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Crisis, fiscal austerity and food insecurity: associated factors, trends and spatial distribution via PNAD and POF

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Abstract *This study aims to identify and analyse factors associated with food insecurity (FI), trends and spatial distributions for geographical strata. The hypothesis of worsening of the outcome of severe FI, measured by the Brazilian Food Insecurity Scale (EBIA) in households, as an effect of the crisis and/or the austerity policy, was investigated. The article involves studies with cross-sectional design and mixed ecological for spatio-temporal trends, based on 4 national IBGE surveys. A weight calibration procedure to match population distribution by gender and age group was adopted, as well as estimation and modelling methods that incorporate effects of the sample design. Poisson regression with robust estimation of variance was used to estimate prevalence ratios of severe FI at the etiological level. For the ecological level, two multilevel modelling approaches were employed for repeated measurements of strata: multiple log-log regression for associations; and modelling of splines for trend estimation. The findings point to impacts of the austerity policy adopted, with changes in trends in the Programa Bolsa Família – PBF (Family Benefit Programme – FBP) and on the increase in severe FI. It is projected that there will be an increase in FI and a shortfall in relation to achievement of the SDG no. 2 in 2030 by Brazil, despite the success obtained in 2014 for MDG no. 1.*
Key words *Cross-sectional studies, Food insecurity*

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Introduction

Affecting about one in every nine people, hunger can be considered one of the world's main health risk factors, and malnutrition is responsible for about half (45%) of the child mortality rate. In this context, the second Sustainable Development Goal (SDG) deals with hunger eradication: "End hunger, achieve food security, improve nutrition, and promote sustainable agriculture."

The 2030 Agenda, synthesized in the SDG, consists of an ambitious action plan that seeks to eradicate extreme poverty, combat inequality and injustice, and contain climate change, among other actions. Added to these campaign efforts are those of the international scientific community, making contributions to the task of identifying and measuring determinants and factors associated with food insecurity (FI), as well as the latter's negative impacts on health.

Among the determinants and factors regarding the increased FI, studies have provided evidence of the effects of major recessions[2], such as that experienced by European countries after the 2009 international financial crisis, as well as the attenuating effects of social protection policies.

The previous Agenda of the Millennium Development Goals (MDG), signed in 2000 and ended in 2015, was the precursor of the current Agenda to combat FI by including as the prime goal: "eradicate extreme poverty and hunger". Brazil has presented significant positive results in this endeavour, as revealed in the 2014 World Food Insecurity Report[3], which attested that Brazil had left the hunger chart because it had drastically reduced hunger, malnutrition and undernourishment in the period. The Undernourishment Prevalence Indicator for Brazil, a measurement employed at the time to assess the scale of hunger and monitor it at the international level by the U.N. Food and Agriculture Organisation (FAO), dropped below 5%, the statistical limit under which a country is deemed to have overcome the hunger problem[4].

The indicator used by the FAO was aimed at monitoring the MDG. Their replacement by the SDG, as of 2015, required use of new methodological approaches for this purpose. Thus, since then, in Brazil, the use of the Brazilian Food Insecurity Scale (EBIA), implemented through major national surveys[5-9], is highlighted.

Of these national surveys[8,9], the two most recent unequivocally pointed out a deterioration of the FI situation in the country after 2013. Consultations of the international scientific literature[10] also indicated this trend change, that is, an increase in FI in Brazil after 2013 based on the EBIA measurements found in the surveys.

Following the country's success in achieving the MDG for the eradication of hunger, faced with the fiscal and political crises Brazil experienced as of 2014, repetition of this good performance to achieve the SDG became an obvious risk, and the international scientific literature was already mentioning the potential impacts of austerity – materialised by the expenditure ceiling constitutional amendment[11] – on the SDG to be reached by the country[12]. This year has been marked by the end of a sequence of nominal surpluses that had started in 2003, and the beginning of successive deficits that have been impacting the economic and social results, materialised by the austere fiscal tightening implemented by the aforementioned constitutional amendment.

Studies in the national scientific literature have pointed out that fiscal austerity measures have compromised non-transmissible disease control goals in Brazil[13], and a case study in the municipality of Cuité-PB also highlighted the dismantling of government initiatives for food and nutritional security[14]. Other studies[15,16] analysed the implications of fiscal austerity measures and the consequent dismantling of public policies to deal with food insecurity.

This article analyses factors associated with severe FI, its trends and spatial distribution based on the microdata gathered by the National Household Sample Survey – PNAD in 2004, 2009 and 2013, and the *Pesquisa de Orçamentos Familiares* – POF [Family Budget Survey – FBS] 2017-2018. The determinants under investigation involved a hypothesis about the impact of the crisis and the austerity measures on the severe FI outcome. The period chosen excluded possible effects of confounding due to the emergence of the COVID-19 pandemic in the country in 2020, whose effects on severe FI are present in the context of the most recent survey[9], not considered here due to a lack of coverage compatible with that of the Brazilian Institute of Geography and Statistics – IBGE surveys considered.

Among the works that analyse FI based on surveys, this one presents three aspects as innovative contributions: first, by proposing less biased, more precise population estimates when using the weight calibration technique of the sample design considering the distribution of the population by gender and age range, in addition to the calibration by the population totals by post-strata used in official statistics; second,

obtain the nationwide distribution of analysis units, with the greatest refinement and capillarity enabled by the sample designs of the surveys for all the geographical strata; and, finally, investigating the hypotheses of an effect of the underlying crisis and austerity as exposures associated with the outcome of FI.

Materials and methods

This article involves two major alternative types of studies, containing cross-sectional and mixed ecological analyses including multiple group analysis of time trends, that is, space-temporal trends. Considering the variables of outcome and joint exposure, in all, data obtained in by the SAGI - Information Evaluation and Management Secretariat, and three major national surveys: PNAD, continuous PNAD – PNADC – and POF, which are population-based studies conducted by IBGE.

There was use of cross-sectional and space-temporal trend designs, because there was use of anonymised individual microdata from large national surveys (cross-sectional studies) conducted in different years, such as the PNADs of 2004, 2009 and 2013[5-7], the 2018[17] annual PNADC and the POF of 2017-2018[8].

The years selected for the PNADs and the POF were those that included EBIA's items in their questionnaires. PNAD, PNADC and POF are surveys whose sampling designs allow estimation of measurements valid for geographical strata that include the states, the Federation Units (UFs), and in some UFs, also estimates for groups of municipalities irrespective of whether they integrated their metropolitan regions (MRs) or not.

When assessing measurements involving aggregates of geographical strata from each survey separately, what one obtains are outlined studies of the exploratory type for each year, the purpose being to analyse, at the ecological level, the spatial distributions of the severe FI prevalences by subnational combinations of geographical areas and strata defined by variables considered modifiers of the effect of the outcome. The dimension of temporal analysis arises when comparing evolution over the years of each spatial distribution.

On the other hand, the set of association measurements obtained from the data of each of the four surveys (three PNAD and one POF) is considered to originate from a study design of the etiological type. Thus, the second type of study addressed involves employing inferential analyses from estimated models for each survey that enable checking of longitudinal changes, or temporal trends in the parameters and association measurements among estimated exposures and outcome, resulting from the impacts of the crisis or the different levels of austerity in the economic policies involved in each year of the period analysed.

These analyses investigate whether, at the etiological (individual) or ecological (aggregate) level, the hypothesis of worsening in the framework of the severe FI outcome in the households, such as effects of the crisis and/or austerity policy. The coefficients of exposure variables, and the confounding or modifying effect of each model, enable analysis of the magnitude of comparison bias, or modifications contributing to the outcome for each level or each variation in value of these variables.

In the specific case of statistical modelling used at the ecological level, there are repeated measurements of the same target population group. This analysis of repeated measurements under different conditions is a feature present in the clinical trials, considering differences in the unit of analysis and in the fact that there is no control over the degree of exposure, that is, the intensity of the austere intervention or the impact of the economic crisis. At this point, a scenario is faced that could also be called a natural experiment, as also indicated for our case by a Brazilian author who addressed the theme[18] in his review of the book by Stuckler and Basu[19], in which several international situations analogous to that in this article were evaluated.

The choice of 2004, 2009, 2013 and 2017-2018 stems from the availability of IBGE national surveys, carried out in partnership with the Ministry of Health, that addressed the theme of FI, whether through PNAD supplements in 2004, 2009 and 2013, or a specific survey contained in the POF, conducted in 2017 and 2018.

Participants

PNAD is an annual probabilistic household sampling survey, conducted throughout the country. The target population is composed of households and their residents in the covered survey area. PNAD adopts a stratified, clustered sample design with one, two or three selection stages, depending on the stratum[20].

PNAD 2004 surveyed 399,354 people from 139,157 households from 7,816 census sectors in 851 municipalities. PNAD 2009 surveyed 399,387

people from 153,837 households from 7,818 census sectors in 851 municipalities. PNAD 2013 surveyed 362,555 people from 148,697 households from 9,166 census sectors in 1,100 municipalities.

In the POF, due to its objectives and characteristics, only permanent private households were surveyed. The household is the lowest level survey sampling unit, also consisting of an important investigation and analysis unit for characterisation of families' living conditions, including housing. Permanent private household is defined as housing, partly or in full, exclusively for one or more persons, linked by kinship ties, domestic dependence or coexistence mode. The survey information unit is the resident who occupies the household as the single or main residence and is not absent from it for a period exceeding 12 months. POF 2017-2018 interviewed 57,920 of the 75,635 households selected in the sampling process, distributed throughout 5,504 primary sampling units[8], and the table of the residents obtained from the microdata includes 178,431 residents interviewed in their households.

Variables

The outcome variable measured at the ecological level consists of estimating the prevalence of severe FI in the population that corresponds to the proportion of people in a condition of severe FI. Individual level outcome is measured by security characteristics or different FI levels in the household that are determined through responses to EBIA questions, as specified in the IBGE[6].

According to the conceptual model of the determinants associated with Food and Nutritional Security (SAN) indicated in the literature[21], the macro-socio-economic determinants would be as follows: the world politico-economic system; economic, social and care policies; agricultural and environmental policies; and recognition of SAN as a human right.

The notions of economic crisis and fiscal austerity, themes of this article, are framed in these SAN determinants. Variables that measure aspects of the labour market, such as employment and income, were chosen to represent the effects of the economic crisis as exposure variables. Also considered as exposure were the expenditure and coverage variables of the Bolsa Família (Family Benefit) Programme representing care policies and attempting to capture the effects of fiscal austerity policy.

Other variables included in the analysis are confounding and/or act as effect modifiers, such as the housing macro-region and as an approximation to the Brazilian Economic Classification Criterion of the Brazilian Association of Survey Companies for each year and survey[22,23].

Statistical methods

As for the choice of methods applied in this article, considering that the data is gathered from survey with probabilistic household samples, *even with a strict data collection protocol, the most frequent presence is that of women and elderly at home compared to that of men and individuals of active age. Thus, the calibration of expansion factors emerges as the best technical alternative to dealing with these typical collection and selection biases*[24].

Regarding the specific procedure adopted, that of weight calibration, considering the distribution of the population by gender and age groups used in all the population estimates of this article, the choice made was that known as raking, or incomplete multidimensional post-stratification[25]. This was due to its greater parsimony in view of the very large number of category levels of the variables used for calibration. Regarding the calibration performance evaluation, which marked the choice of specific procedure performed, suggestions found in the specialised literature were used[26].

Some articles published in the collective health literature drew attention in their sections with considerations and final comments to the possible consequences of neglect of this characteristic peculiar to the national surveys for estimates of parameters of population bases with this type of sampling[20,27,28]. Our statistical modelling and analysis have advanced in the sense of using modelling tools that also incorporate the effect of complex sampling design on the Poisson regression parameter estimation procedure via the *svyglm* function of the *survey* package[29-31], which runs on the R[32] platform .

Poisson regression was employed through the *svyglm* function with inclusion of the argument, "family=quasipoisson(log)", which serves, through robust variance estimation, to alleviate the problem of excess zeros that usually corrupt Poisson's distribution premise of outcomes. Although this type of modelling in cross-sectional studies does not allow exact estimation of the prevalence ratio (PR), it is one of the procedures indicated in the literature[33 34 35] for the purpose of estimating the PRs of these severe FI, for this version at the individual outcome level, in the

adjustments made in the PNAD 2004 and POF 2017-2018 bases. Only in these years was there information about receiving the FBP benefit in the survey microdata initially considered.

As for estimates aggregated by geographical strata, we used two alternative approaches of multilevel modelling for the four repeated measurements of these strata with PNADs 2004, 2009 and 2013, and POF 2017-2018: a multiple version of the log-log type to estimate the elasticity of the explanatory variables for the prevalence of severe FI; and, another version with the cubic splines artifice for estimation of the prevailing trends of severe FI in each stratum. Both used the population strata size as a weight in the estimation via the *lmer* function of the *lme4*[36] package also available in R.

In log-log models, where dependent and explanatory variables receive logarithmic transformation, elasticity is the size of the impact that change in one variable exerts on another. In a generic sense, it is the percentage change of one variable, given the percentage change in another, *ceteris paribus*. Thus, elasticity is synonymous with sensitivity, response, reaction of a variable, in the face of changes in other variables[37], and directly consists of the adjusted coefficients of the log-log models.

All the statistical modelling and data analysis procedures were performed in the R programme. For adjustment of the trend models, the analysis strategy was the same as that implemented in Sergio and de Leon[38], and divided into four steps. In the first, the data were analysed according to the "empty" model, that is, without explanatory variables, only with the fixed effect of the intercept (overall mean) and its random effects on the two levels of the data hierarchy.

Next, the FI behaviour was analysed in terms of time. The temporal trends were described by a parametric spline function. This function is appropriate for modelling longitudinal measurements[39,40]. In the modelling process, polynomials can be adjusted by intervals and interconnected in the nodes, although, due to the small quantity of time repetitions, this interconnection resource was not used. For further details about this modelling technique, see Snijders & Bosker[41].

The selection of the final models was performed manually following the analogous approach to that known as *stepwise backward*[42], supported at significance levels less than 15%, whether from the estimated coefficients or, when available, the probability ratio tests.

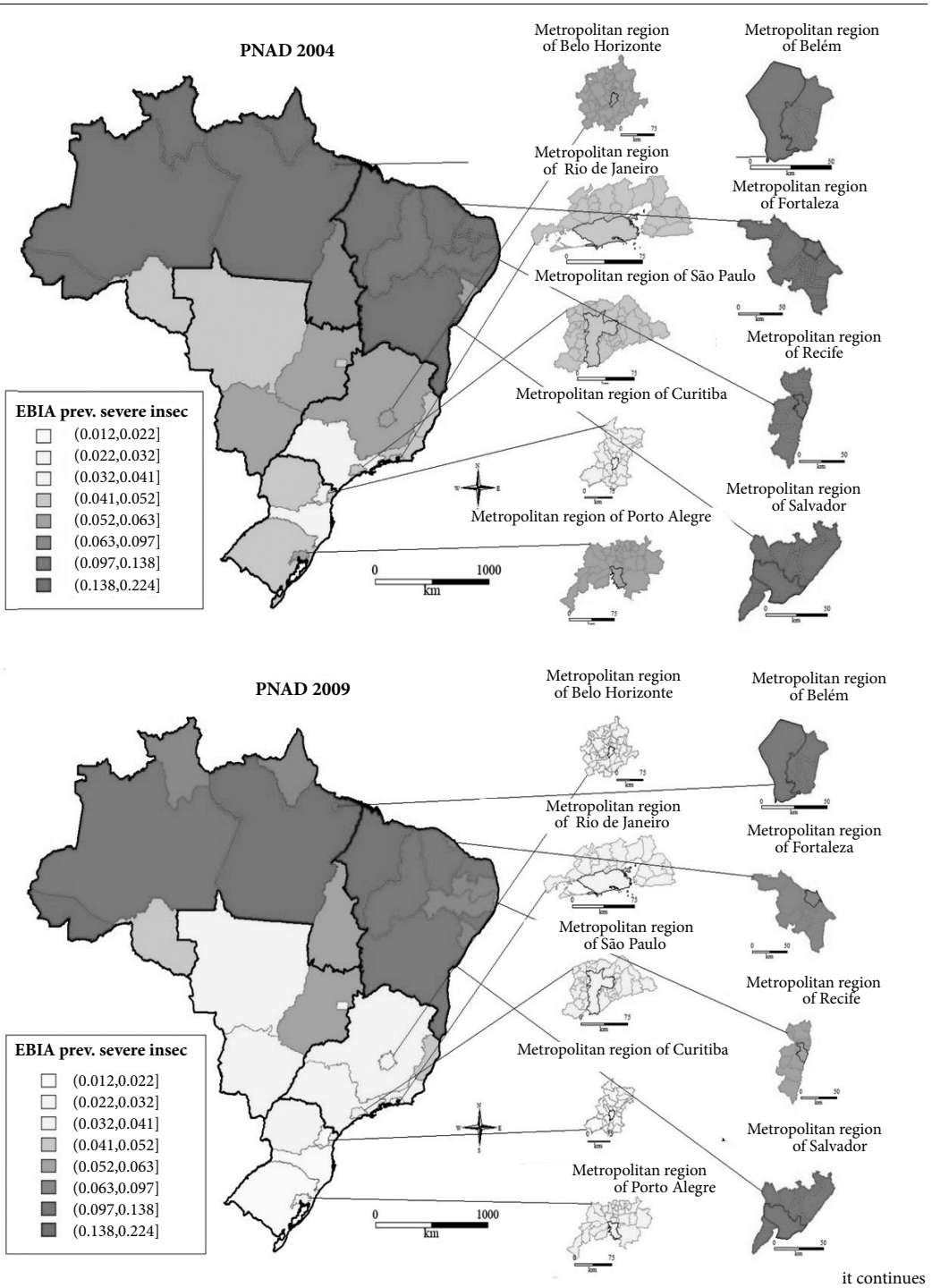
Results

The four maps in Figure 1 were composed from estimates of the population with a prevalence of FI using the PNADs and POF in the four periods indicated. To be comparable, heat map colours (lighter colours and yellows for lower severe FI prevalence, ranging to redder and darker colours for greater prevalence) were used to characterize severe FI prevalence in each geographical stratum and period (144 in all, including 27 UFs and 9 MRs in each of the four years). All 144 estimates were gathered, and eight categories were created with nine limits corresponding to the minimum, maximum and another seven octiles, separating measurements that divide the total distribution into eight equal parts with 18 estimates (12.5% of the distribution) in each category. The population estimates that gave rise to Figure 1 are published[43].

In view of the disparity in population densities and the fact that these are larger in the MRs, they have remained relatively small areas and are of difficult visual perception in the cartograms of Brazil in Figure 1. For this reason, each year, there are maps on separate enlarged scales, along two columns to the right of the cartograms on the nine MRs maps, containing some MRs from the southeastern states in the left column and others in the north and northeast in the right column. The Federal District, despite being predominantly metropolitan, is not included in the MRs category, in accordance with the law referring to UFs.

This approach enables visual identification of distribution and space-time evolutionary patterns of severe FI in the period. The lowest prevalence of severe FI in the period was 1.29%, observed in the Belo Horizonte MR in 2013, and the highest, 22.26% in Maranhão State in 2004. These first values already indicated in advance space-temporal disparity patterns that were repeated throughout the 4 mappings: highest prevalence of severe FI in the North and Northeast (N-NE) versus lower ones in the South, Centre West and Southeast, and higher prevalences in 2004 and lower ones in 2013.

In Table 1, from the evolution of the aggregate measurements of four repeated exposure variables in the four years, the only variable that did not show a trend change was the average income per capita, which was presenting growth in real terms regarding food purchasing power, throughout the period, both in the aggregate of the MRs and in that of the UFs. For this purchasing power, what appears to have changed after



it continues

Figure 1. Spatial and temporal distribution of severe FI prevalence estimates in Brazil by geographical strata in 2004, 2009, 2013 and 2017-2018.

2013 were their coefficients of variation (CVs), although this phenomenon cannot be credited, in principle, with the worsening in the known concentration pattern of income distribution. This is because the POF had a sample size less than half those of the PNADs. On the other hand,

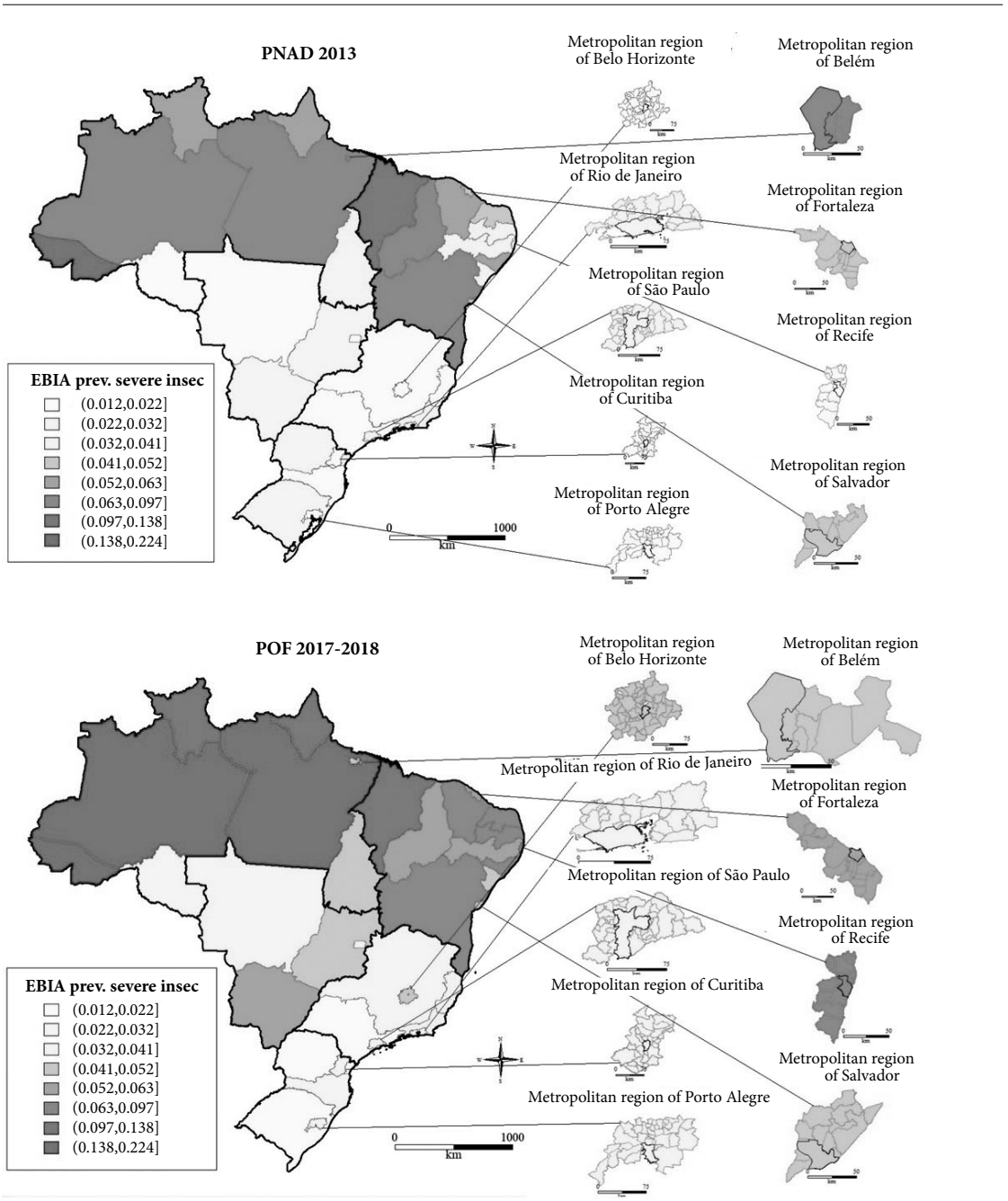


Figure 1. Spatial and temporal distribution of severe FI prevalence estimates in Brazil by geographical strata in 2004, 2009, 2013 and 2017-2018.

Note: to illustrate the geographical areas of PNADs 2004, 2009 and 2013, the 2005 IBGE municipal network was used, and for POF 2017, the 2017 agricultural census was used.

Source: Authors, devised from PNAD microdata (2004, 2009 and 2013) and POF (2017-2018).

the fall in CVs from 2004 to 2013 reflects a reduction in the inequality of income distribution in the country in the period.

If, on the one hand, the cartograms point out similarities in the distributions in the geographical strata of the 2004 and 2017-2018 severe FI

Table 1. Population estimates and coefficients of variation or aggregates of the variables of exposure to crisis/ austerity in the aggregated geographical strata in Brazil in 2003, 2009, 2013 and 2017-2018.

Exposure to crisis/ austerity variable Geographic strata – Brazil aggregate	Estimate or aggregate				CV (%) of estimate				Mean annual rate of change (%)	
	2004	2009	2013	2017-2018	2004	2009	2013	2017-2018	2014/2004	2017/2014
Average income per capita at Jan/2018 prices [1]										
All	897.79	1,120.52	1,21647	1,407.42	1.01	0.92	0.89	1.78	3.43	3.71
Metropolitan region	1,175.93	1,455.08	1,599.45	1,953.73	1.75	1.66	1.77	3.56	3.48	5.13
Rest of the Ufs	769.42	972.18	1,052.12	1,171.17	1.27	1.11	0.94	1.76	3.55	2.72
Unemployment rate (%) [2]										
All	8.97	8.43	6.65	12.69	1.25	1.23	1.23	1.00	-3.27	17.54
Metropolitan region	13.19	10.64	7.79	14.39	1.39	1.45	1.80	1.77	-5.69	16.58
Rest of the Ufs	7.02	7.39	6.12	11.83	2.02	1.83	1.65	1.24	-1.53	17.93
Average monthly expenditure of households covered by FBP [3]										
All	14.71	33.21	42.79	37.62	-	-	-	-	12.60	-3.17
Metropolitan region	7.69	19.59	25.40	24.25	-	-	-	-	14.20	-1.16
Rest of the Ufs	18.08	39.61	50.89	43.64	-	-	-	-	12.19	-3.77
Average monthly proportion of households covered by FBP [4]										
All	0.09	0.21	0.22	0.21	-	-	-	-	10.48	-0.80
Metropolitan region	0.05	0.13	0.14	0.15	-	-	-	-	12.05	1.73
Rest of the Ufs	0.11	0.24	0.25	0.24	-	-	-	-	10.04	-1.59

[1] PNADS 2004, 2009 and 2013 and POF 2017-2018 using the INPC/IBGE Food and Beverages group as a monetary restatement index for Jan/2018.
[2] PNADS 2004, 2009 and 2013 and PNADC 2017.
[3] Average monthly expenditure in the year using the Food and Beverages group of the INPC/IBGE as a monetary update index for Jan/2018, Source: SAGI.
[4] Households covered by the FBP, source: SAGI. Estimates of household sources: PNADS 2004, 2009 and 2013 and POF 2017-2018

Source: Authors, from PNAD, PNADC, POF and SAGI/Ministry of Citizenship microdata, accessible at https://applicacoes.mds.gov.br/sagi/vis/data3/data-explorer.php (accessed 6/4/2022).

prevalences, in spite of pendular evolution in time, the pictures of these same years, provided by etiological associations (adjusted RPS) that emerge from the results of the models between the study variables and the severe FI in Table 2, present reasonable dissimilarities in these associations at both ends of this 14-year interval.

In considering the estimates of the annual FI prevalence by geographical stratum of the 4 surveys analysed in conjunction with the estimates and totals of exposure variables, confounding and modifying effect, through the results of elasticities from the multilevel log-log modelling gathered in Table 3, one can observe some highlights analogous to those evidenced in Table 2: 1) existence of confounding bias of simple regression analysis in comparison with the analysis adjusted by multiple regression; 2) existence of modifying interactions of effect.

The model used to generate the adjusted data displayed in Figure 2, although also from a multilevel model of repeated geographical strata, is different from the model used to generate the data in Table 3, because the purpose of this second multilevel model was not to measure the effects of exposure variables and effect modifiers (thus, not included), on FI prevalences, but only to describe the temporal trends of the severe FI outcome by cubic splines.

Discussion

The contrast between colour tones points out that the North-NE versus South-Centre West -SE s-based disparity pattern of Figure 1 is also presented for MRs in 2004, but evolves into a progressive decrease of these severe FI prevalence disparities between MRs over the period, even for 2017-2018. This year, the disparities among the UFs reverted to worsening, featuring a widespread, accelerated increase of FI in the short 5-year period. This movement made the 2017-2018 cartogram more reminiscent of the distri-

Table 2. Population estimates of the gross adjusted prevalence ratios (PRs) of severe FI, with respective confidence intervals of 95% from Poisson regression.

Individual exposure (similar ecological exposure)	Models at individual level by Poisson regression for Severe Food insecurity			
	PNAD 2004		POF 2017-2018	
	Crude PR (IC95%)	Adjust. PR (IC95%)	Crude PR (IC95%)	Adjust. PR (IC95%)
FBP: ref. – "Does not recieve" (Families covered %) "Receives"	2.79 (2.58;3.02)	0.87 (0.71;1.06)	4.39 (3.9;4.93)	-
ABEP class: ref= "E" (does not have similar ecological) "A"	0 (0;0.01)	0.21 (0.10;0.47)	0 (0;0.01)	0.02 (0.01;0.06)
"B"	0.04 (0.03;0.05)	0.26 (0.21;0.33)	0.04 (0.03;0.05)	0.11 (0.07;0.17)
"C"	0.18 (0.16;0.2)	0.43 (0.37;0.50)	0.2 (0.17;0.24)	0.30 (0.22;0.42)
"D"	0.51 (0.46;0.56)	0.80 (0.70;0.90)	0.55 (0.47;0.65)	0.74 (0.55;1.00)
Region: ref.= "North" (identical to ecological) "Northest"	1.01 (0.84;1.22)	0.81 (0.69;0.96)	0.66 (0.57;0.76)	0.65 (0.56;0.74)
"Southeast"	0.29 (0.24;0.35)	0.58 (0.50;0.68)	0.25 (0.21;0.31)	0.52 (0.42;0.63)
"South"	0.26 (0.22;0.32)	0.58 (0.49;0.69)	0.2 (0.16;0.27)	0.57 (0.43;0.75)
"Centre West"	0.35 (0.29;0.43)	0.63 (0.53;0.74)	0.41 (0.32;0.53)	0.96 (0.75;1.24)
Stratum: ref. = "Rest of the UF" (identical to ecological) "Metropolitan region"	0.72 (0.66;0.78)	1.90 (1.61;2.25)	0.77 (0.64;0.91)	1.57 (1.33;1.84)
Employment: ref. = "Employed" (Unemployment rate) "Unemployed"	1.33 (1.29;1.38)	1.06 (1.00;1.13)	1.36 (1.28;1.44)	0.85 (0.78;0.92)
Household income per capital (identical to ecological) continuous variable	0.99 (0.99;0.99)	0.99 (0.99;0.99)	0.99 (0.99;0.99)	0.99 (0.99;0.99)
Interaction: FBP vs. ABEP Class "receives"; "A"	-	*	-	0.00 (0.00;0.00)
"receives"; "C"	-	1.68 (1.28;2.20)	-	*
"receives"; "D"	-	1.23 (0.98;1.55)	-	*
Interaction: PBF vs. Class ABEP vs. employment "receives"; "D"; "unnemployed"	-	1.19 (1.08;1.32)	-	-
Interaction: Class ABEP vs. stratum "C"; "Metropolitan region"	-	0.77 (0.64;0.93)	-	-
"D"; "Metropolitan region"	-	0.83 (0.71;0.97)	-	-
Interaction: Class ABEP vs. stratum "B"; "unnemployed"	-	0.81 (0.67;0.98)	-	-
"C"; "unnemployed"	-	0.93 (0.85;1.01)	-	-
"D"; "unnemployed"	-	0.82 (0.76;0.88)	-	-
Interaction: PBF vs. Employment "receives"."unnemployed"	-	-	-	1.46 (1.04;2.04)

- Not - included in the model; * included in the model, but not statistically significant

Source: Authors, from the PNADs 2004, 2009, 2013, POF 2017-2018, SAGI and INPC/IBGE microdata.

Table 3. Estimates of gross and adjusted elasticities, with respective confidence intervals of 95% arising from a multilevel model for severe FI prevalence with repeated geographical strata measurements in 2004, 2009, 2013 and 2017-2018.

Individual exposure (similar ecological exposure)	Ecological models for Severe Food Insecurity Prevalence: Measurements 2014-2018 repeated from strata	
	Crude elasticity (IC95%)	Adjusted elasticity (IC95%)
Proportion of families covered (FBP: ref. = "does not receive") – continuous variable	-0.38 (-0.50;-0.25)	-8.09 (-18.52;2.34)
Region: ref.="North"		
"Northeast"	-0.11 (-0.44;0.22)	-0.31 (-0.63;0.02)
"Southeast"	-1.14 (-1.48;-0.80)	-0.73 (-1.14;-0.33)
"South"	-1.31 (-1.68;-0.94)	-0.64 (-1.14;-0.13)
"Centre West"	-0.90 (-1.31;-0.48)	-0.33 (-0.81;0.15)
Unemployment rate (Employment: ref. = "Employed") – continuous variable	0.28 (0.07;0.50)	-11.64 (-19.30;-3.99)
Average household income per capita – continuous variable	-1.20 (-1.44;-0.96)	2.99 (0.27;5.71)
Average household expenditure of the FBP (FBO benefit per capita) – continuous variable	-0.40 (-0.51;-0.30)	-0.60 (-1.15;-0.05)
Interaction: proportion of families covered by FBP vs. Unemployment rate (FBP vs. Employment) – continuous variable	-	-3.95 (-8.19;0.29)
Interaction: proportion of families covered by FBP vs. household income (FBP vs. Employment) – continuous variable	-	1.31 (-0.20;2.82)
Interaction: household income vs. unemployment rate – continuous variable	-	1.81 (0.66;2.95)
Interaction: proportion of families covered by FBP vs. household income vs. unemployment rate – continuous variable	-	0.60 (-0.02;1.22)

Source: Authors, from PNADs 2004, 2009, 2013, POF 2017-2018, SAGI and INPC/IBGE microdata.

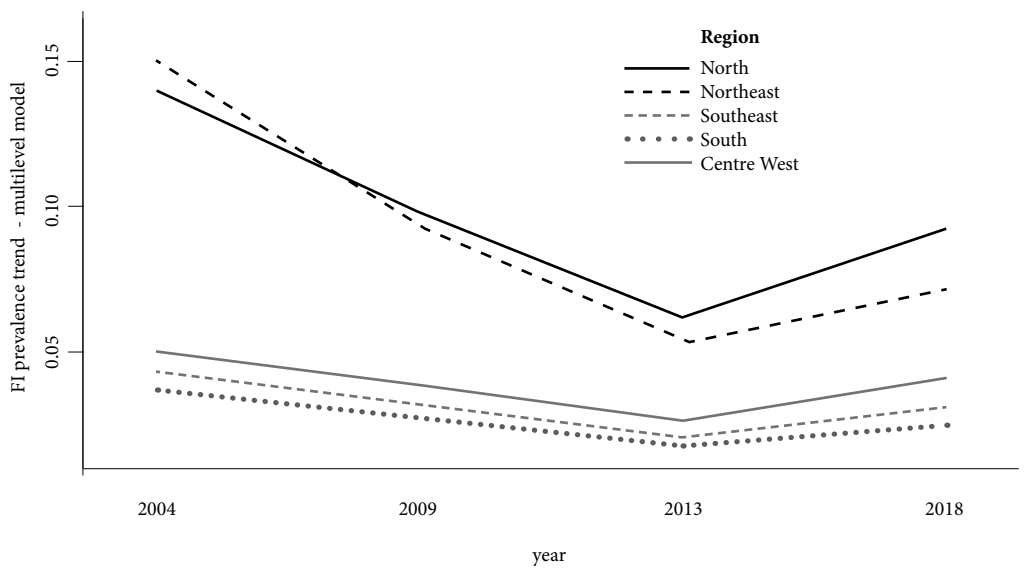


Figure 2. Trends adjusted by geographical stratum and macroregions from a multilevel model for severe FI prevalence with repeated measurements of geographical strata and cubic splines in 2004, 2009, 2013 and 2017-2018.

Source: Authors, from the PNAD (2004, 2009 and 2013) and POF (2017-2018) microdata.

bution pattern of the 14-year map in 2004, when it shifted away from the 2013 pattern, a year with lower prevalences and regional disparities of the severe FI of the period analysed.

In short and in general terms, from analysis of the cartograms of Figure 1, there emerged a progressive movement and consistent fall in the country with reduced disparities between 2004 and 2013 and an inverse, accelerated movement of severe FI prevalence growth with expansion of macroregional disparities from 2013 to 2017-2018.

As for the other exposure variables in Table 1, not addressed in the previous section (all except income), the most outstanding were: 1) an almost double increase in the post-2013 unemployment rates, 2017-2018 reaching levels above those in 2004, reversing a falling trend between 2004 and 2013; 2) reversal of the growth trend in FBP expenditure in the country, a movement that happened faster in the rest of the UFs than in the MRs; 3) accelerated growth and more than double the FBP coverage between 2004 and 2009, and remaining practically constant since then for the rest of the period analysed.

Within each year displayed in Table 2, it is observed that the PRs are strongly skewed in the gross associations of exposures and outcomes, reaching the point of reversing the direction of the estimated association in 2004, when the gross PR pointed towards a severe FI of the FBP beneficiaries 2.79 times above the non-beneficiaries, whereas adjusted PR indicated 1/0.87 = 1.15 times below. The first case would indicate an inefficient focus of the FBP, whereas the second case pointing to the possibility of mitigating the FBP's severe FI outcome, when the confounding effects of other variables that are also the target of government actions and policies are correctly disregarding the confounding effects of other variables that are disregarding economic policies. In 2017-2018, this scenario of bias also occurred, albeit with different magnitudes, and when, unlike 2004, there was no more statistical evidence in favour of the mitigation capacity of severe FI by the FBP.

Table 2 also highlights: 1) existence of modifying interactions affecting the outcomes that substantially change behaviour (different variable groups) in the 2 years extremes were compared; 2) persistence, stability and precision in the capacity of per capita income to mitigate the occurrence of severe FI; 3) the prevalence of severe FI was 1.06 times higher among the unemployed in 2004, becoming 1/0.85 = 1.18 times lower among the unemployed in 2017-2018; 4) belonging to any different economic class that is lower, and reside in any region other than the North, are protective factors for the prevalence of severe FI.

Furthermore, from the data in Table 3, there is evidence that, within what was imagined as the type of impact, each upward percentage unit variation in the proportion of families in the geographical strata benefited by the FBP, tends to cause an 8.09% drop in the prevalence of severe FI, as well as an increase in the order of 1% in the average expenditure per household receiving FBP tends to cause a 0.6% reduction in the prevalence of severe FI.

On the other hand, Table 3 provides unexpected evidence that, in the strata where the Unemployment rates were 1% above, these were characterized by severe FI prevalence, on average, 11.64% lower in the study. Concomitantly intriguing is the realisation that, in the strata where the average per capita household performance was 1% above, they were also characterized by severe FI prevalences about 3% above.

Possible contributors to this strange situation are: 1) the well-known effect of bias or ecological fallacy; 2) there may be a focus of the FBP with a higher concentration in areas where Unemployment is also larger, decreasing, in relative terms, the prevalence of severe FI in these areas; 3) in areas where incomes are higher, the disparities of these tend to be higher as well, resulting in higher prevalence of severe FI, or even the income disparities themselves between areas, with the presence of extreme values, may be distorting the coefficients estimated by the model.

Finally, Figure 2 largely confirms the analytical aspects that have already been highlighted through analysis of the cartograms.

Quoting several authors, an argument extracted from the international literature indicates that Europe offers a quasi-experimental scenario to study FI macroeconomic and potentially mitigating factors due to significant variation in the extent to which these countries were affected by the recent economic crisis, and the way they responded to it[2]. Regarding Brazil, it can be argued that the response to the crisis in terms of a single austerity policy for all government spheres through EC 95/2016[11], was, in an analogous manner, also a quasi-experimental study scenario due to different austerity policy scenarios in the extensive analysis period considered in this article.

The period under analysis in this study is rich in distribution patterns and oscillating trends of the values of the outcome variables, exposure,

confounding and modifying effects. For this reason, this study, as expected, presents strong similarities to experimental studies, where these oscillations are purposely provoked, which allows classification as a type of natural experiment that happened in Brazil during this period.

This enables relative confidence in the measurements of estimated associations that allow assessment of the impacts of the economic crisis and fiscal austerity policies on the re-emergence of the hunger problem in the country, even before the amplification of these impacts due to the COVID-19 pandemic.

Previously referenced in the national literature, the articles that address the theme analogous to that analysed here[13-16], also reflect, in their discussions and analysis, the diversity of scenarios experienced in Brazil: crisis, austerity and their undesirable health and food insecurity effects, each with its own focus and specificity. Our approach is more aggregate and broader as regards the selected indicators and variables, but more refined from the spatial distribution point of view, offering association models and measures that allow not only addressing the hypotheses under analysis, but also serve as quantitative instruments for evaluation of the impact of decisions by public policy managers on severe FI.

There was an inflection in the policy pattern that was being implemented in Brazil after the change of government due to an impeachment process begun in 2015, namely the approval of Constitutional Amendment No. 95[11] by Congress at the end of 2016, known as the expenditure ceiling amendment. These changes have implied progressive abandonment of the social welfare policies, which had been implemented and expanded in the country since the mid-90s, in favour of the tight purse strings announced in the constitutional text as an inflexible state policy to remain in force until 2036.

Conclusions

The findings of this study demonstrate the negative impacts of the austerity measures in force, manifested in the expenditure trends and the scope of the FBP, the main policy to cope with hunger in the country. The negative effects were pointed out by statistical models about the serious increase in severe FI. These findings enable projection of the increasing FI in the country and potential deviation from the target of Goal No. 2 of the SDG by 2030.

This objective is entitled "Hunger Zero and Sustainable Agriculture" and deals with "ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture" [44]. Subsection 2.1 of this goal is: "... by 2030, eradicate hunger and ensure access for everybody, in particular the poor and those in vulnerable situations, including children, to food that is safe, nutritious and in sufficient supply throughout the year"[44].

This paper's findings forecast that, in proceeding along the austerity path established by the expenditure ceiling constitutional amendment, despite overcoming the effects of Covid, Brazil will continue to head in the opposite direction from SDG 2.1, and will not, despite the success already achieved in 2014, achieve the first goal of the MDG.

Collaborations

MRS Amaral contributed to the theoretical conception, implementation of the study materials and methods, analysis, interpretation of results, writing and critical review of the manuscript. PLN Silva co-supervised the doctoral thesis work from which this article derives, specifically in the definition and implementation of sample data analysis methods for cross-sectional studies and also in the writing and critical review of the content. ACM Ponce de Leon supervised the doctoral thesis work, contributing to the analysis, interpretation of data, writing and critical review of the content.

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