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Cities and Innovation

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SEQUENTIAL CITY GROWTH IN THE US: DOES AGE MATTER?*

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ABSTRACT: We provide empirical evidence of the dynamics of city size distribution for the whole of the twentieth century in U.S. cities and metropolitan areas. We focus our analysis on the new cities that were created during the period of analysis. The main contribution of this paper, therefore, is the parametric and nonparametric analysis of the population growth experienced by these new-born cities. Our results enable us to confirm that, when cities appear, they grow very rapidly and, as the decades pass, their growth slows or even falls into decline. This is consistent with the theoretical framework regarding mean reversion (convergence) in the steady state and with the theories of sequential city growth.

JEL Codes: O18, R11, R12

Keywords: Cities, sequential city growth, city size distribution.

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1. Introduction

The evolution of city size distribution has attracted the attention of researchers for many years. It is an important issue, especially when talking about a country such as the United States (US) with its relatively recent urban development. Over the last decades of the nineteenth century and throughout the whole of the twentieth century, the US witnessed a major transition from a rural to an urban society. Indeed, as Kim and Margo (2004) relate, in the first fifty years of the twentieth century, both the number and the size of cities increased rapidly. Moreover, these cities were geographically concentrated at the site of the early processes of industrialization in the country. However, in the second half of the twentieth century, there was shift in this pattern. From 1960 to 1990, the largest cities saw their population numbers decline, as people moved away from the city centres and out into the suburbs, in a process that saw a rise in importance of the metropolitan areas, especially in the south.

A large body of literature seeks to explain the city size distribution that accounts for this growth pattern. There are two main empirical regularities: Zipf's law and Gibrat's law. The former holds that city sizes follow a power law whereby the largest city is twice as big as the second largest, three times as big as the third largest city, and so on (see Gabaix and Ioannides, 2004, for a fuller discussion). Alternatively, Gibrat's law postulates that the growth rate of the population is independent of its initial size. Gabaix (1999), from a theoretical perspective, points out that, whatever the specific determinants of city growth, as soon as they satisfy Gibrat's law, their distribution will converge to Zipf's law in the steady state under certain conditions (Skouras, 2010).

Several papers have identified which of these two empirical regularities holds for the US context. Krugman (1996), for example, in a cross-sectional analysis, shows that Zipf's law works for one specific year. Others, such as Ioannides and Overman (2003), focus their attention on the dynamics and conclude that Gibrat's law holds, while others, including Black and Henderson (2003), reject this hypothesis. Interestingly, Eeckhout (2004) demonstrates that while Gibrat's law explains city size distribution for the entire sample of US cities, Zipf's law holds for the upper tail of the distribution. Ioannides and Skouras (2012) estimate the switching point between the body and the upper tail of the distribution. Meanwhile, Reed (2002), drawing on regional data from Spain as well as the US, finds a generalized distribution in the steady state that can reconcile Zipf's and Gibrat's law for all cities. Finally, González-Val (2010), using the same database as ours, also finds that Gibrat's law holds for mean growth rates when considering the whole sample of cities, but that only Zipf's law holds when restricting the sample to the largest cities.

While most studies have examined the city size distribution of the US, a few papers do examine data from other countries. Bosker *et al.* (2008), drawing on data for cities in West Germany with more than 50,000 inhabitants, show that Gibrat's law can be rejected and that, therefore, growth is not random. In contrast, Giesen and Südekum (2011), also using data for West Germany, albeit for a shorter period of time and for bigger cities (71 cities with more than 100,000 inhabitants), show that Gibrat's law does hold for all the German regions independently of how the latter might be defined.

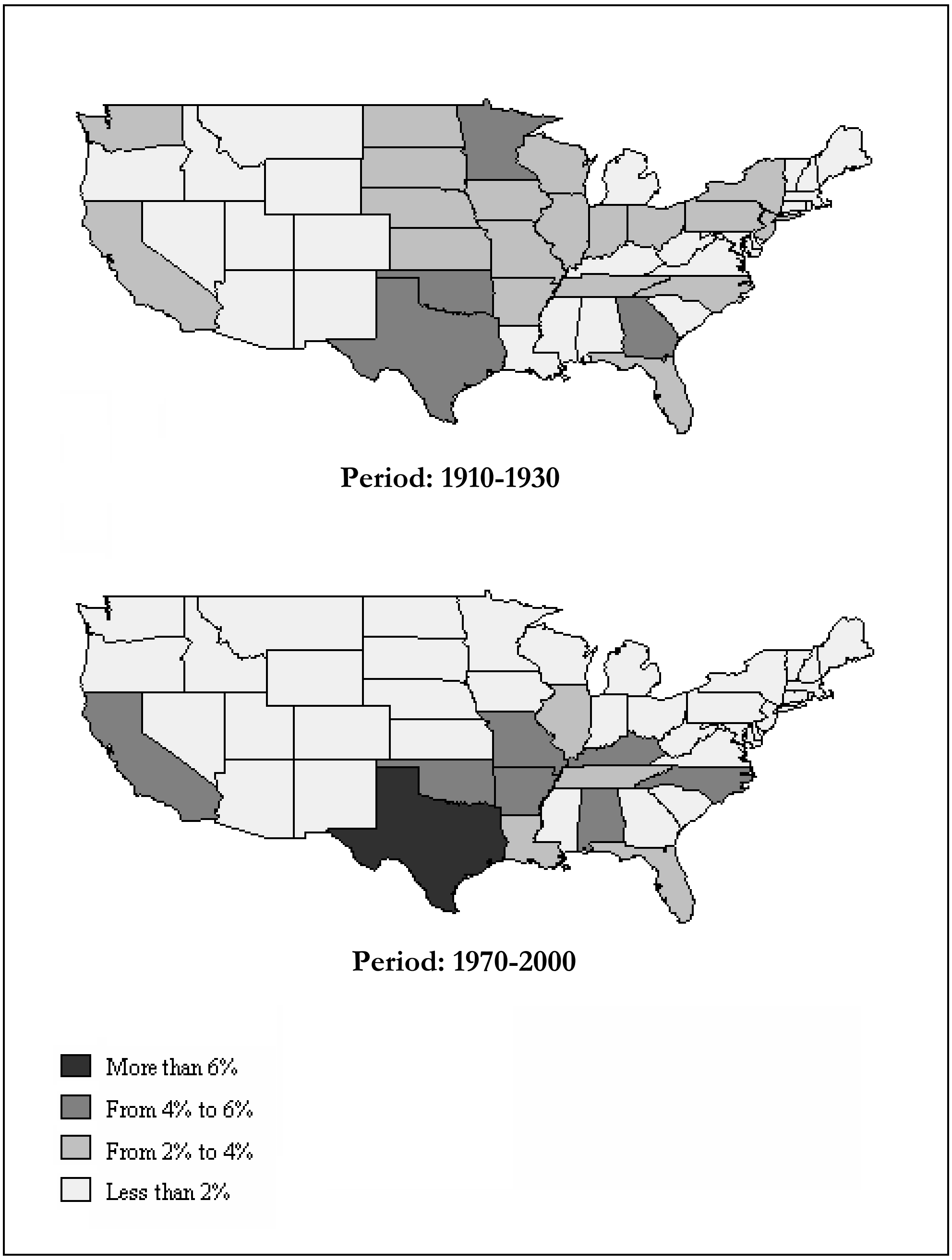
Here, however, we are not concerned with studying the dichotomy between Zipf's and Gibrat's laws. Our focus is more specifically on the dynamics and, as such, we seek to evaluate whether Gibrat's law holds for our dataset by adopting a parametric approach. Moreover, although we do not specifically study the steady state, we can draw some conclusions about the existence of mean reversion (convergence) by conducting a nonparametric analysis.

In the majority of the studies discussed above, the number of cities or metropolitan areas is considered constant; yet, others do allow new cities to be included in the sample. Gabaix and Ioannides (2004), for example, wonder what would happen to city size distribution when new cities emerge. Dobkins and Ioannides (2000) address this issue and allow new geographical units to enter the sample, but only when they reach a 50,000-inhabitant threshold (given that they use data for metropolitan areas).

The inclusion of new cities is of special relevance in the case of the US because of the great development the country underwent during the 20th century. At the beginning of this period there were 10,496 cities (identified as 'incorporated places' – see discussion in Section 2 below), while by the year 2000 there were 19,211 - i.e. the number of cities almost doubled between 1900 and 2000 with a total of 10,124 new cities being created. In fact, the appearance of new cities declined over this period (although a slight increase was registered around 1960 coinciding with the creation of the Sun Belt), which means that with the passing decades, fewer cities appeared and there was a transition to a stable situation. Apart from the increase in the number of cities, their population and size also grew. Figure 1 shows the share of new cities by state in the periods 1910-1930 and 1970-2000 as a percentage of the total number of new cities in the US in those particular periods. Thus, the map highlights the evolution in the creation of new cities in the first and last thirds of that century. We can observe that in the first three decades of the 20th century the appearance of new cities was a generalized phenomenon. In fact, 62.26% of the cities created in the whole century "were born" during those decades, while the average rate of new creations for the rest of the period stands at around 5% per decade. In the second half of the century, people started to move south in order to enjoy the warm, temperate climate (Glaeser and Shapiro, 2003), creating what came to be known as the Sun Belt. During the last decades of the

20th century, when the trend had stabilized, most of the new-born cities were concentrated among the southern states.

Figure 1. Share of new cities by state over the total US new cities



Source: Based on US census data

There are many examples of cities appearing during the 20th century. The case of Long Beach in the State of New York is of particular interest in this regard. The city was incorporated in 1913 as a village and in 1922 as a city (entering our dataset in 1920)[1] .Today, it is the 15th biggest city in the State (the 18th in 2000). Its population when first created was 282 inhabitants,

[1] As our data are divided by decades (not years), in 1920 we would have cities incorporated from 1911 to 1920. The same holds for the other nine decades of the century.

since when it has grown to 35,462 inhabitants (2000). During the first three decades of its existence, Long Beach's annual growth rate was between 4.5 and 5.5%. As the decades passed, its growth did slow, registering an annual rate of 0.5% in 1990.

The second half of the twentieth century is characterized by processes of suburbanization and the proliferation of cities in the south of the country. Good examples of this phenomenon are provided by Carson City and San Marcos, two cities in California. The former is, in fact, a suburb of Los Angeles and the latter of San Diego. Both cities were created during the 1960s as a consequence of the aforementioned process of the creation of the Sun Belt. Carson City was born in 1968, grew at an annual rate of 1.3% during its first decade of existence and then at a slower rate up to 2000. The case of San Marcos differs slightly. The decline in its growth rate with the passing decades is the same as in the previous case, but its annual growth rates have been much higher: ranging from 15% on average for the first decade of its existence to 3% over the last decade, growing from a settlement of just 3,896 inhabitants in 1970 to 54,977 in 2000. Yet, the development of the south was not limited solely to California. Port St Lucie, today one of the ten most important cities in Florida (ranked 15th at the end of the twentieth century), was incorporated in 1961 with a population of 330 inhabitants. Its annual growth rate was 18% on average until 2000, when its population had reached 88,769. During this next decade, its growth began to fall and stabilize.

The evidence derived from the previous examples might well lead us to conclude that certain connections exist between the age (and size) of a city and its rate of growth. This is what the literature refers to as sequential city growth. Cuberes (2009; 2011), for example, drawing on data for cities from 54 countries and on data for metropolitan areas from 115 countries, tests a model in which cities grow sequentially, i.e., within a country, a few cities initially grow much faster than the rest, but at some point their growth slows and other cities start to grow, and so on. Its models present two cities with different initial stocks of physical capital and population moving together with this capital. Therefore, at the beginning the investment goes to the city with the larger stock but at some point, the rise in congestion costs makes both cities equally productive and investment is split between them. At the steady state both cities are identical. His results stress that, throughout history, urban agglomerations have followed a sequential growth pattern. Henderson and Venables (2009) also present a model in which cities grow sequentially, allowing for the entrance of new cities in the sample but taking into account the immobility of housing and urban structures. These constraints and the fact that the agents are forward looking drive the sequential pattern of city formation in their model. They show that the efficient formation of cities requires local government intervention to finance development. Both sets of studies work on sequential city growth by focusing on the size of a city.

Our research falls within the same framework. Here, we undertake a similar analysis, taking as our key variable the age of the city, given the apparent linkage between age and city size. In fact, Giesen and Südekum (2012) point out that there exists a correlation between the age and the size of a city in a static study for 2000. We are specifically interested in determining the way in which new cities enter the sample based on their rate of population growth. We empirically test this issue with parametric and nonparametric methods. Thus, in the parametric analysis we explore the hypothesis that new-born cities are the fastest growing cities and as the decades pass their growth slows. In this way, we seek to capture the effect of a city's age on its growth rate. However, we are not only interested in the dynamics of the process, but we are also concerned with undertaking a long-term interpretation. According to Eeckhout (2004) and Ioannides and Overman (2003), Gibrat's law holds and so convergence cannot exist in the steady state. However, others, such as Black and Henderson (2003), using data for the US metropolitan areas, and Henderson and Wang (2007), who use a global metropolitan area dataset, postulate that mean reversion occurs when reaching the steady state and, so, they reject Gibrat's law. Thus, in our parametric analysis we evaluate the acceptance or rejection of Gibrat's law for all cities and in the nonparametric test we assess the existence of mean reversion by studying the behaviour of new-born cities. Our results are consistent with those of Henderson and Wang (2007).

Here, we draw on data for US cities and metropolitan areas in order to analyze their pattern of growth and evolution after they enter the sample. To the best of our knowledge, this is the first paper to analyze the growth patterns of new-born cities (and metropolitan areas) within a country. Our results show that when cities first appear they grow rapidly, but then their growth rate slows and stagnates. As our definition of a city is that of an 'incorporated place', we replicate the analysis for metropolitan areas as they represent more accurate economic areas than cities. However, our results do not confirm our earlier findings for cities. This could reflect the fact that a metropolitan area is an aggregation of different cities; even if the area is new, the cities within it might not be. Moreover, it is not possible to know how old the area is since it does not enter the sample until it reaches the minimum population threshold of 50,000 inhabitants. As such, larger - and, therefore, more mature - cities within the area, have lower growth rates than smaller cities within the same area and the aggregate effects may disappear.

The rest of the paper is structured as follows. Section 2 presents the data. Section 3 explains the empirical methodology. In section 4 we discuss the main results. Section 5 provides the nonparametric analysis and section 6 concludes.

2. Data

We use data for US cities and Metropolitan Statistical Areas (MSAs) for the whole of the 20th century. The database is the same as that employed by González-Val (2010) with the addition of extra periods for the MSA dataset. The information for both geographical units was obtained from the annual census published by the US Census Bureau. From the outset, it should be borne in mind that a city can be defined in many ways. Here, for our analysis, we use that of the 'incorporated place'. According to the census, an incorporated place is *a type of governmental unit incorporated under state law as a city, a town (except in New England, New York and Wisconsin), a borough (except in Alaska and New York city), or a village and having legally prescribed limits, powers and functions*. The Census Bureau recognizes incorporated places in all states except Hawaii, for which reason it is excluded from our sample. In addition, the states of Puerto Rico and Alaska are excluded as they (together with Hawaii) were not annexed until the second half of the 20th century. As Eeckhout (2004) stresses, the whole sample of cities in each state without restriction of size needs to be considered since otherwise a truncated distribution can produce biased results.

Data for MSAs are also used so as to take into account that part of the population that lives outside incorporated places and so as to be able to compare the results provided by both geographical units. In line with Ioannides and Overman (2003), for the period from 1900 to 1950, we use data from Bogue's Standard Metropolitan Areas (1953). These are based on the definition of Standard Metropolitan Areas (SMAs)[2] for 1950, used to reconstruct the population for the period 1900 to 1940. This means, however, that in 1900 some of the SMAs were below the 50,000-inhabitant threshold, and these are excluded until they reach that cutoff. For the period 1950 to 2000 our MSA data are taken from the Census Bureau.

As Glaeser and Shapiro (2003) point out, MSAs are multi-county units that capture labor markets and, as such, might serve as more effective economic units than incorporated places. Yet, the use of MSAs gives rise to a problem that is directly related to their definition: as an MSA usually comprises a group of counties that requires a central city with a minimum of 50,000 inhabitants (a criterion that has changed over the period of analysis), only larger cities are considered. But as we seek to include all the data without any restriction of size in our sample, we need to take more than just these largest cities into account.

Using MSAs gives rise to another more specific problem for the analysis we conduct here. As Dobkins and Ioannides (2001) show, the US system is characterized by the entry of new cities that can have an impact on its city size distribution. As we are particularly interested in these

[2] The definition of a metropolitan area was first issued in 1949 under the name of Standard Metropolitan Area (SMA). It changed to Standard Metropolitan Statistical Area (SMSA) in 1959 and in 1983 was replaced by Metropolitan Statistical Area (MSA).

cities, the data on incorporated places provide more information than those on the MSAs. However, MSAs are larger geographical areas and include a large proportion of the population living in rural areas. Yet, despite the fact that the sample of incorporated places accounts for a lower percentage of the total population, it is considerably more urban (94.18% in 2000) than that of the MSAs (88.35%).

Table 1 shows the descriptive statistics for the population of incorporated places in each decade of the twentieth century, while Table 2 presents the same statistics for the MSAs, the minimum threshold being 50,000 inhabitants. An initial inspection shows that the number of cities and MSAs increases over time as does their size. In fact, new-born cities represent 42.52% of the total sample of incorporated places while the number of new MSAs amounts to 180, which represents 49.85% of the sample. What these tables illustrate, therefore, is the urbanization process that the US experienced over the last century. The number of cities in 2000 is almost twice that in 1900; the number of MSAs has increased more than threefold. This is clearly indicative of the importance of taking into consideration the appearance of new units (cities or MSAs) when studying the US population growth process.

Table 1. Descriptive statistics of incorporated places

Year	Cities	Mean Size	Standard Deviation	Minimum	Maximum
1900	10,496	3,468.27	42,617.51	7	3,437,202
1910	13,577	3,610.36	50,348.78	7	4,766,883
1920	15,073	4,087.61	57,540.69	3	5,620,048
1930	16,183	4,771.31	68,462.35	1	6,930,446
1940	16,400	4,977.44	72,001.37	1	7,454,995
1950	16,923	5,662.07	76,487.59	2	7,891,957
1960	17,825	6,455.86	75,195.01	1	7,781,984
1970	18,302	7,149.50	75,690.26	4	7,895,563
1980	18,752	7,431.72	69,475.36	2	7,071,639
1990	18,953	7,998.27	72,178.75	2	7,322,564
2000	19,211	8,939.77	78,175.03	1	8,008,278

Note: Alaska, Hawaii and Puerto Rico are excluded

Table 2. Descriptive statistics of MSAs

Year	MSAs	Mean Size	Standard Deviation	Minimum	Maximum
1900	104	280,916	586,361	52,577	5,048,750
1910	130	307,262	719,325	50,731	7,049,047
1920	139	362,905	847,072	51,284	8,490,694
1930	145	445,147	1,063,769	50,872	10,900,000
1940	148	473,984	1,125,419	51,782	11,700,000
1950	150	570,481	1,272,541	56,141	12,900,000
1960	265	478,076	1,093,796	51,616	13,000,000
1970	270	560,024	1,314,282	53,766	16,100,000
1980	281	616,211	1,450,101	57,118	18,900,000
1990	351	586,738	1,451,268	51,359	19,500,000
2000	353	656,758	1,504,512	52,457	18,300,000

Note: Alaska, Hawaii and Puerto Rico are excluded

3. Empirical analysis

In the context of studies of city size distribution and, in particular, in relation to the sequential city growth literature, here using a panel dataset we seek to test which US cities that grew the most during each decade of the 20th century. In line with this literature, we expect the new-born cities to grow rapidly during the first decades of their life before stabilizing (and even declining) in the decades that follow. In order to test this hypothesis, we estimate the following model:

$$g_{i,t} = \sum_{k \geq 1} \beta_k d_{k,i,t} + \delta_t + \gamma_s + \eta_r + \mu_s + \varepsilon_{i,t} \tag{1}$$

where the dependent variable g_{it} is the growth rate for each city (or MSA) i at time t calculated as $g_{it} = \ln p_{it} - \ln p_{it-1}$, where p is the population. The coefficient β_k represents the estimated parameter for a dummy variable (d_k), capturing the age of the cities. In other words, it represents the number of periods that a city is present in our sample. In the first period[3], d_1 (d_k when $k=1$) is equal to one if the city is "new" and zero if not. A city is considered new when it records a positive population in one decade while having no population in the previous one(s). When the value is zero it could either be because the city did not yet exist or because the city had existed since the first decade of the sample and as such cannot be considered a "new" place. Moreover, δ_t is a time fixed effect, γ_s is a state fixed effect, η_r is a region fixed effect and μ_s is a dummy capturing other location fixed effects. $\varepsilon_{i,t}$ is the error term.

[3] Corresponding to the first decade of the 20th century (1900-1910).

Table 3 shows the evolution of the nine dummies over the course of the 20th century. For each decade, d_1 is the number of new cities created in that particular decade so that in 1910 a total of 3,291 new cities entered the sample, in 1920 a total of 1,747 new cities were born, and so on. For each decade, d_2 is the number of new-born cities that appeared in the previous decade, column d_3 shows the cities that entered two decades before, and so on. The total number of cities by age (independently of the year of their creation) is displayed at the end of each column. This total number is the sample size used in the nonparametric analysis conducted in Section 5. Moreover, we can trace their evolution from the year they first appeared until the end of the period by observing the diagonals in the table. Thus, it becomes apparent that some cities disappeared during the century. This is attributable to a variety of causes including hurricanes, the death of the town's benefactor or the fact that some cities expanded their borders and absorbed others, especially during the first half of the century[4] .

Table 3. Evolution of cities over the 20th century

year	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9
1910	3,291	0	0	0	0	0	0	0	0
1920	1,747	3,229	0	0	0	0	0	0	0
1930	1,267	1,711	3,171	0	0	0	0	0	0
1940	505	1,245	1,684	3,132	0	0	0	0	0
1950	646	489	1,210	1,657	3,088	0	0	0	0
1960	1,046	627	470	1,164	1,614	3,025	0	0	0
1970	756	1,025	619	459	1,155	1,597	3,010	0	0
1980	553	750	1,008	612	457	1,143	1,588	2,987	0
1990	313	553	750	1,008	612	457	1,143	1,588	2,987
Total	10,124	9,629	8,912	8,032	6,926	6,222	5,741	4,575	2,987

Source: Self elaboration with US Census Bureau data

Based on the hypothesis we seek to test here, we expect β_k to be positive and significant during the first decades following the birth of the city but, as the decades pass, we expect this coefficient to decrease, losing its statistical significance and even acquiring a negative value. However, in order to avoid any bias in these estimations, we need to add a number of controls that capture the time or space effects that might influence these results. Thus, we incorporate time and state fixed effects in our estimation.

Additionally, Black and Henderson (2003) found that US cities with coastal locations grow faster and they incorporate regional variables in their analysis so as to capture this market potential. Other studies, including Rappaport and Sachs (2001), Mitchener and McLean (2003) and Bleakley and Lin (2012), also point out that having access to navigable waters plays an

[4] See Blanchard (1960) for a fuller discussion of ghost towns in parts of the US.

important role in accounting for population distribution and growth. Thus, to control for these characteristics, we also include a dummy variable that captures access to navigable waters (including access to rivers, lakes and oceans) at the state level, and four dummy variables, one for each of the major US regions: the Northeast, the Midwest, the South and the West.

We include one final control variable to capture changes in industrial composition in the US over the course of the 20^{th} century. As Kim and Margo (2004) explain, during the first half of the twentieth century, the rise of the industrial economy and the manufacturing (or 'rust') belt saw people move west. Since 1950, thanks to the diffusion of air conditioning and milder winters, the population has grown in the southern part of the country, leading to the creation of the Sun Belt. Thus, we include two dummies at the state level, one for each of the rust and sun belts respectively, in order to control for these regional and industrial impacts on the population growth rate.

For some of the model specifications that we estimate, we include a variable capturing initial city size ($\ln p_{it-1}$). In line with the literature, by including this variable we are able to test the mean reversion hypothesis. When the coefficient of this variable is negative, we can assume mean reversion (convergence) in the steady state. A non-significant coefficient can be interpreted as being indicative of independence between growth and initial size, supporting Gibrat's law and, therefore, rejecting the mean reversion hypothesis. Black and Henderson (2003) and Henderson and Wang (2007) found that the smallest cities grow fastest, supporting the mean reversion hypothesis; as such, there is some kind of size effect on growth. However, as the main focus of our analysis are new-born cities and the dynamics before the steady state, it might be the case that this size effect can make the time effects less effective. This reflects the fact that new cities tend to be smaller than the rest, so it can be hard to distinguish just which of these two effects (size or time) are driving the results. In Section 5 we adopt a nonparametric approach to examine the relationship between the temporal dimension of growth (the age of the city) and its initial size. Moreover, the city size may, in some cases, be a source of possible endogeneity. However, in our analysis the results do not vary greater when the city size variable is included or not.

We replicate the analysis for the MSAs in order to test whether the growth pattern of cities still applies when aggregating the geographical units. Table 4 shows the evolution of the nine age-dummies for the MSAs during the 20^{th} century. Two main differences can be seen between Tables 3 and 4: first, no MSAs disappear from the sample (once an MSA reaches the minimum population threshold it never falls below it) and, second, the falling trend in the appearance of new MSAs is not as clear as that for incorporated places. The latter is attributable to the change in the criterion used to define an MSA in 1960 (47.2% of the MSAs were created that decade).

Table 4. Evolution of MSAs over the 20th century									
year	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9
1910	23	0	0	0	0	0	0	0	0
1920	7	23	0	0	0	0	0	0	0
1930	6	7	23	0	0	0	0	0	0
1940	3	6	7	23	0	0	0	0	0
1950	2	3	6	7	23	0	0	0	0
1960	85	2	3	6	7	23	0	0	0
1970	6	85	2	3	6	7	23	0	0
1980	48	6	85	2	3	6	7	23	0
1990	0	48	6	85	2	3	6	7	23
Total	180	180	132	126	41	39	36	30	23

Source: Self elaboration with US Census Bureau data

4. Results

In this section we present the results of the estimation of Eq. (1). Table 5 shows the results for incorporated places while Table 6 presents those for the MSAs. All regressions include the nine key dummy variables, the inclusion of the control variables being switched from one regression to another. For both geographical units (cities and MSAs), the regressions corresponding to each column represent the same specification with only the unit of analysis being changed from city to MSA.

The coefficients can be interpreted as the impact, measured in logarithmic points, on the growth rate of a specific city *i* (or MSA) depending on the age of that city (or MSA). As explained above, d_1 represents the city when it is newly born, d_2 when it has existed for one decade, d_3 two decades and so on, meaning that d_9 represents more mature cities than d_1. It is because of this that we are interested in the trend presented by the coefficients from d_1 to d_9, as this represents the dynamic effects.

Table 5 presents the results for cities. The first two columns (1) and (2) are the results of estimating Eq. (1) by OLS without the control variables. They differ in the fact that column (2) includes the city size variable that seeks to capture the existence of mean reversion and, as a consequence, the rejection of Gibrat's law. At first glance, we see that the coefficients of the nine dummies follow the expected pattern: they are significantly positive for d_1 and become smaller until they record negative values. The coefficients vary little from one regression to the other. Moreover, the city size variable is significantly positive. In line with the preceding discussion, it should be significantly negative in order to accept the mean reversion hypothesis. We argue that the OLS procedure is a between estimator, and, as a consequence, the city size variable is significantly positive because we conduct the comparison across cities while controlling for age (but only for newborn cities which are typically the smallest), and so nothing can be said about mean reversion. For this reason we estimate the same equation in column (4) using a fixed-effects methodology in order to obtain a within estimator that enables us to interpret the coefficient in "mean reversion terms".

However, note that the results from (1) and (2) might lack precision as there may well be a considerable amount of missing and uncontrolled information in these specifications. In order to solve any problem of bias, we estimate equations (3), (4), (5) and (6) using different control variables. In column (3) we estimate the same equation but take into account the possibility that time effects might be driving part of the results. However, the coefficients are similar to those estimated in the previous regressions as is the overall trend. As before, the coefficient associated with d_1 is significantly positive and it decreases with the increase in city age, becoming negative when the city is mature.

Column (4) presents the results of the city fixed effect estimation. Here, the coefficients show how new-born city *i* grows in decade *t>1* in comparison with how new-born city *i* grew in decade *t*. We also include the city size variable in this estimation in order to analyse the mean reversion hypothesis properly. An analysis of the coefficients reveals that the trend followed is the same as that in the previous estimations (the coefficient associated with d_1 being higher than that associated with d_2 and so on), indicating that the growth of a new-born city is greater than that of a mature city. However, the overall size of the coefficients is smaller than before. In fact, the first two dummies are not significant because they are the base category[5] but from d_3 to d_9 they become significantly negative. In this case, as the estimation is more accurate than that undertaken in column (2), the coefficient associated with the city size variable is significantly negative, showing that an inverse relationship exists between city size and growth rates. This indicates that smaller cities grow more. This result supports the presence of mean reversion (convergence) across cities and rejects Gibrat's law for new-born cities. However, as these new cities are mostly small, the size effect captured by the city size variable could make the time effects associated with the cities' age more ineffective. In column (5) we estimate the same model, but instead of controlling for a time effect, we include a state fixed effect to control for a spatial dimension. The results, again, present the same pattern with significantly positive coefficients associated with d_1 and a decreasing trend until d_9.[6]

Finally, column (6) shows the results when estimating Eq. (1) including all the control variables: time, state and regional fixed effects and the other location dummy variables of access

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5 We estimated the same regression without the incumbent cities and the results were seen to be robust.

6 It is not, in fact, a perfectly decreasing trend because with the passing decades growth tends to stabilize and only declines at the end of the period.

to navigable waters and belonging to the Sun or Rust belts, both at the state level. As in all the previous cases, the coefficients follow the same decreasing trend allowing us to demonstrate that when a city is born, its growth is high and as the decades pass, the growth becomes more moderate and even declines. The impact of the age of a city in the first decade of its creation on its growth rate is about 0.128 logarithmic points. One decade later the coefficient falls by more than half (from 0.128 to 0.045), although the impact on growth remains positive. Thus, the most significant growth occurs during the first decade of a city's existence. However, if we focus on the coefficient associated with the last decade (-0.019 logarithmic points), we see that the older the city becomes the lower is its growth. These results are consistent with the theories of sequential city growth.

Table 5. Estimation of the dynamic effects of cities

Decades of existence	(1)	(2)	(3)	(4)	(5)	(6)
d_1	0.142***	0.169***	0.154***	-0.079	0.118***	0.128***
	(0.005)	(0.005)	(0.005)	(0.079)	(0.005)	(0.005)
d_2	0.048***	0.07***	0.070***	-0.129	0.025***	0.045***
	(0.004)	(0.004)	(0.004)	(0.079)	(0.004)	(0.004)
d_3	0.017***	0.036***	0.036***	-0.144*	-0.004	0.013***
	(0.003)	(0.003)	(0.003)	(0.079)	(0.003)	(0.003)
d_4	0.003	0.019***	0.004	-0.159**	-0.016***	-0.015***
	(0.003)	(0.003)	(0.003)	(0.079)	(0.003)	(0.003)
d_5	-0.016***	-0.0007	-0.023***	-0.173**	-0.032***	-0.038***
	(0.003)	(0.003)	(0.004)	(0.079)	(0.003)	(0.003)
d_6	-0.025***	-0.009***	-0.016***	-0.160**	-0.039***	-0.028***
	(0.003)	(0.003)	(0.003)	(0.079)	(0.003)	(0.003)
d_7	-0.028***	-0.013***	-0.015***	-0.155*	-0.041***	-0.023***
	(0.003)	(0.003)	(0.003)	(0.079)	(0.003)	(0.003)
d_8	-0.096***	-0.082***	-0.033***	-0.170**	-0.106***	-0.036***
	(0.003)	(0.003)	(0.004)	(0.079)	(0.003)	(0.003)
d_9	-0.02***	-0.005	-0.020***	-0.162**	-0.026***	-0.019***
	(0.004)	(0.004)	(0.005)	(0.079)	(0.004)	(0.005)
City size $_{t-1}$		0.025***		-0.219***		
		(0.0005)		(0.003)		
City fixed effects	No	No	No	Yes	No	No
Time effects	No	No	Yes	Yes	No	Yes
State effects	No	No	No	No	Yes	Yes
Region effects	No	No	No	No	No	Yes
Navigable waters	No	No	No	No	No	Yes
Sun & Rust Belts	No	No	No	No	No	Yes
Observations	160,292	160,292	160,292	160,292	160,292	160,292
R-squared	0.019	0.034	0.042	0.194	0.064	0.087
F	192.8	396.6	299.4	501.7	136.4	176.2

Note: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Table 6 presents the results for the MSAs, its six columns being the same as those in Table 5. At first glance, we see that most of the coefficients associated with the dummy variables are not statistically significant. In the first two columns (1) and (2) we cannot identify the same decreasing trend as that found in Table 5. However, as before, the coefficient in column (2) associated with the city size variable is positive and not negative. Yet, in this case, it is not significant.

These specifications might lack precision, as those first two identified above for the cities. For this reason, we also estimate the model incorporating time fixed effects, city fixed effects and state fixed effects in columns (3), (4) and (5) respectively. None of these three regressions presents the same results as in those for the cities (in column (4) none of the coefficients is significant) in terms of a declining growth trend. The only variable consistent with the cities' results is that of size (MSA size in this case) in regression 4, which presents a significantly negative value. This allows us to confirm, as above, the existence of mean reversion in the steady state when examining the MSAs. This finding is consistent with results reported in previous studies that use MSAs as their geographical unit of analysis for testing Gibrat's law.

Finally, column (6) as above includes state, time and region fixed effects and the navigable waters and Rust and Sun belt variables. As with the previous columns, almost all the coefficients are not statistically significant and the expected decreasing trend is not seen. Thus, we can conclude that the MSAs do not present the same trend as that presented by the incorporated places and that the aggregation of geographical units does not provide the same results. A plausible explanation for this lies in the definition of an MSA. A metropolitan area typically comprises a group of counties with a central city with a minimum of 50,000 inhabitants and a number of other smaller places located at points in the orbit of this central city. According to the sequential growth literature, the central city (assumed to be older and therefore larger than most surrounding places) will present different growth patterns over the time period to those of other cities within the same MSA. More specifically, the central city will be more mature than the rest and its growth rate is therefore not expected to be as high. By contrast, there will be other smaller and younger cities that will grow more rapidly during the same period. As such, the final growth rate of the MSA is the average of many rates of different cities weighted by city size. Another plausible explanation is that in order to become an MSA a city with more than 50,000 inhabitants is needed. Therefore, a new MSA is nothing but the evolution of the cities within it and it might be the case that the definition of a new MSA is not as accurate as the one of a newborn city.

Table 6. Estimation of the dynamic effects of MSAs

Decades of existence	(1)	(2)	(3)	(4)	(5)	(6)
d_1	0.055***	0.058***	0.101***	0.009	-0.024*	0.019
	(0.015)	(0.016)	(0.015)	(0.034)	(0.013)	(0.014)
d_2	0.069***	0.072***	0.098***	0.018	-0.009	0.016
	(0.016)	(0.016)	(0.016)	(0.031)	(0.014)	(0.014)
d_3	0.005	0.006	0.094***	0.006	-0.085***	-0.0009
	(0.014)	(0.015)	(0.014)	(0.028)	(0.012)	(0.011)
d_4	0.022*	0.024*	0.073***	-0.004	-0.070***	-0.024*
	(0.013)	(0.014)	(0.013)	(0.025)	(0.013)	(0.012)
d_5	0.157***	0.158***	0.121***	0.041	0.057*	0.027
	(0.029)	(0.029)	(0.027)	(0.033)	(0.030)	(0.026)
d_6	0.018	0.018	0.071***	0.001	-0.080***	-0.019
	(0.027)	(0.027)	(0.027)	(0.025)	(0.027)	(0.026)
d_7	0.020	0.020	0.067**	0.010	-0.071***	-0.018
	(0.028)	(0.028)	(0.027)	(0.024)	(0.027)	(0.025)
d_8	-0.040*	-0.040*	0.072***	0.017	-0.133***	-0.018
	(0.024)	(0.024)	(0.024)	(0.014)	(0.018)	(0.017)
d_9	-0.041**	-0.041**	0.048**	---	-0.131***	-0.038**
	(0.019)	(0.018)	(0.020)		(0.018)	(0.019)
City size $_{t-1}$		0.001		-0.125***		
		(0.003)		(0.019)		
MSA fixed effects	No	No	No	Yes	No	No
Time effects	No	No	Yes	Yes	No	Yes
State effects	No	No	No	No	Yes	Yes
Region effects	No	No	No	No	No	Yes
Navigable waters	No	No	No	No	No	Yes
Sun & Rust Belts	No	No	No	No	No	Yes
Observations	1,734	1,734	1,734	1,734	1,734	1,734
R-squared	0.041	0.042	0.205	0.345	0.270	0.429
F	7.692	6.962	25.71	42.44	12.85	16.51

Note: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)
Note: d9 is not included because collinearity problems with the city-fixed effects

5. Nonparametric analysis

A number of studies employ nonparametric terms to evaluate the relationship between growth and city size and to examine whether Gibrat's law and mean reversion in the steady state holds. Ioannides and Overman (2003), for example, undertake such an analysis with a time-series dataset for metropolitan areas. This same methodology is adopted by Eeckhout (2004) and González-Val (2010). The former uses it to evaluate the impact of size on growth for all the cities in the US for two specific years: 1990 and 2000. González-Val (2010) uses the same database as the one described here which includes all cities without restriction. All three studies find that

Gibrat's law holds (at least for means) for their data and periods studied.

Desmet and Rappaport (2011) apply the same type of analysis to the United States but employ an alternative methodology and use different geographical units. Using data on counties and MSAs, they find that Gibrat's law does not hold. Similarly, Michaels *et al.* (2012) regress population growth on a full set of fixed effects for initial population density using their self-made dataset of county subdivisions. They find an increasing relationship between population growth and initial population density in intermediate densities.

Our nonparametric approach, in common with Eeckhout (2004) and González-Val (2010), is based on the same methodology as that developed by Ioannides and Overman (2003), but differs in terms of the data we use. Thus, we include only the cities identified as being new-born in each decade and estimate a pool for any possible city age, from one to nine[7] . This means that in decade one, we include the total number of cities with one decade of existence, no matter the year in which they were created (the last row in Table 3 is the sample size for each estimation from the first to the last).

The regression we estimate is the following:

$$g_i = m(s_i) + \varepsilon_i$$

where g_i is the normalized growth rate, i.e., the difference between growth and the contemporary sample mean divided by the contemporary standard deviation and s_i is the logarithm of the population size of a city. ε_i is the error term. The aim of adopting this approach is to provide an estimation of $m(s_i)$ without imposing any specific parametric functional form. The estimation of $m(s_i)$ is a local average that smooths the value around the point *s*. The smoothing is conducted using a kernel which is a symmetrical, weighted and continuous function around *s*. The Nadaraya-Watson method[8] is used to calculate the estimate of *m*, based on the following expression:

$$\hat{m}(s) = \frac{n^{-1}\sum_{i=1}^{n} K_h(s - s_i) g_i}{n^{-1}\sum_{i=1}^{n} K_h(s - s_i)}$$

[7] We consider a city age up to nine decades (i.e., over the course of the twentieth century). To be able to consider a city with an age of ten decades, data for 1890 are required.
[8] Employed here as used in Härdle (1990).
[9] The results are robust to different bandwidths including the optimal one for each decade

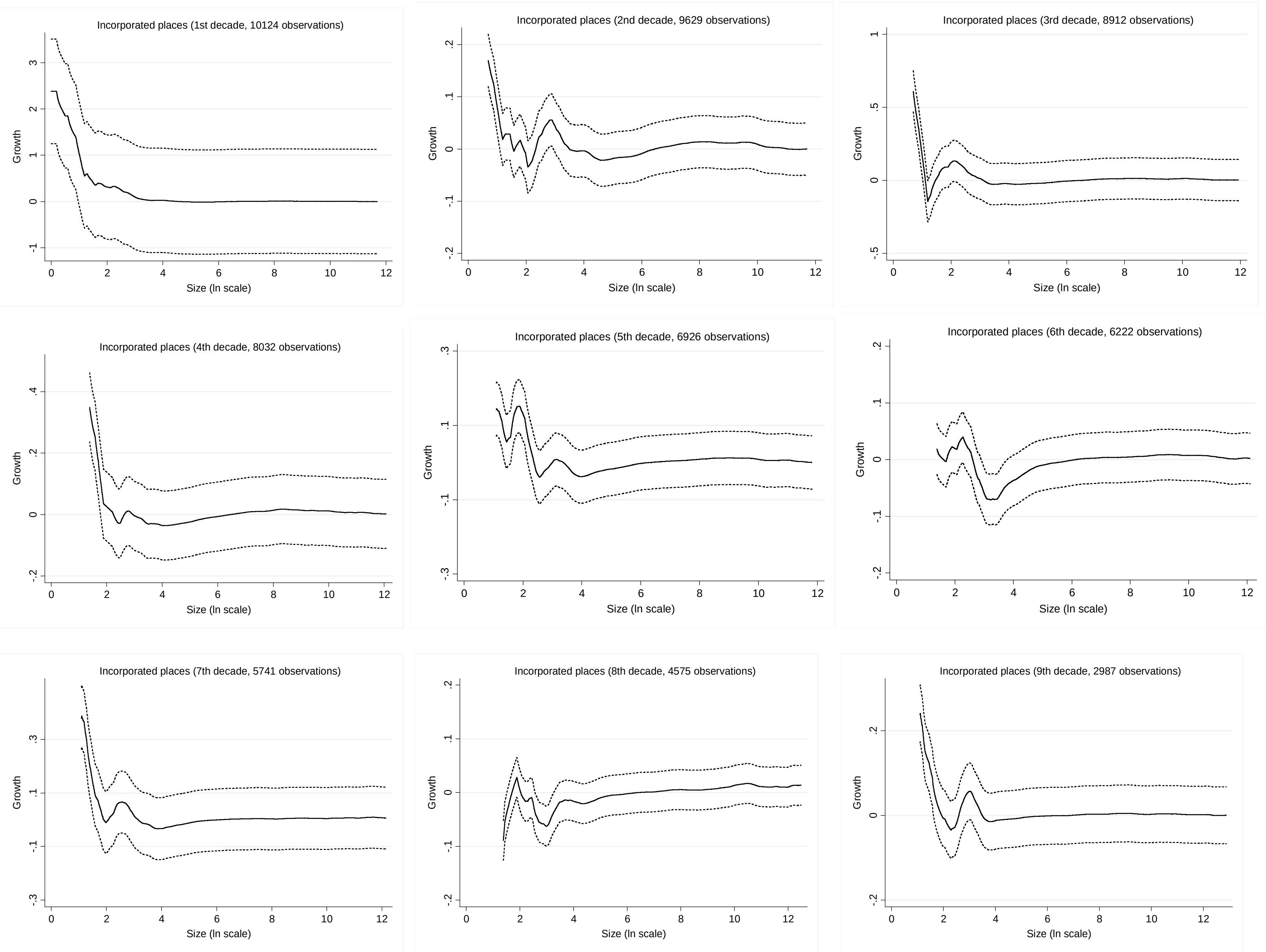
where K_h denotes the dependence of K on the bandwidth h, and where K is an Epanechnikov kernel. Figure 2 shows the results for $\hat{m}(s)$ calculated for a bandwidth of $h = 0.5$[9] for every decade of the twentieth century including only the new-born cities. Bootstrapped 95 percent confidence bands, calculated using 500 random samples with replacement, are also displayed.

This type of analysis allows us to visually compute the temporal evolution of incorporated places by city size. In Figure 2, it is immediately apparent that smaller cities present higher growth rates, and that the larger the city the lower its growth rate tends to be. It can be readily detected that random growth does not exist as the average growth of the smallest cities differs from that of the largest places. If this were not the case, the figures would only present horizontal lines coinciding with the zero value of the “growth” axis and there would be no deviation from the mean. As a city becomes bigger (city size increases), the average growth stabilizes in the mean. Therefore, it seems that the temporal effects we record may be driven by the smallest cities, meaning that a new city is usually one of the smallest cities to appear in its decade of creation and, as a consequence, its impact on growth is higher than that of the average growth rate for the decade.

Moreover, apart from the dynamic part of this analysis, we can also infer information about the steady state by interpreting the dynamics. If in each decade smaller cities grow above the mean and larger cities maintain their growth around the average, in the steady state we may have a mean reversion (convergence) situation. In other words, deviations from the mean growth rate experienced by smaller cities can be expected to revert to the average as soon as the city becomes older (and bigger).

Our results as regards mean reversion are in line with those of Henderson and Wang (2007) and Black and Henderson (2003). However, our findings do not contradict those of other studies employing US data and which conclude that Gibrat’s law holds. This can be explained by the fact that we only include the new cities and not the whole distribution in the kernel regression. Therefore, we do not reject Gibrat’s law for the entire distribution but only for the new entrants.

Figure 2. Growth and size by age



6. Conclusions

In this paper we have drawn on data for cities and MSAs in the United States in order to study the evolution of city growth throughout the twentieth century. More specifically, we have focused our attention on the role played by the new-born cities that have been created at some time during the decades of our period of analysis. We have obtained two main results by applying parametric and nonparametric methods. Our first finding is that differences exist in city growth rates according to the age of the city in question. In general, when a city is born it records very high rates of growth but as the decades pass it matures and its growth stabilizes or even declines. These results are consistent with those of the sequential city growth literature, which reports that in each decade a few cities will grow at a faster rate than the others.

Our second finding is related to the analysis of the dynamics of the city size distribution, i.e. the study of Gibrat's law and the steady state situation. However, it should be stressed that, despite we are not exactly studying the steady state but rather the dynamics that precede it, some conclusions can be drawn anyway. We perform parametric and nonparametric regressions to examine the relationship between the temporal dimension of growth (the age of the city) and a city's initial size. Our results enable us to conclude that, in the case of new-born cities, Gibrat's law does not hold. Moreover, it becomes apparent that new-born cities are usually the smallest and the ones that present the most rapid growth at the outset. This state of affairs is evidence in support of the mean reversion hypothesis.

Our results are very much in line with those presented by the city growth literature and, in particular, with those in studies of sequential city growth. Furthermore, our findings could provide interesting input for policy makers in countries such as China and India, which are now experiencing their own processes of urbanization. In recent decades, both countries have experienced a change from a rural to an urban society, i.e., the same pattern followed by the US and many other developed countries. As urban policies slowly adjust to the dynamics of growth, and given the huge populations of both India and China, it must surely be in the best interests of these countries' policy makers to learn lessons from experiences such as that of the US. In fact, if there is a statistical regularity driving some of the population growth of cities, dependent on their initial size or age, some investment (especially in public infrastructure) can be performed strategically.

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