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ARTICLE

Explanatory factors for the rapid decline in fertility in the Brazilian Semi-arid region[1]

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Abstract

In recent decades, Brazil has experienced an accelerated reduction in fertility levels, reaching an average of 1.8 children per woman in the reproductive period in 2015, an effect that affected one of the most vulnerable regions of Latin America: the Brazilian Semi-arid region. The objective was to identify demographic, socioeconomic and health factors that influenced the reduction of fertility levels in the 1,262 municipalities that compose the Brazilian Semi-arid region, in the period 1991-2010. The application of the panel data regression model showed that the reduction in the Gini Index and the Illiteracy Rate and also the increase in Life Expectancy at Birth and in the Aging Rate contributed significantly to the decrease in fertility levels in the Semi-arid region. The results indicated that fertility levels converged in the period towards a regional homogenization close to the replacement level, which declined at a faster pace than the improvement in the region's levels of development.

Keywords: Fertility; Brazilian Semi-arid; Regression Models for Panel Data.

1. Introduction

Brazil has experienced an accelerated decline in fertility levels in recent decades, reaching an average of 1.8 children per woman in 2015, affecting in an overwhelming way the most vulnerable group that includes the poorest women. This tendency, which has also occurred in numerous countries, can be noticed in one of the most vulnerable regions of Latin America: the Brazilian Semi-arid region (IPEA; FJP; PNUD, 2013; IBGE, 2018).

Among the Semi-arid regions of the world, the Brazilian Semi-arid region is the largest among them in terms of extension and population density. In the last census carried out in 2010, this region had a population of over 22 million inhabitants, covering 1,262 municipalities, with the highest concentration of rural Brazilian population in poverty and extreme poverty. The Semi-arid region also has different and adverse geographic, climatic and socioeconomic development conditions and in 2010 it accounted for about 43% of the population and 56% of the area of the Northeast region, respectively (INSA, 2012; SUDENE, 2017).

In demographic terms, an unprecedented great revolution has been taking place in the Brazilian Semi-arid region, whose process of reducing fertility levels - unleashed since the 1980s - has been more intense than the national average. In 1991, the region's average Total Fertility Rate was 4.6, while in 2000 it dropped to 3.2 and in 2010 it dropped further to 2.3 (IPEA; FJP; UNDP, 2013). Studies have shown that this continuous reduction is closely related to the general living conditions of the population, such as inverse relationships with factors as income, education level, degree of urbanization and occupation, among other socioeconomic characteristics of the population (ALVES; CAVENAGHI, 2012; UNFPA, 2018).

Although the measurement of traditional socioeconomic indicators, such as per capita income, the Gross Domestic Product (GDP), the Human Development Index (HDI), the Gini Coefficient and the level of education in the Semi-arid region have improved their levels in recent decades gradually, the rate of decline in fertility levels occurred at a much greater speed, with more than 39% of the municipalities being positioned below the replacement level in 2015, with this percentage being less than 1% in 2000 and 1991 (IPEA; FJP; UNDP, 2013; SILVA 2018). The mismatch in the pace of changes, both in the aforementioned indicators and in the fertility levels in recent decades, raises questions like: the rapid reduction in fertility levels in the Brazilian Semi-arid region was associated with the improvement of indicators that express the living conditions of the population, as happened with other regional or country experiences (IPEA, 2010; IBGE, 2016).

Brazil's regional and social heterogeneities and socioeconomic inequalities are widely known and documented. Regarding fertility, studies have highlighted (SIMÕES, 2016; GONÇALVES et al. 2019) that the decrease in levels at the national and regional scopes has been occurring in all social strata and that lead to discussions about which variables are most effectively responsible for changes in fertility. Fertility levels for different Brazilian regions, such as the Northeast (BONIFÁCIO; WONG, 2021). However, these discussions are scarce, if not absent, when referring exclusively to the Brazilian Semi-arid region. Thus, the objective was to identify which demographic, socioeconomic and health factors were associated with the fertility levels of the 1,262 municipalities that made up the Brazilian Semi-arid region in the period 1991-2010.

2. Materials and Methods

This is a longitudinal ecological study for the 1,262 municipalities in the Brazilian Semi-arid region. A year-by-year database was set up for the period from 1991 to 2010 in Microsoft Excel (2010) and through the free language R (2022), data analysis was performed. The reason why it was not possible to update the indicators that refer in this study to the period from 1991 to 2010 is due to the fact that the results of the 2022 census were not yet available until the completion of this study.

Considering the multiple linear regression model, the Total Fertility Rate (TFR) was assigned as the dependent variable (response) of the study, which was transformed into the natural logarithm (log(TFR)) in order to meet the assumption of linearity for application of regression models in panel data. Nevertheless, for the final model, the equation was rewritten by applying the exponential function, recovering the interpretation of the association of factors with TFR.

Estimates of TFRs for municipalities are available in the Atlas of Human Development (ADH) in Brazil, which were calculated by the João Pinheiro Foundation (FJP), Institute for Applied Economic Research (IPEA) and the United Nations Development Program (UNDP), (IPEA, FJP; UNDP, 2013). To accomplish this, the ADH used indirect demographic techniques to obtain it, since during the study period most municipalities in the Semi-arid region did not have reliable birth statistics, in addition to having small population contingents, those facts made impossible application of direct techniques.

A series of causes and motivations are defended by specialists as explanations for the reduction in

Brazilian fertility; these causes include social, economic, political-institutional factors and other deter minants, commonly called intermediary variables that inhibit fertility, such as some of a demographic nature and the knowledge and use of contraceptive methods, among others (MARTINS, 2016; COUTINHO; GOLGHER, 2018; GONÇALVES; CARVALHO; WONG; TURRA, 2019). Filho and Reichert (2017) pointed out significant correlations between the number of children had by women and variables of education, access to information, income and urbanization in Brazil; the United Nations Population Fund (2018) highlighted the role of education and income, two of the most relevant inequalities in Brazil, which directly impacted fertility rates; Paes and Silva (2018) found a direct association between fertility levels and infant mortality for the Semi-arid region; Dus Poiatti (2020) pointed out that female education is the most important socioeconomic variable to explain the number of children per woman using an international database.

Taking these and other studies as a reference, the following independent (explanatory) variables were selected to compose the regression model applied here, which were extracted from the ADH in Brazil (IPEA, FJP; UNDP, 2013): Gini Index; Percentage of Women aged 10 to 17 who had children; Life Expectancy at Birth; Aging Rate; Illiteracy Rate (15 years and over); Municipal Human Development Index (MHDI); MHDI Income; MHDI Longevity; MHDI Education; Percentage of the Poor and Proportion of Population Living in Rural Areas.

For the census years (1991, 2000 and 2010) a descriptive analysis of the TFRs was carried out through the mean, median, standard deviation, values of the total range and quartiles. Multiple linear regression for panel data was used to analyze the association of TFR with the selected variables and to obtain the final model considering the period 1991-2010.

Before proceeding with the modeling, we investigated the association between the TFR and the study variables using Spearman's Correlation Coefficient, since not all variables were normally distributed. Thus, we sought to include variables already reported in the literature as determinants of fertility in the model, seeking to elucidate whether the associations found in other regions would apply to the Semi-arid region of Brazil.

Models for panel data can be differentiated into Pooled Models OLS (Ordinary Least Square or Ordinary Least Squares), also called Model for Stacked Data; Fixed Effects Models or Random Effects Models, depending on how it controls time-invariant characteristics of the unit of analysis (WOOLDRIDGE, 2015).

The population regression function for stacked data can be expressed as follows:

$$Y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ijt} + \varepsilon_{it}, i = 1,\ldots,N, j = 1,\ldots,k \; and \; t = 1,\ldots,T$$

where, Y_{it} is a dependent variable for individual *i* at time *t; X_{ijt}* is the regressor *j* for individual *i* at time *t*; β_0 is the intercept; β_j is the slope for the regressor *j*; the number of regressors is equal to *k*; the number of inividuals is represented by *N* and *T* (how many time periods considered) and ε_{it} is the error term for the *i-th* individual at the *t-th* time, because of this variation it is called idiosyncratic error, following a normal distribution with avarege zero, variance σ^2 and they are independent.

The fixed effects population regression function can be expressed as:

$$Y_{it} = \alpha_i + \sum_{j=1}^{k} \beta_j X_{ijt} + \varepsilon_{it}, i = 1,\ldots,N, j = 1,\ldots,k \; and \; t = 1,\ldots,T$$

where α_i is the effect that differs individuals, equivalent to having an intercept for each individual. The estimation method for this type of model is called Least Squares with Dummy Variables for Fixed Effects (MQVD). This model considers both the heterogeneity of individuals and the time effect

(GUJARATI; PORTER, 2011).

The random effects population regression function can be written as:

$$Y_{it} = \beta_{0i} + \sum_{j=1}^{k} \beta_j X_{ijt} + \varepsilon_{it}, i = 1, \ldots, N, j = 1, \ldots, k \text{ and } t = 1, \ldots, T$$

In which β_{0i} is a random variable with the average value β_0, where

$$\beta_{0i} = \beta_0 + u_i$$

Thus, u_i is a normal error term with zero mean and variance σ_u^2. Therefore, the idiosyncratic term (as it varies between individuals and over time) is written as $\delta_{it} = u_i + \varepsilon_{it}$, being completely independent of each other, not correlated with the individual and temporal units, and also with any exploratory variables of the model.

If there is a correlation between the regressor variable and the idiosyncratic error, the fixed effects model will be the most recommended. In case T is small and N is large, there will be no differences between the models. Otherwise, randomness must be checked.

To choose between these three types of model, the specification tests used were: Chow F Test, Breusch-Pagan LM Test and the Hausman Test. The significance level adopted was 5%.

Arellano method was considered to calculate the robust standard errors of models that did not meet the assumptions of homoscedasticity and absence of autocorrelation. The results of models with robust standard errors for heteroscedasticity and serial autocorrelation estimated by the Arellano method are more recommended for small panel fixed effects models (when $N>T$, where N is the total of municipalities and T is the total of years) (WOOLDRIDGE, 2015).

The study data have free *online* access, thus justifying the absence of submission to Brazil Platform and subsequent referral to the Research Ethics Committee.

3. Results and Discussion

In the 1991/2000 and 2000/2010 decades, it was observed a rapid reduction in Total Fertility Rates (TFR) in the municipalities of the Brazilian Semi-arid region, as can be seen in Figure 1 and Table 1. Figure 1 shows that in 2000 very few municipalities in this region were below the "replacement level", that is, 2.1 children on average per woman. While in 2010, approximately one third of them were below this level.

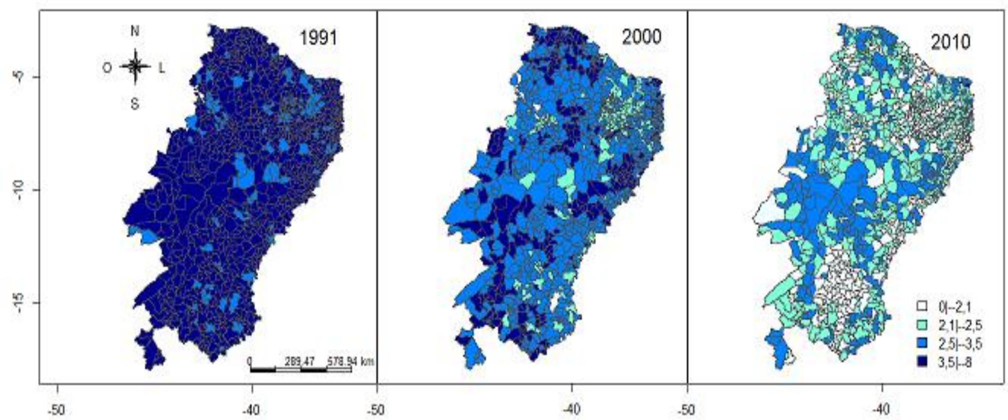

Figure 1. Evolution of the Total Fertility Rate in the Brazilian Semi-arid Region in the census years 1991, 2000 and 2010.

Table 1. Descriptive statistics of the Total Fertility Rate of municipalities in the Brazilian Semi-arid region for the census years 1991, 2000 and 2010

Year	Average	Standard Deviation	Minimum	1st Quartile	Median	3rd Quartile	Maximum
1991	4.55	0.95	2.55	3.86	4.40	5.14	7.84
2000	3.15	0.61	2.05	2.69	3.07	3.51	6.09
2010	2.26	0.35	1.41	2.01	2.24	2.49	3.68

Source: Atlas of Human Development in Brazil, 2013.

The extreme values (minimum and maximum) of TFR presented halved in approximately 20 years (Table 1). There was not only a drastic reduction in fertility levels, but also in the variability of TFRs among the municipalities, that is, in 2010 the standard deviation was a little less than a third of the deviation of 1991, which suggests a trend of homogeneity of TFRs among municipalities.

The descriptive statistics of the Log (Total Fertility Rate) of municipalities in the Brazilian Semi-arid region can be seen in Table 2. The natural logarithm (Total Fertility Rate) was assigned as the dependent variable (response) of the study, in order to meet the assumption of linearity for application of regression models in panel data.

Table 2. Descriptive statistics of the Log (Total Fertility Rate) of municipalities in the Brazilian Semi-arid region for the census years 1991, 2000 and 2010

Year	Average	Standard Deviation	Minimum	1st Quartile	Median	3rd Quartile	Maximum	Kurtosis	Skewness
1991	0.65	0.09	0.41	0.58	0.64	0.71	0.87	-0.40	0.09
2000	0.49	0.08	0.31	0.43	0.49	0.54	0.79	-0.38	0.29
2010	0.35	0.07	0.15	0.30	0.35	0.39	0.57	-0.12	-0.08

The TFRs considered in the study were obtained from census data from the Brazilian Institute of Geography and Statistics – IBGE, thus, the analysis included in the modeling the most updated information until the moment of the study (2010). Tables 1 and 2 present the statistics of the years considered in the modeling, while Table 3 contextualizes the Total Fertility Rate of the Semi-arid region within the scope of Brazilian regions for discussion purposes.

The changes in TFR levels, however, did not occur only in the Brazilian Semi-arid, but also in all Brazilian regions, as shown in Table 3. According to the Brazilian Institute of Geography and Statistics – IBGE (2018), in 2020 the TFR level in Brazil would return to that of 2010, after an increase in 2015, driven by the Center-South of the country. In the opposite direction of this behavior would be the North and Northeast regions. For the latter, where most of the Semi-arid region is concentrated, the level of this indicator exceeded that of the country in 2010, however the projections would be reversed from 2015 onwards. For IBGE, in 2020 all regions of Brazil would have TFR below the replacement level.

Table 3. Total Fertility Rate of the regions and Brazil, for the years 2010, 2015 and 2020

Year	North	Northeast	Southeast	South	Central-West	Brazil
2010	2.21	1.82	1.63	1.63	1.77	1.75
2015	2.11	1.78	1.73	1.77	1.90	1.80
2020	2.00	1.73	1.70	1.74	1.85	1.76

Source: IBGE/Research Directorate. Projection of the population of Brazil and Federation Units by sex and age for the period 2010-2060, 2018.

The results for the Semi-arid region of Brazil corroborate other investigations that point to the total decline in fertility levels in the country in the 2000s. The generalized and sustained decline in fertility that occurred at different times among Brazilian regions was only possible when women with low income levels, which accounted for a large part of the population, began to have access to some form of family planning, whether temporary or not (OLIVEIRA; SILVA, 1986; GONÇALVES;

CARVALHO; WONG; TURRA, 2019).

To investigate which socioeconomic, demographic and health factors were statistically contributory to the decline in fertility levels in the Semi-arid region (Table 2), were constructed different multiple regression analysis models for panel data considering combinations of independent variables (matrix of correlations). Thus, the problem of multicollinearity among the variables can be minimized, as for example, the high correlation between the MHDI Income and the Per Capita Income.

When tests were carried out to identify the type of panel data model, the p-values of Chow F Test ($p<0.001$) indicated that pooled regression models (H_0) were rejected in all models, so, fixed effects models were more suitable. In turn, the results of the Breusch-Pagan LM Test showed a greater suitability of the random effects models, when comparing them to the pooled models (H_0). Thus, to decide between the fixed effects and random effects models, the Hausman Test indicated the rejection of the null hypothesis that the random effects models are more adequate, that is, the fixed effects models better explained the variations in the log(TFR) for all models ($p<0.001$).

Studies have already shown that fixed effects models are preferable in impact assessments, as they allow the correlation between the non-measurable and constant term over time and the other independent variables (KHANDKER; KOOLWAL; SAMAD, 2009; RASELLA et al., 2013; SILVA, 2017).

Four models were presented. Table 4 presents the results for each of them with their respective robust standard errors for heteroscedasticity and serial autocorrelation estimated by the Arellano method, which is recommended for small panel fixed effects models (when $N > T$, where N is the total of municipalities and T is the total number of years).

Table 4. Fixed effects regression models with robust estimators calculated by the Arellano method when considering the indicators associated with fertility, Brazilian Semi-arid region, 1991, 2000 and 2010

	Dependent Variable: Log (Total Fertility Rate)			
	Models			
	I	**II**	III	IV
Gini index			0.192*	-0.561
			(0,046)	(0.054)
% of Women from 10 to 17 years old who had children	-0.008*** (0.002)	-0.009*** (0.002)		-0.009*** (0.002)
Life Expectancy at Birth			-0.016***	
			(0.001)	
Aging Rate			-0.036***	
			(0.004)	
Illiteracy Rate			0.018***	
			(0.001)	
MHDI	-1.968***			
	(0.074)			
MHDI Income		-0.806***		
		(0.116)		
MHDI Longevity		-1.221***		
		(0.089)		
MHDI Education		-0.738***		
		(0.052)		
% of Poor people	0.002***			0.015***
	(0.001)			(0.0002)
Proportion of Population		0.228***		0.296***

living in Rural Area		(0.043)		(0.051)
Adjusted R^2 (*within*)	0.808	0.799	**0.820**	0.763

Source of basic data: Atlas of Human Development in Brazil, 2013.
*Note: *p<0.1; **p<0.05; ***p<0.01; P-value: information in parentheses.*

When using multiple regression analysis for panel data, Model III resulted in the best adjusted R^2 (*within*), considered quite satisfactory, and being explained by 82.0% of the internal association between covariates and TFR, as shown in Table 4, when considering the years 1991, 2000 and 2010. Several models were tested, however, the models with higher adjusted R^2 (*within*) were presented.

Table 5 shows for the Final Model III of fixed effects regression, the estimated coefficients ($\widehat{\beta}$), the robust standard errors for heteroscedasticity calculated by the Arellano method and the p-values of the variables used in the Model. The normality of the residuals was not rejected for Model III according to the Anderson-Darin test and by the quantile-quantile plot using the quantiles of the Normal distribution (0.1). And the linearity of the model was evidenced by the comparison graph of the predicted value versus the real value of the Log(TFR). The Final Model III can be respecified as:

$$TFR_{it} = \exp(\alpha_i + 0{,}192IG_{it} - 0{,}016EVA_{it} - 0{,}036TE_{it} + 0{,}018TA_{it})$$

Where: TFR_{it} - Total Fertility Rate for individual i at time t; GI- Gini index; LEB- Life Expectancy at Birth; AR- Aging Rate and IR- Illiteracy Rate.

The results produced by the Final Model III indicate that there were evidences of significance at the level of $p<0.01$ in the relationship between TFR and the following explanatory variables: levels of Life Expectancy at Birth, Aging Rate, Illiteracy Rate and Gini (Table 5).

Table 5. Final Model (III) considering fixed effects with robust estimators calculated by the Arellano method for municipalities in the Brazilian Semi-arid region, 1991, 2000 and 2010

Variable	$\hat{\beta}$	Standard Error	p-value
Gini Index	0.192	0.046	< 0.0001
Life Expectancy at Birth	-0.016	0.001	< 0.0001
Aging Rate	-0.036	0.004	< 0.0001
Illiteracy Rate	0.018	0.001	< 0.0001
Adjusted R^2 (*within*)			0.820

Source of basic data: Atlas of Human Development in Brazil, 2013.

The Gini Index variable pointed out that the increase in income equality within the Semi-arid municipalities had an effect of reducing the fertility level in the period 1991 - 2010. In other words, income inequality would favor an increase in the fertility level. In an investigation focused on adolescent fertility in Brazil, Cavenaghi (2013) identified that among women living in households with a per capita family income two to three times higher than the minimum wage, the fertility rate was 31 births per 1,000 women and, among those who lived in households with higher incomes (equal to or greater than five times the minimum wage) the rate was 8 per thousand. This inverse relationship is a situation in which the development process, linked to an increase in income in a population and associated with lower income inequality, would tend to produce a decrease in fertility levels. There are studies that show that this inverse relationship can be found even for regions in stages of socioeconomic development that are delayed in relation to more developed ones. In this sense, it is possible to follow the position of Potter et al. (2010), Araujo Junior, Salvato and Queiroz (2013) and Alves (2018), for example. These authors argue that some regions manage to reduce fertility levels even in a low-income setting. That is, even considering that the income levels of the Semi-arid municipalities are below other regions with higher income levels, it was still possible to evidence an association between income and fertility, due to the income heterogeneities among the Semi-arid municipalities.

The development process that includes not only the increase in income and the reduction of income inequalities of individuals in the regions, involves other dimensions, among which, the improvement of the general educational level of the population is highlighted. Thus, in the model, the

Illiteracy Rate had a direct effect on the relationship with fertility levels, as shown in the modeling (Table 5). Work in this direction warns that education is linked to access and knowledge of contraceptive methods and greater awareness of family planning, which tend to favor a decline in fertility levels (CAVENAGHI, 2013; CARVALHO, 2019).

The Aging Rate, a variable related to the population structure, greatly reflects the stage of the demographic transition in which a region is (IBGE, 2016). After successive stages in Brazil at the beginning of the 21st century, the demographic profile was characterized by low infant and birth mortality rates, high life expectancy at birth, few children per woman and an aging age structure, with a proportion of elderly high (UNFPA, 2018).

Population aging has gained prominence in debates in Brazil, mainly due to the numerous consequences it brings, whose phenomenon is linked to the epidemiological profile of the population, which is altered by the increase in life expectancy, diseases and non-communicable diseases. The latter are now responsible for the main causes of mortality and disability (VERAS; OLIVEIRA, 2018; MACINKO et al., 2019; GUIMARÃES, ANDRADE, 2020).

In this way, both the increase in Life Expectancy at Birth, in the Aging Rate and in the educational level, during the period from 1991 to 2010 in the Semi-arid region, was accompanied by a decrease in the TFR level, although the levels of the increase in the three first indicators have occurred at a slower rate than the decline in fertility, as shown by the indicators shown in Tables 1 and 5. In turn, there was an indication of a decline in the level of the Gini Index from the year 2000, after an increase in the same.

Table 5. Median of the Gini Index, Life Expectancy at Birth, Aging and Illiteracy in the municipalities of the Brazilian Semi-arid region for the years 1991, 2000 and 2010

Year	Gini Index	Life Expectancy at Birth	Aging Rate	Illiteracy Rate
1991	0.520	59.010	6.020	50.445
2000	0.560	64.330	6.950	36.095
2010	0.520	70.600	8.760	27.820

Source: Atlas of Human Development in Brazil, 2013.

4. Conclusions

Significant statistical results were obtained when considering panel data for the assessment of the association between the Total Fertility Rate and socioeconomic, demographic and also health indicators as an alternative to the use of classic cross-sectional data.

When considering the problems arising from the high level of inequality in the Brazilian Semi-arid region, it was essential to analyze the different causes that impact the fertility rates in the region. In this direction, this study showed that the reduction in the levels of the Gini Index, the Illiteracy Rate, the increase in Life Expectancy at Birth and in the Aging Rate intervened directly or inversely in the decline of fertility in the Semi-arid region of Brazil, in the period 1991-2015.

Thus, it is expected that this study can bring a greater understanding of these relationships, facilitate the planning and execution of public policies that help in better attention to the reproductive behavior of the population of the Semi-arid region.

The decline in fertility in the Semi-arid region may open a demographic window of opportunity (bonus). When properly used, it can boost the growth of per capita income and well-being, on the other words, it is possible to have an economic gain and greater development for the region, although it signals a future demographic burden, whose consequences can instigate population policies. The growth of the elderly population brings challenges, but gives rise to new perspectives. Since the aging process has almost irreversible characteristics, the moment indicates that it would be advantageous to seek the opportunities generated by this process of change in the intergenerational composition and create conditions for the Semi-arid to have active, healthy elderly people with adequate educational levels and with a fair quality of life.

It is true that this study requires an update, given the lack of data that make it possible to calculate the fertility rate and the availability of indicators for the municipalities in the Brazilian Semi-arid region for more recent years. However, it is believed that the mentioned relationships are justified as a proxy for analyses in subsequent years when taking advantage of the results from the 2022 Demographic Census.

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Conflicts of Interest

The authors declare no conflict of interest.

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