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Research Article

Urban–rural differentials in Latin American infant mortality

Jenny Garcia

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Jenny Garcia[1]

BACKGROUND
Infant mortality in Latin America has declined dramatically over the past six decades. The health transition in the region began in the main cities and has tended to proceed more rapidly in countries with higher levels of urbanization. Although urban–rural mortality differentials have consistently favoured cities, these gaps vary significantly across countries, subpopulations, and geographical areas.

OBJECTIVE
I aim to analyse, first, urban–rural infant mortality trends in seven Latin American countries during the period 1980 to 2010 and, second, whether or not an urban penalty has emerged in the region.

METHODS
I estimate IMR by distinguishing urban–rural areas and cities according to their size. Yearly rates are produced using a semi-parametric regression model. The model summarizes and predicts IMR trends based on: (1) indirect estimation methods used on 19 censuses conducted in 1990, 2000, and 2010; (2) vital statistics data; and (3) official estimates.

RESULTS
A convergence of urban–rural IMR is found in most of the countries due to a period of accelerated improvements in lagging subpopulations. The subpopulation differential increases in relative terms only for Brazil and Colombia.

CONCLUSION
There is no evidence that an urban penalty exists in Latin American infant mortality. By analysing cities according to their size, it is possible to see that improvements have followed the urbanization process, with not only urban areas but the main cities retaining the greatest advantages in infant mortality decline.

[1] Institut National d'Études Démographiques (INED) and Université Paris 1 Panthéon Sorbonne, Paris, France. Email: jenny.garcia@ined.fr.

CONTRIBUTION
I have demonstrated the benefits of analysing the urban–rural gap through a continuum approach (by grouping cities according to size) to track the path of urban advantages in Latin American infant mortality.

1. Introduction

It is undeniable that a significant reduction in infant mortality has occurred around the world over the last century, and evidence points to an even greater acceleration of this decline since 2000 in developing countries when compared with previous decades (Goli and Arokiasamy 2014). In Latin America, reductions in infant mortality began in the mid-20th century, in parallel to an accelerated urbanization process (Arriaga and Davis 1969; ECLAC 2010; Palloni, Pinto-Aguirre, and Beltran-Sanchez 2015; Schultz 1993). The infant mortality rate fell from 128.7 in 1950 to 22.5 in 2010 (ECLAC 2016b). Yet, despite all efforts, tremendous variations in mortality levels persist across subpopulations and geographical areas. When studying urban–rural mortality differentials during the 20th century, cities seems to be consistently favoured. This is because the evolution of living conditions in the region has been unequal across geographical lines (Curto 1993; Prata 1992). A high concentration of goods and services in cities – especially the capitals – has left rural areas behind (Jones and Carbridge 2010; Preston 1979; Schkolnik and Chackiel 1997). What is more, good housing, high incomes, and higher education have historically been more accessible to urban than to rural populations.

Even though decreasing infant mortality in Latin America is a well-studied topic, there are hardly any updated studies of long-term trends in the urban–rural differential (Sastry 2004). There is also a dearth of studies that examine whether the previous urban advantage continues in recent decades, considering the problems derived from uncontrolled urbanization and the increasing social inequalities within the urban space (UN-Habitat 2012). Due to a lack of accurate data on the majority of Latin American cities, intercountry mortality studies have barely taken into account potential differentials in the long-term trends of cities when their sizes are considered. In this sense, this study aims to analyse trends in urban–rural infant mortality during the period 1980 to 2010. In doing so, we hope to, first, find evidence of converging urban–rural infant mortality rates and, second, ascertain the existence of either an emergent urban penalty or a true catching-up process in rural areas.

One must keep in mind that the differences between urban and rural populations are usually seen in degree rather than in opposition. So a basic dichotomous division could be inadequate for urban–rural analysis (National Research Council 2003). Instead, a more suitable approach would capture the complex system of cities and their constant metropolization. In this sense, a term that may better describe and categorize human settlements in Latin America is "urbanness," a concept proposed by Dorelian et al. (2013) in which the definition of urban is viewed as a continuum rather than an "urban versus rural" dichotomy. I have taken both approaches to study seven Latin American countries: Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Venezuela. These countries display different levels of infant mortality rates and percentages of the urban population.

An increased understanding of urban–rural differences in Latin American mortality will contribute to two ongoing debates. The first one concerns the current role played by urbanization in the mortality transition in developing countries, while the second addresses how mortality differentials are impacted by environmental and community characteristics. To do so, we explore the role given to urban–rural differentials within the processes of mortality decline and health transition; second, we examine the contextual framework for understanding the relationship between urbanization and mortality in Latin America. A third section of this article is dedicated to explaining the methods applied to produce accurate infant mortality estimations, and in a fourth section, we display the results. Finally, we provide a brief conclusion that puts in perspective the convergence of urban–rural differentials in infant mortality in Latin America.

2. Background

2.1 Urban–rural differentials in mortality

Inequalities in mortality across subpopulations have been widely studied in recent years, with authors examining how they correlate with income, level of education, household conditions (Braveman and Gottlieb 2014; Howe et al. 2012; Pickett and Wilkinson 2015), and environmental and community characteristics (Montgomery and Hewett 2005; Pradhan, Sahn, and Younger 2003), among others. To that effect, the literature suggests a long-term association between urban–rural residence and infant mortality risk. A lively debate continues in regard to whether urban areas are "graveyards" or "healthy places" (Woods 2003). Studying 61 countries in the mid-20th century, the United Nations found a clear inverse association between levels of infant mortality and urbanization, irrespective of the degree of economic development (UN 1952). This relationship turned out not to be so straightforward when the study was revisited in 2001; results pointed out that in some developing countries, lower infant mortality rates were found in rural areas compared to urban ones rather than the other way around (UN 2001).

An urban advantage in health for some developing countries is traceable to the 19th century, when cities began providing social services to immigrant colonial settlers (Gould 1998). This advantage has remained in many countries because amenities, preventive programs, and medical facilities are concentrated in urban areas (Oris and Fariñas 2016). Urban advantage results from a combination of factors. First, absolute poverty and lack of services (both positively correlated with mortality) are mainly rural phenomena. Second, public health coverage is higher in urban than in rural areas. Third, the dissemination and uptake of public health interventions are likely to be more effective in urban settings due to proximity (Leon 2008). Analysing consecutive demographic and health surveys of 18 developing countries, Harpham et al. found strong evidence to indicate a clear advantage in urban mortality and health, even more, compelling evidence for advantageous children's height-to-weight ratios in respect to their rural counterparts (Harpham et al. 2003).

On the contrary, despite an initial urban advantage in mortality, rapid urbanization without economic development has led in the long term to an urban disadvantage in other developing countries. The unparalleled industrialization processes inherent to recent urbanizations have stagnated the capacity of societies to respond, and urbanization has represented an obstacle to development (Todaro and Stilkind 1981). Social inequality created by rural poverty, city-ward migration, and urban marginality has led to cities not only becoming impoverished slums filled with crime but also having worse living conditions than rural areas (Smith 1987). The negative consequences of these circumstances on infant mortality have been compared to the urban penalty of Europe's Victorian era (Reher 2001). In this context, differences in health outcomes are more important when based on social strata within and between urban areas than on area of residence: Slum residents exhibit notable inequalities in health relative to non-slum urban and even rural populations. This phenomenon has been documented in mortality studies on sub-Saharan countries (Günther and Harttgen 2012; Menashe-Oren and Stecklov 2018; Rossier et al. 2014; Rossier et al. 2016). The spatial proximity of urban residents and their dependence on public resources leave them more vulnerable to contagious diseases than rural inhabitants (Freudenberg, Galea, and Vlahov 2005; Harpham et al. 2003; Leon 2008).

Regardless of where (dis)advantages are located, a convergence process has been taking place in the urban–rural differentials within developing countries since the 1980s (Oris and Fariñas 2016). Countries such as China and India (where a previous urban penalty was found in adult mortality) have witnessed a considerable reduction in their urban–rural gaps over recent decades due to the rising prevalence of diseases associated with urban lifestyles in rural areas (Gu et al. 2002; Reddy et al. 2005; Wang et al.

2007). At the same time, breast-feeding and knowledge of oral rehydration therapy contribute to narrowing the urban advantage in Indian infant mortality (Saikia et al. 2013).

One way to analyse urban–rural gaps in infant mortality is to examine the context of the health transition. This framework informs a well-known debate on mortality research, namely whether differences in mortality decrease (converge) or increase (diverge) over the long term between countries or subpopulations (Vallin and Meslé 2004). Its main assumption is that the most favoured segments of the population benefit more rapidly from overall improvements than do the rest of the population. Consequently, the mortality reduction process occurs in successive stages of divergence/convergence among subpopulations. Favoured populations are pioneers in that they benefit from initial advantages that lagging (less favoured) populations will eventually catch up to.

When regional heterogeneity in mortality levels is related to urbanization in developing countries, the health transition generally appears first in urban locations (Tanner and Harpham 2014). Later, declining mortality spreads to the rest of the population in a spatial diffusion gradient (De Vries 1990). Mortality declines faster in urban areas because urban populations switch from being the most vulnerable to being the chief beneficiaries of advances in medicine and improvements in public hygiene (Fox 2012). However, in the long term, urban and rural differentials can be explained by the time paths of their changes within the same country or society (De Vries 1990). In consideration of this approach, I intend to answer the following questions: Is the health transition an explicative framework of the evolution of the urban–rural differential in infant mortality in Latin America? Is there a trend of convergence or divergence in the urban–rural infant mortality? Which subpopulations are the pioneers, holding the lowest levels of IMR during the period, and which ones lag? Are changes in the differential driven by a persistent urban advantage or an emerging urban penalty in infant mortality? To put these questions in perspective, the next section explores the relation between urbanization and infant mortality in Latin America.

2.2 Urbanization and mortality in Latin America

During the last century, Latin American countries experienced accelerated changes in mortality patterns: a fast decrease in mortality rates and a cause-of-death structure in which noncommunicable diseases took the place of infectious and parasitic diseases (Di Cessare 2011). In parallel to the decreasing mortality, a continuous and rapid urbanization process occurred; it became even more concentrated in the last half century (ECLAC 2005; Rodríguez and Martine 2008). In 1950, only 42% of the population lived in urban areas. By 2010, urban population was around 78% (ECLAC 2016b), with proportions closer to Europe (73%) than to Africa or Asia (around 45%). The amount and pace of urbanization is made evident in the constant metropolization of cities (Da Cunha and Rodríguez 2009). In 2010, more than 14% of the region's urban population lived in megacities, with more than five million inhabitants, while around 25% lived in cities whose populations ranged from 500,000 to fewer than five million inhabitants (UN-Habitat 2012).

The process of mortality decline has been characterized as reversible, discontinuous, and dissimilar to the patterns followed by developed countries (Palloni 1981). Even more, it is not closely related to economic and/or technological development. In Latin America, mortality rates declined much more rapidly than in developed economies (Arriaga 1970; Butterworth and Chance 1981). The impact of economic development on mortality reduction was relevant only until the early 20th century, when the decline was still incipient (Arriaga and Davis 1969). Following the 1930s, the decline began to be accentuated. The starting point was marked by substantial sanitary controls, mass vaccinations that eliminated disease vectors, the distribution of antibiotics, large-scale provision of potable water and sewage disposal, and an expanded health system (Preston 1976). Deaths caused by infectious and parasitic diseases were among the first to be reduced in all countries (Palloni and Pinto-Aguirre 2011).

Mortality decline started to be seen first in infant populations, decreasing around 25% per decennium during the 1950s and 1960s, from 128.7 deaths per 1,000 live births in 1950 to 92.7 in 1970. After the 1970s, infant mortality decline was faster. By 2000, the average rate had fallen to one-third of what it was in the 1970s, to 32 deaths per 1,000 live births (ECLAC 2016b). This decline has been related mostly to improvements in the population's quality of life and in private living standards, in areas such as nutrition, clothing, transportation, and access to medical care (Palloni and Pinto-Aguirre 2011). During the first decade of the 21st century, the infant mortality rate in Latin America decreased around 28%, to 22.5 deaths per 1,000 live births (ECLAC 2016b).

None of the changes in mortality patterns were observed to be linear stages or homogeneous processes in this region, which is characterized mainly by its heterogeneity. A first stage of divergence became apparent at the beginning of the decline, when Argentina, Uruguay, Cuba, and Chile pulled ahead of the other Latin American countries in their mortality declines (Palloni and Pinto-Aguirre 2011). This widened the range in which – up to this point – only high and stable levels of infant mortality could be found. Later, a convergence stage began, and all the other countries managed to catch up with those initial advantages (Schkolnik and Chackiel 1997). Improvements in infant mortality have occurred, despite the fact that, on the one hand, the region's economies continue to be volatile and see slow growth during certain periods while, on the other hand, the first decade of the 21st century experienced high levels of poverty that were similar to those of the early 1980s (ECLAC-UNICEF 2008).

Although, continuous improvement is the main characteristic of the infant mortality decline in the region, a sort of stagnation has been observed for some countries in recent times (Aguirre and Alejandro-Vela 2015; Ahmad, Lopez and Inoue 2000). Stagnation has been linked to the major disparities in access to health care services and opportunities among countries, geographic regions, and subpopulation groups. The most worrisome gaps in Latin American countries continue to be those related to the exclusion of rural, poorly educated, indigenous, and Afro-descendant populations (ECLAC 1996, 2014, 2016a). High infant mortality rates are perhaps the most characteristic demographic dimension of poverty for some subpopulations in the region (Chackie and Villa 1993).

These differentials in mortality emerged at the beginning of the urbanization process, when some areas developed more rapidly than others. For the period 1970–2000, urban infant mortality fell from 87 to 27 deaths per 1,000 live births, while its rural counterpart dropped from 101 to 38. This means that the urban–rural ratio increased from 1.2 to 1.4 (ECLAC 2016b). Throughout the 1970s and 1980s, the urban areas of Chile, Brazil, and Costa Rica were favoured by significant infant mortality differentials (Bähr and Wehrhahn 1993; Oya-Sawyer, Fernandez-Castilla, and Monte-Mor 1987; Sastry 1997). Equally, the urban infant mortality rate fell faster than its rural counterpart in Honduras, Paraguay, and Guatemala (Guzman 1989). Important urban–rural differentials among subpopulations are found even when countries have already achieved low mortality rates. In Panama and Peru, for example, the risk of dying before one's first birthday in 2000 was nearly three times higher in rural than in urban areas (ECLAC 2010; WHO 2009). In this sense, the Brazilian case turns out to be illustrative. Brazilian infant mortality rates declined in urban areas where industry prospered. Urbanization and industrialization caused environmental changes in terms of communication, transportation, and sanitation infrastructures, all of which favoured declines in mortality rates (Oya-Sawyer, Fernandez-Castilla, and Monte-Mor 1987). Over the long term, urban areas benefited more rapidly than the country as a whole.

In terms of allocating resources, the historical advantage of cities is even higher for the capital cities in Latin America (Baeninger 2002; Browning 1967; Redclift 1984), with per-capita education and health expenditure in the capital cities exceeding by far that in any other geographical areas (Chackie and Villa 1993; ECLAC 1994; Lipton 1977, 1984; Lloyd-Sherlock 2000). Access to piped water and toilet facilities in the home is important in preventing infectious diseases like diarrhoea, which is responsible for a large proportion of infant mortality, and such access has been substantially better in urban areas and even more so in the capital cities (Timæus and Lush 1995). Buenos

Aires, Santiago de Chile, Bogotá, Mexico City, and Lima have historically shown much better outcomes in infant mortality than the national averages of their respective countries (Jordan, Rehner, and Samaniego 2010). What is more, the health transition has advanced more rapidly in Latin American countries that have higher levels of urbanization (ECLAC 2014; Jaspers and Orellana 1994). However, the long-held belief that health indices such as stunting, infectious disease, and mortality are better in urban than in rural areas does not necessarily hold nowadays, particularly when considering the heterogeneity of the cities (Dufour and Piperata 2004). A variety of health problems has accompanied the uncontrolled urbanization and demographic growth of peripheral areas around some Latin American cities, and not all cities, even capitals, are showing the same mortality pattern.

Based on the current state of research on this topic, it is my general hypothesis that the patterns seen in the urban–rural differential in infant mortality in Latin America coincide with the health transition in which mortality decline in a given country occurs in consecutives cycles of convergence and divergence between its (dis)advantaged subpopulations. The urban areas, particular the main cities, are the pioneers in infant mortality reduction in Latin America; they remain the most advantaged subpopulations for all the period of analysis. Cycles of convergence and divergence are seen in urban–rural infant mortality in Latin America because periods of enlarged urban advantage are followed by the catching up of rural areas, not because of an emerging urban penalty in infant mortality.

3. Data and methods

3.1 Settings

Countries selected for this analysis display different levels of infant mortality rates and percentages of the urban population (See Table 1). Among them, there is not a unified threshold in use to divide urban from rural areas. Each country has adopted different criteria and limits to distinguish urban from rural areas. (In Box 1 we summarize countries' criteria on their census rounds.) I calculated annual IMR from 1980 to 2010 using both the traditional dichotomous urban–rural approach and that of a continuum. Embracing the idea of an urban–rural continuum and grouping cities by size are not new concepts. In studying migration and Latin American urbanization processes, several authors have stressed the importance of the city as a geographical unit for demographic analysis (Da Cunha and Rodríguez 2009; Rodríguez 2002). However, little progress has been made on mortality analysis. Recent studies have focused on comparing specific cities within the same country and across different countries (e.g., Cardona et al. 2008; Cabrera 2015), but broad intercountry comparisons on a large sample of cities are rare.

Table 1: Selected countries

	Infant mortality rate*	
% urban population**	≤ 25.6 per 1,000	> 25.6 per 1,000
> 80%	Chile, Venezuela	Brazil
60% to 80%	Colombia, Mexico	Ecuador, Peru

Source: Economic Commission for Latin America and the Caribbean (CELADE), Population Division of ECLAC, 2016 revision.
* Average Latin American IMR and percentage of urban population in the year 2000.
** According to the official urban definition adopted by each country.

Any definition of city size based on the number of inhabitants is imprecise because a categorical notion of size is relative to the country context. Cities with more than 500,000 inhabitants are considered medium-size in Brazil and Mexico, while in Ecuador this limit would separate the largest cities (Guayaquil and Quito) from the rest of the country. To illustrate the range between the most populated city and the most uninhabited areas, I used the ECLAC classification of Latin American cities in the year 2000 as follows: main and large cities (more than 500,000 inhabitants); medium-size and small cities (20,000 to 500,000 inhabitants); towns and dispersed settlements together (fewer than 20,000 inhabitants) (ECLAC 2005). This grouping is based on similarities found in terms of demographic behaviours during city urbanization processes and urban infrastructure and equipment deploy.

In the analysis of Latin American urbanization processes, cities with more than 500,000 inhabitants exhibit similar paths in terms of population growth, migration, and the flow from city centre to the periphery (ECLAC 2005). These cities experienced rapid growth due mostly to rural-to-urban migration before the period contemplated for this study, followed by slower population growth and consolidation of the previously expanded peripheries over recent decades. At the same time, the deconcentration policies of the largest cities have acted in favour of small cities (20,000 to 50,000 inhabitants) and medium-size cities (50,000 to 499,000 inhabitants), causing them to maintain quite similar demographic and living standard patterns over recent decades. These similarities are even more accentuated in the most populous countries, such as Brazil and Mexico (ECLAC 2005; UN-Habitat 2012). In recent decades, small and medium-size cities (where most of the urban populations live) have grown at higher rates than the largest cities (Da Cunha and Rodríguez 2009). These two groups tend to have infrastructures, equipment, and services that are similar to those offered by large cities while maintaining certain advantages in matters of governance and quality of life. However, they still lag behind in several dimensions, such as access to education, culture, recreation, high levels of technological diversification, and other benefits (Piña 2014; Rodríguez 2017). Finally, the 20,000-inhabitant threshold is conventionally used in comparative studies as a guarantor of proper urban conditions in Latin America. This is because, regardless of the urban definition adopted by each country, towns with fewer than 20,000 inhabitants are closer to rural areas than to urban centres that are over this limit (Rodríguez and Villa 1998).

Box 1: Urban definition in Latin America

Urban–rural distinction varies across countries, as national governments do not define "urban" equally. National statistical offices in Latin America compile data by distinguishing between urban and rural areas while considering a combination of criteria: political boundaries (political-administrative hierarchy), population size or density (thresholds vary among countries), economic function, landscape, number of urban facilities and services, and so on. The definitions adopted may also vary over time in a single country. Here, census definitions of urban and rural areas are shown.

Primary and secondary criteria for defining urban and rural

	Primary criteria		
Secondary criteria	population size	production activity	political-administrative hierarchy
population size	Venezuela, Mexico	Chile (1992, 2002)	Peru (1993, 2007)
landscape	Chile (1982)		
political-administrative hierarchy			Brazil, Ecuador, Colombia (1993, 2005)

Source: Rodriguez (2002).

Population size is the most used criterion to distinguish urban from rural areas, and it also varies among countries. Chile considers agglomerations of 2,000 inhabitants as a threshold for defining urban areas; Venezuela, Mexico, and Peru instead use 2,500 inhabitants (Rodríguez 2002).

The current number of cities by country in my sample is obviously related to the size of the national population. Thus, Brazil and Mexico have more cities while Ecuador has fewer (see Table 2). Once the cities have been grouped by size, the next important step is to identify the area/population belonging to a given city, because the size of a city's population is a function of how and where the physical boundaries are drawn. Table 2 proportionally distributes the population into three groups for the reference year 2000 to illustrate the weight of each group within the total population. Chile and Venezuela, the most urbanized countries in the sample, contain almost half of their populations (44% and 48%, respectively) in the main cities group, while Ecuador and Peru have 37% of their populations in this group. The city classification based on size was tracked over time and via different databases to guarantee comparability.

Table 2: Number of cities and percentage of population by group of cities in 2000s census round

Country		Groups of cities by size			
		Main and large > 500,000 inhab.	Small and medium-size 20,000–500,000 inhab.	Towns and dispersed < 20,000 inhab.	Total
Brazil	N° Cities	23	714	9501	10238
	% Population	40	30	30	100
Chile	N° Cities	3	64	455	522
	% Population	44	34	22	100
Colombia	N° Cities	8	133	7369	7510
	% Population	43	28	29	100
Ecuador	N° Cities	2	44	1103	1149
	% Population	37	37	26	100
Mexico	N° Cities	21	309	7089	7419
	% Population	40	31	29	100
Peru	N° Cities	3	95	1736	1834
	% Population	37	39	24	100
Venezuela	N° Cities	7	94	1039	1140
	% Population	48	36	16	100

Source: Population censuses, 2000s round, national statistical offices in each country.

Grouping cities by population size through time involves including changes in population size and in territorial boundaries, especially in view of various population dynamics. From a purely practical standpoint, I have the added reality of a lack of uniformity in coding units of geographical variables in the different databases over time. To face these constraints, I adopt an alternative solution by using the official minor administrative division (MIAD) for each city. These divisions are equivalent to counties in the United States and *départements* in France; both have local elected authorities as well as autonomous structures and budgets. In Table 3 are displayed the respective MIADs associated with each city-size group. The census rounds are used as an illustrative summary of how MIADs are followed throughout all the demographic databases under consideration in this research.

Table 3: Number of MIADs by group of cities and census rounds

Country	Main and large			Medium-size and small			Town and dispersed			Total		
Census	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Brazil	279	313	318	674	685	726	3,538	4,509	4,521	4,491	5,507	5,565
Chile	40	42	43	65	68	70	230	232	233	335	342	346
Colombia	32	32	32	129	130	130	870	952	961	1,031	1,114	1,123
Ecuador	9	11	11	38	40	40	124	169	173	171	220	224
Mexico*	82	83	83	299	301	301	2,024	2,059	2,072	2,405	2,443	2,456
Peru	4	4	4	57	59	59	127	132	133	188	195	196
Venezuela	40	46	46	98	104	104	142	185	185	280	335	335
Total	486	529	529	1,360	1,387	1,430	7,055	8,238	8,278	8,901	10,156	10,245

Source: Population censuses, 2000s round, national statistical offices in each country.
* Mexico includes counties and 15 of Mexico City's districts.

3.2 Indirect methods using census data

Producing acceptable historical IMRs in Latin America is one of the greatest challenges to this research. The most reliable data for tracking infant mortality is civil registration data. However, two major problems emerge in Latin America in this regard. First, despite huge improvements, coverage levels in vital statistics systems remain questionable in some countries (Palloni and Pinto-Aguirre 2011), especially for subnational estimates. Second, the urban–rural distinction does not always exist as a variable within the vital statistics data. One way to deal with these drawbacks is by applying indirect estimation methods to the summary birth histories (SBH) collected from censuses. With censuses, we can combine information about the number of children ever born and the number of dead children, and then link it to geographical units: neighbourhood, urban or rural area, city, county, and state, among others.

Model-based methods derived from Brass's initial proposal are commonly used to analyse SBH information (UN 1986). Here, Trussell's variant of the original Brass method (Moultrie et al. 2013) is applied to 19 censuses in the seven countries from the years 1990, 2000, and 2010. Trussell's variant of Brass's model-based method converts the proportions of children ever born and those dead according to their mother's age into a standard life table function by adjusting the model age patterns of fertility and mortality. The probability of dying depends on the mother's age and the proportion of children dead. Trussell's variant uses a regression approach that relies on the West model of the Coale–Demeny life tables, by which it calculates multipliers to transform proportions of children dead into cohort-specific probabilities of dying (Dorrington

2013). This method gives retrospective mortality information, which makes it possible to make estimates using SBH data on infant mortality levels for a period of about 15 years prior to data collection.

Indirect estimates derived from SBH tend to overestimate infant mortality when violations of underlying assumptions occur. Breaking the assumption of stable mortality usually leads to severe upward biases in estimates on women aged 15 to 19. This bias is associated with higher prevalence of mortality in young mothers. Additionally, breaking the assumption of stable fertility distorts parity ratios, which generate underestimates of exposure length (Hill 2013; Hill and Choi 2006; Hill et al. 2012). Analysis based on demographic micro-simulations shows that the Brass method has a tendency to overestimate mortality levels and produce declining rates if assumptions are violated. On average, the overestimate of IMR is 15% for Latin American countries (Verhulst 2016). To avoid distortions in the IMR levels, estimates obtained by the Brass method are used to determine the gaps among city groups and areas compared to national levels. Because the period of reference obtained via indirect estimation varies for each subpopulation, gaps between the group of cities and area of residency (related to national levels) are estimated in a linear regression model. Five independent models are produced for each country to obtain the ratio between each area/group of cities and the national IMR estimates. Then, each group's and area's ratio of IMR to its national estimate is applied to ECLAC's official country estimate for the years 1980 to 2010 (ECLAC 2016b). This action minimizes potential problems regarding overestimation, and it also allows us to represent the gaps among city groups and areas in each country.

3.3 Direct estimations in vital statistics

In addition to the estimates gained using indirect methods on census data, I took into account a set of official estimates made using different methods and databases (depending on their availability in each country): demographic and health surveys (DHS), registered births and deaths, and official national statistics estimates. This means I am considering all official estimations published by national statistics estimates for urban–rural IMRs corresponding to any point in time within the period of analysis. Additionally, direct IMR estimations are done using all available civil registry data for the same period, by urban or rural area (when possible) and by group of cities based on size. Table 4 summarizes by year the official estimates and survey IMR estimates taken, and the estimation carried out in the framework of this research via direct method on civil registry data.

Table 4: Data sources available

Year	Brazil	Chile	Colombia	Ecuador	Mexico	Peru	Venezuela
1985	S						
1986	S		S			S	
1987				S	S		
1990	S				R		
1991					R	S	
1992				R	R		
1993				R	R		
1994	R			R	R		
1995	R		S	R	R		
1996	R, S			R	R	S	
1997	R			R	R		
1998	R		R	R	R		
1999	R	O	R	R	R		
2000	R	O	R, S	R	R	S	R
2001	R	O	R	R	R		R
2002	R	R, O	R	R	R		R
2003	R	R, O	R	R	R	R	R
2004	R	R, O	R	R	R	R, S	R
2005	R	R, O	R, S	R	R	R, S	R
2006	R	R, O	R	R	R	R, O	R
2007	R	R, O	R	R	R	S	R
2008	R	R, O	R	R	R	R	R
2009	R	R, O	R	R	R	R, O, S	R
2010	R	R, O	R, S	R	R	R, S	R
2011	R	R, O	R		R	R, S	R
2012	R	R			R	R, S, O	
2013						R	
2015			S				

Data: R: civil registry; O: official estimates; S: survey.
Source: Own inventory from national statistical offices in each country.

Differences in the data source are not dependent on just their public availability but also on the geographical information attached to the vital event. Most vital statistics registration systems identify the decedent's or newborn's mother's place of residence according to only the political-administrative hierarchy, which is normally a state, a county, or occasionally a lower geographical level. They do not make publicly available the urban–rural distinction for the deceased's or newborn's mother's place of residence. The same situation occurs when identifying cities; it is possible that neither the mortality databases nor the birth estimates clearly identify the cities of residence.

In summary, urban/rural estimates rely mostly on census data, since the only countries with urban/rural references publicly available in their online vital statistics databases are Chile, Colombia, and Ecuador. The same situation occurs with IMR estimates during the 1980s, when it is difficult to find registered micro-data at the subnational level. In official estimates for Brazil, Colombia, and Peru, it is possible to find an urban/rural reference in the DHS results for some years. IMR estimates for groups of cities come from both indirect methods in census data and direct methods in vital statistics databases.

3.4 Infant mortality estimates

Once different estimations are gathered and produced via direct and indirect methods, I use a p-spline model to smooth and summarize them into annual IMR estimations by area and group of cities in each country. The model has a cubic base and uses maximum restricted likelihood (RELM) to produce annual infant mortality rates for all subpopulations. This method preserves possible changes in patterns while eliminating irregularities introduced into the series from combining several data sources and adjustment methods (Ahmad, Lopez, and Inoue 2000). The p-spline method uses the independent variable as the base for the regression, then a penalty based on differences between adjacent coefficients is introduced (Durbán, Lee, and Ugarte 2008). The function is expressed as a mixed model:

$$y_i = f(x_i) + \varepsilon_i,\ \ \varepsilon_i \sim N(0, \sigma_\varepsilon^2), \tag{1}$$

where y_i refers to the previous IMR estimate, x_i to the years, and ε_i to the error. The smoothing parameter λ was estimated using maximum restricted likelihood, and the number of nodes K are calculated as $K = \min(n/5, 20)$, in which n is the number of previous IMR estimates inserted into the model. Computations were done with the R package SemiPar, created by Wand (Ruppert, Wand, and Carroll 2009; Wand 2018). The assumptions of this model are the same as those that underlie mixed linear models: errors are independent, have constant variance, and are normally distributed. A statistical model is fitted, allowing annual estimations by predicting the years without data and by summarizing patterns when more than one input estimation is given.

3.5 Analysing convergence/divergence in IMR differentials

To test whether progress in infant mortality indicates convergence or divergence in urban–rural infant mortality rates (Gächter and Theurl 2011), I use scatter plots to examine reductions in IMRs; the change in IMR between 1980 and 2010 is plotted against the initial level (1980) for all subpopulations. In addition, I calculate and compare the relative convergence for both the beginning and end of the period.

Later, an σ-*convergence* is measured as the difference in the coefficient of variation (CV) between two different periods. CV is calculated by each country $CV_c = \frac{\sigma_{c,t}}{\mu_{c,t}}$, where $\sigma_{c,t}$ is the standard deviation of the IMRs in country *c* at time *t* and μ is the mean. CV signifies whether or not IMR distribution is becoming more equitable. Then, σ-*convergence* is CV_{t2}-CV_{t1}. If the result is negative, dispersion is decreasing.

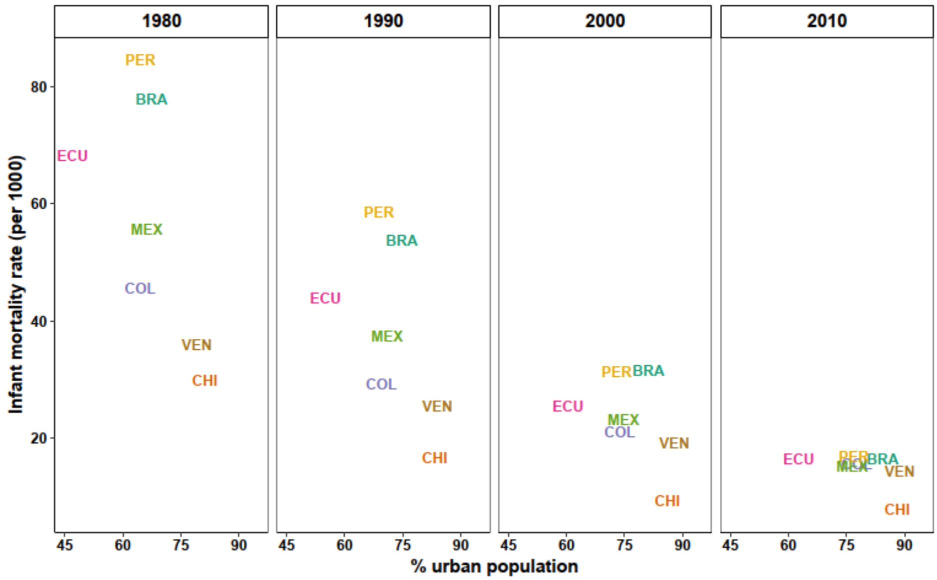
I present here the evolution of the average decennial reduction rates by each group of cities and area while dividing the period of analysis into three decades: 1980–1990, 1990–2000, and 2000–2010. My intention is to show whether there are changes in trends according to the health transition theory. This means successive stages of divergence/convergence among subpopulations that were first produced by early improvements in pioneer subpopulations, followed by lagging subpopulations catching up.

4. Results

4.1 Infant mortality and urbanization

By comparing Latin American IMR at national levels, it is possible to observe a huge reduction and convergence in all the selected countries (see Figure 1). At the same time, a continuous urbanization process accompanies IMR reduction. The most urbanized countries maintain the lowest IMRs. In fact, a statistically significant relationship is found between the percentage of urban population and IMR levels: for each 1% of urban population increase, there is a –0.7283 reduction in IMR when considering the progressive changes by calendar year. (See Appendix Table A-1.)

Figure 1: Infant mortality rates and percentage of urban population in 1980, 1990, 2000, and 2010



Source: ECLAC, 2016.

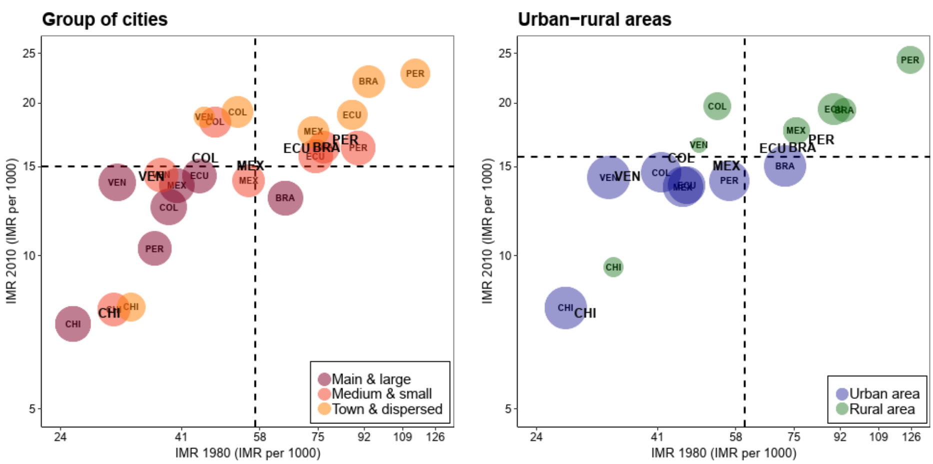
Decreases in IMR during the period did not occur at the same pace for all countries. This is due to slower reductions in countries that had previously achieved low levels of IMR, such as Chile and Venezuela. The biggest improvements are seen in Peru and Brazil, which had the highest IMRs in 1980 and then managed to rapidly catch up with Colombia and Mexico in the 1990s before reaching the same levels as Ecuador in 2010. Chile has the lowest IMR for the whole period but not the largest proportion of urban population at the end of the period; Venezuela reached the Chilean proportion of urban population in the first decade of the 21st century, doing so without achieving the same levels of IMR.

Among all countries during the whole period, Chile and Ecuador present contrasting cases at the national level. Compared to less urban Ecuador and its high IMR, Chile is urbanized and has low IMR. Broader differences are seen in terms of urbanization than in IMR levels at the end of the period, which means that a higher variance in IMR is observed at the beginning, when Peru and Brazil more than doubled Chilean and Venezuelan IMRs. Still, at different levels of urbanization, IMR is less dispersed in 2010 as a result of lagging countries catching up.

4.2 Group of cities and urban–rural estimates

IMRs for urban and rural areas and groups, according to size, are estimated using all publicly available sources in each country. (Annual estimates are displayed in Appendix Figure A-2, and the comparative trends of all countries' subpopulations are in Appendix Figure A-3.) A summary of IMR estimates at the beginning and end of the period is shown in Figure 2. The IMRs for 1980 are contrasted with those of 2010 in log scale for every group of cities (at left) and area (at right). The intention is to follow the relative position of the subpopulations at the beginning and end of the analysis. Which subpopulations are the pioneers, holding the lowest levels of IMR during the period, and which ones are lagging? The averages of the groups and areas are used separately as a graphical reference to describe their distributions. The bottom left quadrant gathers subpopulations with the best performance of the sample in both times, initial and final, versus the top right quadrant, which clusters the worst performance. Additionally, the percentage of total population gathered in each subpopulation at the end of the period is represented by the size of the bubbles. The IMRs by country are added as a reminder of the region's different levels.

Figure 2: Infant mortality by group of cities and areas, 1980 vs. 2010



Note: The dotted lines represent means for the years 1980 and 2010. The bubble sizes are adjusted to the proportion of the population gathered in each category.

IMR country differential is broadly seen in subpopulation distribution. Peruvian rural areas and the towns and dispersed settlements group have the highest IMRs and the worst performance in both the initial and final years, since Peru is the country with the highest IMR for the period of analysis. The exact contrary situation happens with the main and large group of cities and urban areas in Chile; they display the lowest IMRs, since considerably low IMRs are seen in Chile throughout the period of analysis. A very low starting point places all its subpopulations below the average for the two periods. However, country level is not in all cases overlapping the subpopulation distribution. With some exceptions, such as urban Brazil in 1980 and rural Chile, urban areas and the main and large cities group maintain the best performance at the beginning and end of the period under analysis, regardless of their respective national IMRs.

For all countries, urban areas and the main and large cities groups retain the lowest IMRs in both comparative years, while medium-size cities occupy an intermediate level between the main and large cities and the towns and dispersed settlements. There are almost no changes in the ranking sequence of the subpopulations during the period. Only the medium-size cities in Mexico, Venezuela, and Chile have IMR levels below the 1980 and 2010 averages. Two exceptions are seen in this regard. First, the Colombian medium-size cities group, which is closer to the towns and dispersed settlements group, is the only group whose position moves backwards. It begins at below average in 1980 and then presents higher-than-average levels in 2010. This broad difference among Colombian cities goes unnoticed when taking a dichotomous approach. The second exception is seen in Brazil's urban areas: this group improved its position from 1980 to 2010 and is below average by the end of the period. The main and large cities group drives the change in the hierarchy of Brazilian urban areas – the only group of cities experiencing the same upgrade. This group catches up with the IMR levels achieved by the Mexican and Colombian main and large cities groups before 1980, and it surpasses Venezuelan improvements up to 2010.

Urban-area IMRs in Brazil, Chile, Colombia, and Venezuela seem to be more influential on national IMR patterns when compared to other countries during the period of analysis. In contrast, the national IMRs of Ecuador, Mexico, and Peru swing from urban to rural subpopulation levels. This is without a doubt due to the weight of the population distribution among areas. Considering the groups of cities for all countries (except Colombia), IMRs at the national level are closer to the medium-size and small cities group than to any other group. However, gaps among the groups of cities vary. In Venezuela and Mexico, gaps are considerably smaller when comparing medium-size and small cities groups to main and large cities groups rather than to towns and dispersed settlements groups. In these cases, the urban and rural differential seems to be sufficiently understood in a dichotomous approach, because the urban and rural distinction overcomes the group of cities pattern if 'rural' is defined as fewer than 20,000 inhabitants.

For their part, Chilean and Colombian medium size and small cities groups are considerably more like the towns and dispersed settlements groups, which highlights that gaps between the main and large cities group and the rest of the country seem to be more important than the simple urban–rural distinction. In Brazil, Peru, and Ecuador, gaps among the three groups are larger and similar. Analysis using a continuum approach gives the idea of distinguishing three separate scenarios for these latter countries.

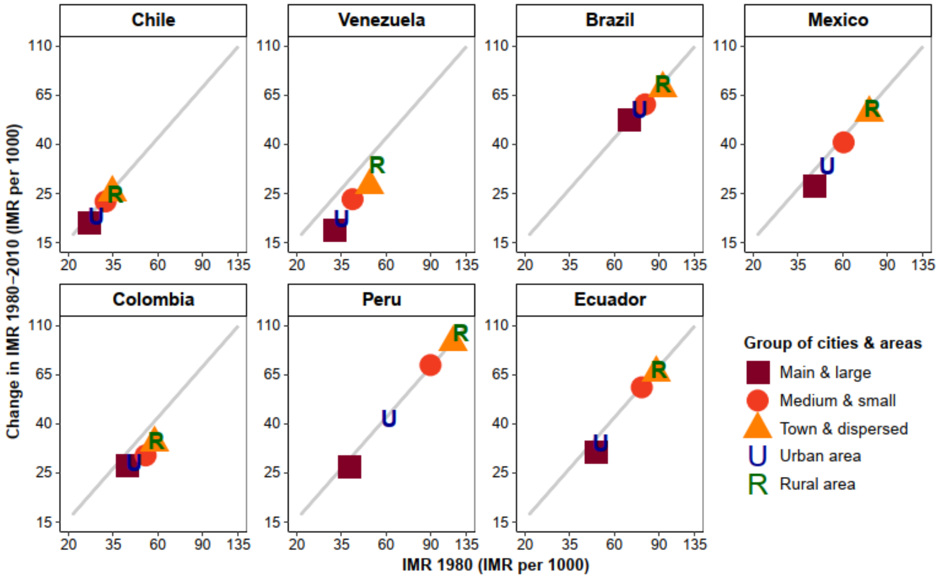
4.3 Group of cities and urban–rural gaps

Figure 3 provides, as scatter plots in log scale for each country, graphical evidence of the trend in changes among all subpopulations for the period 1980–2010 (Y-axis) compared to their 1980 levels (X-axis). Countries are ordered from high to low urbanization levels, and each subpopulation (group of cities or area) is represented by a different symbol. The idea is to keep track of increasing or decreasing urban–rural gaps in the period, especially if changes are due to the catching up of particular subpopulations or to the stagnation or slowing down of a previous pioneer population in the long term.

Absolute reductions in the differential are greater in those countries with wider gaps at the beginning of the period (Ecuador, Mexico, and Peru) and smaller in those with less of a differential, such as Chile and Venezuela. Brazil and Colombia seem to have dissimilar patterns, despite having high levels of IMR at the beginning of the period; their gaps were smaller than others holding the same levels. When relating urban and rural areas and cities by size, the overall decrease in IMR is greater among those subpopulations that are considered to be lagging at the beginning of the period in most countries. Beyond the hierarchy established by the country IMR and urbanization levels, there are major absolute advances in rural areas and the towns and dispersed settlements groups for all countries, yet improvements are not enough to surpass the initial advantages held by pioneer subpopulations.

Scrutinizing cities by size indicates that initial disparities between urban and rural areas were indeed due to the advantages held by the main and large cities and not to the superiority of the urban areas as a whole. For most of the countries, the main cities held the greatest advantages at the beginning of the period and gained less in absolute terms at the end. This is the situation for Mexico, Ecuador, Venezuela, and Peru. The medium-size and small cities in these countries are the biggest winners. They obtained almost as much improvement as the towns and dispersed settlements groups, but with slightly higher initial levels. The advantage of the medium-size and small cities remains hidden when taking a dichotomous approach, especially in countries such as Mexico, Ecuador, and Venezuela, where urban-area IMRs are more likely to reflect the lower gains of the main and large cities during the period.

Figure 3: IMR in 1980 vs. 1980–2010 gains in IMR, by group of cities and areas



Note: The grey line represents the limit at which change in IMR 1980–2010 is half of the initial level of IMR in 1980.

Contrasting initial IMRs and their gains, in absolute terms, points out that general improvements lead to convergence of subpopulations by the catching-up process among lagging subpopulations: rural areas, and towns and dispersed settlements. However, in relative terms, almost all subpopulations managed to halve their initial levels. To give an idea of the relative differential of IMRs among the subpopulations, urban–rural IMR ratios and main and large cities–towns and dispersed settlements IMR ratios for the years 1980 and 2010 are shown in Table 5.

Table 5: Urban–rural IMR ratios and main and large cities–towns and dispersed settlements IMR ratios, 1980 and 2010

Country	Urban–rural			Main cities–towns and dispersed settlements		
	1980	2010	Change (%)	1980	2010	Change (%)
Brazil	1.29	1.30	+0.8	1.44	1.69	+17.3
Chile	1.23	1.20	–2.4	1.29	1.07	–17.0
Colombia	1.28	1.35	+5.4	1.35	1.53	+13.3
Ecuador	1.91	1.41	–26.1	1.96	1.31	–33.1
Mexico	1.65	1.29	–21.8	1.83	1.27	–30.6
Peru	2.22	1.73	–22.0	3.16	2.20	–30.3
Venezuela	1.48	1.15	–22.2	1.46	1.34	–8.2

In relative terms, decreasing gaps are seen in all countries but Brazil and Colombia. Despite the fact that their greatest absolute improvements in IMR are obtained in rural areas and in the towns and dispersed settlements groups – subpopulations with the highest IMRs in 1980 – relative gains do not seem enough to represent convergence among their subpopulations. Only these two countries exhibit relative increments in the year 2010 compared to the 1980 ratios, both by area and by group of cities. Increasing gaps come from greater relative gains in the main and large cities groups in comparison with initial levels versus gains of the other groups and areas. On the contrary, the biggest reductions are seen in Ecuador, where gaps in 1980 were the second greatest.

Even when following the same trend, changes vary depending on the strategy of analysis, whether by area or group of cities. This difference is mostly due to the role played by the main and large cities group as pioneers within urban areas in 1980, especially in countries such as Mexico and Peru, where progress made by urban areas before 1980 was mostly driven by improvements recorded by the main and large cities group. It is just at the end of the period that these improvements expand to other urban and rural areas. In others cases, difference comes from a catching up of rural areas to the trend found in the towns and dispersed settlements group. This means that dispersed areas (with fewer than 2,000 inhabitants) recovered from their worse performance in declining mortality at the starting point; they levelled IMR in agglomerations in the range of 2,000 to 19,999 inhabitants. It this scenario we found Venezuela, where gap reduction in 2010 is substantially less when considering groups of cities than when considering areas.

4.4 Convergence as a process

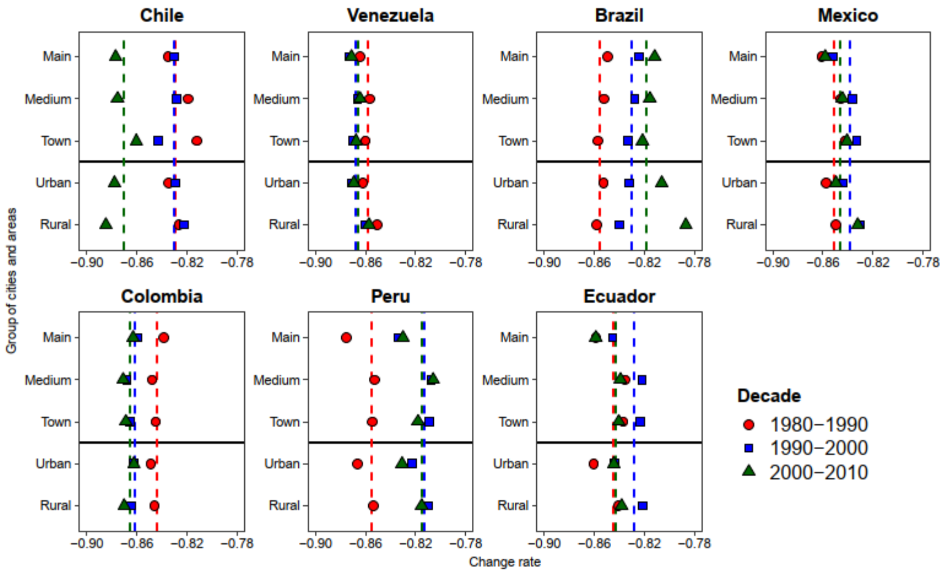
The σ-coefficients are calculated to evaluate the general evolution of the dispersion in IMR for the period. To track the process in detail, Table 6 exhibits the total and decennial coefficient of variation and changes in the σ-coefficient. A negative value of σ-coefficient is indicative of decreasing differential or convergence, while a positive value points out divergence among subpopulations. Results of the entire 1980–2010 period confirm the scatter plots (that is, the predominance of convergence over the whole period), namely as a result of reductions in the gaps among subpopulations in Ecuador, Mexico, Peru, and Venezuela, while Colombia and Brazil experience increasing dispersion and divergence. Compared with Colombia, the Brazilian differential increases just up to 2000. Chile presents once again an atypical pattern, with two cycles of increases and decreases in the gap. Ecuador and Mexico are the countries with the biggest reductions in differentials over the whole period: –0.14 and –0.13, respectively.

Table 6: Coefficient of variation (CV) and changes in the σ-coefficient, 1980–2010

Country	Coefficient of variation				σ-coefficient			
	1980	1990	2000	2010	1980–2010	1980–1990	1990–2000	2000–2010
Brazil	0.15	0.17	0.2	0.19	0.04	0.02	0.03	–0.01
Chile	0.11	0.08	0.09	0.09	–0.02	–0.03	0.01	0.00
Colombia	0.13	0.13	0.15	0.17	0.04	0.00	0.02	0.02
Ecuador	0.28	0.23	0.18	0.14	–0.14	–0.05	–0.05	–0.04
Mexico	0.25	0.22	0.17	0.12	–0.13	–0.03	–0.05	–0.05
Peru	0.4	0.36	0.33	0.3	–0.10	–0.04	–0.03	–0.03
Venezuela	0.19	0.16	0.14	0.12	–0.07	–0.03	–0.02	–0.02

Changes in the average rate of IMR reduction in each subpopulation are displayed in Figure 4 by decade and country. My intention is to trail the progressive changes in the subpopulations, as these changes lead to the decline in IMR, as well as to see which populations are responsible for changes in the coefficient of variation. In Figure 4, I display the average annual rate of change in IMR by decade and subpopulation. Each colour, in points (average reduction IMR by each subpopulation) and in dashed lines (average reduction in IMR in the country), represents changes by decade. The average annual rate of change in 1980–1990 is in red; 1990–2000 is in blue; 2000–2010 is in green. Because I am analysing scenarios of overall declining mortality, changes are negative, representing reductions. The more skewed to the left is the average, the larger the reduction in IMR for the decade.

Figure 4: Average annual rate of change in infant mortality by subpopulation and country in 1980–1990, 1990–2000, and 2000–2010



During the 1980–1990 decade in all countries – except for Brazil and Colombia – the biggest reductions in IMR occur in the main and large cities groups. In Mexico, Peru, and Ecuador, this pattern continues up until the end of the period. The urban–rural IMR convergence arrives because, inside urban areas, the medium-size and small cities groups decrease more slowly, which counteracts the faster decline of the main and large cities groups, thus making urban areas in total slow enough for rural IMR to catch up. These three countries maintain similar patterns in terms of average changes in their subpopulations over time.

Peru and Ecuador, with higher primacy of their capital cities and low numbers of larger cities (one large non-capital city in Ecuador and two large non-capital cities in Peru), exhibit even broader differentials than Mexico among their main and large cities groups and medium-size and small cities groups. This pattern highlights the importance of IMR reduction in the capital city relative to the rest of the country. Brazilian and Colombian urban areas show an inverted situation, and it is during the 2000–2010 decade that they begin to show faster declines in IMR. In Brazil, all urban areas improve in comparison with rural ones, but the medium-size cities, small cities, and towns benefit most from faster IMR reduction.

The Chilean average annual rate of reduction in infant mortality is the trend that is most consistent with the health transition. The first decade under analysis has greater IMR reduction in the main and large cities group, followed by the average rate of change catching up in the medium-size and small cities group before, finally, an even faster decline in the towns and dispersed settlements group during the 1990–2000 decade. Later, a greater decrease occurs once again in the main, large, medium-size, and small cities groups.

When comparing groups of cities and areas, it is possible to see three distinct trends. First, in Peru, Colombia, and Ecuador, 1980–1990 Brazil, and 1990–2000 Mexico, average changes in towns and rural areas are comparable to average changes in rural areas alone. This indicates that using the 20,000-inhabitant limit for dividing urban and rural works when analysing the rate of IMR reduction in these countries. Second, the average IMR reductions in Chile (2000–2010 and 1980–1990), Brazil (1990–2000), and Mexico (1980–1990) speak of faster improvements in properly rural areas (less than 2,000 inhabitants) than in towns (2,000 to 19,999 inhabitants). Third, Venezuela, Chile (1990–2000), Brazil (2000–2010), and Mexico (2000–2010) show faster declines in towns compared with properly rural areas. This variability in the countries could be due to a diversification process in the city systems as a result of policies promoting deconcentration of the larger cities.

5. Discussion

In this paper, I briefly reviewed four issues. The first concerns the well-documented relationship between urbanization and mortality decline in Latin America, in which the decline in mortality tends to proceed more rapidly in countries with higher levels of urbanization and the health transition takes place first in urban areas, the pioneer subpopulation. By looking closely at a sample of countries that are representative of different levels of urbanization, it is possible to say that the analysis period of this research corresponds to the second part of the first cycle of divergence/convergence in mortality, which itself is related to a homogeneous post-transition phase reappearing after overcoming death due to infectious diseases (Oeppen 1999).

Second, I evaluated the convergence/divergence in urban–rural IMR among countries over the period 1980–2010. National differences are recognizable when studying IMR at subpopulation levels, so all Chilean subpopulations have lower levels of IMR than Peruvians do. Still, the similarity of the gaps introduced by the urbanization process in all countries is undeniable. Here we can see how lines can be geographically drawn to distinguish disadvantaged from advantaged subpopulations in terms of their places of residence. Main and large cities in Latin America maintain the best performance in declining infant mortality regardless of their respective national levels. Concerning the historical urban advantage, convergence in urban–rural IMR is ongoing for most of the countries in absolute and relative terms. Two exceptions are Brazil and Colombia, which break the pattern by exhibiting increases in urban–rural gaps.

The exceptional behaviour of Brazil may be due to the fact that until the 1950s, mortality was lower in Brazilian rural areas than in urban ones (Carvalho and Wood 1978); and during the 1960s, the lowest income groups in rural areas had lower mortality than their urban counterparts (Sawyer and Soares 1983). The concentrated and controlled pattern of industrial growth turned Brazilian cities into centres of wealth and poverty at the same time (Oya-Sawyer et al. 1987). What is more, during the 1970s – just before the period of analysis – health services in urban areas were severely overwhelmed (Sastry 2004). All these aspects had a negative effect on declining urban infant mortality in the largest Brazilian cities, and they delayed progress compared with other urban areas in Latin America during the same period. It is during the decades considered in this research that the main and large cities and urban areas in Brazil accelerate their decline in IMR. In this sense, divergence of the Brazilian urban–rural infant mortality comes from the faster-declining rates in large cities. Similar result have been found by other studies of urban–rural IMR in Brazil; they showed that the faster reduction in urban areas was even in all Brazilian regions and was superior to that recorded by rural areas in the period 1975–1990 (IBGE 1999; Sastry 1997).

In Colombia's case, armed conflict has historically been concentrated in rural areas and towns. Conflict has not enabled a more rapid decline in Colombian IMR (Urdinola 2004) and has hampered improvements in rural areas and dispersed settlements. In fact, if there had not been any type of armed activity between 1990 and 2002, around 14% of child deaths could have been prevented (Torres and Diaz 2005) and the improvements in the less urban subpopulations might have been enough to catch up with the urban ones.

The path from a high infant mortality regime to low infant mortality in Latin America passes by cyclical patterns of catching up and lagging behind over time. Analysing IMR reduction by decades reinforces the idea of consecutive cycles of progress, represented by faster improvements in pioneer subpopulations (urban areas and main and large cities) and delayed improvements in those lagging behind (rural areas and dispersed settlements), as stipulated by the health transition (Vallin and Meslé 2004). Chile provides us with the clearest example in this regard. Infant mortality declines first in main and large cities because they remain the most advantaged subpopulation throughout the rapid urbanization process. This initial decline leads to greater absolute and relative differentiation between the larger cities and the rest of the country. Later on, lagging urban medium-size and small cities catch up the initial advantage in a second stage, without adding major changes in the dichotomous urban–rural differential. A third stage implies declining IMR in rural areas at even greater rate than in the urban ones. This catching-up process has led to a faster reduction of the absolute differences in comparison to the relative ones. In relative terms, the reduction of differentials for the entire period is not more than one-quarter of its initial value under the dichotomous approach; neither is it more than one-third under the continuous approach.

Third, regarding whether an urban penalty exists, the results presented in this study tell a consistent story about what has been found in national variation levels: Urban areas, especially the main cities, are the persistently advantaged populations and consequently are pioneers in infant mortality decline. In 1967 Browning wrote that the superiority of urban areas over rural areas was not likely to be considerably reduced during the coming decades in Latin American countries (Browning 1967). It seems she was not wrong. A long tradition of highly developed urbanism has led to the urban sector dominating the rural areas. Once mortality is characterized among the disparities across the rural–urban continuum (for example, by considering different levels of urbanization), it is possible to see how the main cities in most of the countries can boast of trends that are completely distinct from the rest of the territory. In this regard, it is worth bearing in mind that the process of urbanization in Latin America is characterized by constant metropolization: “One in three Latin Americans currently lives in a city of one million or more inhabitants” (Da Cunha and Rodríguez 2009). Chile, the country in our sample with the lowest infant mortality level, is not only the most urbanized but is also the one with the highest levels of metropolization and main-city primacy.

Some studies have shown that the urban advantage may rely on the composition of the population. An analysis of the under-5 population in the Brazilian state of Sao Paulo from 1970 to 1991 found higher mortality in urban areas than in rural ones when the results were adjusted for household wealth (Sastry 2004). Certainly, Sao Paulo has an atypical history of rapid development, industrialization, immigration, and urbanization in comparison with other Brazilian states or even other regions in Latin America, which is why it is perhaps not the most pertinent example for a generalization. However, what could be applied to all Latin America countries is that large cities concentrate most of the wealth in the region. Consequently, an advantage of urban areas may be the higher concentration of non-poor populations in larger cities rather than the setting itself. In summary, there is no evidence to support the existence of an urban penalty in Latin American infant mortality. In fact, wealth in the region continues to be very concentrated in a small number of urban centres: Only 40 major cities in Latin America generate approximately 30% of regional GDP (UN-Habitat 2012). In this sense, future research should check the extent to which national infant mortality trends over recent decades are driven by compositional changes in urban–rural populations.

The historically inferior living conditions in rural areas are one factor that explains the rural disadvantage (Rodríguez and Villa 1998). This is clear when examining the average outcomes in living standards, education, health, and the general welfare of the population. Studies on poverty show that during the first decade of the 21st century, around 53% of the rural population lived in poverty (ECLAC 2012). The number of people living below the poverty line was around 25 percentage points greater in rural areas than in urban areas (Montero and Garcia 2017). The rural poverty associated with peasant family agriculture and indigenous settlements merits being called persistent poverty, because it has been perpetuated over the years in the absence of upward mobility processes in most Latin American countries (Ramirez et al. 2009; Cuervo 2017). This is related to the relative absence of the state in remote areas (Jones and Carbridge 2010). On the contrary, urban poverty – which is represented by precarious work conditions and self-built housing – is simultaneously beneficiary of a comparatively better investment in schooling and health care.

The fourth issue concerns the pertinence of the scale of territorial division in urban–rural analysis. There are vast numbers of studies highlighting the positive relationship between urbanization and development in Latin America. However, the gradient in the urban spectrum is lost when applying a dichotomous approach. Even when IMR holds a persistent urban advantage, group-of-cities gaps vary among countries. In Mexico and Venezuela, the urban/rural dichotomous approach could be sufficient for describing IMR differences if the threshold to distinguish urban from rural is set at 20,000 inhabitants. This is because IMRs of large, intermediate-size, and small cities are closer to one another and are clearly distinct from those of towns and rural areas. In these cases, the urban–rural distinction overcomes group-of-cities patterns. In the rest of the countries, the continuum approach seems to provide a better framework for explaining IMR patterns. In the Chilean and Colombian cases, the gaps between the main and large cities group and the rest of the country are more important than the simple urban–rural distinction; while in Brazil, Peru, and Ecuador, gaps among the three groups are largely similar, giving us an idea of three separate settings in living standards. In general, the IMR differences in subpopulations do not exhibit a monotonic pattern between dispersed land and metropolises. In most Latin American countries, changes in economic policies aimed toward deconcentrating the largest cities have doubtlessly favoured intermediate-size and small cities in general, making them economically competitive. However, they still lag behind in several dimensions (Lipton 1984; Rodríguez 2017; ECLAC 2012). Even when other issues may also play a role in the reduction of IMR in each country, accurately characterizing disparities across the rural–urban continuum constitutes a key element for understanding the differentials that exist, and how the expansion of services and public goods in all countries has changed the dichotomist distinction between urban and rural areas (Cohen 2006).

6. Conclusions

Concentrating some goods and services in large cities seems to consistently result in resources being used suitably and efficiently for infant mortality decline. Accordingly, the urban advantage in infant mortality in Latin America can be viewed as an outcome of resource reallocation and livelihood strategies, applied by countries reacting to rapid population growth and urban concentration. So the urban advantage in mortality is persistent in the region. The process of urbanization in Latin America has been continuous and rapid over the last half century, even during periods of full-blown macroeconomic, political, and institutional instability. It is during these periods that the privilege given to the main cities at the macro level plays a key role for understanding the urban–rural differential in mortality decline. Although crisis and instability have made it difficult for some countries to stop the negative effects introduced by rapid urbanization, large cities show in all scenarios, of low or high infant mortality at the national level, much better outcomes than the rest of their respective countries.

7. Acknowledgments

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Appendix

Table A-1: Linear regression model of urbanization and infant mortality

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
Model 1: lm (formula = IMR ~Urban population)				
(Intercept)	126.8678	22.3831	5.668	5.82e–06***
% Urban population	–1.2702	0.3002	–4.231	0.000255***
Residual standard error: 16.3 on 26 degrees of freedom				
Multiple R-squared: 0.4078, adjusted R-squared: 0.385				
F-statistic: 17.9 on 1 and 26 DF, p-value: 0.0002554				
Model 2: lm (formula = IMR ~Urban population + Year)				
(Intercept)	2315.4482	431.9782	5.360	1.47e–05***
% Urban population	–0.7283	0.2401	–3.033	0.00557**
Residual standard error: 11.67 on 25 degrees of freedom				
Multiple R-squared: 0.708, adjusted R-squared: 0.6846				
F-statistic: 30.31 on 2 and 25 DF, p-value: 2.077e–07				

		Analysis of variance			
Model	**Df**	**Sum q**	**Mean Sq**	**F value**	**Pr(>F)**
Model 1: lm (formula = IMR ~Urban population)					
% Urban population	1	4756.2	4756.2	17.902	0.0002554***
Residuals	26	6907.8	265.7		
Model 2: lm (formula = IMR ~Urban population + Year)					
% Urban population	1	4756.2	4756.2	34.911	3.634e-06***
Year	1	3501.8	3501.8	25.704	3.111e-05***
Residuals	25	3405.9	136.2		

Note : Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

Figure A-2: Infant mortality rates by city-size group and area, different estimates, 1980 to 2010

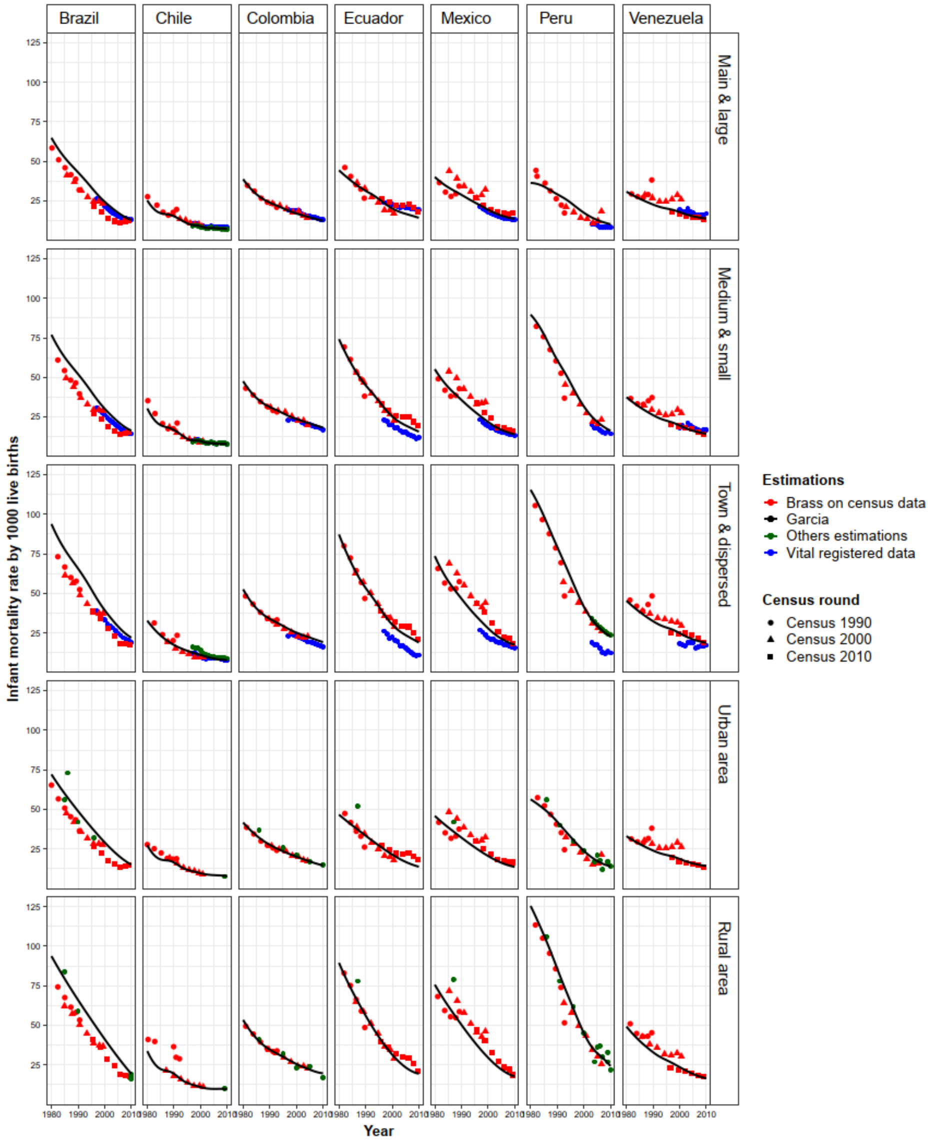

Figure A-3: Estimated infant mortality rates by city-size group and area, 1980 to 2010