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Use of a predictive model for food insecurity estimates in Brazil

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SUMMARY. In 2004 the National Household Survey (*Pesquisa Nacional por Amostras de Domicílios* - PNAD) estimated the prevalence of food and nutrition insecurity in Brazil. However, PNAD data cannot be disaggregated at the municipal level. The objective of this study was to build a statistical model to predict severe food insecurity for Brazilian municipalities based on the PNAD dataset. Exclusion criteria were: incomplete food security data (19.30%); informants younger than 18 years old (0.07%); collective households (0.05%); households headed by indigenous persons (0.19%). The modeling was carried out in three stages, beginning with the selection of variables related to food insecurity using univariate logistic regression. The variables chosen to construct the municipal estimates were selected from those included in PNAD as well as the 2000 Census. Multivariate logistic regression was then initiated, removing the non-significant variables with odds ratios adjusted by multiple logistic regression. The Wald Test was applied to check the significance of the coefficients in the logistic equation. The final model included the variables: per capita income; years of schooling; race and gender of the household head; urban or rural residence; access to public water supply; presence of children; total number of household inhabitants and state of residence. The adequacy of the model was tested using the Hosmer-Lemeshow test (p=0.561) and ROC curve (area=0.823). Tests indicated that the model has strong predictive power and can be used to determine household food insecurity in Brazilian municipalities, suggesting that similar predictive models may be useful tools in other Latin American countries.
Key words: Predictive statistical model, severe food insecurity, municipalities

RESUMEN. Uso de un modelo estadístico predictivo para inseguridad alimentaria grave en Brasil. La Investigación Nacional por Muestreo de Domicilios de 2004 (PNAD), generó estimativas de la prevalencia de inseguridad alimentaria y nutricional en Brasil. Todavía las informaciones de PNAD no pueden ser desagregadas para las municipalidades. El objetivo de este estudio fue construir un modelo estadístico predictivo para inseguridad alimentaria grave en las municipalidades empleando la base de datos PNAD. Los criterios de exclusión fueran: hogares con datos incompletos (19.30%), informantes menores de 18 anos (0.07%), hogares colectivos (0.05%) y hogar con jefe indígena (0.19%). El modelaje fue realizado en 3 etapas, la primera fue la selección de las variables relacionadas con inseguridad alimentar grave mediante regresión logística única. Fueron escogidas variables presentes en PNAD y en el Censo Demográfico de 2000. Por último se realizó regresión logística múltiple, siendo retiradas las variables no significativas según el Odds Ratio ajustado. Fue usado el test de Wald para evaluar la significancia estadística de los coeficientes en la ecuación logística. El modelo final incluye las variables: renta domiciliar per cápita, años de escolaridad, raza y sexo del jefe de familia, localización urbana o rural del domicilio, disponibilidad de red de agua potable, presencia de niños, total de miembros en la familia y provincia de residencia. Se verificó la adecuación del modelo usando el test de Hosmer-Lemeshow (p=0,56) y la Curva de ROC (área=0,823). Los testes indican que el modelo tiene gran poder predictivo para estimar la inseguridad alimentaria grave en municipalidades brasileñas, sugiriendo que modelos predictivos similares puedan ser herramientas útiles en otros países Latinoamericanos.
Palabras clave: Modelo estadístico predictivo, inseguridad alimentar grave, municipalidades.

INTRODUCTION

Food and nutrition security is the realization of everyone's right to regular and permanent access to food of good quality, in sufficient quantity, without compromising access to other basic needs, and based on food practices that promote health and respect cultural diversity and are environmentally, culturally, economically, and socially sustainable (1). Food insecurity and hunger are thus conditions resulting from economic restrictions and not other problems such as lack of time to eat. Hunger, from this perspective, is considered as the most severe level of food and nutrition insecurity (2).

Food and nutrition insecurity is a complex and multi-dimensional phenomenon which develops as a continuous process differentiated in stages, as economic restrictions become more severe. Each stage corresponds to a specific experience of food insufficiency and behavior resulting from this condition. Today it is possible to study the extent of food insecurity and hunger caused by financial limitations and how this is experienced and reported by households (2).

The relevance of this theme today is incontestable, occupying increasingly more space in the public policy arena in Brazil (3) and Latin America. Nevertheless, data on food and nutrition security are still scarce. The search for viable indi-

cators of Food and Nutrition Security is ongoing. Up until recently, measures of consumption, poverty and malnutrition were used as proxy events, whereas income indicators were used as more distal determinants (4).

In 2003, an adapted version of the Core Food Security Module (CFSM) used by the United States Department of Agriculture (USDA) was validated for use in Brazil. This instrument, known today as the Brazilian Food Insecurity Scale (BFIS), is composed of 15 questions (5,6). The Brazilian experience with adaptation and validation of the CFSM contributed to the construction of the Latin-American and Caribbean Food Insecurity Scale (ELCSA), which is very similar to the BFIS.

The 2004 National Household Survey (*Pesquisa Nacional por Amostras de Domicílios* - PNAD) included the BFIS as one of its modules, enabling reliable estimates of the prevalence of food and nutrition insecurity in Brazil at the national, regional, and state levels (7). However, the sampling scheme used for PNAD does not allow disaggregation of its estimates at levels of detail below the state level. The importance of having more disaggregated estimates of the prevalence of food and nutrition insecurity available, particularly at the municipal level, must be acknowledged. After all, the municipality is the primary unit of political organization in the country, and the largely successful trend towards municipal administration of social policies in Brazil is noteworthy (8).

Population-based food and nutrition security surveys have been undertaken in only a few Brazilian municipalities (9,10,11). However these few municipalities tend to be less affected by food and nutrition insecurity due to their social and economic characteristics (7).

Previous studies have indicated the utility of employing predictive models to calculate estimates of the prevalence of child malnutrition for all Brazilian municipalities (12,13), to analyze targeting of a Conditional Cash Transfer program in Brazil based on the occurrence of malnutrition (14) and to estimate the prevalence of child stunting in all municipalities of the Dominican Republic (15).

However these policy documents were not peer-reviewed (12-14), which motivated us to report here, in detail, the methodology for estimating municipal level prevalence of sever food insecurity. The objective of this article is to present a statistical model for predicting severe food insecurity in Brazil that makes it possible to estimate the prevalence of food and nutrition insecurity in the 5,507 municipalities based on projections from the 2000 Census. We hope that this predictive model can be a tool for countries that use the ELCSA or similar scales to generate detailed data about the projected food insecurity distribution, enabling more focused public policies to fight hunger.

METHODOLOGY

The dataset from the 2004 National Household Survey (*Pesquisa Nacional por Amostras de Domicílios* - PNAD) was used to build the model.

The PNAD studied a complex probabilistic sample representative of the five geographic macro-regions and the 27 Brazilian states. The sample was obtained in three selection stages: primary units – municipalities; secondary units – census tracts; and tertiary units – households, which were the sampling units. This process resulted in a sample of 139,157 households and 399,354 persons.

Food and nutrition insecurity was evaluated using the Brazilian Food Insecurity Scale (BFIS), composed of fifteen questions that generated a score classifying household food insecurity in three levels: light, moderate, and severe (5). The reliability of the estimates was assured through proper training of the interviewers who applied the questionnaire, as well as the representativeness of the sample studied.

The present study focused on severe food insecurity (SFI). Households were classified in two categories: secure or insecure (when found to have SFI - severe food insecurity). Exclusion criteria were: a) records with incomplete food security data (19.30%); (b) informants younger than 18 years old (0.07%); (c) collective households (0.05%); (d) household headed by an indigenous person (0.19%). The later criterion was included because the indigenous population in Brazil presents particularly unique characteristics as regards food security concepts (16). Thus, the present study included 111,922 households (80.4% of the total).

For the selection of the predictive variables, their availability and similarity of measurement in the 2004 PNAD and 2000 Census samples were considered, aiming to apply the model afterwards to predict food and nutrition insecurity in Brazilian municipalities.

Traditional variables related to the occurrence of food insecurity were selected: monthly household income per capita; educational level, race, sex, and age of the head of household; area of residence (urban/rural); housing situation (rented, loaned, or owned); existence of public water supply in at least one room; type of family composition; total number of children under the age of 10; and total number of people residing in the household. The variables with p values less than or equal to 0.2 were selected to test in the multivariate model.

For variables with a small percentage of households presenting missing information (total number of people residing in the household and public water supply), values were imputed using the SPSS “linear trend at point” method which substitutes the missing values for these variables based on the linear trend.

Logistic regression was used to predict severe food insecurity. The logistic model makes it possible to analyze the estimated odds of an event occurring (in this case, SFI) in relation to the odds of it not occurring. The dependent variable Y can assume two possible states: (1) when the household has SFI, or (0) when it does not.

Prior to the construction of the multivariate model, univariate logistic regression was carried out for each of the potential predictor variables with the response variable. The modeling process began with the inclusion of the most statistically significance variables from the univariate analysis (income per capita). The other variables were then added one by one, in order of decreasing statistical significance, according to the Wald Test. The variables that were found to be statistically significant were maintained in the final model.

The predictive capacity of the final model was evaluated using the Hosmer-Lemeshow (17) test and the ROC curve. The external validity was analyzed comparing estimates generated by the model with data reported by population based studies (9-11). To do so, it was necessary to adjust the municipal estimates according to state level estimates corrected for 2004. The adjustment factors were 0.9610 for the state of São Paulo, 1.1339 for the Federal District and 0.8522 for Rio de Janeiro).

All data was processed taking into account the complex structure of the sample, using the SPSS statistical package, version 15.0 for Windows.

RESULTS

The results from the adjusted predictive model are presented in Table 1.

Most of the poverty indicator variables presented a smaller magnitude in the multivariate logistic regression compared to the univariate analysis. The odds ratios for the variable referring to rural residence inverted from a risk factor in the univariate analysis to a protective factor in the model.

It can be observed that SFI shows an inverse association with monthly per capita income, being greater (OR=11,33) in households with income below one-fourth of one minimum monthly wage per capita (MMWPC) compared to those with income greater than or equal to one MMWPC.

The characteristics of the head of household also influence the occurrence of SFI, being consistently greater in households headed by individuals who never attended school (OR: 4.76), are black (OR: 1.49), or are female (OR: 1.60).

Adverse conditions of basic sanitation, such as lack of public water supply, increase the odds of food insecurity.

Variation in the prevalence of severe food insecurity is observed according to family type and composition. SFI is 57% higher in families with three or more children, and a direct association is also detected between SFI and the number of people living in the household.

Large variation in the prevalence of severe food insecurity is found among the states of the Federation. The lowest prevalence is found in the southern state of Santa Catarina (baseline), while the states of the northern and northeastern regions present much higher risk of SFI. Although not all states were statistically significant, it was decided to maintain all the variables referring to the states in the model in order to improve its predictive capacity.

We tested different models for each of the five Brazilian regions and also for the urban / rural locations and concluded that this procedure did not improve the model's performance.

The evaluation of the mean adjustment to the model can be measured using the Hosmer-Lemeshow test (17), which presented a value of p=0.561. This demonstrates that within each decile of the estimated probability, the percentages of SFI households observed and predicted by the model are similar. The overall predictive capacity of the model was evaluated using the ROC curve, with area was 0.829. This finding indicates that the model has good predictive capacity.

External validity was verified comparing estimates generated by the model with SFI prevalence reported in three population based studies (9-11) (Table 2). Two of the municipal studies (Campinas and Brasília) focused only households with children, which is a known risk factor for SFI. The estimates calculated by the model, applicable to the entire population, were coherently lower that the ones registered in the empirical field studies. But the calculated prevalence was reasonably close to the lower limit of the Confidence Interval, reinforcing the hypothesis of differences attributable to the diverse sampling frame. On the other hand, in Duque de Caxias the value estimated by the model was within the boundaries of the Confidence Interval, i.e., may be considered as a coincident values.

When the model was concluded, we estimated the SFI prevalence of the 5,507 Brazilian municipalities for the year 2004. The estimated SFI prevalence for Brazil using the model was 8.3%, with considerable variability among Brazilian municipalities. The region with the highest prevalence of SFI was the Northeast, with a mean of 14.5%, compared to 3.6% in the South (the region with the lowest mean municipal prevalence). The mean SFI prevalence for the 5,507 municipalities studied is presented in Figure 1.

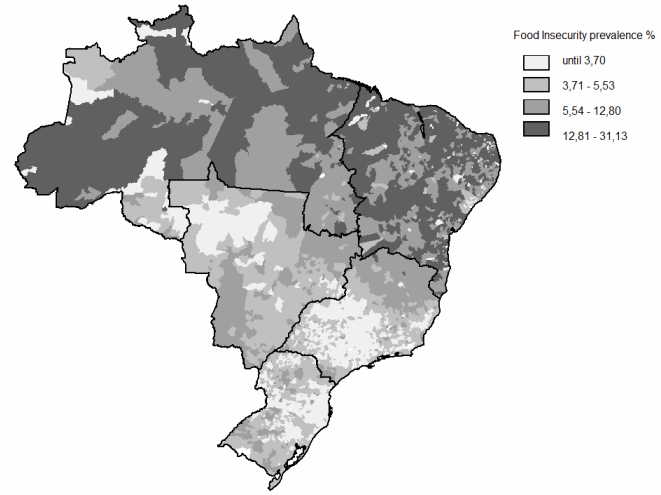
TABLE 1
Adjusted predictive model for severe food insecurity. Brazil, 2004

Parameters	β	p value	Odds ratio	95% CI Low	95% CI Upper
Intercept	-5.171	<0,001			
Income (minimum monthly wage per capita - MMWPC)		<0,001			
< 1/4 MMWPC	2.428	<0,001	11.33	10.08	12.74
>1/4 a <1/2 MMWPC	1.575	<0,001	4.83	4.35	5.37
>1/2 a < 1 MMWPC	0.813	<0,001	2.25	2.04	2.49
>1 MMWPC			1.00		
Years of study (Head of Household)		<0,001			
< 1	1.561	<0,001	4.76	4.19	5.42
1 a 3	1.214	<0,001	3.37	2.94	3.85
4 a 7	0.966	<0,001	2.63	2.33	2.97
8 a 10	0.723	<0,001	2.06	1.77	2.40
11 or more			1.00		
Race (Head of Household)		<0,001			
Black/mullato	0.402	<0,001	1.49	1.39	1.61
White/Yellow			1.00		
Gender (Head of Household)		<0,001			
Woman	0.471	<0,001	1.60	1.50	1.71
Man			1.00		
Public water supply		<0,001			
No	0.576	<0,001	1.78	1.59	1.99
Yes			1.00		
Situation		<0,001			
Rural	-0.685	<0,001	0.50	0.44	0.58
Urban			1.00		
Number of children		<0,001			
three oe more	0.452	<0,001	1.57	1.42	1.74
None to two			1.00		
State		<0,001			
Roraima	1.149	<0,001	3.16	2.06	4.83
Amapá	0.997	<0,001	2.71	1.78	4.14
Rio Grande do Norte	0.886	<0,001	2.43	1.51	3.91
Pará	0.846	<0,001	2.33	1.57	3.45
Paraiba	0.841	<0,001	2.32	1.54	3.48
Maranhão	0.737	0.001	2.09	1.36	3.22
Amazonas	0.693	0.018	2.00	1.13	3.54
Acre	0.681	0.031	1.98	1.07	3.66
Ceará	0.624	0.003	1.87	1.24	2.80
Bahia	0.610	0.002	1.84	1.26	2.69
Rio Grande do Sul	0.517	0.003	1.68	1.20	2.34
Pernambuco	0.396	0.015	1.49	1.08	2.04
Tocantins	0.335	0.156	1.40	0.88	2.22
Goiás	0.397	0.092	1.35	0.95	1.90
Mato Grosso do Sul	0.291	0.196	1.34	0.86	2.08
Rio de Janeiro	0.272	0.105	1.31	0.94	1.82
São Paulo	0.261	0.110	1.30	0.94	1.79
Paraná	0.248	0.174	1.28	0.90	1.83
Piauí	0.187	0.370	1.21	0.80	1.81
Distrito Federal	0.177	0.371	1.19	0.81	1.76
Minas Gerais	0.117	0.477	1.12	0.81	1.55
Mato Grosso	0.084	0.654	1.09	0.75	1.57
Espírito Santo	0.067	0.735	1.07	0.73	1.57
Alagoas	0.024	0.893	1.02	0.72	1.47
Rondônia	-0.147	0.523	0.86	0.55	1.36
Sergipe	-0.596	0.013	0.55	0.34	0.88
Santa Catarina			1.00		
Number of persons	-0.079	<0,001	0.93		

TABLE 2
Comparison of estimates of severe food insecurity generated by the model, with prevalence obtained in population based studies. Brazil, selected municipalities, 2003 – 2005

Municipality, state and year of study	Prevalence of severe food insecurity (SFI)		
	Reported in the field study [$CI_{95\%}$]	Estimated by the model	Ref
Campinas (São Paulo), 2003	6.6% [4.3 - 8.9]	2.7%	9
Brasília (Federal District), 2003	7.7% [6.5 - 8.9]	4.1%	10
Duque de Caxias (Rio de Janeiro), 2005	6.3% [3.9 - 8.4]	5.2%	11

FIGURE 1
Food Insecurity prevalence in Brazilian municipalities calculated by proposed predictive model presented in quartiles. Brazil, 2004



DISCUSSION

The construction of a predictive model for severe food insecurity capable of providing Brazilian municipalities with reliable estimates of the number of households in this situation is, without a doubt, of utmost importance for planning purposes at federal or state levels, e.g. fund allocation and setting priority criteria for municipalities. However the model *per se* is not sufficient for targeting at local level; as a consequence the need for municipalities to identify poverty stricken areas and households for program allocation still remains. Currently, the lack of information at the municipal level is an impediment to having a credible portrait of the Brazilian reality, as there are great discrepancies among states, and consequently, very differentiated characteristics with respect to the condition of food insecurity and its determinants.

The heterogeneity among the states can be seen in the data from the PNAD[7] itself, which show that while Maranhão is the state with the highest level of food insecurity (18.5%), only 2.0% of the population of Santa Catarina was found to be in this situation. The inter-state discrepancies are demonstrated, for example, by the Gini Index of Maranhão, calculated to be 0.57 according to data from the 2004 PNAD.

To build the predictive model, it was decided to work only with SFI, which is less frequent but is characterized by the need to restrict food consumption, and is thus more serious[5]. Since the BFIS classifies food insecurity in three categories, each with different particularities, in opting to study only cases of severe food insecurity, the study focuses only on those characterized necessarily by some type of restriction in quantity of food consumed, or hunger, presumably among the household residents.

The objective of this study was to develop a predictive model that could be easily applied by municipalities to diagnose the food security situation of their populations in order to plan the actions and public policies needed. The basic socioeconomic information needed is available, every ten years, from the Brazilian Census, or can be easily measured at anytime. Considering that the model used only variables related to per capita income, characteristics of the household and the head of household and geographic location, this objective is believed to have been achieved, as all are variables that are easily measured and available at the state level annually in the PNAD.

With respect to the variables selected to build the model, it can be observed that most of them are intimately associated with income, the variable with the greatest predictive power (income below one-fourth of a minimum monthly wage per capita) is associated with a 20-fold increase in the risk of SFI. The influence of income on the occurrence of food insecurity is well-documented (18) and explained by the fact that, except in exceptional situations, the acquisition of food generally depends on money, and insufficient income necessarily implies difficult access to food (4). Nevertheless, all the other variables in the model were statistically significant and contributed to the predictive power of the model, justifying keeping them in the modeling process.

Educational level of the head of household also appears

as an important factor in severe food insecurity, with low educational level being found to be a determinant of SFI in other studies, as well. Low educational level is normally associated with lower income and higher rates of unemployment (19). A study carried out in the municipality of Rio de Janeiro found that 7.2% of households in which the head of household was illiterate or had less than eight years of schooling were affected by severe food insecurity, compared to 0.7% of households headed by high school graduates (11).

In Brazil, the discrepancy in social factors according to race has been well-documented, which helps to explain the greater occurrence of severe food insecurity in households headed by a person of black or mulatto race (7). These groups suffer from precarious social insertion determined by socially differentiated opportunities. Some indicators have even worsened in recent years, such as participation of this social group in higher education, in terms of enrollment as well as graduation. According to data from 2007, 13.4% of whites and 4.0% of blacks and mulattos in Brazil had graduated from college (19).

When the household was headed by a woman, food security was found to be compromised. A possible explanation for this is that the woman only appears as the head of household when the partner is absent, which implies a lower per capita income. In Brazil, around 17.4% of family arrangements take this form (19). It is worth mentioning that the mean income for women the year the PNAD was carried out corresponded to 69.5% of income earned by men (7).

It is interesting to note that rural residence was associated with an increased risk for SFI in the univariate analyis (OR = 1.57), a relationship observed previously in other studies (5,20,21). However, when included in the model, and consequently controlled for income, rural residence becomes a protective factor against food insecurity. This can be explained by the fact that, in studies where SFI was found to be greater among residents of rural areas, lack of income to acquire food was also greater among these households (20). Excluding the problem of income, residing in a rural area presents favorable characteristics for food security, such as greater frequency of familial food production, availability of food from plants and trees growing in the area (5,21), factors which appear to compensate for other unfavorable conditions for poor Brazilians living in urban areas. According to the 2004 PNAD, close to 7.4 million farming families produced food for their own consumption, and of these, 3.4 million worked only with this end (7). Rural families probably can rely on solidarity and social networking in times of severe hardship, which are behaviors more common in rural areas.

The presence in the household of children under ten years of age was also associated with severe food insecurity. Families with children are more susceptible to being food insecure because the parents are normally younger and the families are larger (22). It is important to emphasize the obvious, that the presence of food is a necessary condition for normal growth and development of children. Consequently, food insecurity is an important condition to examine in the context of child well-being.

An important consideration must be made with respect to the population studied. Households headed by indigenous people were excluded due to the occurrence of special cultural characteristics (16). So the model will be of limited use only in those (rare) municipalities whose ethnic composition is largely indigenous. It is thus recommended that a different model be constructed especially for this population. However, given that only 0.4% of the Brazilian population is composed of this ethnic group no municipality remained without SFI estimates (19). Collective households were excluded because the BFIS questionnaire was designed as a family tool, so not appropriate for asylum, orphanages and such.

The model's adequacy was tested and the results were considered satisfactory, despite the fact that the Pseudo-R (2) test showed low predictive power of the model. The external validity test showed that the model had an adequate performance. However one should note the small number of municipalities with complete population based studies to compare with and the need for further validation and refinement of the model.

The application of the model presented here points out the importance of this tool for allocating resources directed to food insecurity prevention and control in countries as heterogeneous as Brazil with respect to the economic and social characteristics.

FINAL CONSIDERATIONS

This article sought to analyze characteristics of severe food insecurity in the Brazilian population using multivariate analysis, which made it possible to identify the determinants of severe food insecurity. In the process of exploring the variables studied, it became evident that income per capita, characteristics of the household and the head of household, and geographical location are very important factors in the determination of food insecurity. The cumulative effect of these unequal characteristics was found to translate into large differences in the occurrence of food insecurity in Brazil.

Following testing of the model, it was found to have great predictive power, indicating that it can be used to estimate household food insecurity in Brazilian municipalities. The reality in Brazil is the same as in many other countries in Latin America and the Caribbean. The development of predictive models similar to the one proposed here can fill important gaps in information and provide support for the formulation of public policies to eradicate poverty and hunger.

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