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Unveiling Mexico's urban growth. From a primate distribution to polycentric dynamics

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Abstract - This article examines urban growth and hierarchies in Mexico from 1990 to 2020. Utilizing data from the historical population census of urban areas published by the Mexican National Institute of Statistics and Economic Studies (INEGI), this study employs a range of statistical and econometric tools, including stationarity tests in panel data and Markov processes, to elucidate the transformations within the Mexican urban system. The findings provide compelling evidence that, despite its complexity, Mexico's urban dynamics align with the long-term trends observed in an inverted U model. The country's urban landscape undergoes a dynamic growth process reflective of its economy's technological and industrial advancements, with medium-sized cities emerging as pivotal players in this evolution.

JEL Classification

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Key-words

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1. INTRODUCTION

Since the late 20th century, a substantial body of literature has developed regarding the shifting urban hierarchies and associated demographic growth across various countries and regions. Most of these studies aim to analyze urban growth processes in European and OECD countries, for which available longitudinal data series are available (Parr, 1985; Alperovich, 1993; Fujita *et al.*, 1999; Gabaix, 1999; Dobkins & Ioannides, 2000; Gabaix & Ioannides, 2004; Black & Henderson, 2003; Bosker *et al.*, 2008; Dimou & Schaffar, 2009; De La Roca & Puga, 2017; Puente Ajovin & Ramos, 2015; Duben & Krause, 2021; González-Val *et al.*, 2024). Some studies, however, focus on developing countries, where urban changes occur at a faster pace and mega-agglomeration phenomena appear to have less institutional control (Soo, 2007; Schaffar & Dimou, 2012; Pérez-Campuzano *et al.*, 2015; Schaffar & Nassori, 2016).

Some studies implicitly support the hypothesis that in most countries, long-term urban dynamics follow a Kuznets' inverted U-curve with respect to their level of economic development (Catin, Hanchane & Kamal, 2008). This suggests that an initial phase of urban concentration is followed by population dispersal among small- and medium-sized cities (Parr, 1985; Guerin-Pace, 1995; Catin & Schaffar, 2011). In such a model, a pre-urban period, characterized by inadequate transport infrastructure and a lack of economies of agglomeration, is followed by a stage of urban concentration where public infrastructure develops, and cities specialize in particular industries, leading to the emergence of economies of scale. This concentration process continues until the gradual emergence and reinforcement of diseconomies of agglomeration trigger a reversal of the trend and lead to urban dispersal. This dispersal is facilitated by improvements in interregional transport infrastructure, enabling the relocation of production activities to peripheral regions and cities.

A few empirical studies have confirmed this model's explanatory and predictive nature despite significant national variations (Soo, 2005; Catin, Cuenca & Kamal, 2008; Le *et al.*, 2008; Catin & Schaffar, 2011; Catin & Kamal, 2011; Schaffar & Pavleas, 2014). Its validity implies managing the rapid formation of large metropolitan areas during urban concentration. The initial structure of these areas may not always be suitable in terms of land availability, public facilities, or resident services to accommodate a continuous influx of immigrants from rural areas or smaller cities within a relatively short period. This appears to be the case for major metropolitan areas in emerging countries such as Morrocco, India, and Brazil, which are positioned on the ascending slope of the bell curve. This trend inevitably directs planners and public authorities to prioritize public action in some metropolitan regions, often viewed as the driving force behind national economic growth. However, a closer examination of city demographics in certain countries and a more nuanced analysis of changes in urban hierarchies invite us to challenge this rigid view of urban dynamics.

Drawing on a set of econometric tools developed by several studies on urban hierarchies and city growth (Black & Henderson, 2003; Ioannides & Overman, 2003; Schaffar & Dimou, 2012; Gabaix, 2016), this paper seeks to study urban dynamics in Mexico between 1990 and 2020. From 1960 to 2010, Mexico's urban population increased from 50% to 80% of the country's total population (World Bank, 2015). Mexico's urbanization rate now matches European standards and surpasses the BRICS average. This urban development can be attributed to the industrialization process (1940-1979) and the subsequent tertiarization of the country's economy since the 1980s, which shifted away from the dominance of agricultural production and the rural sector. The distribution of cities by size indicates that the country has transitioned from being predominantly rural to urban. However, over the past few decades, medium-sized cities have experienced significant demographic growth, consistent with the inverted U-curve hypothesis (Pérez-Campuzano *et al.*, 2015; García Meza *et al.*, 2019).

This paper aims to study the urban growth process in Mexico at the level of its 2,469 municipalities/cities from 1990 to 2020. This approach aligns with other studies (García Meza *et al.*, 2019) on urban development in Mexico. This paper brings evidence that urban dynamics in Mexico, though complex, confirm the long-term trends of an inverted U model. Mexico's urban system experiences a dynamic urban growth process corresponding to the technological and industrial changes in the country's economy, with medium-sized cities taking the lead over the rest of the country.

The paper is organized as follows: The second section revisits the main theoretical approaches to urban growth. The third section presents the methodological instrumentation adopted and describes the database construction used in this work. Section 4 focuses on a descriptive approach to the Mexican system and examines the evolution of urban hierarchies. Section 5 analyzes the nature of urban growth in Mexico. The last section offers a brief conclusion summarizing the results obtained.

2. A BRIEF LITERATURE REVIEW ON URBAN GROWTH

Economic literature studies urban hierarchies in different countries and regions. A series of papers examine and compare demographic changes in various urban systems using different specifications of the rank-size model (Rosen & Resnick, 1980; Parr, 1985; Gabaix, 1999; Soo, 2005; Gonzalez-Val *et al.*, 2015; Schaffar & Dimou, 2012; Su, 2020; Mulligan & Carruthers, 2021; Düben & Krause, 2021). These models, where the rank coefficient characterizes the level of urban concentration, primarily provide descriptive insights and do not allow to identify the driving forces behind the demographic growth of cities.

Urban growth models aim to analyze the determinants of changes in urban hierarchies. Schaffar (2009) first identified two main families of urban growth models: random and deterministic growth models. Random growth models (Gabaix, 1999; Gabaix & Ioannides, 2004; Cordoba, 2008; Schaffar & Dimou, 2012; Sanchez-Vidal *et al.*, 2014; Gonzalez-Val *et al.*, 2014; Frick & Rodriguez-Pose, 2018; Bettencourt & Zund, 2020) posit that under certain restrictive conditions such as limited household mobility, urban growth appears as a stochastic process that depends solely on exogenous, randomly distributed shocks. These shocks may include significant events like natural disasters or wars and smaller-scale occurrences such as the effects of local industrial and fiscal policies. The random growth models confirm Gibrat's law. At the steady state, when all movements stop, the city size distribution follows the Zipf law (a Pareto distribution with a ranking coefficient equal to 1).

Deterministic growth models (Eaton & Eckstein, 1997; Black & Henderson, 1999; Rossi-Hansberg & Wright, 2007; Duranton & Puga, 2014; Desmet & Henderson, 2015; De la Roca & Puga, 2017) consider that urban growth processes depend on the characteristics and productive specialization of each city. At the intersection of Lucas' (1988) endogenous growth models and Henderson's (1988) theoretical framework emphasizing agglomeration externalities, these models suggest that the firms' location decisions fundamentally influence urban population growth. Unlike random growth models, Zipf's law is not necessarily upheld in the stationary state. The hypothesis of convergence of city sizes towards an optimal size is widely accepted.

A body of empirical studies has examined the effects of exogenous shocks on urban growth, employing a wide range of econometric tools (Bosker *et al.*, 2008; Schaffar & Dimou, 2012; Schaffar & Nassori, 2016; Bettencourt & Zund, 2020; Vervabatz & Bartelemy, 2020). Some of these studies corroborate predictions from random growth theories, while others support the assumption of city-size convergence proposed by endogenous growth theories.

Duranton (2006) develops a series of hybrid models that incorporate size effects and exogenous shocks at the intersection of the previous two theoretical frameworks. In these models, urban growth originates from firms' decisions regarding location or relocation in response to innovations or the introduction of new products. Duranton (2007) presents a spatial variation of Grossman and Helpman's model of growth in quality scales of goods, demonstrating that demographic changes in a system of cities arise from firms' location choices following intersectoral innovations or the creation of new varieties of goods. In another work, Duranton and Turner (2012) highlight the influence of additional factors on urban growth, such as the significance of the road network, the quality of urban amenities, and education as a driver of human capital. More recently, Duranton and Puga (2023) developed an urban growth model where human capital spillovers foster entrepreneurship and learning in heterogeneous cities. The model shows how residents limit city expansion through planning regulations so that commuting and housing costs do not outweigh productivity gains from agglomeration.

This paper follows previous empirical work of Brakman *et al.* (1999), Bosker *et al.* (2008), Le Gallo and Chasco (2008), and Catin and Schaffar (2011), by exploring the hypothesis that urban growth dynamics may vary over time within the same country, influenced by its stage of development. This means that short or medium-term growth processes may be less deterministic than the ones described by different theoretical urban growth models.

3. METHODOLOGY

The database used in this study is based on population census data conducted by the Instituto Nacional de Estadística y Geografía (INEGI) for the years 1990, 1995, 2000, 2005, 2010, 2015, and 2020. Population time-series data is provided at the level of individual cities rather than for metropolitan areas surveyed by INEGI. Hiernaux and Lindón (2004) underscored the urban structure of Mexico, characterized by the intensification of urban nuclei, such as Mexico City. This study examines municipalities individually to elucidate their socio-urban dynamics and role within the broader urban system. Additionally, municipalities are institutionally independent and can develop their strategies regarding real estate, housing, and public infrastructure, thus potentially influencing the process of urban growth positively or negatively.

To determine whether urban growth processes in Mexican municipalities are random or deterministic and whether city sizes converge, we examine the stationarity of city sizes using unit root tests. If the series of city sizes exhibit a unit root, the effects of random shocks persist over time, and city sizes follow a random growth process. Conversely, if the series does not feature a unit root, it suggests that city sizes follow a deterministic growth process, potentially leading to convergence in city size under certain conditions (Schaffar, 2010).

We assume that the size of a city follows a first-order autocorrelation process, enabling us to test the convergence of city sizes:

$$ln\, S_{it} = \varphi_i\, ln\, S_{it-1} + \varepsilon_{ti} \text{ with } \varepsilon_t i.i.d. (0, \sigma_\varepsilon^2)$$

where lnS_{it} is the logarithm of the size of city i in t, φ_i the first order autoregressive coefficient and ε_{ti} an identically and independently distributed shock in t. We specify a panel data model with fixed effects and time drift to account for each city's characteristics and national dynamics.

$$\Delta\, ln\, S_{it} = \alpha_i + \delta_i t + \gamma_i\, ln\, S_{it-1} + \sum_{j=1}^{p} \rho_{ij} \Delta\, ln\, S_{it-j} + \mu_{it}$$

where $\gamma_i = \varphi_j - 1$, α captures each city's specificity, and $\theta_i t$ is the trend term. The null hypothesis posits no stationarity, confirming the Gibrat law for cities. Conversely, the alternative hypothesis rejects it and concludes that city sizes converge.

The performed tests are based on the methodologies developed by Levin *et al.* (2002), Im *et al.* (2003), Choi (2002), and Pesaran (2007). The first two tests are first-generation and assume individual interdependence, meaning that each city follows a growth process independent of the others. However, in our case, cities likely share common macroeconomic influences such as regional policies and migration facilitated by proximity. The third and fourth tests are second-generation, aiming to account for correlations between city sizes and interdependence.

Next, we follow the methodology of Ioannides and Overman (2003) to establish a non-parametric relation between the size of the cities S and their demographic growth rate g. For a city size S_0, the relationship function mm between the growth rate and city size is given by:

$$\widehat{m}(S_0) = \sum_{i=1}^{n} w_i(S_0) g_i \text{ with } w_i(S_0) = \frac{K\left(\frac{S_i - S_0}{\lambda}\right)}{\sum_{i=1}^{n} K\left(\frac{S_i - S_0}{\lambda}\right)}$$

where $K(\cdot)$ denotes a Gaussian kernel function, $\lambda > 0$ is Silverman's (1986) smoothing parameter and n is the sample size. The function $w_i(S_0)$ defines the weight to be assigned to the pair of observations (S_i, g_i). The conditional density function $\hat{f}(g|S = S_0)$ is the quotient between the joint density $\hat{f}(g_0, S_0)$ and the marginal density of S_0, denoted as $\hat{f}(S_0)$:

$$\hat{f}(g_0|S = S_0) = \frac{\hat{f}(g_0, S_0)}{\hat{f}(S_0)} \text{ with } \hat{f}(S_0) = \frac{1}{n\lambda} \sum_{i=1}^{n} K\left(\frac{S_0 - S_i}{\lambda}\right) \text{ the marginal density}$$

We can plot the conditional density of urban growth rates by city size, showing the distribution of the population growth rates for each given city size.

Table 1: Distribution of Mexican municipalities

	C1	C2	C3	C4	C5
Intervals	Sij < 1.05m	1.05m < Sij < 1.12m	1.12m < Sij < 1.19m	1.19m < Sij < 1.29m	1.29m < Sij
Intervals	Sij < 25,000	25,000 < Sij < 50,000	50,000 < Sij < 100,000	100,000 < Sij < 250,000	250,000 < Sij
% of municipalities	0.693	0.170	0.064	0.044	0.029

Source: Author's calculations based on Censo de Población y Vivienda, INEGI, 1990-2020.

Finally, Markov chains analyze the intra-distributional dynamics of Mexico's municipalities, which had more than 1,500 inhabitants from 1990 to 2020. The Markov chains offer insights into the relative dynamics of the rank-size distribution of municipalities (Black & Henderson, 2003; Bosker *et al.*, 2008; Dimou & Schaffar, 2009; Barois, 2019). A Markov chain assumes that the growth of the size of a city S at time t can be predicted without considering past sizes. All cities are distributed in five classes; however, these classes are not homogeneous. The significant number of small municipalities prevents homogeneity in constructing these classes. The cut-off points have been determined based on the size of the cities to differentiate the dynamics of large metropolitan areas from those of small and medium-sized cities (Table 1).

The probability for a city's size to grow and move to the next class at time t+1 is given by:

$$P\big((S_{t+1} = j \big| S_0 = i_0, S_1 = i_1, \dots, S_t = i_{t,})\big) = P((S_{t+1} = ii | S_t = i_t)$$

We build two matrices: the transition matrix captures the probability of a municipality moving from one class to another; the mean time to the first passage matrix shows the minimum number of years it takes for a municipality to move from one class to another.

4. A DESCRIPTIVE ANALYSIS

Since the early twentieth century, aside from the revolutionary period (1910-1921), the Mexican population has experienced consistent growth. In 1900, Mexico was predominantly rural, with only 10.6% of its population in urban areas. Six out of the 33 cities in the country with more than 15,000 inhabitants accounted for half of the total urban population. From 1900 to 1940, Mexico's population steadily increased, driven by significant rural-urban migration (Aguilar & Graizbord, 2000; Garcia Meza *et al.*, 2019).

From 1940 to 1979, urbanization accelerated, fueled by the country's industrialization. By the end of the 1970s, the urban population reached 46% of the total population, with the number of cities with more than 15,000 inhabitants rising to 167. The country experienced substantial industrial development, particularly in Mexico City, Monterrey, and Guadalajara.

Between 1980 and 2020, Mexico met a pivotal phase in its demographic and urban development. The average annual demographic growth rate slowed to 1.9%, compared to 3% during 1960-1980, and continued to decline between 2000 and 2020, reaching 1.3%. The privatization of urban planning and development, initiated during the implementation of neoliberal policies, continues to drive the growth of metropolitan areas. The State has shifted away from producing social housing. It favors public-private partnerships, leading to a rise in large-scale infrastructure and real estate projects, primarily on the peripheries of large cities. These endeavors aim to position medium-sized cities within the global landscape, enhance infrastructure with advanced technological features, and bolster urban competitiveness (Hassaine-Bau, 2021; Barois & Hassaine-Bau, 2023).

Table 2 shows the distribution of the Mexican municipalities and delivers two critical information. First, the weight of the country's largest cities in terms of the total Mexican population has remained the same throughout the period. In 1990, the top 5 cities accounted for nearly 8.39% of the total population, whereas in 2020, they accounted for 7%. Second, there has been a net increase in the weight of medium-sized cities between 1990 and 2020 (Table 2).[1]

Table 2: Detail of the distribution functions of Mexican municipalities

Rank of cities	1990			2020		
	City size in millions	Weight (%)	Cumulative weight (%)	City size in millions	Weight (%)	Cumulative weight (%)
1 to 5	1.256 to 1.650	8.39	-	1.692 to 1.922	7.00	-
6 to 10	0.786 to 1.218	5.58	13.97	1.114 to 1.645	5.31	12.31
11 to 20	0.556 to 0.747	7.79	21.77	0.911 to 1.077	7.79	20.10
21 to 30	0.464 to 0.535	6.12	27.89	0.704 to 0.910	6.25	26.35
31 to 40	0.362 to 0.456	5.13	33.02	0.604 to 0.699	5.20	31.55
41 to 50	0.295 to 0.339	3.84	36.86	0.516 to 0.592	4.33	35.88
51 to 70	0.206 to 0.288	6.03	42.89	0.392 to 0.501	6.93	42.81
71 to 100	0.136 to 0.204	5.87	48.76	0.248 to 0.391	7.37	50.19

Source: Censo de Población y Vivienda, INEGI, 1990-2020.

We examine urban hierarchies in Mexico using two models. First, we use the correction of Gabaix and Ibragimov (2011)[2] for small samples to study the relation between the city size and the city rank:

$$\ln\left(R - \frac{1}{2}\right) = \alpha + \beta \ln{(S)}$$

where R is the rank of the given city, S is its size, and β is the hierarchy coefficient (Pareto coefficient). Second, we use the Rosen and Resnick (1980) model which suggests that the relationship between the size and the rank of cities deviates from strict linearity and is better represented by a quadratic pattern:

$$ln\,(R)_{\,i} = \alpha + \beta\, ln\,(S)_i + \theta ln\,(S)_i^{\,2}$$

If θ is positive, the distribution curve is convex, indicating a scarcity of medium-sized cities compared to what Zipf's law predicts. Conversely, if θ is negative, the curve is concave, suggesting a prevalence of medium-sized cities and a more balanced distribution.

Table 3 illustrates the variations in Pareto and Rosen and Resnick's exponents for the size distributions of Mexican municipalities with over 1,500 inhabitants

[1] These first three categories are based on the divisions proposed by the United Nations Population Division. The fourth includes areas of between 2,500 and 100,000 people, based on the division proposed by the INEGI.
[2] For a detailed presentation of the advantages of this equation see Schaffar (2009).

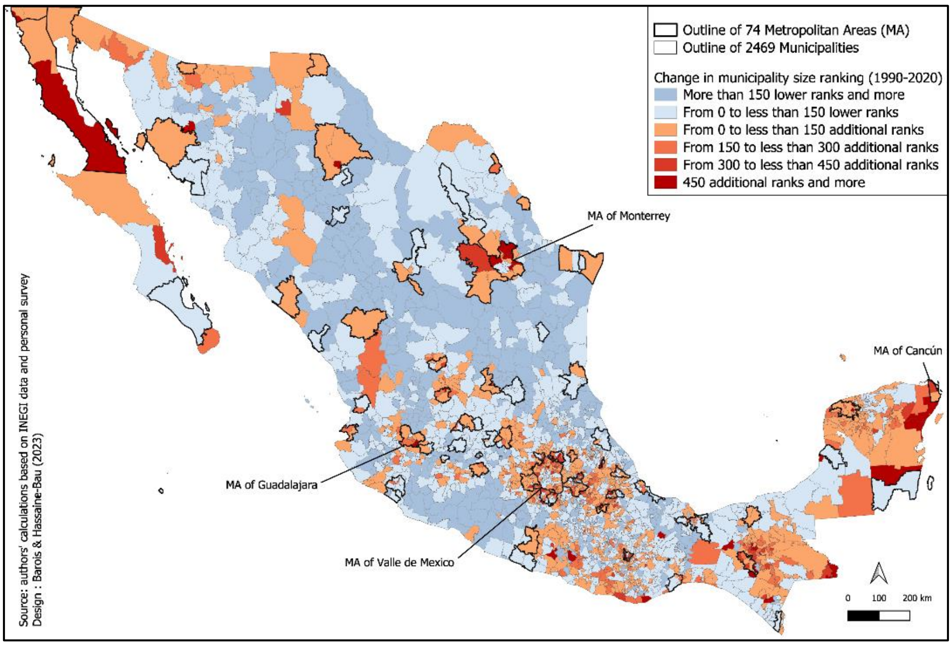
between 1990 and 2020. In the first model, the absolute value of β remains below 1, indicating a pronounced primatial urban system. However, it gradually increases over this period, suggesting a shift towards a more balanced distribution. In the second model, the gradual decrease of the θ coefficient shows a progressive rise in the significance of medium-sized cities.

Table 3: Two rank-size models for the 2,469 Mexican cities in the sample (1990 - 2020)

	1990	1995	2000	2005	2010	2015	2020
β	-0.741 ***	-0.747 ***	-0.760 ***	-0.775 ***	-0.792 ***	-0.801 ***	-0.827 ***
R^2 adj.	0.940	0.937	0.938	0.939	0.933	0.931	0.931
θ	0.123 ***	0.121 ***	0.119 ***	0.115 ***	0.111 ***	0.110 ***	0.107 ***
R^2 adj.	0.978	0.977	0.978	0.978	0.978	0.979	0.980
N° of obs.	2,253	2,246	2,250	2,222	2,245	2,245	2,238

Source: Authors calculations based on data from Censo de Población y Vivienda, INEGI, 1990-2020.

Figure 1: Map of rank-size evolution (1990-2020) of the 2469 municipalities



Source: Censo de Población y Vivienda, INEGI, 1990-2020.

The evolution of the rank of Mexican municipalities between 1990 and 2020 illustrates the major national imbalances that punctuate demographic and urban growth. Figure 1 shows that the north of the country, which is less populated but more urbanized and concentrates industrial activity, contrasts with the rural and generally poorer southern areas (Valette, 2021). Medium-sized cities now serve as a growth engine for the urban system. Cities between 500,000 and 1 million have experienced the highest growth since 1990. More than 50% of the population resides in a city with over 250,000 inhabitants.

5. THE NATURE OF URBAN GROWTH IN MEXICO

We first study the convergence trends of city sizes in Mexico from 1990 to 2020 using first- and second-generation unit root tests. Table 4 summarizes the models' results according to the different tests.

Table 4: Stationarity tests (size of Mexican municipalities 1990-2020)

Tests	Statistics	No trend model (2)	Models with trend (3)
Levin, Lin & Chu (2002)	LL	-66.451 *** (0.000)	-114.286 *** (0.000)
Im, Pesaran & Shin (2003)	Zt	-4.213 *** (0.000)	-68.971 *** (0.000)
	Wt	-4.478 *** (0.000)	-34.095 *** (0.000)
Choi (2002)	P	-0.813 (0.792)	20.016 *** (0.000)
	Z	12.081 (1.000)	-2.680 *** (0.003)
	L*	11.969 (1.000)	1.821 (0.965)
Pesaran (2007)	CIPS	-1.986 (0.110)	-2.712 *** (0.001)
	CIPS *	-1.986 (0.110)	-2.691 *** (0.001)

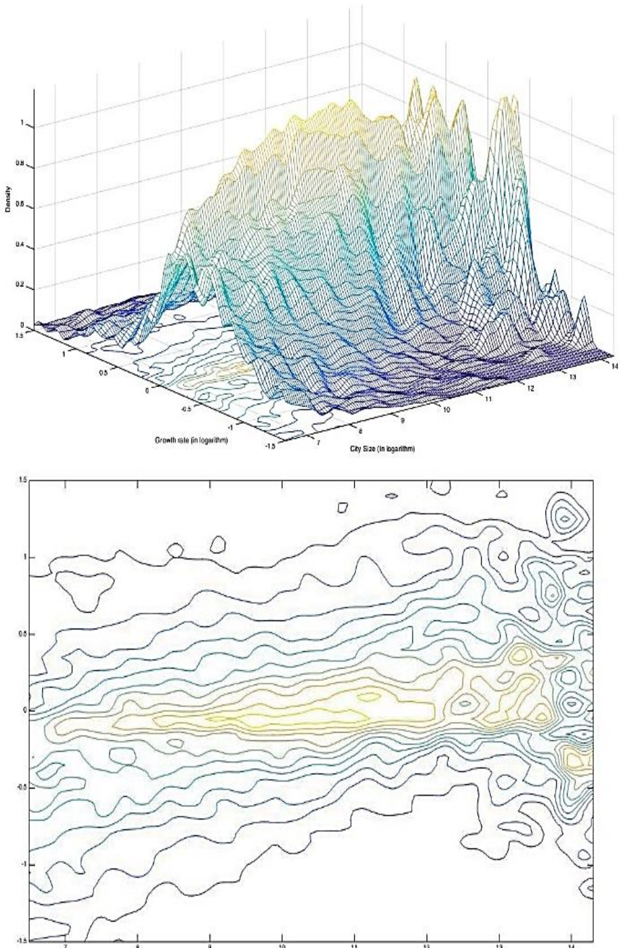
Source: Author's calculations based on Censo de Población y Vivienda, INEGI, 1990-2020.

The Levin, Lin, and Chu (2002) and IPS (2003) tests reject the null hypothesis of non-stationarity for almost all cities, indicating that at least one of the 2,469 municipalities in Mexico has a stationary size. However, caution should be exercised in interpreting the results of the first-generation tests, as they assume inter-individual independence. Second-generation tests, including Choi's (2002) test and the more robust Pesaran (2007) test, also lead to rejecting the null hypothesis in Mexico. This suggests a convergence process of city sizes towards an optimal size and refutes Gibrat's law for cities.

Second, we seek to establish the non-parametric correlation between the population growth rate and the size of the cities, following the work of Ioannides and Overman (2003). Figure 2a shows the conditional density of the growth rate of municipalities according to their size, and Figure 2b shows the associated lines to this conditional density.

The two figures depict a parallel growth process for all cities independent of size, except for the largest cities at the top of the distribution, which feature lower growth rates. However, the standard deviation of growth rates decreases with city size, with medium-sized cities featuring a lower deviation than small and large ones.

Figure 2: Conditional density 2A and associated lines 2B of growth rates by size of Mexican cities



Source: Author's calculations based on Censo de Población y Vivienda, INEGI, 1990-2020.

Although the non-parametric relation between city size and city growth does not confirm a convergence process, it indicates a deterministic process attributed to a threshold effect. Cities with a population between 400,000 and 900,000 inhabitants exhibit higher growth rates than smaller cities and larger metropolitan areas. This finding corroborates previous observations regarding the growing importance of medium and large cities, which are sometimes located on the peripheries of metropolitan areas, and their significant contribution to Mexico's urban growth dynamics.

Finally, Markov chains allow us to study the long-term intra-distributional dynamics of Mexican cities. First, we examine the intra-distributional dynamics of these municipalities (Table 5). Several observations can be made. First, classes 1 and 5 exhibit the highest stability, with 99.8% and 99.6% of municipalities remaining within their initial groups, respectively. Second, the upward mobility of municipalities is slightly higher than the downward mobility for classes 3 and 4, but it is the opposite for class 2. This suggests that the larger medium-size municipalities experience significant growth and tend, over time, to transition towards the group of largest cities, while smaller medium-size municipalities tend towards Class 1 type cities.

Table 5: Intra-distributional dynamics of Mexican municipalities

Pij	C1	C2	C3	C4	C5
C1	0.998 (0.000)	0.002 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
C2	0.010 (0.001)	0.980 (0.001)	0.010 (0.001)	0.000 (0.000)	0.000 (0.000)
C3	0.000 (0.000)	0.008 (0.001)	0.980 (0.002)	0.012 (0.001)	0.000 (0.000)
C4	0.000 (0.000)	0.000 (0.000)	0.006 (0.001)	0.986 (0.001)	0.008 (0.001)
C5	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.004 (0.001)	0.996 (0.001)

Source: Author's calculations based on Censo de Población y Vivienda, INEGI, 1990-2020.

Table 6 provides additional information concerning the mean first passage from one class to another. It requires 461 years for a city to progress from class C1 to class C2 and 578 years from class C4 to class C5. Moving from class 1 to class 5 theoretically takes more than 2000 years. Both upward and downward trends exhibit similar durations, indicating that urban dynamics in Mexico evolve at slow paces.

Table 6: Time of first passage of Mexican municipalities

Mp,ij	C1	C2	C3	C4	C5
C1	0.00	461.20	979.40	1,488.30	2,066.80
C2	800.80	0.00	518.10	1,027.00	1,605.50
C3	1,431.80	631.10	0.00	519.00	1,097.50
C4	1,862.20	1,061.10	494.00	0.00	578.50
C5	2,118.80	1,311.10	743.80	249.90	0.00

Source: Author's calculations based on Censo de Población y Vivienda, INEGI, 1990-2020.

Table 7 compares the initial 1990 distribution with the ergodic distribution, which emerges at the steady state. This occurs when any upward or downward movement of municipalities within the distribution ceases. While in the initial distribution, 69.3% of the Mexican municipalities were in C1, and only 0,29% in C5, in the ergodic state distribution, 36% of Mexico's municipalities appear in Class C1 and 30.2% in Class C5. The intermediate C2 and C3 classes almost disappear.

In the ergodic state, there is a notable concentration of municipalities in the extreme classes C1 and C5. This concentration arises from substantial urban growth in class 3 and 4 municipalities, which gradually catch up with the largest cities in class 5.

Table 7: Initial and ergodic distribution of Mexican municipalities

	C1	C2	C3	C4	C5
Initial State	0.693	0.170	0.064	0.044	0.029
Ergodic State	0.365	0.081	0.094	0.158	0.302

Source: Author's calculations based on Censo de Población y Vivienda, INEGI, 1990-2020.

The urban system in Mexico is expected to consist of large metropolitan areas which harbor most of the population and economic resources alongside numerous smaller municipalities. This dual process can be explained by the demographic trend of medium-sized cities. Most municipalities located on the immediate periphery of metropolitan areas should undergo sustained demographic growth, reinforcing their influence. Conversely, small towns may experience decreased attractiveness, reducing their importance within the urban hierarchy.

The various methods employed to study Mexico's urban growth allow us to characterize the country's urban system evolution. There is a noticeable deceleration in the demographical concentration process within the most significant metropolitan areas. Several medium-size cities experience substantial demographic growth and converge toward the population size of larger metropolitan areas. These areas have had the strongest economic growth over the last few years. Conversely, despite encountering high growth rates, many small municipalities remain within the class of the smaller city sizes. This suggests a dual convergence process for both large- and small-sized cities. Mexico's urban system appears to have reached the inflection point of the inverse U trend, where the growth rate of the largest metropolitan areas slows down, and urban growth begins to spread toward large, medium-sized cities. However, the demographic diffusion effect towards smaller cities has not yet started.

6. CONCLUSION

This paper examines the evolution of Mexico's urban system from 1990 to 2020, marked by accelerated urbanization, with 8 out of 10 inhabitants residing in cities by 2010. Population data from the Censo de Población y Vivienda, INEGI, spanning 1990-2020, along with various econometric and statistical tools, were employed to analyze the country's urban growth and hierarchies.

Mexico's urban dynamics reveal a gradual slowdown in demographic concentration within the largest metropolitan areas, juxtaposed with robust growth in medium- and large-sized cities. This shift shows a transition from a primatial urban system to a polycentric one. Over 50% of the population resides in cities boasting more than 250,000 inhabitants, up from less than 40% in 1990. This trend aligns with an urban growth pattern following an inverted U curve. Initially characterized by urban concentration, the subsequent phase involves demographic diffusion towards medium- and small-sized cities.

However, the diffusion of the population to small cities has yet to materialize. While small cities in Mexico exhibit notable growth rates, they tend to converge towards similar small sizes in contrast to their larger counterparts. This phenomenon underscores the emergence of a dual urban system in the long run, featuring both large metropolitan areas and small cities.

In the coming years, the restructuring of Mexico's urban system is expected to intensify. The findings from various econometric tests and non-parametric methods consistently indicate a convergence of urban sizes, mirroring the evolution of a demographic bell curve. This trend suggests a potential shift away from the congestion of metropolitan areas toward smaller towns (up to 100,000 inhabitants) and medium-sized towns (100,000 to 250,000 inhabitants). However, the distribution may remain entrenched at this dual level for an extended period before demographic diffusion occurs. To expedite this process, efficient regional policies are needed to stimulate investments and promote economic development in small-scale cities. Such policies could help unlock the growth potential of these towns and contribute to a more balanced and sustainable urban landscape in Mexico.

Further research on Mexico’s urban hierarchies is required. First, potential interactions among cities within the same metropolitan area or neighboring cities must be explored. Addressing spatial autocorrelation issues remains a challenge in urban growth models (Le Gallo & Chasco, 2008; Schaffar, 2009), and future studies should aim to incorporate and analyze these interactions.

Secondly, mapping cities' demographic growth could unveil regional macroeconomic disparities, potentially influencing shifts in urban hierarchies. In particular, beyond the de-concentration of economic activity in the capital, Mexico City, toward neighboring states, the evolution of the urban hierarchy must be considered alongside the formation of industrial corridors in neighboring states that connect the central region with the northeastern region of the country (see, for example, Flores et al., 2018 for the period 2004-2014), in a context of strong dependence of these regions on the U.S. economy. Investigating these disparities will provide valuable insights into the underlying dynamics driving urban development across different regions.

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La croissance urbaine au Mexique : d'une distribution primatiale à des dynamiques polycentriques

Résumé - Cet article examine la croissance et les hiérarchies urbaines au Mexique de 1990 à 2020. A partir des données du recensement historique de la population des zones urbaines publiées par l'Institut National de Statistique et de Géographie du Mexique (INEGI), divers outils statistiques et économétriques sont utilisés, notamment des tests de stationnarité en données de panel et des processus de Markov, afin d'éclairer les transformations du système urbain mexicain. Les résultats montrent que, malgré sa complexité, la dynamique urbaine du Mexique suit les tendances à long terme observées selon un modèle en U inversé. Le paysage urbain du pays connaît un processus de croissance reflétant les avancées technologiques et industrielles de son économie, avec les villes de taille moyenne jouant un rôle clé dans cette évolution.

Mots-clés

Croissance urbaine
Distribution rang-taille
Urbanisation
Taille des villes
Mexique