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Concentration, development and evolution of the urban system in Chile between 1885 and 2002

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Resumen

Durante el último siglo, Chile ha experimentado una transformación demográfica y económica que ha configurado a su organización espacial. Este artículo analiza la evolución de su sistema de ciudades entre 1885 y 2002. Se estiman los cambios experimentados por el coeficiente de Zipf así como la estabilidad de la jerarquía de centros urbanos a partir de información de los Censos de Población y Vivienda. Los resultados muestran una marcada tendencia hacia la conformación de un sistema de ciudades cada vez más asimétrico, hasta llegar a no cumplir la ley de Zipf en las dos últimas décadas. Al mismo tiempo, la jerarquía de ciudades ha tendido a consolidarse, con un claro predominio de las grandes ciudades existentes al principio del siglo XIX y mostrando cada vez menos variabilidad en la ciudades de rango inferior.

Palabras clave: Ley de Zipf, economía urbana, desarrollo.

Código JEL: R11, R12, O10.

Abstract

Over the last century, Chile has experienced a demographic and economic transformation that has shaped its economic geography. This article examines the evolution of the Chilean urban system between 1885 and 2002. We estimate changes in the Zipf coefficient and the stability of the hierarchy of urban centers based on information from the Population and Housing Censuses. The results show a marked trend towards the formation of an increasingly asymmetrical system of cities that does not satisfy Zipf's law in the last two decades. At the same time, the hierarchy of cities has tended to be more stable, with a clear dominance of large cities that existed at the end of the nineteenth century and an increasing reduction in the variability among low-ranking cities.

Key words: Zipf law, urban economics, development.

JEL classification: R11, R12, O10.

INTRODUCTION

Between 1885 and 2002, Chile experienced two major transformations. First, the urbanization rate increased from 42% to 86% of total population. Furthermore, the initial, agricultural economic structure changed into a service-oriented economy after a brief stage of industrialization. During this period, the system of cities became highly concentrated around the metropolitan area of Santiago, which grew from containing 7.66% of the urban population to over 30% of it. Chile is currently among the countries of the Americas with a high rate of primacy, which can become an obstacle to economic growth (Brülhart and Sbergami 2009; Henderson, 2000a; 2000b).

This article aims to analyze the evolution of the Chilean urban system between 1885 and 2002 based on information from the historical and recent Censuses. For this purpose, we estimate the degree of concentration of the urban system by means of the Zipf coefficient (Singer, 1936) and evaluate the changes in the hierarchy of cities.

Zipf's law poses an empirical regularity whereby the size distribution of cities within a country follows a Pareto distribution with a coefficient equal to 1. This implies that the population of a city within a system of cities is an inverse function of its rank within the system. In other words, the largest city of the system doubles the population of the second, triples the third, and so on. Several studies link the evolution of the Zipf coefficient with the stages of economic development of a country (Brakman et al., 1999; 2001; 2009; Parr, 1985). These authors identify three basic stages of development: a greater symmetry of the urban system in the initial stages of development, an increase of asymmetry during the processes of industrialization and

development of the countries and again, a greater symmetry of the system of cities at the post-industrialization stage.

The case of Chile is of interest for two main reasons. The first is that despite almost three decades of rapid economic growth, the country has maintained high levels of spatial concentration. The second reason relates to the period under review, because Chile has experienced the three stages of development mentioned above in a relatively short time compared to developed countries, which allows us to study how the country follows the hypothesis made in the literature on the relationship between development and the asymmetry of the urban system (Brakman et al., 1999; 2001; 2009; Parr, 1985).

This article has five sections. The first one describes Zipf's law and the changes in the hierarchy of cities related to the stages of economic development of a country; in the second section, the stages of economic development in Chile during the period of study are identified and described; the third section explains the data sources and the methodology used; the fourth section presents the results. Finally, the main conclusions are summarized.

THE RANK-SIZE LAW IN URBAN SYSTEMS AND ECONOMIC DEVELOPMENT

The empirical study of systems of cities and population ranks of urban agglomerations has a statistical regularity that has been studied since the early twentieth century (Gabaix and Ioannides, 2004). This regularity, known as Zipf's law, is based on the assumption that the relationship between the ranking (rank 1 for the largest city, rank 2 for the second one and so on) and the size of cities follows a Pareto distribution that conforms to the following expression:

$$R = AN^{-\alpha} \quad (0.1)$$

which is usually stated in its logarithmic¹ form as:

$$\log R = \log A - \alpha \log N \quad (1.2)$$

¹ In this work, $\log(\bullet)$ represents the natural logarithm.

where R is the rank of the city in the hierarchy of cities by size, N is the respective population (size) and A represents the size of the largest city of the system. Zipf's law states that the coefficient has a value equal to 1. This law implies a system of cities where the largest urban nucleus is double the size of the second and so on. Singer (1936) argues that the Zipf coefficient is a quantitative measure of the relative role of small and large human agglomerations. Unlike the primacy index, typically calculated as the ratio of the size of the n main cities over the total urban population, the Zipf coefficient provides information about the entire urban system and can be interpreted similarly to the Gini index: higher values of the Zipf index imply a more uniform distribution of city sizes, while lower values indicate a more concentrated distribution of population (Soo, 2007).

Numerous studies, both cross-sectional (Soo, 2005; Rosen and Resnick, 1980) and longitudinal (Black and Henderson, 2003; Dobkins and Ioannides, 1999; Parr, 1985), have estimated the fit of Zipf's law to the distribution of city size in several countries. The most common estimation technique of equation (1.2) is the use of ordinary least squares (OLS) (Nishiyama et al., 2008; Gabaix and Ibragimov, 2007). The results show that, in most countries, the coefficient is close to 1, although the value of the coefficient depends on the criteria by which cities are defined, as well as which sample was considered in each country (Brakman et al., 1999; 2001; 2009; Soo, 2005; Nitsch, 2005). As long as the dispersion of the Zipf coefficient is wide, Gabaix and Ioannides (2004) suggest that the main question from an empirical perspective is not whether Zipf's law is perfectly fulfilled, but to what extent the law is fulfilled, taking into account any errors. These authors suggest the range [0.8, 1.2] of the coefficient as a conservative criterion by which to judge whether the system of cities in a country conforms to Zipf's law.

There have been attempts to provide a theoretical basis for Zipf's law. Gan et al. (2006) claim the need to find an economic basis for Zipf's law because the law is a statistical artifact arising from a spurious regression. According to Xu and Harriss (2010), models based on stochastic processes have dominated the attempts to give substance to Zipf's law, either as the result of the multiplicative growth process based on the Gibrat's law (Córdoba, 2008; Gabaix, 1999; Simon, 1955) or as the stochastic result of innovation and local spillovers that are the basis for random growth models (Duranton, 2006; 2007). Because this study aims to use the Zipf coefficient as an indicator of spatial inequality, we will not address the causal analysis of the mechanism that generates the distribution of cities in Chile.

The analysis of the Zipf coefficient evolution is of particular interest due to the relationship between the process of urbanization and economic development (El-Shakhs, 1972). Parr (1985) used the Zipf coefficient to measure the degree of urban concentration in twelve countries across different time periods. Parr identifies patterns of evolution in the coefficient. As a country develops, the Zipf coefficient decreases initially and increases later, following a U-shaped pattern.

When the level of development is low, transport costs are high, and the available technology exhibits weak returns to scale. Consequently, the population is dispersed in the territory (Combes et al., 2008), which is a situation associated with a high Zipf coefficient. As a country develops and reduces transportation costs, the population and economic activity tends to concentrate to take advantage of both internal and external economies of scale (Fujita et al., 2001; Parr, 1985; Williamson, 1965). This concentration leads to a decrease in the value of the Zipf coefficient. At a certain critical level of development and transport costs, the benefits of agglomeration are lower than the costs due to diseconomies of agglomeration, such as vehicular congestion and rising housing prices. Following this tipping point, there comes a process of dispersion of both population and economic activity from the core to the periphery, which therefore further increases the value of the Zipf coefficient.

This point is also addressed by Brakman et al. (1999; 2001; 2009), who point out that the Zipf coefficient undergoes changes over time, which reflects changes in the economic geography of a country. These changes are caused by the structural and technological changes that characterize economic development. In his analysis of the Netherlands from 1600 and present, Brakman et al. (1999; 2001; 2009) consider three representative periods of economic development:

- Pre-industrialization, characterized by high transport costs, a reduced trade integration and the prevalence of the primary sector;
- Industrialization: characterized by lower transportation costs, greater trade integration and the move to an industrial economy with increasing returns to scale, leading to the agglomeration of activity and population; and

- Post-Industrialization: characterized by continued reduction in transport costs, decline of industrial production and emergence of diseconomies of agglomeration due to congestion in major urban centers.

According to these authors, the Zipf coefficient variations reflect the changes in the system of cities in each period. In particular, they show that during the first period, the Zipf coefficient is below 1, which implies a higher degree of symmetry.² The industrialization process favors the formation of large agglomerations and leads to a Zipf coefficient above 1, while in the post-industrial period, the coefficient falls below 1, implying greater symmetry in the urban system.

The Zipf coefficient shows the evolution of the urban system as a whole, but does not describe how the process of urbanization takes place or how the hierarchy of cities changes due to variation in degree of concentration in the urban system (Singer, 1936). It is reasonable to think that these changes obtain different characteristics as a country becomes urbanized and developed, given the path-dependent processes that characterize the formation of urban agglomerations (Martin and Sunley, 2006). When urbanization is starting, in the pre-industrialization phase, increasing returns to scale are weak and there are no large cities. It is therefore plausible to expect that urban development leads to more frequent changes in the hierarchy of cities. In the stage of industrialization, when returns to scale are high and urban development occurs through the expansion of the larger cities, changes in the urban hierarchy are probably less frequent. Finally, in the post-industrialization stage, there is a consolidation of all the cities that dominate the urban system, and the urbanization process is completed, which leads to greater stability in the urban hierarchy. In fact, dispersion processes occur, especially in cities that already exist, and hardly modify the hierarchy of the largest cities in the system.

THE ZIPF COEFFICIENT AND STAGES OF ECONOMIC DEVELOPMENT IN CHILE

Soo (2005) presents various estimates of the Zipf coefficient of Chile in 1999, and they all agree on values of approximately 0.8, which is the limit established by Gabaix and Ioannides (2004) that

² Brakman et al. use the specification $\log N = \log A - \alpha \log R$ proposed by Lotka (1925), whose interpretation of the Zipf coefficient is the opposite of the specification used in this article.

determines when a country follows Zipf's law. In turn, Brakman et al. (2001) estimate the Zipf coefficient of Chile using data from the United Nations and obtained a value of 0.77, which denotes a high asymmetry of the system. Given these results and the fact that Chile has grown over the last century from a primary to a service economy, the pertinent task becomes to describe the evolution of the Zipf coefficient and determine how it fits with the hypothesis proposed by Brakman et al. (1999; 2001; 2009) and Parr (1985).

When studying Chile, it is difficult to implement the same methods of identifying the stages of economic development proposed by Brakman et al. (1999; 2001; 2009) in their study of the evolution of the Zipf coefficient in the Netherlands because the changes in Chile have taken place at a much more accelerated pace. In the Netherlands and the rest of Europe, this process took nearly four centuries, while in Chile, it has taken place in barely one hundred years. For the purpose of this study, we identified the following stages with approximate boundaries due to the limited availability of information:

- Pre-industrialization (1885-1940): During this period, primary activities (agriculture and mining) accounted for over 20% of national productivity, reaching a peak in 1928 at 30%. From this year on, primary activities began a downward trend that continues today. Industrial activity has remained relatively constant at approximately 11% of national product, and the process of urbanization was relatively slow. Over the course of 55 years, the percentage of the total population living in cities grew from 42% to 53%. Finally, the development of roads was poor, increasing from 36,000 kilometers to 40,771 kilometers, of which only 1.3% was paved (Diaz and Wagner, 2010);
- Industrialization (1940-1972): During this period, there was a brief episode of industrial growth in Chile based on a strategy of import substitution industrialization (ISI). Manufacturing more than doubled its contribution to national product, from 12.3% to 25.1%, while primary activities fell to a 9.4% share of GDP. This process contributed to an accelerated growth in urban population over thirty years, from 53% to over 75% of the total. At the same time, there was a significant increase in road infrastructure. In 1972, there were 72,242 kilometers of roads, of which 11.8% was paved (Diaz and Wagner, 2010);

- **Post-Industrialization (1972-2002):** This period is characterized by the progressive reduction in the share of industrial output from 25.1% to 16.5% of the GDP and by the consolidation of a service economy. The process of urbanization ended, with 86.6% of the population living in urban environments, and there were increasing efforts to improve internal transportation, especially paved roads. In 2002, there were 79,520 kilometers of roads, of which almost 20% was paved (Diaz and Wagner, 2010).

Due to the significant transformation that Chile experienced both in terms of the size of its urban population and its productive structure, it is interesting to study both how the Zipf coefficient evolves as well as to what extent this process of urbanization is due to the expansion of existing cities versus the emergence of new cities. Therefore, in addition to analyzing the evolution of the Zipf coefficient, we study the stability of the urban hierarchy in Chile at each stage of development. The hypotheses raised in this work are:

Hypothesis 0: Chile fulfills Zipf's law according to the empirical criteria proposed by Gabaix and Ioannides (2004).

Hypothesis 1: There is a U relationship between the Zipf coefficient and the stages of development in Chile, as proposed by Brakman et al. (1999; 2001; 2009).

Hypothesis 2: The hierarchy of cities in Chile tends to increase in stability over the period of analysis.

DATA AND METHODOLOGY

DATA SOURCES AND UNITS OF ANALYSIS

Data for the estimation of Zipf's law and the stability of the system of cities in Chile come from the National Census of Population and Housing covering the period 1885-2002 Instituto Nacional de Estadísticas (INE) (1995; 1999; 2005).³ Such censuses were done approximately every ten years, which means there are twelve observations.

³ Data from 1875, the first Chilean Census, were not considered because it was only after the Pacific War (1879-1883) that Chile realized its current territorial borders.

A critical aspect of estimating the Zipf coefficient is the definition of the unit of analysis, the city, which determines the size of the sample used for each period and the size of urban centers. In this paper, a city will be any urban agglomeration over four thousand inhabitants. We do not consider the administrative definition of cities but use a definition based on urban agglomerations; this takes into account the interrelationships and interdependence among urban units due to their growth and sprawl. This involves considering the conurbations and absorptions that occurred during the period under review, some of which were already incorporated in the databases compiled by the INE, such as Gran Santiago.⁴ There were, however, three other major conurbations of Chile (Gran Concepción, Gran La Serena and Gran Valparaíso) that were not considered by the INE and that were added to the dataset. It is difficult to determine when these conurbations took place. These determinations would require detailed historical research, which is outside the scope of this article. Therefore, these three conurbations are computed from 1885, despite the fact that this procedure might lead to an overestimation in the level of asymmetry of the urban system during the first decades and consequently to lower values of the Zipf coefficient.

Table 1 shows the sample size for each period. As one can see, the sample size progressively increases due to the rapid urbanization process experienced by Chile.

TABLE 1. SAMPLE OF CITIES

Year	1885	1895	1907	1920	1930	1940	1952	1960	1970	1982	1992	2002
Sample Size	36	38	52	57	66	78	90	107	132	149	178	206

Source: Authors based on INE

METHODOLOGY

The most common method used in the literature to estimate the Zipf coefficient is OLS by means of the following equation:

$$\log R = \log A - \alpha \log N + u \quad (0.2)$$

Various works, not only in economics but also in physics, consider the coefficients based on OLS estimation to be biased due to the existence of positive autocorrelation of the errors and no minimum variances caused by the presence of heteroscedasticity in the errors (Gabaix and

⁴ For a complete list of conurbations and absorptions, see INE (1995, 2005).

Ibragimov, 2007; Nishiyama et al., 2008; Clauset et al., 2007; Konishi and Nishiyama, 2009). For this reason, other methodologies that have been proposed include both parametric (Terra, 2009; Gabaix and Ibragimov, 2007; Nishiyama et al., 2008) and nonparametric (Dobkins and Ioannides, 1999; Ioannides and Overman, 2000) calculations of the Zipf coefficient. In this paper, we apply parametric techniques because when samples are sectioned per period, the nonparametric estimates lose statistical robustness. Due to the small size of the sample during the first decades of the period under analysis, we opted to use the method proposed by Gabaix and Ibragimov (2007). These authors prove that the OLS coefficient is biased due to the presence of positive autocorrelation in the errors and correct it by means of the following expression:

$$\log\left(R - \frac{1}{2}\right) = \log A - \alpha_c \log N + u \quad (0.3)$$

Gabaix and Ibragimov (2007) prove that the estimation obtained by (1.4) minimizes the bias in the coefficient α estimated by (1.2) with small samples. In turn, these authors argue that the standard error, valid to α_c , is:

$$\sigma(\hat{\alpha}_c) = \hat{\alpha}_c \sqrt{\frac{2}{n}} \quad (0.4)$$

The study of Zipf's law has also focused on the identification of the theoretical distribution that best fits the system of cities. It is generally accepted that the Pareto distribution is appropriate (Anderson and Ge, 2005). However, Eeckhout (2004) indicates that, when the sample is not truncated, a lognormal distribution fits the size distribution of cities better, thereby questioning the validity of Zipf's law. Giesen et al. (2010) prove that a mixed distribution called Double Pareto Lognormal (DPL) best fits the data, using non-truncated samples from eight countries. The distribution DPL has a lognormal body, while its upper and lower tails follow a Pareto distribution. This reconciles the criticism of Eeckhout (2004, 2009) with the rest of the literature because the upper tail, where the main cities of the system are located, behaves like a Pareto distribution in both truncated and non-truncated samples. In any case, it is convenient to analyze whether the samples follow a Pareto distribution before the estimation of the Zipf coefficient. For this purpose,

Kolmogorov-Smirnov (KS) and Cramer-von Mises (CV) statistical tests are performed using the procedure described in Terra (2009) for each sample. These tests compare the cumulative probability functions (CDF) of the empirical data and the theoretical distribution in order to check the fit between the CDF and to determine whether the data behave similarly.

Finally, we analyze whether the observed changes in the Zipf coefficient gave rise to changes in the stability of the system of cities in each of the stages of analysis. As a first approximation, the size distribution of cities is calculated by means of a kernel estimation, which is performed using the Gaussian method with optimum "bandwidth" (window) as proposed by Silverman (1986). In order to control for changes in the size of the population mean, we normalize the size of the cities in each year as a ratio of the average size of each year. Furthermore, the evolution of the ranking of the top 30 cities in 1885 is analyzed to assess its variability in each period.

RESULTS

This section presents the results an analysis of the evolution of Chilean system of cities between 1885 and 2002. First, we estimate the Zipf coefficient to assess to what extent it can be argued that Chile's urban system followed Zipf's law during the twentieth century. Then, we study the evolution of those coefficients to estimate whether it conforms to the hypothesis proposed by Brakman et al. (1999; 2001; 2009). Finally, we analyze whether the changes observed in the Zipf coefficients have resulted in changes in the hierarchy of cities.

DOES CHILE FOLLOW ZIPF'S LAW?

Table 2 shows the estimated Zipf coefficient using equation (1.4) and, in parentheses, the standard deviation calculated by (1.5). According to the criteria established by Gabaix and Ioannides (2004), Chile fulfills Zipf's law, except in the last two decades, when the coefficient is at the proposed lower limit. The hypothesis of the coefficient being equal to -1 is not rejected within a 95% confidence interval, except in the last two periods. Table 3 reports the values of the KS D-test and

the CV w^2 -test with their corresponding p values calculated by a Monte Carlo simulation of the KS and CV test.⁵

TABLE 2. ZIPF COEFFICIENT (1907 – 2002)

	Zipf Coefficient
1885	-1,1072* (0,2610)
1895	-1,0212* (0,2343)
1907	-1,0448* (0,2049)
1920	-0,9927* (0,1859)
1930	-0,9926* (0,1728)
1940	-0,9890* (0,1584)
1952	-0,9605* (0,1432)
1960	-0,9183* (0,1255)
1970	-0,8767* (0,1079)
1982	-0,8316* (0,0963)
1992	-0,8238 (0,0873)
2002	-0,8251 (0,0811)

Source: Authors

* The coefficient is not statistically different from -1 with 95% confidence

⁵ Following Clauset et al. (2007), 2500 simulations were executed to obtain an accurate value of the p value to two digits.

TABLE 3. STATISTICS: D FROM KOLMOGOROV-SMIRNOV AND W2 FROM CRAMER-VON MISES WITH ASSOCIATED P VALUES

	D	p	w ²	P
1885	0,8480	0,25	0,1510	0,18
1895	0,8934	0,20	0,1343	0,21
1907	0,7237	0,49	0,0700	0,60
1920	0,5961	0,75	0,0750	0,56
1930	0,9916	0,16	0,1784	0,18
1940	0,7190	0,50	0,1100	0,35
1952	1,0029	0,18	0,2977	0,09
1960	1,3700	0,16	0,5047	0,15
1970	0,8595	0,33	0,2151	0,19
1982	1,1705	0,11	0,4629	0,07
1992	1,2765	0,18	0,5200	0,14
2002	1,6281	0,11	1,1388	0,09

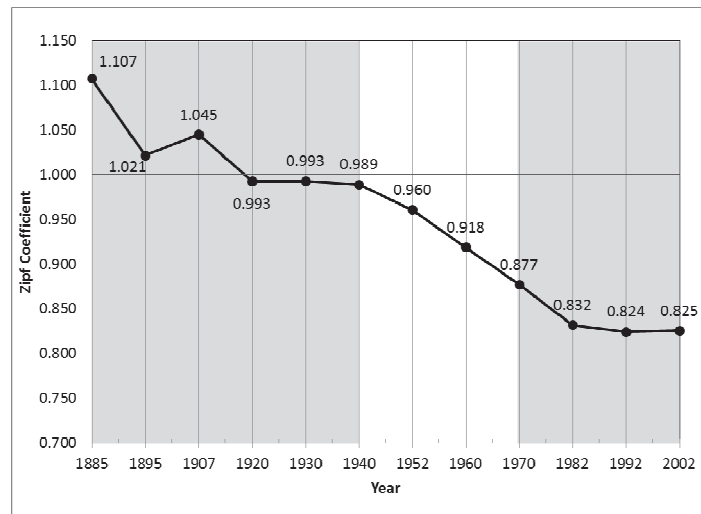
Source: Authors

According to the previous results, the hypothesis that the Chilean urban system follows a Pareto distribution with a coefficient equal to the Zipf coefficient reported in Table 2 cannot be rejected with 95% confidence. Therefore, cities in Chile follow a Pareto distribution for all periods, but Zipf's law does not hold for the last two periods. The coefficients for 1992 and 2002 are located slightly above the lower limit proposed by Gabaix and Ioannides (2004), denoting a high degree of concentration of the urban system. From another perspective, this result is consistent with other recent cross-section works that analyze the determinants of urban primacy and suggest that Chile is currently within the group of countries that have an excess of spatial concentration when their size and level of development are taken into account (Henderson, 2000b; Brülhart and Sbergami, 2009).

ZIPF COEFFICIENT EVOLUTION

The Zipf coefficient of Chile experienced a steady decline between 1907 and 2002 (Figure 1). This decline represents an increase in the asymmetry of the urban system during a period of profound demographic and economic transformation.

FIGURE 1. ZIPF COEFFICIENT EVOLUTION



Source: Authors

During the pre-industrialization stage, as expected, the Zipf coefficient was approximately one, but it was greater than one in the first two decades.⁶ In 1885, the Zipf coefficient was 1.107 and, in 1940, decreased to 0.989. Despite the fact that, in the Latin American context, Chile underwent a very early urbanization (42% of the population in 1885), the concentration of the urban population was low (Geisse, 1977). In 1907, Santiago contained 23.9% of the urban population and 10.29% of the total population. At the end of the period, the concentration increased, and Santiago represented 36.07% of the urban population and 18.95% of the total population. Gran Valparaíso, the second city of the system, represented 4.45% of the total population and 10.71% of the urban population in 1885. It increased to 5.81% of the total population and 11.06% of the urban population in 1940. The same behavior was witnessed in the third largest city, Gran Concepción, which increased in size from containing 1.24% of the total population to 2.56% and from containing 2.98% of the urban population to 4.79%.

Primary activities were dominant during this period, contributing 24.44% of GDP, while the existing manufacturing sector, mainly light industries, contributed an average of 11.25% to GDP. It is only after the adoption of ISI policies and the creation of the Production Development Corporation (CORFO) in 1939 that Chile consolidated its industrial sector (Carmagnani, 1998).

⁶ It is important to remember that the incorporation of the conurbations from the beginning of the period could imply an underestimation of the Zipf index.

Throughout the stage of industrialization, between 1940 and 1972, the Zipf coefficient was less than 1 and at the end of the period, approached the lower limit proposed by Gabaix and Ioannides (2004), with a value of 0.877, indicating an increase in the asymmetry of the urban system. Chilean industrialization arose under an ISI policy (Carmagnani, 1998) that promoted industrial concentration in the metropolitan area of Santiago (Geisse 1977; 1978; De Mattos, 1999) and the rapid growth of the city of Santiago (Miranda Muñoz, 1997; Geisse 1977; 1978). This city grew by 134.32% between 1940 and 1970 and increased from having 18.95% to having 23.49% of the total population of Chile. Gran Valparaíso held the second place in the hierarchy of the system and grew by 74% but decreased its share of the total population from 5.81% to 5.72% and from 11.06% to 7.61% of the urban population. The third city of the system, Gran Concepción, behaved similarly to Santiago and grew by 161%, increasing from having 4.75% of the total population to 4.95%, and from 2.52% to 3.72% of the urban population.

The Metropolitan Region (RM) reached an average participation of 50.4% in the industrial GDP between 1960 and 1972; it represented 36% of the total population, received 91.5% of internal migration and concentrated 60% of all the industrial jobs and 30% of the economically active population (Geisse, 1977: 27-28). This finding confirms the hypothesis of Parr (1985) and Brakman et al. (1999; 2001; 2009) on the reduction of the Zipf coefficient to less than 1 during periods of industrialization.

In contrast, the hypothesis that the value of the Zipf coefficient increases during the period of post-industrialization is not confirmed. On the contrary, between 1970 and 1992, the Zipf coefficient for Chile continued to decrease until it reached a minimum value of 0.824. Far from moving towards a less asymmetrical urban system, Chile consolidated an over-concentrated urban system that did not follow Zipf's law.

Chile abandoned ISI policies in 1975, when they adopted a set of neoliberal policies that changed its productive structure (De Mattos, 1999). The industrial sector reduced its share of GDP from 25.1% in 1972 to 16.1% in 2002. The decline in manufacturing was offset by an increase in the services sector to 53% of GDP in 2002. Despite a continued dependence on natural resources, the Chilean economy is currently oriented towards the production of services with a clear concentration in the Metropolitan Region, a situation that reinforces the concentration process started in the previous period (De Mattos, 1999). In 2002, the metropolitan area of Santiago

represented 66.7% of Trade, Restaurants and Hotels GDP, 78.9% of Financial and Firm Services, and 54.6% of Personal Services. Throughout this period, the primacy of Santiago in the urban system continued to increase, with up to 35.91% of the total population and 43.01% of the urban population. In contrast, the participation of Gran Valparaíso and Gran Concepción decreased to 6.37% and 5.28% of the urban population respectively and to 5.32% and 4.41% of the total population. Nevertheless, the participation of these three cities continues to rise. Only during the last decade has the increasing asymmetry of the Chilean urban system seem to have begun to reverse. It is not possible to say, however, whether this change marks a new trend because the time period for which data are available is still short.

STABILITY OF THE SYSTEM OF CITIES IN CHILE

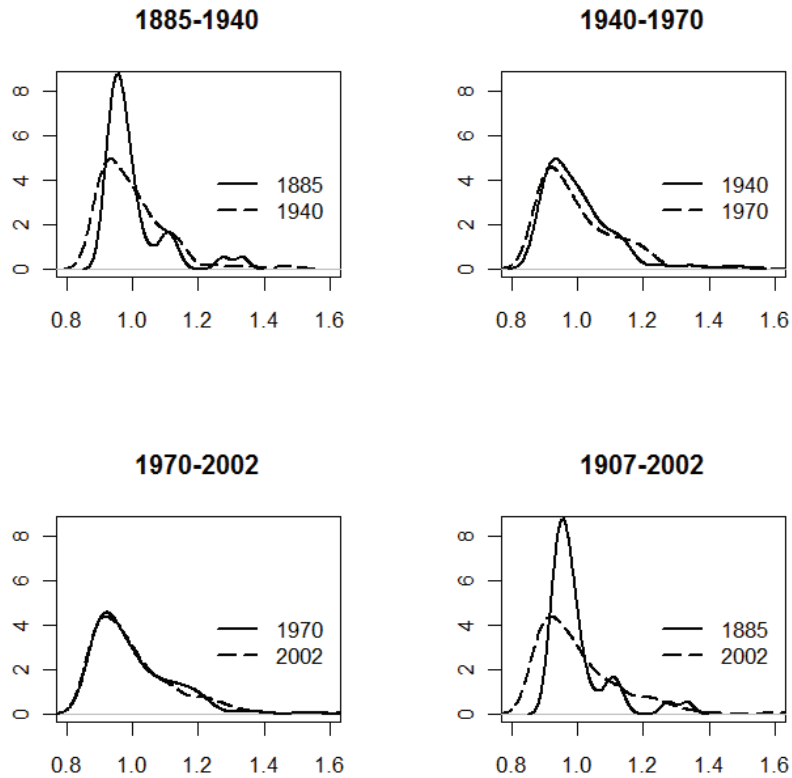
The growth of the asymmetry of the urban system in Chile between 1885 and 2002 took place in a period of rapid urbanization of the country, which could cause changes in the hierarchy of cities. To study in more detail how the changes in city rank have occurred, we used a kernel of the Chilean urban system for each of the stages proposed and one for the whole period. The value of 1 on the horizontal axis indicates the average size of cities relative to each year, while the vertical axis represents the density corresponding to each size of cities.

The kernels present distinct characteristics in each stage of development. More specifically, in the stages of pre-industrialization and industrialization, the size distribution of cities shows significant changes in the density and an increase in the standard deviation of the distribution. This trend is especially evident in the second period, which shows an increase in the density of cities above and below the average size, implying that the rate of growth of large cities is higher than the medium cities. This trend also indicates a concentration that matches the rapid growth in Santiago.

In contrast, during the period 1970-2002, the distributions are almost identical, which implies a marked stability of the Chilean urban hierarchy during these decades. Only minute changes are observed in the presence of cities below average. The only increase in concentration is seen in large cities, especially Santiago, because in this period, the urbanization process was already completed. This stability is observed in the progressive increase in the dispersion of the distribution, characterized by a small mass density gradually moving away from the mean of the

distribution, implying that the group of larger cities has diminished (lost mass), but the group's growth has been substantially higher than the average.

FIGURE 2. EMPIRICAL DISTRIBUTION OF CITY SIZES IN CHILE



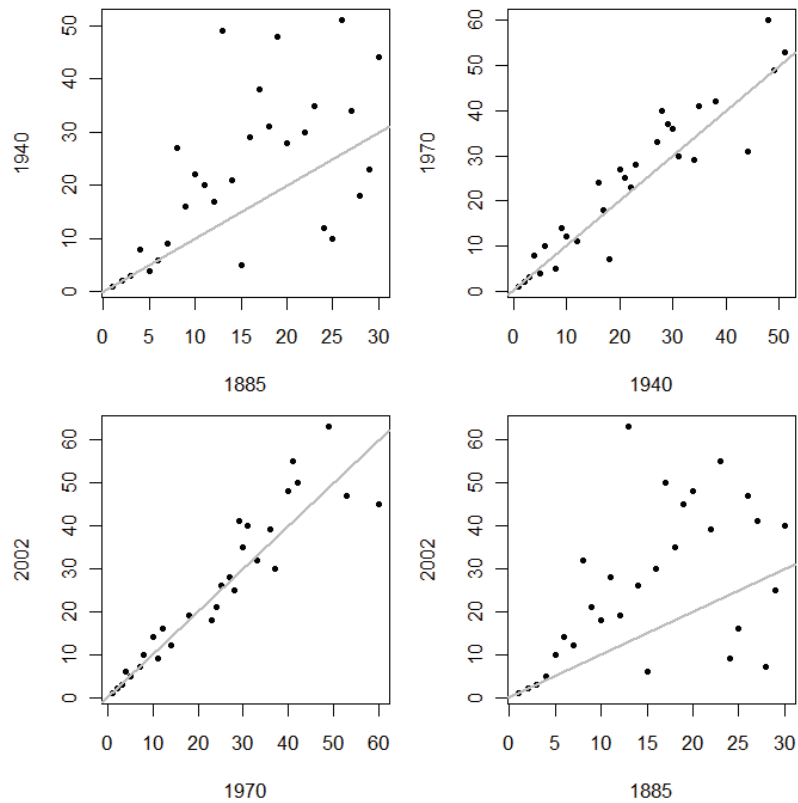
Source: Authors

Kernel analysis confirms the trend of the Zipf coefficients towards a greater asymmetry in the Chilean urban system but does not reflect the dynamics of change in the urban hierarchy that could be behind this process. A first approach at explaining these changes is made by means of comparing changes in the ranking of the top 30 cities in each stage since 1885 (Bosker et al., 2008).⁷ Figure 3 shows this comparison for the three stages as well as the whole period. A line angled at 45° is added to facilitate interpretation. If the city ranking remains unchanged, the point

⁷ Limache was removed in this analysis. This city was ranked 21st in 1885, but its population was below 4000 inhabitants between 1895 and 1940.

would coincide with that line. Points below the line indicate cities that have increased in rank while points above the line indicate cities that have gone down in rank.

FIGURE 3. CHANGES IN THE HIERARCHY OF THE TOP 30 CITIES IN 1907



Source: Authors

Significant differences are again observed between periods. In this respect, the progressive decrease in the dispersion of the points as time progresses is particularly notable, which implies the consolidation of the urban hierarchy. In the pre-industrial stage, changes in the urban hierarchy predominate, except in the largest cities of the system. In contrast, during the post-industrial stage, there are no great variations in the ranking.

The high stability of the main cities of the Chilean urban system is remarkable. In fact, the ten most populous cities in 1885, with the exception of San Felipe, remain in the top 21 (table 4). Larger and more frequent changes in the rankings occurred in smaller cities, as in Bosker et al. (2008) for Germany. Hypothesis 2 is confirmed by previous results, which show increasing stability

in the urban hierarchy and denote a clear process of path dependence because of the preeminence of major cities already established in the colonial era (Geisse, 1977; 1978). The biggest changes in the hierarchy of cities occur during the pre-industrialization stage, while in the post-industrialization stage, the hierarchy of the Chilean urban system presents no major changes.

TABLE 4. RANKING OF THE TOP 10 CITIES, 1885-2002

	1885	1895	1907	1920	1930	1940	1952	1960	1970	1982	1992	2002
Santiago	1	1	1	1	1	1	1	1	1	1	1	1
Gran Valparaíso	2	2	2	2	2	2	2	2	2	2	2	2
Gran Concepción	3	3	3	3	3	3	3	3	3	3	3	3
Gran La Serena	4	7	8	8	8	8	5	5	5	6	6	5
Talca	5	4	5	6	5	4	6	7	8	9	11	10
Chillan	6	6	7	7	7	6	8	9	10	10	12	14
Iquique	7	5	4	5	6	9	13	12	14	12	13	12
San Felipe	8	10	18	19	27	27	32	34	33	35	31	32
Curicó	9	9	9	14	14	16	17	21	24	23	22	21
Copiapó	10	13	20	23	29	22	24	22	23	20	19	18

Source: Authors

CONCLUSIONS

The Chilean urban system follows Zipf's law until 1982 but does not do so during the last two decades of the twentieth century, even though the urban system follows a Pareto distribution. The estimated coefficients have a clear downward trend. That is, from the late nineteenth and throughout the twentieth century, there has been a progressive increase in the asymmetry of the Chilean urban system. Despite a slight reduction in the last decade, the country currently does not fulfill Zipf's law, mainly because of the high concentration of population in the metropolitan area of Santiago.

The evolution of the Zipf coefficient follows the expected behavior in the first two stages of analysis. In the period from 1885 to 1940, a period of pre-industrialization, the urban system of Chile is characterized by a low concentration, with a Zipf coefficient close to 1. During the

industrialization stage, from 1940 to 1972, the results show a steady increase in the population concentration of the city of Santiago, favored by the ISI strategy, which resulted in a reduction of the Zipf coefficients to the minimum levels determined by Gabaix and Ioannides (2004). In the post-industrialization stage between 1972 and 2002, there has not yet been a drop in the asymmetry of the urban system, contrary to expectations. In contrast, Chile remains strongly concentrated. This situation is attenuated in the last decade under review, leaving some issues unresolved, such as the extent to which Chile has begun a process of urban dispersion and the determinants of the persistence of the asymmetry of the national urban system.

Despite the sustained increase in the asymmetry of the urban system, the stability of the hierarchy of cities shows major changes over the period from 1885 to 1970 as a result of the urbanization process that occurred in Chile during this period. In contrast, the density distribution tends to stabilize between 1970 and 2002. The growth of the main cities of the Chilean urban system throughout the period is markedly higher than the remainder of the cities. This result is consistent with the estimated Zipf coefficient, indicating the greater asymmetry of the urban system in Chile. Also significant is the dependence of the process of urbanization on the past, witnessed by the fact that the 10 most populous cities in 1885 remained within the top 21 cities, and no change occurred in the top three.

The results raise a number of avenues for further research. The first is related to the causal mechanism that explains the evolution of the Chilean urban system. Is Zipf's law in Chile a result of Gibrat's law, or is it related to another causal mechanism? The second line of work, related to the first, aims to deepen the understanding of the dynamics of the urban system using more sophisticated tools. Finally, the third line of research is oriented towards the analysis of the determinants of the changes in the Zipf coefficient and the growth of Chilean cities. This analysis would seek to identify the role of geographical, economic and institutional factors, in order to develop territorial policies to reduce the current excess of asymmetry in the urban system.

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