facts can be interpreted as evidence in favor of the idea that urban agglomerations have historically grown following a sequential growth pattern: within a country, the initially largest city is the first one to grow rapidly for some years. At some point, the growth rate of this city slows down and the second largest city is then the fastest-growing one. Eventually, the third largest city starts growing fast as the two largest cities slow down, and so on.

Keywords: city growth, increasing returns, congestion costs, urbanization, Gibrat's Law

JEL Classification: O14, O33, O57

* I would like to thank Antonio Ciccone, Jan Eeckhout, Yannis Ioannides, Vernon Henderson, Casey Mulligan, Curtis Simon, and Robert Tamura for valuable comments. Useful suggestions were also received from seminar participants at the SERC (LSE), the 2006 Summer Econometric Society, the 2007 North American Regional Science Council, and the 2006 Southern Economic Association Meetings. I acknowledge the financial support of the Ministerio de Ciencia y Tecnología (proyecto SEJ2007-62656) and the Ivie.

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1. Introduction

Using historical data on population of both administratively defined cities and metropolitan areas I document three new empirical facts on the growth process of cities. I first show that, in most decades and countries, the distribution of cities growth rates is skewed to the right, indicating that a few cities grow always much faster than the rest. Second, I study the behavior of the cities that grow the fastest in each decade. The average rank of the 25% fastest growing cities tends to increase over time, which suggests that the initially largest cities are the first ones to grow and that they keep growing faster than the rest until they reach a critical size. Once that happens, the second largest city starts growing, then the third one, and so on. Finally, I show that this process of sequential growth is more pronounced in episodes of fast growth in urban population.

The study of city formation and city growth is important to formulate effective policies in countries whose population is changing rapidly. The novel empirical facts presented in this paper show that the evolution of city population growth exhibits a very consistent time pattern across countries. The specifics of this pattern may have interesting implications for academics and policymakers. Consider, for instance, the analysis of how labor and capital flows will evolve in regions that experience a process of economic and political integration. The most obvious case of such integration is the European Union, which has recently admitted ten new countries and is negotiating the admission of some more in the next few years. The new facts presented here can also help analyzing the patterns of urbanization and city growth in countries with a rapid ongoing process of rural-urban migration or that have suffered natural disasters or wars that have fundamentally altered their geography and the location of their population.

The paper is organized as follows. In Section 2 I briefly review the existing literature that relates to my paper. Section 3 describes the dataset used and the method of sample selection. The three new empirical findings are presented in Section 4. Section 5 presents some robustness checks and finally Section 6 concludes.

2. Related Literature

Different papers have analyzed historical data on cities population and some properties of their distribution. Eaton and Eckstein (1997) study the evolution of the transition matrices of the largest metropolitan areas of France and Japan and conclude that they remained constant during the time interval 1876-1990 for France and 1925-1985 in the case of Japan.

Ioannides and Overman (2003) show that deviations from Gibrat's law[1] are not statistically significant for the main U.S metropolitan areas in the period 1900-1990. They estimate city growth non-parametrically and conclude that, although city growth rates seem to vary with city size, Gibrat’s law does hold.

[1] This law states that the growth rate of a city’s population is independent of its size. See Gibrat (1931) for a general statement of this law and Gabaix and Ioannides (2004) for a review of studies that apply it to cities.

My paper differs from Eaton and Eckstein (1997) and Ioannides and Overman (2003) in several dimensions. First, I provide results for both administratively defined cities and metropolitan areas, while they only analyze the latter. The use of administratively defined cities allows me to greatly expand the number of years in the analysis. Second, the number and identity of urban agglomerations in the mentioned studies is constant over time while I allow for the possibility of adding more cities and metropolitan areas to my sample as countries urbanize. Finally, from a methodological point of view I focus on the experience of city growth in each individual country and analyze two different statistics: the coefficient of skewness and the rank of the fastest growing cities.[2]

Glaeser and Gyourko (2005) document the fact that the distribution of the growth rates of cities is skewed to the right. However, they only consider the U.S. case during the period 1920-2000. My paper expands the analysis to much longer periods and a broader number of countries.

Finally, Davis and Weinstein (2002) use the "quasi natural-experiment" provided by the strategic bombing of Japan during World War II to study the patterns of population growth in cities that have experienced a dramatic shock. They interpret the remarkable recovery of Japan's urban system as evidence against random growth due to the presence of a strong mean-reverting component.

From a theoretical point of view, Henderson and Venables (2009) and Cuberes (2009) have recently developed theoretical models of city formation in which urban agglomerations grow sequentially, where the initially largest ones are the first to grow until they reach a critical size, and are then followed by the second largest cities, then the third largest ones, and so on. The empirical facts reported below are very much consistent with the main predictions of these types of theories.

3. The Data

There currently exist three comprehensive datasets for international comparisons of population of urban agglomerations over long intervals of time. The first one is from Vernon Henderson and it contains data on metropolitan areas (henceforth MAs) in different countries during the period 1960-2000. The second one, by Thomas Brinkhoff, presents information on the population of various administratively defined cities (cities henceforth) in 79 countries during the period 1970-2000. Finally, the most comprehensive dataset, by Jan Lahmeyer, has the size of the largest cities for a large number of countries during the period 1790-2000.

This paper combines city data at a decade frequency from 54 countries from the Lahmeyer's and Brinkhoff's datasets and data on the metropolitan areas of 115 countries from Henderson. A list of the countries and decades studied here is presented in the appendix. Using the two units of analysis is important for several reasons. First, as Eeckhout (2004) argues, the choice of unit

[2] Other papers that analyze the evolution of the U.S. population using long time series are Gonzalez-Val (2007), Beeson et al. (2001), Beeson and DeJong (2002), Ehrlich and Gyourko (2000), and Kim (2007).

depends on the research objective. He also states that "...in past research both MAs and cities have proved to be useful and relevant economic units, and both have been studied extensively."[3]

4. New Empirical Facts on City Growth

4.1. Selection of Relevant Cities

The heterogeneity in data availability and time span across countries makes it difficult to conduct appropriate cross-country comparisons. In this paper I follow Henderson and Wang (2007)- HW henceforth- to select the relevant sample. HW consider metropolitan areas in the period 1960-2000 and choose a cutoff of 100,000 based on Black and Henderson (2003) who state

> *"The 100,000 cutoff is chosen for practical reasons- it is the cutoff employed by many countries. None has a higher cutoff and most do not provide consistent data over time on cities below 100,000. Even USA metro areas which in theory have a cutoff of 50,000, in practice only include comprehensively urban counties with over 85,000 urban residents."*

This sample selection method has the advantage of allowing one to analyze a portion of the city size distribution that is comparable across countries and over time. I use the same cutoff as in HW in the exercises that involve MAs. However, for the city data the choice must be different for two obvious reasons. The first one is that administratively defined cities tend to be considerably smaller units.[4] Second, my sample of cities expands back to 1800, when most cities were much smaller than in 1950, the year at which the HW sample begins.

In order to select an appropriate cutoff I focus on the distribution of city sizes in the United States in 1790.[5] The median city size in that year is 5,077 and its average is 8,402.3. Dividing both numbers gives us a threshold of 0.6. Next, following HW, I select the cities that in each decade satisfy the following inequality:

$$\frac{N_{ijt}}{\overline{N}_{jt}} > \frac{N_{med,US,1790}}{\overline{N}_{US,1790}} = 0.6$$

where N_{ijt} is the population of city *i* in country *j* and period *t*, and $\overline{N}_{jt}$ is the average city population of country *j* in that period. $N_{med,US,1790}$ and $\overline{N}_{US,1790}$ denote the median and the average city population of the United States in 1790 respectively.[6]

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[3] See also Glaeser et al. (1995) for a discussion on the use of cities versus MAs in empirical exercises.

[4] For instance, using the definition of an administratively defined city, New York had a population of 8,008,278 in the year 2000. Its MA however includes a much larger geographical area and so the figure becomes 21,199,865.

[5] I have ran multiple robustness checks choosing different countries and years as a reference point- and hence different cutoffs- and, although the composition and size of the resulting samples change, the qualitative results do not vary much. Some of these exercises are reported in Section 5 of the paper. For a further discussion on truncation points see Eeckhout (2008).

[6] In HW the corresponding ratio is the result of dividing 100,000 by the average size of world cities in 1960 (495,101) giving a ratio of 0.202.

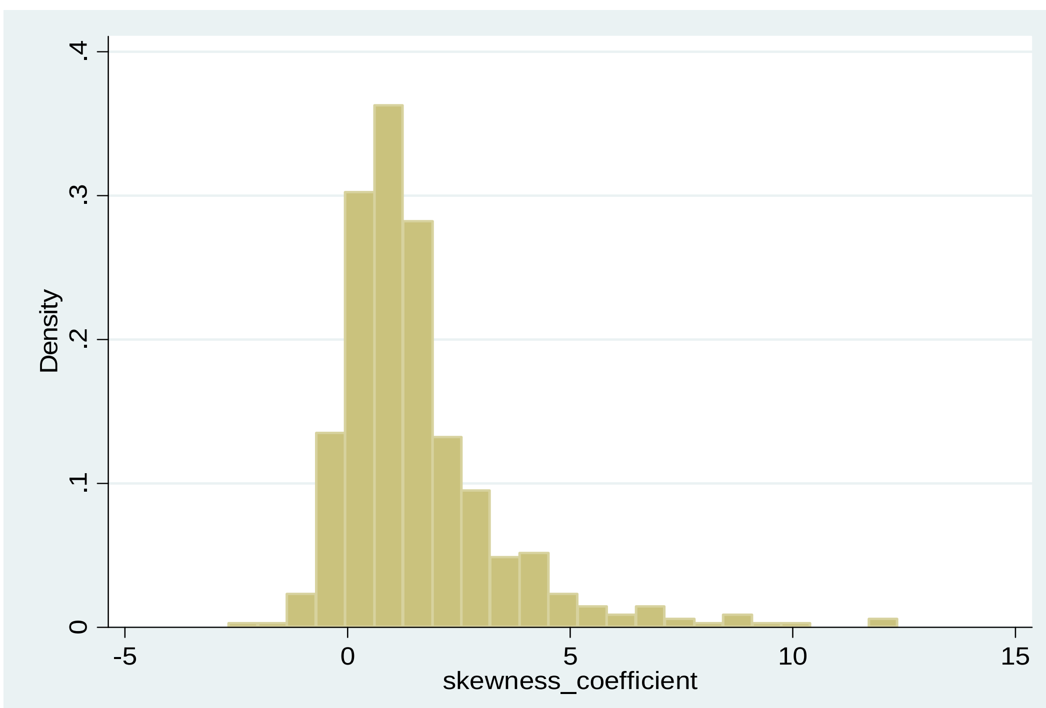
A direct consequence of this methodology is that, as happens in HW, the number of cities and MAs increases as time goes by. Below it is described how I control for this in the regression analysis.

4.2. Right Skewness of Cities Growth Rates

In this section I calculate the coefficient of skewness for each cross section of cities growth rates. A positive (negative) skewness indicates a distribution with an asymmetric tail extending toward more positive (negative) values.

For cities my sample consists of 536 country-decades observations. However, in eighteen cases the number of cities is equal or lower than two and so it is not possible to calculate this coefficient. In 89% of the remaining cases this coefficient is strictly positive. Figure 1 shows a histogram of these skewness coefficients.

Figure 1: Histogram of the Coefficient of Skewness of Cities' Growth Rates



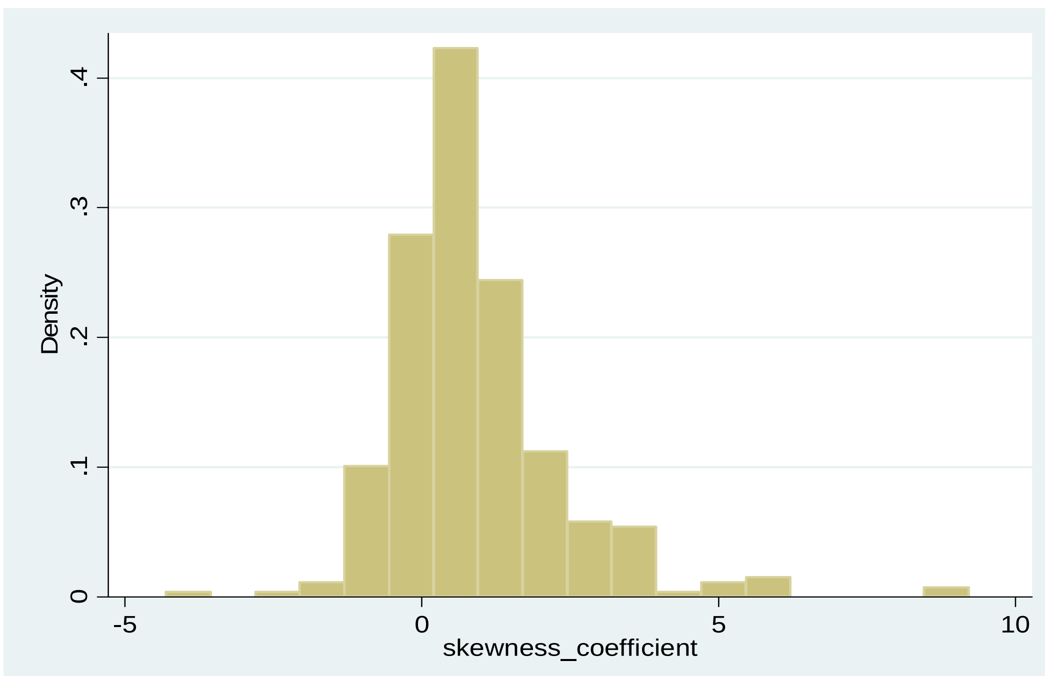
I next run a test to determine how often this positive coefficient is statistically significant. This normality test requires a minimum of eight observations and its null hypothesis is that the distribution of the data is normal.[7] In 73% of the cases this coefficient is positive and significant

[7] More details on this test can be found in D'Agostino et al. (1990) and in Royston (1991).

at conventional levels. This represents a remarkably high percentage given the fact that the number of observations is quite small in many periods and countries.

For MAs the total number country-decade observations is 460. In 77% of the 343 cases in which it is possible to calculate it the coefficient of skewness is positive. When I run the previous test the percentage of significant right skewness is 63%, a figure lower than the one obtained using city data but still fairly large. A histogram of the skewness coefficients for the MAs cross sections is displayed in Figure 2.

Figure 2: Histogram of the Coefficient of Skewness of MAs' Growth Rates



The conclusion of this exercise is that there is very strong evidence indicating that, within a country, a few cities tend to grow much faster than the rest in most decades and that this finding is statistically significant using data on both administratively defined cities and MAs.

4.3. The Average Rank of the Fastest Growing Cities

In this section I expand the previous finding and ask whether one can say something about the identity of the fastest growing cities in each decade. I begin by ranking cities – for each country- by size (in terms of population) on every decade, with the largest city having rank 1, the second largest having rank 2, and so on.

Next, for each country-decade I calculate the 75th percentile of cities growth rates and consider the cities which growth rate is larger or equal to this cutoff.[8] I refer to these cities as "fast-growers" in that decade and I proceed to calculate their average population rank. It is crucial to understand that the logic of this exercise is *not* to follow specific cities over time, but to ask which cities are the ones that grow the fastest at each point in time. In particular, I attempt to answer two questions. First, on a given decade, are the large cities (low rank) or the small ones (high rank) the ones that grow the fastest? Second, does this pattern change from decade to decade?

4.3.1. An Example

Here I provide an example that clarifies my procedure. Consider the population of French cities in the years 1851 and 1861. Table 1 presents this data ordering cities by size -in decreasing order- in 1861. The sixth column illustrates the method of sample selection employed throughout the paper. Only those cities which relative population (relative to the country's average in 1861) is strictly larger than 0.6 are selected. In this particular example, Toulouse is the last city that satisfies this constraint. The growth rates of cities population between these two years are reported in column 5.[9]

Table 1: Rank and Growth Rate of the Largest French Cities in 1861

City	Pop in 1851	Pop in 1861	Rank in 1861	Growth Rate	Ratio pop/avg in 1861
Paris	1,053,300	1,696,100	1	0,61	9,25
Lyon	177,200	318,800	2	0,8	1,74
Marseille	193,300	260,900	3	0,35	1,42
Bourdeaux	130,900	162,800	4	0,24	0,89
Lille	75,800	131,800	5	0,74	0,72
Nantes	96,400	113,600	6	0,18	0,62
Toulouse	94,200	113,200	7	0,2	0,62

Table 2 uses the subsample of cities whose growth rate is strictly larger than the 75th percentile of the growth rates in Table 1. In this example this percentile is equal to 0.739 and so only the cities of Lyon and Lille are classified as "fast-growers". Finally, in the third column of Table 2 I calculate the average 1861-rank of these two cities, which turns out to be 3.5.

[8] This exercise has been done with different cutoffs (70th and 80th percentiles) and the results are very similar. See Section 5.
[9] In this example the number of observations in the 1851-1861 year-pair is 7 and the skewness coefficient of cities growth rates is 0.3.

Table 2: Average Rank of the Fastest Growing Cities in 1861's France

City	Rank in 1861	Average Rank
Lyon	2	3,5
Lille	5	

Table 3 is the analog of Table 1 for a decade later, i.e. 1871. It displays the sample of cities that satisfies the 0.6 cutoff, along with their growth rate with respect to 1861. These cities are again ranked by descending size (based on their size in 1871). Table 4 selects the fastest growing cities among this sample. In particular, the 75th percentile of growth rates is now 0.2. Therefore, the fast-growers on this decade are Marseille, Lille, Saint-Etienne, and Reims. Once again, it is very important to understand that this exercise *does not* attempt to follow individual cities over time, but rather to calculate the rank of a "fictitious city" that is the average of a group of very fast-growing cities. In this example, the data tell us that in 1861 the 75th percent fastest growing cities had an average rank of 3.5 (i.e. this city comes from a group of "relatively large size" cities). In 1871, the fastest growing cities had an average rank of 7 (i.e. this city comes from a group of "relatively small size" cities). So, in this particular case, the average rank of the fastest growing cities has increased from 3.5 to 7 in ten years.

Table 3: Rank and Growth Rate of the Largest French Cities in 1871

City	Pop in 1861	Pop in 1871	Rank in 1871	Growth Rate	Ratio pop/avg in 1871
Paris	1,696,100	1,851,800	1	0,09	16,57
Lyon	318,800	323,400	2	0,01	2,89
Marseille	260,900	312,900	3	0,2	2,8
Bourdeaux	162,800	194,100	4	0,19	1,74
Lille	131,800	158,100	5	0,2	1,41
Toulouse	113,200	124,900	6	0,1	1,12
Nantes	113,600	118,500	7	0,04	1,06
Saint-Etienne	92,300	110,800	8	0,2	0,99
Rouen	102,600	102,500	9	-0,001	0,92
Le Havre	74,300	86,800	10	0,17	0,78
Strasbourg	82,000	85,500	11	0,04	0,76
Reims	55,800	72,000	12	0,29	0,64
Toulon	85,000	69,100	13	-0,19	0,62

Table 4: Average Rank of the Fastest Growing Cities in 1871's France

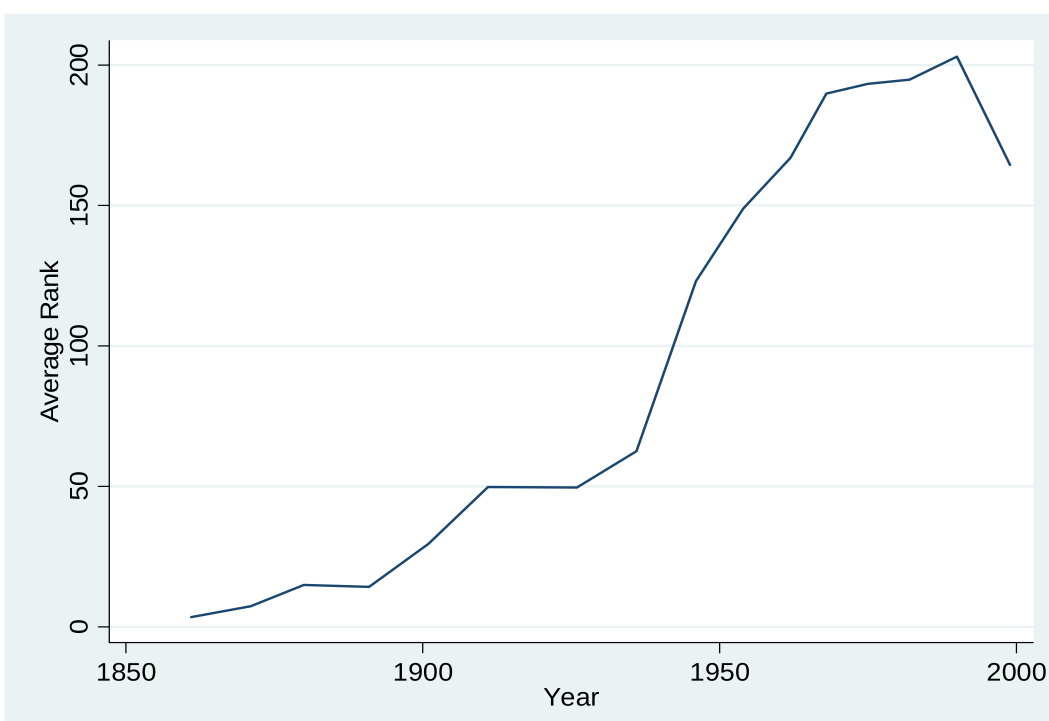
City	Rank in 1871	Average Rank
Marseille	3	
Lille	5	7
Saint-Etienne	8	
Reims	12	

I then repeat this routine for every decade-pair for which the country has available data and so I am able to construct a complete time series of the rank of the fastest growing cities of this country. Table 5 and Figure 3 shows the entire time series of the average rank of the fastest growing cities in France.

Table 5: Average Rank of the Fastest Growing Cities in France: 1861-1999

Year	Average Rank
1861	3,5
1871	7,3
1880	14,9
1891	14,3
1901	29,6
1911	49,9
1926	49,7
1936	62,6
1946	123,2
1954	149,1
1962	167,1
1968	189,9
1975	193,5
1982	195
1990	203
1999	164,5

Figure 3: The Evolution of the Average Rank of the Fastest Growing Cities in France



As it is apparent, the rank of the fastest growing cities exhibits a clear positive trend. In the initial decades, the fastest growing cities in France come from the low rank (large) group of cities. In the final decades, the fastest growing cities came from the high rank (small) group of cities. This is entirely consistent with the idea of sequential city growth: the initially largest cities of a country are the ones that grow the fastest initially. At some point, they reach a critical size - perhaps because they become too congested- and then the relatively smallest cities are the ones that begin growing faster.

One could wrongly argue that this is simply showing reversion to the mean. The largest a city turns, the more difficult it is for it to grow. In other words, the same *absolute* increase in population, leads to a smaller growth rate in a large city than in a small one. But if this is the case, why is the trend of Figure 3 positive? Why is it that in the first decades the largest cities grow very rapidly *in spite* of being already large cities. Reversion to the mean would imply that it is *always* the small cities the ones that should grow faster.

Also note that this pattern is hard to reconcile with a pattern of random growth in which a few cities experience a positive shock on every decade. The reason is that, if growth is random, there is no reason whatsoever why the low rank (large) cities are the first to grow – i.e. the first ones to experience the positive shocks- and are eventually followed by the high rank (small) ones. It is rather hard to think of a theory that delivers this very particular sequence of shocks.

Finally, it is worth pointing out that this pattern is robust to the potential presence of leapfrogging among cities in our sample, i.e. small cities surpassing big ones. The reason is that-by definition- leapfrogging means decreases in rank (remember that a low rank here means a large size). Therefore, if the data displays leapfrogging, relatively high-rank cities (small ones) become low-rank cities (large ones). It is then clear that this possible bias goes against sequential city growth because, in the presence of leapfrogging, the rank of the fastest growing cities grows less than without leapfrogging.[10] The appendix shows this using a simple example.

4.3.2. Evolution of the Average Rank of the Fastest Growing Cities over Time

The previous section has shown that in France the rank of the fastest growing cities exhibits a clear positive trend in the 1851-1999 time interval. Here I study whether this positive trend is common across countries and I test for its statistical significance.

It is important to notice that if total and/or urban population grow over time – as it happens in most countries of my dataset- the method of selecting the "relevant" cities described in Section 4.1 has the obvious consequence of choosing an increasing number of cities as time goes by. This is relevant for my test since the finding that the rank of the fastest growing cities has a positive time trend may in part reflect the fact that in each subsequent decade there are more cities that can potentially grow fast. To account for this I include the number of cities on each decade and country as a control variable. I hence estimate the following panel data regression:

[10] Which is to say that the slope of Figure 3 is lower.

$$\log rf_{it} = \eta_i + \beta_1 \log t + \beta_2 \log N_{it} + \varepsilon_{it} \qquad (1)$$

where rf_{it} and N_{it} are the average rank of the 25% fastest growing cities (or MAs) and the number of cities (or MAs) in country *i* and period *t*, respectively. η_i is a country-fixed effect that includes a common constant term across countries. The variable *t* measures time in decades (potentially from 1 to 20), and ε_{it} is a standard error term. I choose the log-log specification so that one can interpret the estimates as elasticities. One consequence of this specification is that it assumes that as time passes, the effect of an additional ten years on the rank becomes smaller and smaller. However, in results not reported here, I show that the estimates are qualitatively similar if one uses a specification that uses the original variables instead of their logs.[11]

I estimate (1) using fixed effects to control for unobservable country time invariant factors that may affect the evolution of the rank over time. Examples of such unobservable variables are aspects of geography and culture that may have an impact on a country's city growth process.[12] Table 6 shows the estimates of this regression.[13]

Table 6: A Regression of the Average Rank of the 25% Fastest Growing Cities on Time and Number of Cities

	(1)	**(2)**
log time	0.668***	0.063**
	(0.07)	(0.03)
log number cities		0.923***
		(0.03)
constant	1.317***	-0.478***
	(0.11)	(0.06)
R^2	0.331	0.841
N	536	536

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

The first column of the table shows that the rank of the fastest growing cities clearly increases as time goes by. Importantly, although including the number of cities as a regressor

[11] I have also run the regression using the log of the rank as the dependent variable and *t* as a regressor or the rank as the dependent variable and *log(t)* as a covariate. Again, the results are qualitatively similar. All these experiments are available upon request.

[12] Davis and Henderson (2003) also use fixed effects in their study of the determinants of urban primacy.

[13] In all the regressions I cluster the errors by country to account for possible serial correlation within countries. The results are qualitatively similar if one estimates (1) using pooled OLS. To save space I only present the fixed effects estimates here.

(column 2) has an important effect- the size of the time coefficient drops by a factor of ten- the positive sign of the trend coefficient remains statistically significant.

The magnitude of the effect of time on the rank of the fastest growing cities is large. For instance, the increase in time between 1800 and 2000 corresponds to an increase from one decade to twenty decades, i.e. an increase of about 1900% in the variable *t*.[14] The estimated elasticity without controlling for the increase in the number of cities is 0.67. Hence the average rank of the fastest growing cities is predicted to increase by about 1273% in this time interval. This implies that, for example, if the average rank of the fastest growing city is 10 in 1800, this average rank will be 137.3 in the year 2000, a very large increase indeed.

If one uses the estimate that controls for the increase in the number of cities, the elasticity is significantly lower, 0.06. In this case the average rank of the fastest growing cities is predicted to increase by about 114%. Again, assuming that the average rank of the fastest growing city is 10 in 1800, this average rank will be 21.4 in the year 2000.[15]

Take the case of the U.S. According to my calculations, the average rank of the fastest growing cities in the initial year 1790 is 9.33, which corresponds to the city of Providence, NH. Using the 0.06 elasticity, the average predicted rank of the fastest growing city twenty decades later is 14.18, which corresponds to the city of Boston. If one uses the 0.67 elasticity, the predicted rank is 128, which, unfortunately, does not correspond to any city in our sample. The reason is that the 2000 cross-section for the U.S contains only 117 cities. Finally, according to the raw rank calculations – i.e. those that do not involve using the estimated elasticity but just the average rank of the 25th fastest growing cities- this rank is 41.43 in the year 2000. This corresponds to the city of El Paso, TX.

Table 7 repeats the previous estimation for metropolitan areas. Again the results strongly support the hypothesis that the rank of the fastest growing MAs exhibits a positive time trend. Notice that the size of the coefficient in the first specification (column 1) is lower than in the case of cities, probably reflecting the fact that using the Henderson dataset one has only forty years of data per country. The drastic reduction on the time span is also reflected in the much lower R^2 coefficients. As in Table 6 the inclusion of the number of MAs as a regressor has a large effect on the magnitude of the time trend although it remains statistically significant.

[14] Again, note that my regressions are run using the number associated to each decade: 1, 2,…,20. Therefore, while the increase in actual years is of about 11% (from 1800 to 2000), the increase in the number of decades is of 1900% (from 1 to 20).

[15] While significantly smaller than the above estimate, the increase in rank is substantial. The difference between these two predicted increases in rank suggests that it is important to account for the extensive margin – the creation of new cities- when one studies the phenomenon of sequential city growth (as in Henderson and Venables 2009).

Table 7: A Regression of the Average Rank of the 25% Fastest Growing MAs on Time and Number of Cities

	(1)	(2)
log time	0.231***	0.078*
	(0.04)	(0.04)
log number MAs		0.617***
		(0.07)
constant	1.22***	0.131
	(0.03)	(0.13)
R^2	0.093	0.311
N	448	448

*Note: Clustered standard errors in parentheses. *,*** denote significance at the 10% and 1% level, respectively.*

Another piece of evidence supporting the existence of a very clear positive trend on the rank of the fastest growing cities is that in 96% of the countries the average growth rate of this measure – i.e. the slope of its time trend- is strictly positive. Using data on MAs this percentage is 76%.

The results shown in this section clearly indicate that the rank of the cities that grow the fastest significantly increases over time, suggesting that one observes sequential city growth. As in the previous exercise this result strongly holds for both administratively defined cities and metropolitan areas.

4.3.3. Growth of Urban Population and the Rank of the Fastest Growing Cities

The last empirical exercise explores whether the rank of the fastest growing cities grows more rapidly in country-decade pairs in which urban population grows faster than usual. This is a prediction of the existing theories of sequential city growth and it is based on the idea that increases in the size of the urban population exert additional pressure on the existing urban agglomerations, which should then reach a critical size faster. After this size is reached the new population moves to higher rank (smaller) cities or to new ones.

Urban population is defined here as the sum of the population of the cities (or MAs) that are above the 0.6 (0.202) cutoff defined in Section 4.1. For instance, in the example of Section 4.3.1 urban population in France in 1861 is 2,797,200.

I begin by calculating the average growth rate of the rank of the fastest growing cities in periods of unusual rapid growth - defined as a growth rate of urbanization above the country's average- and compare it with the average in the rest of periods. Table 8 shows that this average is much larger in the 210 episodes of rapid urbanization than in the rest of periods, suggesting that sequential growth tends to be more relevant during these decades. In the robustness section I show that this difference is indeed statistically significant.

Once again, it is important to remember that this is not a claim that the rank of a particular city increases when the country urbanizes fast. The correct statement is that when a country experiences rapid urbanization, the cities that grow the fastest become more likely to belong to the "high-rank" (small cities) group than to the "low-rank" (big cities) one.

Table 8: Average Growth Rate of the Rank of the 25% Fastest Growing Cities in Periods of Fast and Slow Urban Growth

	Average Growth Rate of Rank	**N**
fast urban growth	1.05	210
slow urban growth	0.17	322

A more direct way to analyze the relationship between the growth rate of the rank of the fastest growing cities (or MAs) and the growth rate of urban population is to regress one on the other. However, as argued above, the relationship between these two variables may be driven by the fact that the number of observations increases over time in our sample. To take this into account I include the growth rate in the number of cities (or MAs) as an additional regressor. The specification I estimate is then

$$g_{R_{it}} = \delta_i + \beta_1 g_{U_{it}} + \beta_2 g_{N_{it}} + u_{it} \qquad (2)$$

where $g_{R_{it}}$ and $g_{N_{it}}$ denote the growth rate of the rank of the fastest growing cities (or MAs) and the growth rate in the number of cities (or MAs) in country *i* and period *t* respectively. $g_{U_{it}}$ is the growth rate of its urban population. δ_i is a country fixed effect that includes a constant term common across countries. Finally, u_{it} denotes a standard error term.

The results of estimating (2) with city data and including country fixed effects are shown in Table 9.[16] In both specifications the coefficient on urban growth is significantly positive, indicating that rapid growth in the urban population of a country is associated with a larger slope of the rank of its fastest growing cities. Controlling for the growth rate in the number of available cities in the sample has the expected effect of lowering the magnitude of the coefficient on urban growth, although its significance is preserved.

[16] The pooled OLS estimates are similar and available upon request.

Table 9: A Regression of the Growth Rate of the Average Rank of the 25% Fastest Growing Cities on the Growth Rate of Urban Population and the Growth Rate in the Number of Cities

	(1)	(2)
growth rate of urban pop	1.322***	0.598***
	(0.18)	(0.22)
growth rate of number of cities		0.81***
		(0.04)
constant	-0.002	-0.046
	(0.07)	(0.09)
R^2	0.225	0.626
N	479	479

*Note: Clustered standard errors in parentheses. *** denotes significance at the 1% level.*

The results of this test for MAs are displayed in Tables 10 and 11. The first one indicates that using this unit of analysis it is still the case that the average growth rate of the "rank 75 statistic" is larger in periods of fast urbanization than in periods of slow increases in urban population (0.47 versus 0.23). The regression results show that the positive relationship between the rank statistic and urban growth is significant at the 1% level even after controlling for the growth rate in the number of MAs. It is interesting to notice that, as happened in the second test (Section 4.3.2) the magnitude of the coefficient on fast urban growth is smaller than when one uses data on cities. This is the case also when one includes the growth rate in the number of cities (or MAs) as a regressor.[17]

Table 10: Average Growth Rate of the Rank of the 25% Fastest Growing MAs in Periods of Fast and Slow Urban Growth

	Average Growth Rate of Rank	N
fast urban growth	0.47	198
slow urban growth	0.23	245

[17] It is hard to disentangle if these differences (and those between Tables 6 and 7) are due to the use of different unit of analysis (MAs versus administratively defined cities) or to the fact that for MAs one can only find reliable data for the period 1960-2000 in most countries.

Table 11: A Regression of the Growth Rate of the Average Rank of the 25% Fastest Growing MAs on the Growth Rate of Urban Population and the Growth Rate in the Number of MAs

	(1)	(2)
growth rate of urban pop	0.16**	0.238***
	(0.08)	(0.06)
growth rate of number of MAs		0.728***
		(0.2)
constant	0.254***	0.072
	(0.04)	(0.05)
R^2	0.007	0.193
N	332	332

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

In order to facilitate the interpretation of this finding in the appendix I plot the growth rate of urban population in each decade, the country's average growth rate of urban population and the growth rate of the 75-rank statistic. The positive relationship between urban growth and rank growth it is apparent in most countries. Consider, for instance, the case of Algeria. The growth rate of the rank of the fastest growing cities exhibits considerable variation but its evolution is extremely close to that of the growth rate of urban population, especially after 1950. Bangladesh, Brazil, Hungary, and Sweden are some other cases in which the relationship between the two variables is extremely close. Note that, as it was mentioned above, the average growth rate of the rank is positive in almost all countries.

The corresponding figures for MAs are displayed in the appendix. The fact that one has only four decades per country makes the result less visible. However, it is apparent that in most cases the growth rate of urban population and that of the rank move very closely. Some clear examples of this relationship are Egypt, France, Honduras, Mozambique, Paraguay, and Portugal.

The estimates, statistics, and plots shown in this section constitute very strong evidence in favor of the importance of rapid urban growth on the process of sequential city growth.[18]

[18] This finding is also consistent with the hypothesis that Gibrat's law is an approximate good description of the growth process of cities in countries that are not subject to rapid urbanization but not so much for rapidly urbanizing countries.

5. Robustness Checks

In this section I provide several robustness checks that confirming the validity of the empirical results presented in Section 4.

5.1. Different Thresholds to Select Cities

It is apparent from Section 4.1 that the cutoff used to select the relevant sample of cities is inevitably arbitrary.[19] The following two tables are the equivalent to Tables 6 and 9 using a different cutoff to select the sample of cities. The specific cutoff used here is zero, i.e. all available cities are selected.

Table 12: A Regression of the Average Rank of the 25% Fastest Growing Cities on Time and Number of Cities. Zero Cutoff for City Selection.

	(1)	(2)
log time	0.763***	0.092***
	(0.07)	(0.03)
log number cities		0.86***
		(0.02)
constant	1.764***	-0.325***
	(0.11)	(0.08)
R^2	0.38	0.834
N	536	536

*Note: Clustered standard errors in parentheses. *** denotes significance at the 1% level*

[19] This arbitrariness is less conspicuous using the Henderson dataset on MAs. See Henderson and Wang (2007) for more details.

Table 13: A Regression of the Growth Rate of the Average Rank of the 25% Fastest Growing Cities on the Growth Rate of Urban Population and the Growth Rate in the Number of Cities. Zero Cutoff for City Selection.

	(1)	(2)
growth rate of urban pop	1.34**	1.279**
	(0.59)	(0.57)
growth rate of number of cities		0.581***
		(0.03)
constant	0.119	-0.188
	(0.23)	(0.22)
R^2	0.07	0.451
N	479	479

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

As it is clear from the estimates, the qualitative results of the exercise do not change. The rank of the fastest growing cities significantly increases over time and its growth rate is faster in periods of rapid growth in urban population. The magnitude of the coefficients does not differ much from the 0.6 cutoff used in the main text. Moreover, in results not shown here, I show that it is still the case that almost all of the country-decade cities growth rates exhibit significant right skewness. The same is true if one chooses a cutoff larger than 0.6.

5.2. Different Percentiles to Select Fast Growing Cities

Here I use different percentiles in my definition of what constitutes a "fast-growing" city. In the main text a city is a "fast-grower" in a given decade if its growth rate is above the 75th percentile of the growth rates of cities in that country and decade. Below I reproduce Tables 6 and 9 (for cities) and 7 and 11 (for MAs) using the 70th and 80th percentiles of the growth rates of cities respectively.

Tables 14-17 show the results that correspond to choosing the 70th percentile of the of cities growth rates, i.e. the 30% fastest growing cities. The magnitude of all the relevant coefficients increases with respect to the ones I obtained using the 75th percentile. In Tables 18-21 I do the same using the 80th percentile and, although the size of the coefficients is reduced, they remain significant, with the exception of the time trend in specification (2) of Table 18.

Table 14: A Regression of the Average Rank of the 30% Fastest Growing Cities on Time and Number of Cities

	(1)	(2)
log time	0.672***	0.072***
	(0.07)	(0.02)
log number cities		0.915***
		(0.03)
constant	1.315***	-0.464***
	(0.11)	(0.06)
R^2	0.349	0.871
N	536	536

*Note: Clustered standard errors in parentheses. *** denotes significance at the 1% level.*

Table 15: A Regression of the Growth Rate of the Average Rank of the 30% Fastest Growing Cities on the Growth Rate of Urban Population and the Growth Rate in the Number of Cities

	(1)	(2)
growth rate of urban pop	1.315***	0.679**
	(0.21)	(0.27)
growth rate of number of cities		0.712***
		(0.05)
constant	-0.037	-0.075
	(0.08)	(0.09)
R^2	0.263	0.628
N	479	479

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

Table 16: A Regression of the Average Rank of the 30% Fastest Growing MAs on Time and Number of MAs

	(1)	(2)
log time	0.225***	0.07*
	(0.04)	(0.03)
log number MAs		0.628***
		(0.07)
constant	1.242***	0.134
	(0.03)	(0.12)
R^2	0.102	0.364
N	448	448

*Note: Clustered standard errors in parentheses. *,*** denote significance at the 10% and 1% level, respectively.*

Table 17: A Regression of the Growth Rate of the Average Rank of the 30% Fastest Growing MAs on the Growth Rate of Urban Population and the Growth Rate in the Number of MAs

	(1)	(2)
growth rate of urban pop	0.165**	0.238***
	(0.08)	(0.06)
growth rate of number of MAs		0.687***
		(0.18)
constant	0.2***	0.033
	(0.03)	(0.04)
R^2	0.01	0.24
N	332	332

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

Table 18: A Regression of the Average Rank of the 20% Fastest Growing Cities on Time and Number of Cities

	(1)	(2)
log time	0.659***	0.044
	(0.07)	(0.03)
log number cities		0.939***
		(0.03)
constant	1.32***	-0.505***
	(0.11)	(0.07)
R^2	0.305	0.804
N	536	536

*Note: Clustered standard errors in parentheses. *** denotes significance at the 1% level.*

Table 19: A Regression of the Growth Rate of the Average Rank of the 20% Fastest Growing Cities on the Growth Rate of Urban Population and the Growth Rate in the Number of Cities

	(1)	(2)
growth rate of urban pop	1.443***	0.704**
	(0.26)	(0.33)
growth rate of number of cities		0.828***
		(0.07)
constant	0.02	-0.025
	(0.1)	(0.12)
R^2	0.201	0.515
N	479	479

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

Table 20: A Regression of the Average Rank of the 20% Fastest Growing MAs on Time and Number of MAs

	(1)	(2)
log time	0.226***	0.078*
	(0.05)	(0.04)
log number MAs		0.6***
		(0.08)
constant	1.197***	0.139
	(0.04)	(0.15)
R^2	0.074	0.245
N	448	448

*Note: Clustered standard errors in parentheses. *,*** denote significance at the 10% and 1% level, respectively.*

Table 21: A Regression of the Growth Rate of the Average Rank of the 20% Fastest Growing MAs on the Growth Rate of Urban Population and the Growth Rate in the Number of MAs

	(1)	(2)
growth rate of urban pop	0.274***	0.354***
	(0.1)	(0.08)
growth rate of number of MAs		0.752***
		(0.2)
constant	0.247***	0.06
	(0.04)	(0.06)
R^2	0.016	0.176
N	332	332

*Note: Clustered standard errors in parentheses. *** denotes significance at the 1% level.*

5.3. Using Dummies for Fast Growth of Urban Population

Finally, as it was mentioned in Section 4.3.3, one can test if the difference in the average growth rate of the rank of the fastest growing cities in periods of rapid and slow urban growth is statistically significant. One way to do this is to run the following regression:

$$g_{R_{it}} = \alpha + \beta_1 D_{FU_{it}} + \beta_2 g_{N_{it}} + u_{it} \qquad (3)$$

Where as before $g_{R_{it}}$ and $g_{N_{it}}$ denote the growth rate of the rank of the fastest growing cities (or MAs) and the growth rate in the number of cities (or MAs) in country *i* and period *t* respectively. $D_{FU_{it}}$ is a dummy variable that takes value one in periods of fast urban growth and u_{it} is a standard error term.

The results of estimating (3) using fixed effects in my sample of cities and MAs are displayed in Tables 22 and 23 respectively. Clearly, the coefficient on the dummy is positive and significant, confirming the previous findings and the high positive correlation detected in the graphs of Appendices C and D.

Table 22: A Regression of the Growth Rate of the Average Rank of the 25% Fastest Growing Cities on a Dummy for Periods of Fast Urban Growth and the Growth Rate in the Number of Cities

	(1)	**(2)**
dummy fast urban growth	1.008***	0.299**
	(0.15)	(0.12)
growth rate of number of cities		0.864***
		(0.05)
constant	0.118**	0.048
	(0.06)	(0.05)
R^2	0.126	0.596
N	479	479

*Note: Clustered standard errors in parentheses. **,*** denote significance at the 5% and 1% level, respectively.*

Table 23: A Regression of the Growth Rate of the Average Rank of the 25% Fastest Growing MAs on a Dummy for Periods of Fast Urban Growth and the Growth Rate in the Number of MAs

	(1)	(2)
dummy fast urban growth	0.253*	0.273**
	(0.14)	(0.12)
growth rate of number of MAs		0.716***
		(0.2)
constant	0.229***	0.077
	(0.05)	(0.06)
R^2	0.017	0.199
N	332	332

*Note: Clustered standard errors in parentheses. *,**,*** denote significance at the 10%, 5% and 1% level, respectively.*

Comparing these estimates with those in Tables 9 and 11 it is clear that the results are qualitatively very similar. Periods of fast growth in urban population are associated with rapid increases in the rank of the fastest growing cities.

6. Conclusions

In this paper I study the evolution of city sizes in different countries over very long periods of time using data on administratively defined cities and metropolitan areas. I document three novel empirical facts. The first one is that the cross section of cities growth rates is clearly skewed to the right in most countries and decades. This indicates that at each decade a few cities grow much faster than the rest. Second, the rank of these fast growing cities increases as time goes by- the initially largest city is the first one to grow, then the second one, then the third one, and so on. Finally, it is shown that this rank increases more in periods of rapid growth in urban population. These results are robust to the cutoff that determines the sample selection, the definition of what constitutes a "fast-growing" city and a period of "rapid growth in urban population" and to the regression technique employed.

These new empirical facts are consistent with the idea – recently explored in new theories of city growth – that, historically, cities have tended to grow in a sequential order: within a country, the initially largest cities are the ones that grow fast initially. At some point in time, for several reasons (different theories specify different mechanisms) these cities stop growing fast and the ones that grow the fastest are the second-largest ones, then the third ones, and so on.

Appendix

Countries used from the Lahmeyer-Brinkhoff dataset[20]

COUNTRY	YEARS OF DATA
AFGHANISTAN	1950-1988
ALBANIA	1923-1989
ALGERIA	1882-1987
ARGENTINA	1947-1999
AUSTRIA	1870-2001
BANGLADESH	1891-1991
BELGIUM	1894-1999
BOLIVIA	1881-2001
BRAZIL	1890-2000
BULGARIA	1888-1990
CANADA	1861-1996
CHINA	1890-1994
COLOMBIA	1902-1999
CZECH REPUBLIC	1880-1991
ECUADOR	1930-2001
EGYPT	1897-1996
FINLAND	1881-2000
FRANCE	1851-1999
GREECE	1920-2001
HONDURAS	1901-2000
HUNGARY	1858-1999
INDIA	1865-1991
INDONESIA	1920-1990
IRAN	1910-1996
IRELAND	1891-1991
ISRAEL	1931-2000
ITALY	1800-2001
JAPAN	1881-1999
KENIA	1931-1999
LUXEMBOURG	1901-2001
LYBIA	1929-1988
MALAYSIA	1921-1991
MEXICO	1850-1980
MOROCCO	1931-1982
NEPAL	1961-2001
NETHERLANDS	1795-1999
NIGERIA	1909-1991
NORWAY	1801-1980
PAKISTAN	1891-1981
POLAND	1851-2000
PORTUGAL	1864-2001
ROMANIA	1890-2000
RUSSIA	1897-1991
SOUTH AFRICA	1911-1991
SOUTH KOREA	1920-2000
SPAIN	1860-2000
SUDAN	1937-1993
SWEDEN	1910-1994
SWITZERLAND	1910-1990
TURKEY	1927-2000
UNITED KINGDOM	1851-1981
URUGUAY	1919-1996
USA	1790-2000
VENEZUELA	1921-1990

[20] Details on the sources of data for each country can be found in the web page of their authors: http://www.library.uu.nl/wesp/jalahome.htm (Lahmeyer), and http://www.citypopulation.de (Brinkhoff).

Countries used from the Henderson dataset[21]

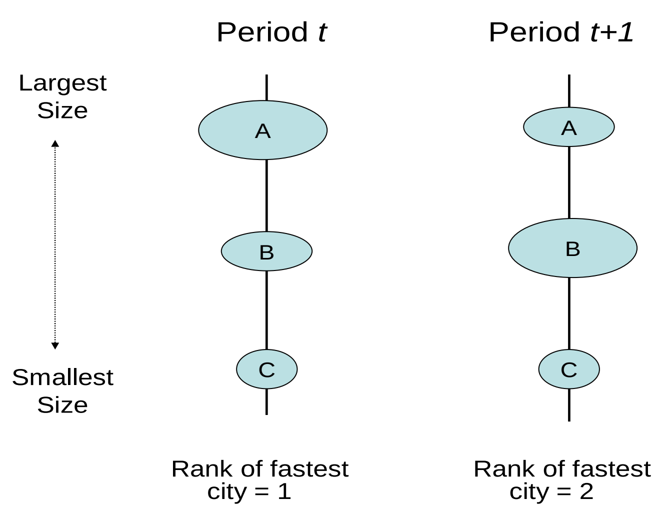
Afghanistan, Albania, Angola, Argentina, Australia, Austria, Azerbaijan, Bangladesh, Belarus, Belgium, Benin, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Cambodia, Cameroon, Canada, Chad, Chile, China, Colombia, Congo Dem. Rep., Cote d'Ivoire, Croatia, Cuba, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Germany, Ghana, Greece, Honduras, Hungary, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Kyrgyzstan, Laos, Latvia, Lebanon, Lithuania, Madagascar, Malawi, Malaysia, Mali, Mexico, Morocco, Mozambique, Myanmar, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Reunion, Romania, Russia, Saudi Arabia, Senegal, Sierra Leone, Slovak Republic, Slovenia, Somalia, South Africa, South Korea, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Tajikistan, Tanzania, Thailand, Tunisia, Turkey, Turkmenistan, Ukraine, United Arab Emirates, United Kingdom, United States, Uzbekistan, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

[21] Details on the sources of data for each country can be found in the web page of its author: http://www.econ.brown.edu/faculty/henderson/worldcities.html. In all cases the time interval covered is 1960-2000. I have dropped 33 countries that lack comprehensive data.

An Example of the Bias Induced by Leapfrogging

Consider a country with three cities. Figure 1A shows the ranking of these cities in terms of their size at years *t* and *t+1*. Cities at the top of the vertical line are larger in size than those at the bottom. For instance, at period *t*, the largest city (rank 1) is city A, followed by city B (rank 2) and city C (rank 3). While reading this figure, the size of the circular areas indicates the magnitude of that city's growth rate. A bigger circle indicates faster growth (so, for example, at period *t* city A grows faster than city B, which in turn grows faster than city C). Finally, for simplicity, suppose that these growth rates are such that the only city that grows above the 75th percentile of cities growth rates is city A at period *t* and city B at period *t+1*. This implies that the rank of the fastest growing cities at period *t* is 1, and that of period *t+1* is 2.[22] In this example, the rank of the fastest growing city increases from 1 to 2, so there is sequential city growth. Note that city B has been the fastest growing city between periods *t* and *t+1*, but it has not grown enough to catch up with the still largest city A.

Figure 1A: Sequential City Growth without Leapfrogging

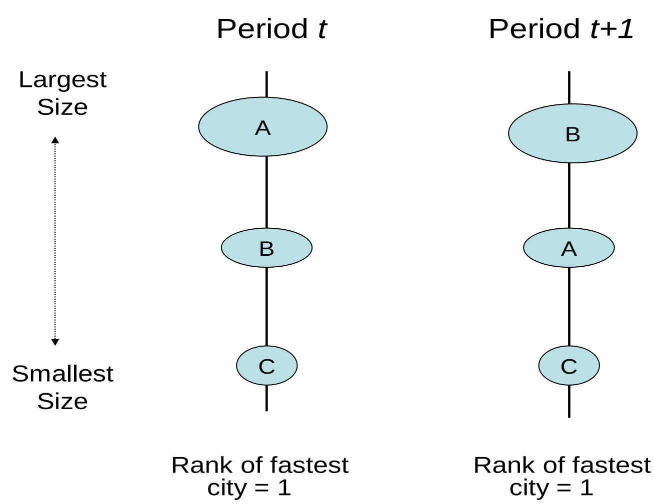


Now consider Figure 2A. The only difference with respect to Figure 1A is that, in this case, the initially second largest city, city B, grows so much from period *t* to period *t+1* that leapfrogging takes place. This means that, at period *t+1* the largest city is now B instead of A. With the same assumptions used above, this of course means that the rank of the fastest growing

[22] This is an innocuous assumption. The argument goes through if one chooses a distribution of growth rates such that cities A and B are above the 75th percentile. In this case, to have sequential city growth, one needs to assume that city C is also a fast-growing city in period *t+1* (because then the average rank of the fastest growing cities at period *t+1* is $\frac{1+2+3}{3}=2$, larger than 1.5 at period *t*). The goal here is to construct an example with sequential city growth and show how leapfrogging may, at most, bias the result against sequential city growth.

city is 1 in both periods *t* and *t+1*. Therefore, the presence of leapfrogging invalidates sequential city growth in this case. More generally, if the data actually displays leapfrogging, the empirical estimates of Section 4.3 would be biased downwards, i.e. leapfrogging goes against the idea of sequential city growth.

Figure 2A: No Sequential City Growth with Leapfrogging



Plots of the rank of the fastest growing cities or metropolitan areas and of the evolution of urban population in each of the countries can be downloaded from:

FOR CITIES:

http://merlin.fae.ua.es/cuberes/APPENDIX_C.pdf

FOR METROPOLITAN AREAS:

http://merlin.fae.ua.es/cuberes/APPENDIX_D.pdf

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