The infant mortality decline and its relation with urban infrastructure services: a spatial analysis in small areas of Brazil*

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Abstract

Since the 1930s Brazil has experienced a significant reduction in infant mortality, which occurs as result of multiple factors, especially related with increase in the access to urban infrastructure services like piped water, electricity, sewage system and garbage collection. Considering these aspects, this paper aims to characterize the process of infant mortality decline in Brazilian microregions, and analyze its relationship with the provision of these urban services. We use data from 2013 Human Development Atlas (UNDP) and the Demographic Census and apply multivariate and spatial regression analysis techniques in 558 Brazilian microregions from 1991 to 2010. We found that the process of infant mortality decline is regionally heterogeneous and it followed the path of expansion in access to basic urban infrastructure. In addition, in very recent periods, electricity has gained an important role to explain the persistent spatial heterogeneity in terms of infant mortality.

Keywords: Infant Mortality; Urban Services; Microregions; Spatial Dependence; Brazil.

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1 – Introduction

Since the 1930s Brazil has experienced a significant reduction in infant mortality, which occurs due to multiple factors. The important factors listed by literature were the expansion of urban infrastructure services, increasing schooling, the process of declining fertility, increase income levels of the population, the urbanization process, and access to public health and recent access to cash transfer programs (Castro & Simões, 2009).

Historically, in Brazil there are large socioeconomic disparities between the Northern and Southern parts of the country. The North and Northeast regions lack of economic resources and social development, and they usually present higher child mortality than the Southern and Southeastern parts, and these last being more developed in terms of lower infant mortality rates (Carvalho, 1974; Carvalho & Saywer, 1978; Vetter & Simões, 1981; Merrick, 1983; Wood & Carvalho, 1988; Barros; Sawyer, 1993; Sastry, 1996, 1997, 2004a; Simões, 2001; Castro & Simões, 2009). These regional differences may be explained by the historical process of prioritizing resources, infrastructure services and increased market interest in the Southern regions of the country, which directly and indirectly influenced the historical process of infant mortality decline (Simões, 2001).

In this context, we assume the existence a relationship between the expansion of access to urban infrastructure services and the process of declining infant mortality in Brazil. Such services were later regulated by the Brazilian Constitution of 1988 and should cover the entire population. Through the epidemiological transition process (Prata, 1992), some studies point out that infant mortality decline in Brazil is regionally heterogeneous, especially in less populated locations, and there are few attempts to study infant and child mortality in macro regions and Federal States (Wood & Carvalho, 1988; Simões, 2001; Paixão & Ferreira, 2012). In addition, not many analyses address the issue of infant mortality using less populated areas, neither extended the empirical study to more recent periods.

Considering these aspects, the work aims to characterize and understand the process of infant mortality decline by Brazilian microregions, from 1991 to 2010. As the research questions, we have: *do regional disparities in infant mortality still persist in Brazil until recent periods?* In positive case, *what are the reasons behind the existence of leads and lags in this process of infant mortality decline? What is the* *importance of urban infrastructure services expansion in de recent decline of infant mortality?* We argue that there is still necessary to verify how the process of infant mortality decline occurs in smaller geographic units and in recent periods. We focus on the analysis on the role played by urban infrastructure services and other traditional contextual variables.

2 – Background

The significant reduction in mortality levels in Brazil began in the mid-1930s and it led to progressive gains in life expectancy at birth. This process happened largely due to the reduction in infectious and parasitic diseases in the first years of life (Simões, 1997). During this period, the average years of life was estimated in 41.5 years and the infant mortality rate was 162.4 deaths of children under one year old per 1,000 live births. This value rose slightly in the mid-1940s to 45.5 years with an infant mortality rate 150 deaths per 1,000 live births (IBGE, 1999; Simões, 2016).

Until the 1950s, important regional differentials in child mortality were identified, as the North-Northeastern parts of the country presented high levels of mortality (Mortara, 1949; Ervatti & Oliveira; Jardim, 2017), while in the South-Southeast of Brazil the levels of infant mortality were much lower (Carvalho & Saywer, 1978). In 1980, life expectancy increased to 62.52 years of age and infant mortality declined to the value of 82.8 deaths per 1,000 live births (IBGE, 1999; Simões, 2016). In 2014, life expectancy at birth rose to 75.44 years (SIMÕES, 2016), and according to the Ministry of Health, in 2011, the infant mortality rate (IMR) fell to 15.7 deaths/1,000 live births. Despite this evolution to a general decline, IMR still presents to this day large spatial differences, with a number of Brazilian Federal Units showing mortality levels near to European cities, and others IMR levels close to cities in India (Szwarcwald et al., 1997).

Until the 1990s, many researchers dedicated to analyze the regional estimates, the urban and rural dichotomy and factors associated with infant mortality, in particular showing the relationship between IMR decline and access to piped water and sewage services (Carvalho, 1974; Carvalho & Saywer, 1978; Carvalho & Wood, 1978; Vetter & Simões, 1981; Merrick, 1983; Wood & Carvalho, 1988; Barros & Sawyer, 1993; Sastry, 1996, 1997, 2004a).

Beyond the accelerated expansion of the basic sewage infrastructure and piped water, the historical gains in reduction of mortality is partly explained by the centralizing policies of the military regime, which invested in the expansion of the maternal and child health care (Vetter & Simões, 1981). Over time, other important social programs have been implemented by successive governments, we list some of them: 1) 1970s the Immunization Program; 2) the Breastfeeding Incentive Program and the Comprehensive Health Care Program for Women and Children in the 1980s; 3) In the 1990s, other three social programs increased the accessibility to the health system, the Infant Mortality Reduction Program, the Community Health Agents Program, and the Family Health Program, this last one being important to this day; 4) In the 2000s, three programs were created the National Pact for the Reduction of Maternal and Neonatal Mortality, Women's Health Integral Care Programs and Bolsa Familia program; 5) 2010s, other important project was the Rede Cegonha project (Ministry of Health, 2004; Macinko et al., 2006; Duarte 2007; Souza et al., 2007; Castro & Simões, 2009; Paixão & Ferreira, 2012; Rasella et al., 2013; Shei 2013).

In addition, Brazilian Constitution of 1988 created one of the main actions to reduce child mortality, the Unified Health System (SUS), which gave to every Brazilian citizen the right to universal and free health, financed with public resources, based on the principles of universality, equity, decentralization and social participation. At the same time, other important civil achievements guaranteed general right to access urban infrastructure services, such as piped water, electricity and sanitation, and general access to vaccination campaigns (Ministry of Health, 2004). In addition these factors, the Brazilian Institute of Geography and Statistics (IBGE) (1991; 2013a) also synthesized the main reasons for the intensification of IMRs decline after the 1980s. They gave special attention to preventive medicine, campaigns of vaccination, prenatal, breastfeeding, decreased child malnutrition and increased female education.

During 1990 and 2010, infant mortality declined even further from 69.1 to 16.8 deaths, e.g. a decrease of 411.1% (IBGE, 2013a) in the period. Despite this general decline, the regional profile of IMRs is kept very heterogeneous by Federal states. For example, the State of Amapá, located in the Amazon rainforest, has the slowest pace in infant mortality decline (a reduction of 33.3%) and the highest level of IMR in 2010. On the other hand, states such as Maranhão had the fastest decline (71.4%), but it still presents high levels of infant mortality, 21.88 infant deaths per thousand live births. In contrast, the Southern states had a very significant reduction, around 60% in the period between 1990 and 2010.

In 2015, the IMR fell to 13.3 deaths per thousand live births, reaching the UN target through the Millennium Development Goals, which set the need for a 2/3 reduction between 1990 and 2015. It is noteworthy that after 2016, for the first time since 1990, the decrease in the infant mortality rate has stopped, rising to 14 deaths per 1,000 live births, revealing the importance of continuing to study IMR and its regional discrepancy in less populated areas.

3.1 – Data

We use official estimates of infant mortality rates, public available and launched by the United Nations Development Program 2013, Human Development Atlas[4] for the years 1991, 2000 and 2010. The original estimates are at municipality level, but we recalculated the mortality measures by reassembling infant deaths and births to 558 Brazilian microregions[5] in order to make it spatially comparable and possible to create a temporal panel.

The control variables associated with the process of infant mortality decline were obtained from the Brazilian Population Censuses 1991, 2000 and 2010. Five important dimensions that affects infant mortality were identified: education, income, urbanization, fertility and public health policies; as well as indicators related to coverage of each of the basic urban infrastructure services (Carvalho & Saywer, 1978; Merrick, 1983; Sastry, 1996, 1997, 2004a, 2004b; Simões, 2001; Guanais & Souza, 2006; Aquino et al., 2009; Gamper-Rabindran et al., 2010; Macinko et al., 2012; Rasella et al., 2013, and others).

For education, we use the illiteracy rates in each microregion, measured as number of illiterate people aged 15 years and over. We selected two variables for income levels: 1) the average household income per capita (at July 2010 prices), and 2) the percentage of the population living with lesser than half of the minimum wage per month, allowing us to measure the effect income as a whole and the amount of poor in each microregion. The degree of urbanization was also introduced in the analyses. The

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[4] Available in: http://atlasbrasil.org.br/2013/, access date 09/12/19.

[5] The microregions are formed by contiguous municipalities and were created in the 1988 Constitution to integrate the organization, planning and execution of public functions of common interest.

reproductive dimension is measured by the child-woman ratio, which relates children under the age of five by women from 15 to 49 years old. The dimension of public policies and health services was discarded, because there are no data sources that cover the entire period analyzed and allow to present estimates for microregions. We also control for spatial dependence in two ways, first in the analysis of infant mortality decline patterns[6], and second in the analysis of factors associated.

3.2 – Analysis of infant mortality decline patterns

As strategy, we decided not to model only the time variations in infant mortality in each microregion, because its interpretation is also influenced by other elements. That is, two regions may have the same decrease rate in infant mortality in a period, and show totally different realities related to its initial IMR (in 1991) and amplitude (difference between 1991 and 2010 infant mortality levels). In addition, a faster decline can be more easily achieved when past IMR values in the region were high.

One way to study this process of IM decline is by applying a logistic distribution, a resource widely used to analyze vital events developments over time (Siegel & Swanson, 2004; Potter et al. 2010). Due to the reduced number of observations over time, the adjustment was not adequate in this study. The alternative was to use the Factor Analysis method and, afterwards, a cluster analysis to create distinct groups, regarding their declining patterns of infant mortality rates.

The indicators selected to describe the trajectory of the decline in IMR in the country were, 1) *the level* of infant mortality rate in 1991, 2) *the amplitude* of IMR between 1991 and 2010, 3) *the rate of decrease* between 1991 and 2010 and 4) *the potential reduction* in the last year, i.e. the IMR distance in 2010 from the value of four infant deaths per 1,000 live births. This is an approximated value, based on the infant mortality rate seen in developed countries[7], and is mostly composed by unavoidable causes. Due to the high correlation between the selected indicators, it was decided to

[6] Spatial dependence was assessed from the Moran Index I, using the spatial correlation test (Bailey & Gatrell, 1995; Almeida, 2012). The neighborhood was defined by the distance between the geographic coordinates of the microregion centroids.

[7] According to UN data, in 2010 Iceland had the lowest IMR in the world, about 2 deaths per 1,000 live births. Already the average of countries belonging to the European Union corresponded to about 4 deaths per thousand live births. The average of some selected countries also corresponded to a value close to 4, so this was the value chosen as the target to be reached by Brazil. According to UN estimated infant mortality rate data in 2010, Japan had 2.4, Sweden 2.5, Spain 3.1, Portugal 3.1, Greece 3.2, Italy 3, Germany 3, 5, France 3.5, Netherlands 3.7, United Kingdom 4.4, Cuba 4.6 and Canada 4.9.

create a synthetic index, with the objective of condensing the information into a single indicator of infant mortality to all microregions.

3.2.1 – Factor Analysis

We applied Factor Analysis (FA) as a way to create a new synthetic variable, which is a linear combination of the four indicators chosen to describe the infant mortality decline between 1991 and 2010 (Everitt & Hothorn, 2011; Hair et al., 2009; Mingoti, 2005). In addition, we also introduced in the analyses the geographical coordinates (latitude and longitude) of each microregion. Because of the violation of the assumption of multivariate normality[8], we used the exploratory Factor Analysis with extraction method as Principal Components (Pedhazur & Schmelkin 1991; Mingoti, 2005).

The overall adequacy of FA to the data set was assessed by the Kaiser Meyer Okin Statistics (KMO) and for each variable by the Sample Adequacy Statistics (MSA). Both indicators range from 0 to 1. KMO values above 0.6 indicate that it is reasonable to use FA (Fávero et al., 2009, p. 242) and MSA values less than 0.5 indicate that the variable should be removed from the analyses (Hair et al., 2009, p. 101). Variable selection was also performed by the communality (h^2), which corresponds to the total amount of variance that an original variable shares with all other variables included in the analysis (Hair et al., 2009). Values of this measure lower than 0.5 may indicate to remove the variable from the model (Hair et al., 2009, p. 121).

The number of factors was determined by two criteria: eigenvalues and the proportion of total variance explained. The eigenvalue criterion, proposed by Kaiser in 1958, corresponds to identifying the ideal number of factors from the total eigenvalues extracted from a correlation matrix that are greater than one (Mingoti, 2005, p. 105). The criterion of the proportion of total variance explained corresponds to choose the number of factors that accumulate at least 60% of the total variance from the original variables together (Hair et al., 2009, p. 114).

[8] It was found from the visual inspection, a multivariate QQ chart, built from the *R* software. The QQ chart makes it possible to compare the distribution of observed data and the normal distribution, where the quartiles of each distribution are plotted. Closer to the bisectrix, more observed data adhere to the normal distribution.

The estimation of FA resulted in one single factor, which presented well the distributed loadings[9] and indicating no need for factor rotation (Mingoti, 2005). The obtained scores of this analysis were later applied in the cluster analysis.

3.2.2 – Cluster Analysis

The methods we used in this study to classify the indicator of infant mortality into categories are the quartile, the standard deviation, natural breaks of Jenks, k-means and hierarchical cluster.

The quartile method consists of partitioning the variable of interest in *n* groups of equal quantity (Bussab & Morettin, 2006). The standard deviation method is based on the probability distribution of the variable of interest, dividing it according to the number of standard deviations of the covariate distribution (Bivand, 2019). The Jenks method aims to identify homogeneous classes with respect to the internal observations of each group and heterogeneous among the formed groups. The algorithm works iteratively finding natural breaks and obtaining groups that minimize the variance between classes obtained (Armstrong et al., 2003). The k-means and hierarchical consist of separating variables in groups based on the criteria of distance matrix (Mingoti, 2005; Hair et al., 2009).

To evaluate the best partition form to be used, we applied the indicator that represents the goodness of variance fit measure (Goodness of Variance Fit Measure). This indicator aims to measure the degree of homogeneity within classes and to identify the optimal number of clusters (Armstrong et al., 2003), and high *GVF* values indicate a better fit. According to this indicator, the Jenks method was the most appropriate to cluster the indicator of infant mortality.

3.3 – Analysis of factors associated with the infant mortality decline

The evaluation of the association between the expansion of urban infrastructure services and the process of infant mortality decline was performed through a spatial panel data model, which allows us to study temporal and geographical effects (Wooldridge, 2002) of these variables and control for spatial dependence at the same time. A non-spatial version of it, with the fixed effect models, was the most recurrent

[9] Loadings express the correlation of the variable with the obtained factor (HAIR et al; 2009).

method used to study the process of infant mortality decline in the country (Alves & Belluzzo, 2005; Aquino et al., 2009; Gamper-Rabindran et al., 2010; Macinko et al., 2006; Paixão & Ferreira, 2012; RASELLA et al., 2013; ZANINI et al., 2009). The spatial and temporal variant effects were considered in the models only in a study of Castro and Simões (2009). However, the authors use a multilevel approach, considering time and microregions as second level covariates. In this paper, we are interested to study variables like regions and different groups of infant mortality decline, which makes the fixed effects approach unfeasible. In addition, time invariant factors lose effects in the estimation process of the panel data.

There are many possibilities for parameterization of the spatial effect, in the case of estimation possibilities implemented by Giovanni and Gianfranco (2012), the dependence can be inserted in the models as three ways: in the residues (Spatial Error - SEM), in the dependent variable (Spatial Lag - SAR), or considering both cases, SARAR, similarly to the specifications for cross-sectional data proposed by Anselin (1988a).

In this study, we use only SARAR model specifications. The random effects in the model are given by the following equation (Almeida, 2012, p. 427):

$$y_{it} = \rho W y_{it} + X_{it}\beta + W X_{it}\tau + \varepsilon_{it} \qquad (1),$$

$$\varepsilon_{it} = \alpha + \lambda W \varepsilon_{it} + \epsilon_{it} \qquad (2).$$

Where,

y_{it} corresponds to the infant mortality rate of microregion *i* at time *t*;

W corresponds to the spatial neighborhood matrix (built through the queen method);

X_{it} corresponds to the variables of basic urban infrastructure services and other contextual variables by microregions according to time;

β corresponds to the estimated coefficient vector for each variable;

α e λ correspond to the error variance parameters;

ρ autoregressive spatial coefficient;

τ spatial coefficient linked to independent variables;

i = 1, …, 557; represents the microregions (excluding the island of Fernando de Noronha);

ε_{it} and ϵ_{it} are the error terms.

The specification and adequacy analysis of the estimated models was performed using Akaike Criterion (AIC) and Lagrange multiplier-based tests (Baltagi & Liu, 2008; Baltagi et al., 2003; Giovanni & Gianfranco, 2012). For the specific case of random effects, Baltagi and Liu (2008) derived tests of Lagrange multipliers of spatial dependence. The authors perform a generalization of tests of Lagrange multipliers, initially proposed by Luc Anselin in 1988 (Anselin, 1988b), for the abstention of spatial effects, and assuming that there are random effects instead. The authors also make two test extensions, the first aiming to evaluate the existence of random effects, and the second with the objective of evaluating whether these effect are different or not from zero (Baltagi & Liu, 2008). In this study, we test for the random effects and existence of spatial dependence in the process of infant mortality decline. We have also performed analyses to avoid collinearity in the regression models.

4 – Results

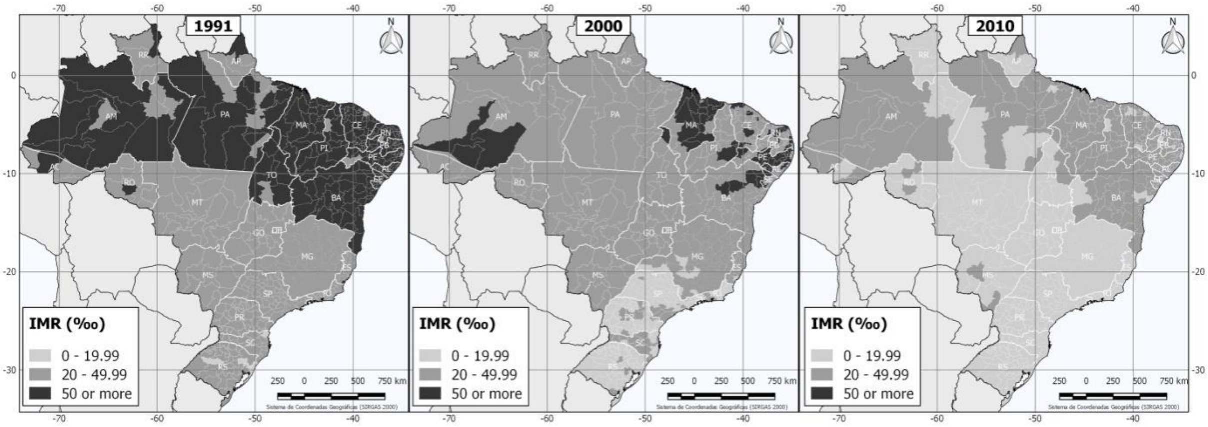
4.1 – Infant mortality decline by region

According to Figure 1, we observe the reduction of infant mortality rates by microregions, in the period between 1991 and 2010. This evolution occurs in the direction South-North. In 1991, a small number of microregions (all from the Southern parts of the country) had already IMR lesser than 20‰ live births. In 2000, this number increased and occupied almost the whole Southern region and the state of São Paulo, Rio de Janeiro and Minas Gerais in Southeast. We also noticed that in 2000, almost all Northern and Northeastern states from Amazonia to Bahia, the microregions presented the highest infant mortality rates (50‰ live births or more).

In 2010, we observed that there are no more microregions with values higher than 50 infant deaths per 1,000 live births. In the same North-Northeastern parts of the country, the values of IMR persist relatively high, between 20‰ and 50‰ live births. This is true especially in the Brazilian semiarid region. This region had historically the highest infant mortality rates in the country (Carvalho, 1974; Carvalho & Saywer, 1978; Carvalho & Wood, 1978; Simões, 2001) and has achieved biggest reductions in

IMRs, but still presenting to this day high levels in some locations. (Castro & Simões, 2009).

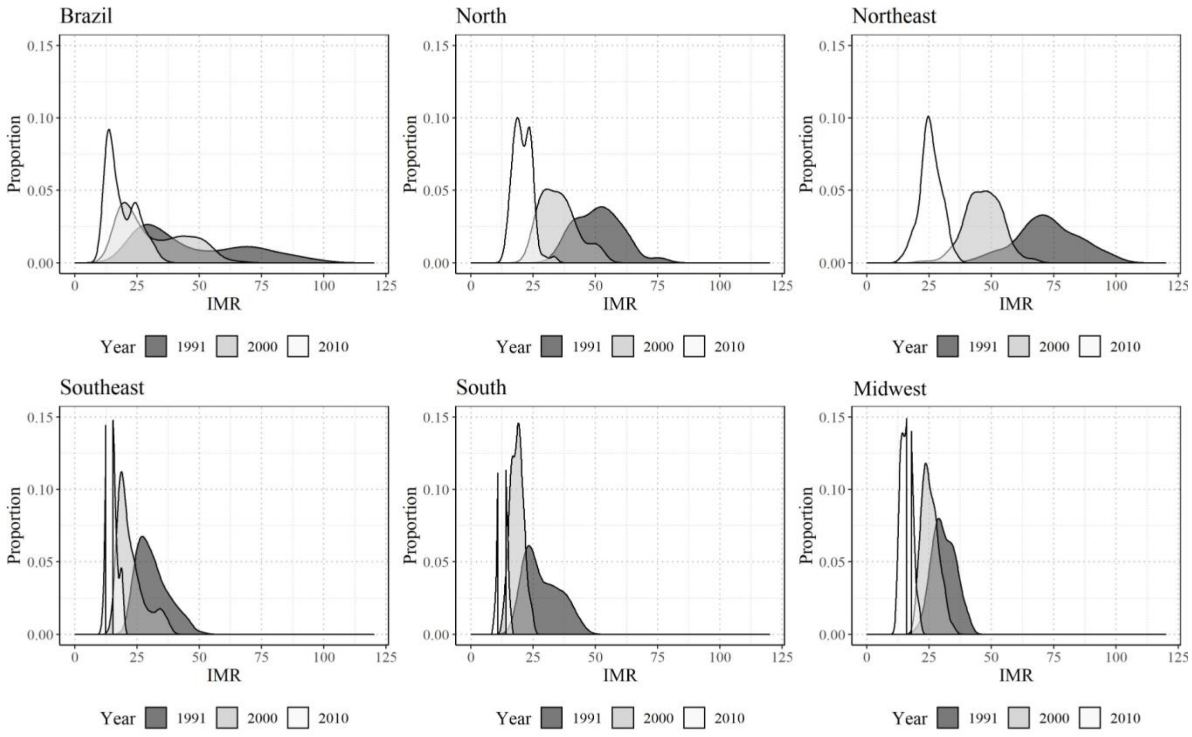
Figure 1 – Infant mortality rates in Brazilian microregions, 1991 to 2010.



Source: 2013 Human Development Atlas - UNDP.
Notes: Categories of legend chosen according to the Ministry of Health (see SIMÕES, 2001).

The regional variability and heterogeneity of the process of infant mortality decline in the country can also be observed in Figure 2. There was a reduction in the variability of the IMR and in all analyzed years.

Figure 2 – Density curves of infant mortality distribution by microregions, Brazil and Regions, 1991 to 2010.



Source: 2013 Human Development Atlas - UNDP.

In addition, we also observe that there is a concentration of microregions with values below the median of the IMR distribution. We also further see that the curves are more symmetric in the Northeast, areas where the process of IMR reduction occurred with more speed.

4.2 – Multivariate results of infant mortality decline in Brazil

Figure 3 presents the summary indicators of the infant mortality decline by microregions. Four maps are presented, 1) the infant mortality rate in 1991, 2) the variation of IMR between 1991 and 2010, 3) the IMR amplitude between 1991 and 2010 and 4) The IMR distance in 2010 from the value of four infant deaths per 1,000 live births.

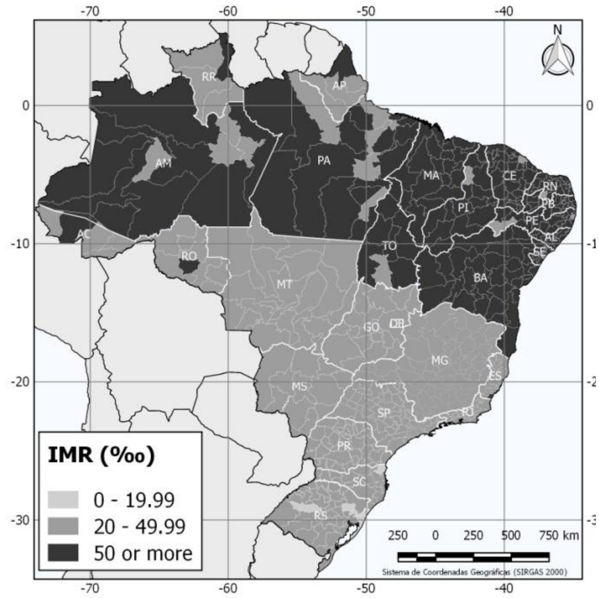
Few microregions achieved a reduction in infant mortality of more than 2/3 in the period between 1991 and 2010, in disagreement with the Millennium Goals for childhood mortality reduction. The lagged microregions are located in the Northeast, especially in the state of Tocantins at the North. The biggest IMR amplitudes we also see in the Northeastern microregions, which largely corresponded to values above the third quartile of the distribution (IMR of 41.61). Overall, we notice that the spatial pattern of this indicator is very close to the rate of decrease, and visually it contributes little to help explain the overall reduction in IMR.

The distance for the ideal IMR (value of 4 in 2010) represents the potential that each microregion can reduce its IMR until the last year of analysis. This indicator helps to refine the analysis of the decrease in infant mortality. The microregion that had the lowest IMR in 2010 was Blumenau, belonging to the South state of Santa Catarina, which would still have to reduce a little its IMR in order to reach the desirable value of 4 infant deaths.

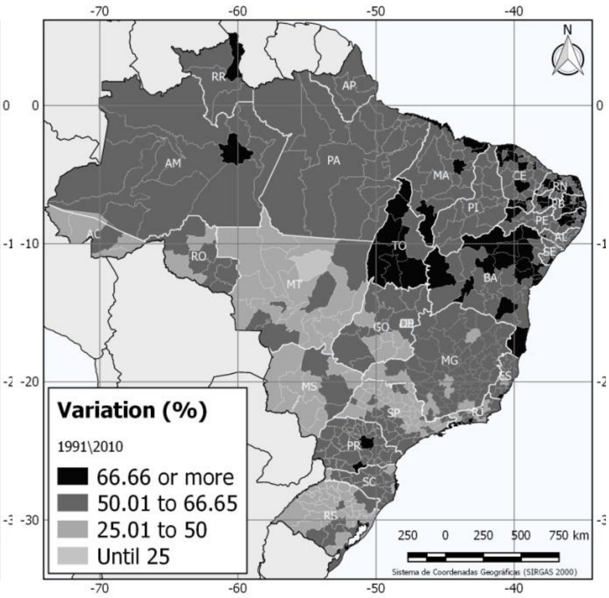
Other important issue is that some locations in the Northeast had a large reduction in IMR, but they still have a long way to go to combat infant deaths from preventable causes. The state of Tocantins, for example, needs to reduce 10 to 15 infant deaths to reach IMR around 4. On the other hand, Paraná had a reduction in IMR by 50% and in 2010 its microregions have IMRs closer to 4.

Figure 3 – Summary indicators of the infant mortality decline process, between 1991 and 2010, Brazilian microregions.

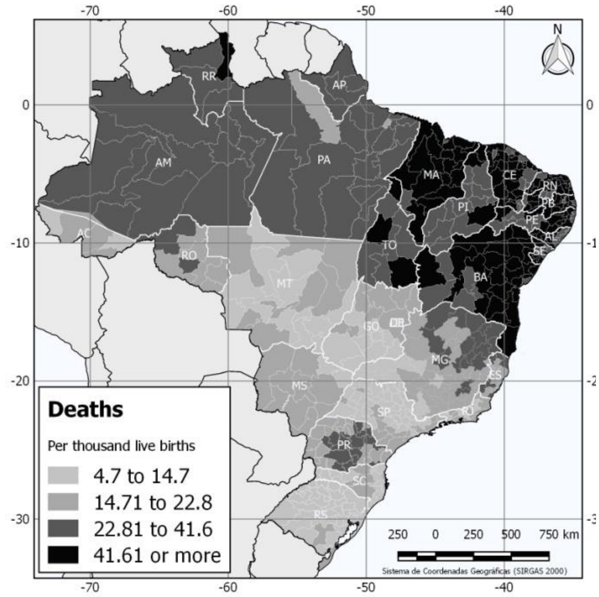
a. Infant Mortality Rate, 1991



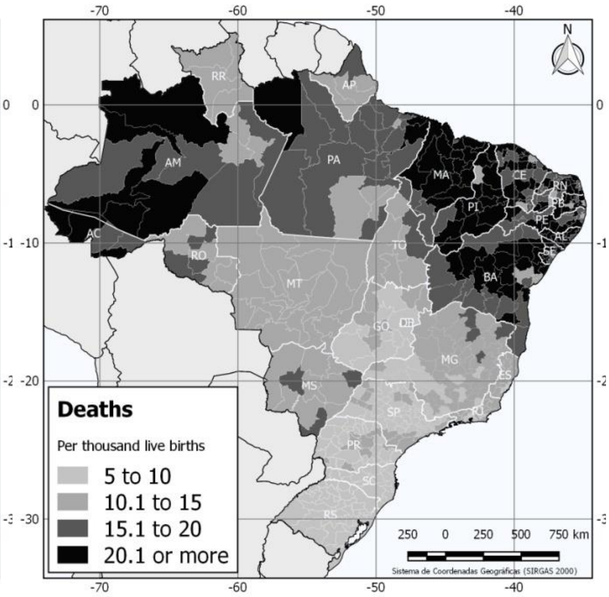
b. Variation in IMR between 1991 and 2010



c. Amplitude between 2010 and 1991



d. Distance from ideal IMR 2010



Source: 2013 Human Development Atlas - UNDP.

4.2.1. Factor Analysis and cluster results

The Factor Analysis results a single factor with 69% of the total variation explained. The estimated loadings were well distributed, indicating that it is not necessary to use factor rotation (Table 2). In addition, the estimated communalities indicated that the adjustment was satisfactory, almost all were greater than 0.5, except for the longitude, which was 0.39.

Table 2 – Loadings (*l*) and communalities (h^2) Factor Analysis for infant mortality decline between 1991 and 2010.

Indicators	*l*	h^2
Variation of IMF between 1991 and 2010	0,78	0,61
Infant Mortality Rate in 1991	0,98	0,95
Distance from ideal IMR in 2010	0,89	0,80
Longitude	0,62	0,39
Latitude	0,83	0,68

Source: 2013 Human Development Atlas - UNDP.

For the characterization of the groups, we contrast the average value of each original variable with the clusters means (Table 3 and Figure 4). The result indicated that there was an ordinal tendency in terms of IMRs decline; that is, each group presented lower averages than the subsequent one. Group 1, for example, is composed by “Advanced” microregions in the process of IM decline. It is represented by 116 microregions and corresponded to the group with the lowest average values of IMR. In addition, the group has the lowest initial infant mortality level (IMR in 1991), the lowest decrease rate between 1991 to 2010 and the shortest distance to the ideal IMR in 2010. On the other hand, group 5 is still “Delayed” in terms of IMR reduction.

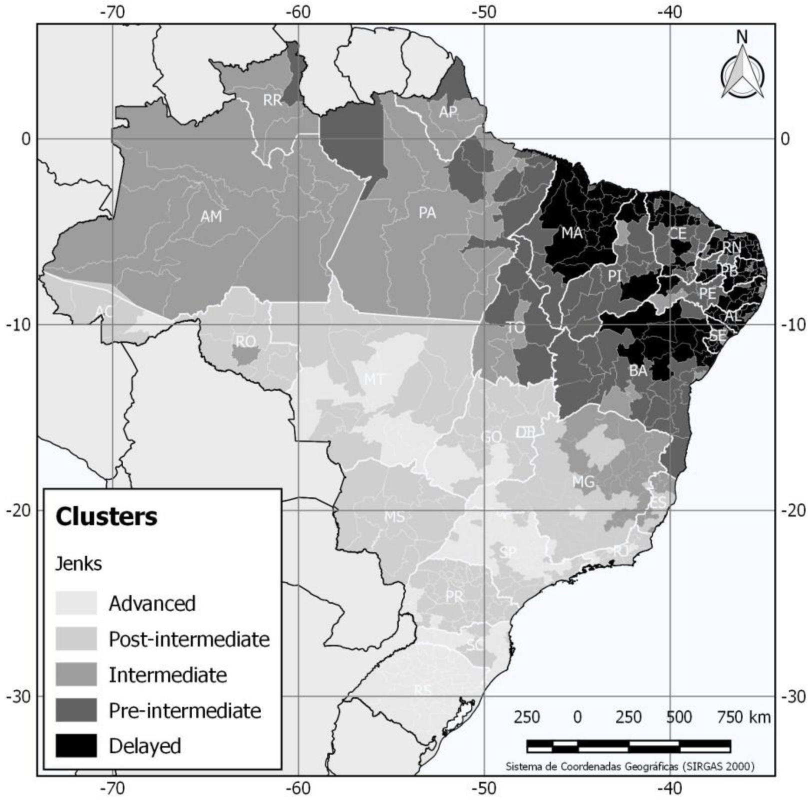
Table 3 – Means of summary indicators of infant mortality decline and geographic coordinates, by microregions in the period between 1991 and 2010, according clusters

Clusters	Infant Mortality Rate, 1991	Variation of IMF between 1991 and 2010	Distance from ideal IMR, 2010	Longitude	Latitude
1 – Advanced (n=116)	24.54	46.68	9.02	-50.87	-24.22
2 – Post-intermediate (n=175)	33.19	54.64	10.98	-49.34	-20.20
3 – Intermediate (n=71)	46.84	59.86	14.75	-49.20	-10.07
4 – Pre-intermediate (n=89)	62.89	63.15	19.04	-41.67	-7.62
5 – Delayed (n=107)	80.95	65.77	23.64	-38.79	-7.06

Source: 2013 Human Development Atlas – UNDP
The classes defined by Jenks, based of GVF test.

Regarding the geographic coordinate variables, when analyzing the latitude and longitude, it is possible to identify a spatial trend from high (lagged microregions) to low (lead microregions) infant death rates, or in the direction Northeast to Southwest of the territory.

Figure 4 – Clusters of Infant mortality decline by Brazilian microregions, 1991\2010.



Source: 2013 Human Development Atlas - UNDP.

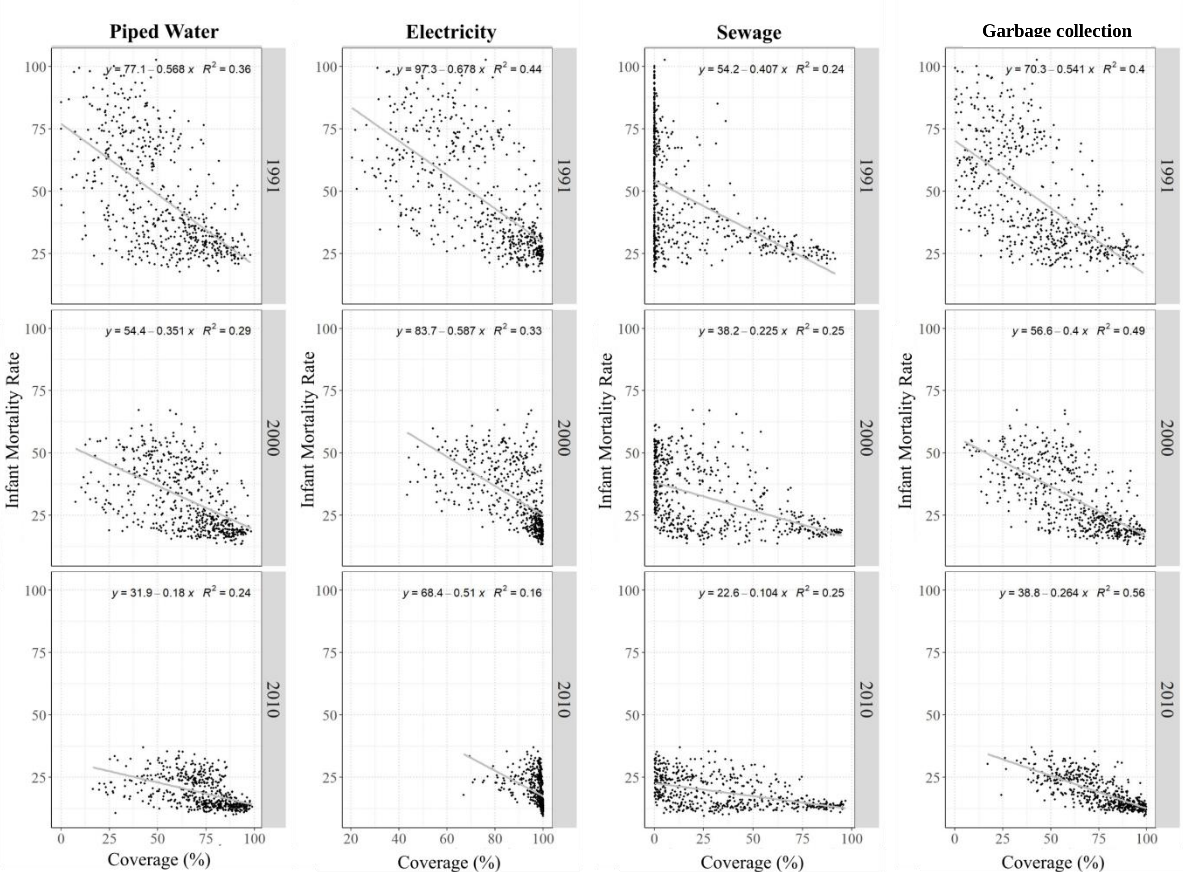
If we look at the spatial distribution, the advanced microregions are largely located in the extreme South-Southeastern parts of the country, moving from São Paulo towards parts of Midwest of the country, a region of expansion of the agricultural business. The Post-Intermediate group is composed by microregions surrounding by advanced areas. The Intermediate group is mainly characterized by locations in the Northern Amazon region of the country with some isolated microregions in Southeast and Northeast of the country. The Pre-Intermediate and Delayed clusters are mainly located in Northeastern states.

4.3 – Factors associated with the process of infant mortality decline

Regarding the association between access to basic urban infrastructure services and the infant mortality rate, it is possible to observe an inverse relationship to all variables considered, in Figure 6. This association decreases over time and presents different intensity according to the type of service. It is possible to observe from the estimated angular coefficient of the regression line that the association is more intense for access to electricity and garbage collection, especially in 1991 and 2000.

Water and sewage services in 2010 still had low coverage in some locations of the country, demonstrating the great heterogeneity of access to these services in Brazil. The electricity service, however, was the one that expanded its coverage faster over the years.

Figure 5 –Infant Mortality Rates by Brazilian microregions and basic urban infrastructure services 1991-2010.



Source: 2013 Human Development Atlas - UNDP and Demographic Census - IBGE.

4.3.1 Spatial Regression analyses

Concerning the regression models, four specifications were used to model the process of infant mortality decline: the classic version of panel data and three possibilities for spatial panel data (SAR, SEM and SARAR). The estimation was performed for each panel, 1991/2010, 1991/2000 and 2000/2010. In all cases, the best model fits was the SARAR model (the only shown here), which incorporates the spatial effect on the dependent variable and the residuals one.

The first estimation of the complete spatial panel data model (SARAR) indicated that garbage collection was not significant in all panels. This variable was also highly correlated with the other variables in the model, so we decided to remove this covariate from further analysis. The final estimates are presented in Table 6.

Table 6 – Spatial panel regressions for IMR decline. Brazilian microregions 1991-2010.

Variables	1991- 2010		1991-2000		2000-2010	
Intercept	60.790	***	84.119	***	39.529	***
Region						
Southeast	-		-		-	
Midwest	-1.840	*	3.155	.	-0.747	
Northeast	-7.832	***	12.467	***	-5.044	***
North	-6.299	***	8.301	***	-5.003	***
South	0.404		-0.611		-0.432	
Cluster of IMR decline						
Delayed	-		-		-	
Pre-intermediate	-6.388	***	-8.655	***	-3.802	***
Intermediate	-9.388	***	-13.299	***	-4.651	***
Post-intermediate	-11.203	***	-18.271	***	-5.528	***
Advanced	-11.978	***	-21.519	***	-4.847	***
Services type						
Piped Water	-0.044	***	-0.033	*	-0.022	.
Sewage system	-0.015	.	0.008		-0.009	
Electricity	-0.072	***	-0.005		-0.089	***
Other control variables						
% population gain ½ of minimum wage	-0.131	***	-0.055	.	-0.007	
Average household income per capita (log)	-6.519	***	-3.589	**	-4.059	***
Illiteracy rate	0.279	***	0.225	***	0.235	***
Urbanization	9.520	***	3.748	*	5.570	***
Child woman ratio	17.054	***	6.284	*	11.093	***
Error Variance Parameters						
$\hat{\alpha}$	0.489	***	0.501	***	0.454	***
$\hat{\lambda}$	0.077		0.958	***	0.117	
Autoregressive Spatial Coefficient						
$\hat{\rho}$	0.596	***	-0.538	***	0.599	***
Log Likelihood	-4915		-3320		-2933	
AIC	9865		6674		5902	
Lagrange Multiplier Tests						
$H_0^a: \rho = 0 = \sigma_\alpha^2; H_1^a: \rho \neq 0\ ou\ \sigma_\alpha^2 \neq 0$	35.426***		27.393***		20.870***	
$H_0^b: \rho = 0\ \forall\ \sigma_\alpha^2 \geq 0;\ H_1^b: \rho \neq 0\ \forall\ \sigma_\alpha^2 \geq 0$	27.003***		23.278***		22.712***	
$H_0^c: \sigma_\alpha^2 = 0\ \forall\ \rho \geq 0; H_1^c: \sigma_\alpha^2 \neq 0\ \forall\ \rho \geq 0$	12.469***		11.328***		7.842***	

Source: 2013 Human Development Atlas - UNDP and Demographic Census - IBGE.
Notes: Models SARAR. Dependent variable: Infant Mortality Rate.
*** p-value until 0.001, ** p-value until 0.01, * p-value until 0.05, "." p-value until 0.1 and empty to non significant.

The Lagrange multiplier tests indicated that the model specification was adequate. All control variables added were statistical significant in the full panel (1991, 2000 and 2010), however, the same cannot be said in the other half panels.

From the urban services considered, the access to electricity is significant and has the highest beta coefficient among all, showing also the role played by this service that has contributed the decline in infant mortality, especially in very recent periods. Piped water was also important in the full panel, but it shows statistic significance only between the years 1991 to 2000. Sewage services lose its statistical significance in all periods considered, and that can be explained by the strong negative association between some control variables expressed by economic and social development and the reductions in IMR. In addition, a lot of Brazil uses septic tanks, which is also a form of adequate sewage.

The spatial approach has also contributed to understand the process of infant mortality decline in Brazil. The degree of access to urban infrastructure services varies according to different time periods and is also very heterogeneous. The increase in coverage of some services, especially between 1991/2000, was more important to explain the reduction in IMR than the other classic differential factors in child mortality, such as income, education, urbanization and fertility. Electricity has gained important role in infant survival, especially in recent years.

5– Discussion

In this work, we tried to analyze the spatial process of infant mortality decline in Brazil, between 1991 and 2010. Although in the last year no longer any microregion present infant mortality over 50 deaths per 1,000 live births, some locations in the country still have high values of infant deaths; and most of them are located in the Northern and Northeastern parts of the country. These regions are historically the most backward in the process of infant mortality decline.

Despite this, these locations have also experienced a considerable decline in IMR. Some studies point out that the recent reductions in infant and child mortality was mainly due to social programs that focused on these regions (Aquino et al., 2009; Castro & Simões, 2009; Frias et al., 2011; Rasella et al., 2013). In particular, we can cite the Bolsa Familia cash transfer program, which most of its beneficiaries lived in the North-Northeast of the country. Despite the large reduction in the infant mortality rate observed in time, regional inequality is still an obstacle for further improvements in infant survival.

In addition, it was observed that the access to urban infrastructure services play also a significant role in this process IM decline. However, its expansion was heterogeneous in Brazil, favoring some areas to a large extent and leaving behind other parts of the country, especially in relation to adequate sewage system (Simões, 2001; Alves & Belluzzo, 2005; Gamper-Rabindran et al., 2010; Paixão & Ferreira, 2012).

In our analyses, basic urban infrastructure services were also important factors, alongside with the other socioeconomic variables analyzed. However, with exception of access to electricity, the urban services showed greater explanatory power in the process of infant mortality decline between 1991/2000 decade, and other variables in the 2000/2010 period. This is probably due to the past expansion of basic urban infrastructure services, and especially recent increasing access to electricity. Moreover, we may argue that continue expansion of electricity is important to increase infant survival, especially in the historically forgotten Northern and Northeastern regions of Brazil (Simões, 2001).

Many studies point out that the access to safe drinking water and adequate sewage as the main causes to reduce infant and child mortality in Brazil (Vetter & Simões, 1981; Merrick & Berquo, 1983; Sastry, 1996; Simões, 1999; Alves & Belluzzo, 2005; Paixão & Ferreira, 2012; Rasella et al., 2013). Our analyses showed that they did not play the major role between 2000 and 2010. This may have occurred because the population seeks other ways to get access to these services.

Our empirical findings indicate that the expansion of electricity was of great importance to reduce infant deaths in 2000-2010 decade. It is noteworthy that the electricity facilitates the use of health equipment, in addition to improving the living conditions and well-being of the population, enabling people to storage of food. In addition, electricity is a proxy for access of information (via radio, TV, internet and other media), which influences knowledge of vaccination campaigns, the importance of boiling water before ingesting, etc.

Access to TV, especially Brazilian soap operas, influenced women behaviour to indirectly reduce the number of desired children in the household (Ferrara et al., 2012; Rios-Neto, 2001), in turn, it might also affect children mortality. The process of TV-Globo expansion, for example, was only possible by the access to electricity. In addition, we can also argue that the process of fertility decline is intimately related to infant mortality decline. (Carvalho & Saywer, 1978; Gamper-Rabindran et al., 2010; Macinko et al., 2006; Rasella et al., 2013; Sastry, 1996, 1997; Simões, 2001). Because, in the past, women tended to compensate high infant mortality by having more children. In addition, the expansion of the Brazilian electricity transmission system over time has prioritized the major urban centers, initially in the South and Southeast of Brazil (Gomes & Vieira, 2009). Later, over the years, the expansion went into the interior of the country, following a similar trajectory to the process of infant mortality reductions.

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