Socio-Economic Characteristics are Associated with Nutritional Deprivation in the Paraguayan Households

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November 1, 2018

Abstract

This study examined the nutritional deprivation of Paraguayan households (understood as households′ access to diverse diets) and investigated the association between nutritional deprivation and socioeconomics characteristics in a large sample. We used an extension of Alkire-Foster methodology, a technique widely employed in multidimensional poverty measurement, to calculate both the incidence and intensity of nutritional deprivation. The resulting nutritional deprivation index allows to consider minimum food group requirements that vary by food groups as well as by individual characteristics such as age, gender, and activity level. Using data from a nationally representative Household Survey of Income and Expenditures 2011-12, we found that just over 3 in every 5 Paraguayan households (62%) were inadequately nourished in at least four food groups. Although no significant differences were found between rural and urban households, the incidence of multi-dimensionally deprived households generally decreased in income. Logistic regression results further showed that nutritional deprivation decreased in household income, mother′s education, and age of household head, and increased in household size.[1]

Keywords: Dietary Diversity, Economic Status, Household Surveys, Latin America

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[1]This article was written under the auspices of the project "Nutritional Transition in Paraguay: Where Do We Stand?" (PINV15-1304). This project was executed by Instituto Desarrollo and funded by the Paraguayan National Council for Science and Technology (CONACYT) through the PROCIENCIA program. We thank seminar participants at the 18th Latin American Congress of Pediatrics (ALAPE 2018) for comments.

1 Introduction

Dietary diversity has been long recognized as a key element of food-based dietary guidelines. The underlying concept is based on the idea that no one food contains all of the necessary ingredients and that increasing the variety of foods both across and within food groups is needed to ensure an adequate intake of essential nutrients and to promote good health [10]. Indeed, a number of studies have found a positive relationship between dietary diversity and nutrient adequacy, both in developed and in developing countries [7; 12].

Dietary diversity has been traditionally evaluated using a simple count of food groups consumed over a given reference period. However, this approach has several limitations, especially when the dietary diversity is used as a population-level indicator. These limitations include, among others, failing to account for the *extent* of inadequate food consumption (effectively treating individuals who consume but a few food groups as equally deprived as those who consume the required minimum number of food groups, thus measuring merely the incidence and not the extent of inadequate food consumption), disregarding the amount of food group(s) consumed, and neglecting person-specific (idiosyncratic) variations in food requirements.

In this paper, we seek to address these weaknesses by applying an extended version of a technique widely used in multidimensional poverty measurement, the Alkire-Foster (AF) methodology [1; 2]. The AF methodology allows to measure simultaneous deprivations in multiple dimensions using a counting approach.[2] Specifically, given the collection of all dimensions achieved by an individual/household, the AF methodology applies a dual cut-off that first translates dimensions into deprivations and then determines if the individual/household is jointly deprived in a pre-specified number of dimensions. Therefore, one can calculate both the incidence of the jointly deprived individuals/households (also referred to as a headcount ratio) as well as the intensity of simultaneous deprivations. Assuming that dimensions

[2]For example, the methodology is applied in the Multidimensional Poverty Index (MPI) to monitor multidimensional poverty using indicators spanning health, education, and living standards [3].

represent the food groups, it is straightforward to see that this methodology allows to account for both the number of under-consumed food groups (incidence) and the amount of each food group consumed (intensity).

An extension of the AF methodology, recently proposed by Oldiges [13], and referred to as a Nutritional Deprivation Index (NDI), allows to account for the third weakness mentioned in that it directly considers idiosyncratic food requirements. In particular, the NDI generalizes the AF methodology by allowing to consider minimum food group requirements (cut-off thresholds) that vary from person to person based on their age, gender, occupation, health status, and/or other characteristics.

Our study applies the NDI to data from the Paraguayan Household Survey of Income and Expenditures 2011-12, the most recent nationally representative survey that provides information on household food consumption. To the extent that household-level dietary diversity has been found to be strongly associated with household per capita income [8], the study also examines the relationship between the nutritional deprivation and household economic status (that is, the extent to which poorer households are at greater risk nutritional deprivation than richer households), while controlling for a number of potentially confounding factors.

2 Methods and Materials

The following section presents the methodology underlying the construction of the NDI index. The methodology presented here is adjusted for the use of household data. The main components of the NDI index include households' consumption matrix (X), the minimum consumption requirement matrix (S_n), and the corresponding households' cut-off matrix (Z).

2.1 Nutritional Deprivation Index

Let us first define an $(N \times D)$-dimensional households' food groups consumption matrix

$$X = \begin{bmatrix} x_{11} & \dots & x_{1D} \\ \vdots & \ddots & \vdots \\ x_{n1} & \dots & x_{iD} \\ \vdots & \ddots & \vdots \\ x_{N1} & \dots & x_{nD}, \end{bmatrix}$$

where the generic element x_{ij} indicates the amount of food group d consumed by n-th household.

Next, for each household $n = 1, \dots, N$ let us define a $(k_n \times d)$-dimensional matrix of household's minimum consumption requirements for the k_n members of the n-th household

$$S_n = \begin{bmatrix} s_{11} & \dots & s_{1D} \\ \vdots & \ddots & \vdots \\ s_{k_n 1} & \dots & s_{k_n D}, \end{bmatrix}$$

Each row in S_n corresponds to a distinct member of the n-th household for which the minimum consumption requirement are calculated based on her/his characteristics (age, sex, and/or other factors). Note that the dimension k_n will vary from one household to another based on the number of individuals in the household.

The $(N \times D)$-dimensional matrix of households-specific cut-offs Z can then be obtained by placing at each row n of Z the corresponding row sum of the sub-matrix S_n:

$$Z = \begin{bmatrix} \sum_{j=1}^{k_1} s_{j1} & \dots & \sum_{j=1}^{k_1} s_{jd} \\ \vdots & \ddots & \vdots \\ \sum_{j=1}^{k_n} s_{j1} & \dots & \sum_{j=1}^{k_n} s_{jd} \\ \vdots & \ddots & \vdots \\ \sum_{j=1}^{k_N} s_{j1} & \dots & \sum_{j=1}^{k_N} s_{jd} \end{bmatrix} = \begin{bmatrix} z_{11} & \dots & z_{1D} \\ \vdots & \ddots & \vdots \\ z_{n1} & \dots & z_{nD} \\ \vdots & \ddots & \vdots \\ z_{N1} & \dots & z_{ND} \end{bmatrix}$$

We can then compute the $(N \times D)$ deprivation matrix B^{0_Z} in which the generic element $b_{nd}^{0_z} = 1$ if $x_{nd} < z_{nd}$ and $d_{nd}^{0_z} = 0$ otherwise.

Finally, given the vector of weights $w = (w_1, \dots, w_D)$ for the food groups, we can calculate the deprivation score for each household as

$$NDI_n = \sum_{d=1}^{D} w_d \, b_{nd}^{0_z} \qquad \forall n = 1, \dots, N$$

The values of the NDI index, which fall within the range of $[0, \sum_d w_d)$, are higher the higher the number of food group deprivations.

Applying the second cut-off (corresponding to a minimum number of deprivations required to be considered malnourished), we obtain a binary version of the NDI index, also referred to as censored deprivation index

$$NDI_n(k) = \sum_{d=1}^{D} w_d \left(b_{nd}^{0_z} \, \mathbb{I}(n,k) \right) \qquad \forall n = 1, \dots, N,$$

where $\mathbb{I}(n,k) = \mathbb{I}\left[\left(\sum_d b_{nd}^{0_z} \right) \geq k \right]$ is an indicator function that assumes the value of 1 if the household n is deprived in at least k food groups and 0 otherwise.

Finally, we can calculate the intensity of deprivation as $A = \frac{1}{Q} \sum_{n=i}^{Q} NDI_n(k)$, with $Q = \sum_{n=1}^{N} \mathbb{I}(n,k)$, and the incidence (headcount ratio) of the jointly deprived households as

$H = \frac{Q}{N}$. The adjusted headcount ratio is then obtained as

$$M_0 = H \times A = \frac{1}{N} \sum_{n=1}^{N} NDI_n(k)$$

2.2 National Income and Expenditure Survey 2011-2012

The data used in this study were obtained from the National Income and Expenditure Survey of 2011-12 (EIG 2011-12). This was a nationally and sub-nationally representative national household survey conducted by the General Directorate of Statistics, Surveys and Censuses (DGEEC) between August 2011 and July 2012.[3]

The survey collected demographic, socio-economic and expenditure data from a sample of 5,417 households, of which 3,446 (63%) were urban and 1,971 (37%) were rural. These households contained a total of 21,130 individuals, implying an average size of a household of 3.9 members.[4] The survey used a two-stage stratified household design.

2.3 Household's consumption matrices

The use of the NDI index requires the construction of the minimum consumption requirement matrix (S_n), households' cut-off matrix (Z), and household consumption matrix (X).

We followed the healthy U.S.-style eating pattern as a basis for the construction of household's minimum consumption requirements matrix (S_n) [17]. This pattern identifies recommended intake amounts (RIAs) of foods, in nutrient-dense forms, that an individual should consume from five major food groups (fruits, vegetables, grains, dairy, protein foods, and oils) and their sub-groups in order to meet nutrient and dietary guidelines standards.[5] The pattern considers 12 calorie levels (from 1,000 kcal/day to 3,200 kcal/day) to meet the needs of an individual across the lifespan. We used the calorie needs estimates provided by

[3]The acronym EIG comes from the Spanish name of survey "Encuesta de Ingresos y Gastos". The dataset is publicly available from the http://www.dgeec.gov.py.

[4]We note that 1 out of 4 households had 6 members or more.

[5]The pattern considers a limit on the maximum number of calories available for other uses, such as added sugars, solid fats, added refined starches, or alcohol.

the Institute of Medicine (IOM) [9] to determine the calorie level for each member of the household conditional on her age, sex, and the level of physical activity.[6] In other words, the household-specific minimum consumption requirement matrix is determined by vectors of age-, sex-, and activity-specific RIAs for each household member.

Applying the same procedure to all households returned matrices $S_1, ..., S_N$ of households' minimum consumption requirements. The households' cut-off matrix can be calculated as described in the previous section, with each row consisting of D sums of the minimum consumption requirements across all household members, where D represents the number of food groups. Again, recall that we do not consider individual-level cut-offs because the survey only provides consumption data at the aggregated, household-level (see Section 2.2).

Construction of the household's consumption matrix (X) requires the knowledge of the *actual* household consumption. Although our data do not provide the actual amounts of foods consumed by the household, they provide a detailed information about the quantities of (as well as the corresponding expenditures on) over 900 different food items purchased or otherwise acquired by the household over the previous 7 days.[7]

Using this data, we first classified food items into 6 food groups, including fruits, vegetables, grains, protein foods, dairy and dairy products, and oils [17].[8] Specifically, the fruits group was constructed by including all the fruit varieties, including fresh, frozen, canned, and dried fruits and fruit juices (e.g., bananas, grapes, raisins, oranges, and orange juice); the vegetables

[6]These estimates are based on the Estimated Energy Requirements (EER) equations, using reference heights (average) and reference weights (healthy) for each age-sex group. For adults, the reference man is 5 feet 10 inches tall and weighs 154 pounds; the reference woman is 5 feet 4 inches tall and weighs 126 pounds. For children and adolescents, reference height and weight vary [9]. We restricted our analysis to the sedentary level of physical activity.

[7]For the purpose of our analysis, we only considered food items that the household either purchased or self-produced; we did not consider food items that the household received from another household, from a social protection or nutrition program, or as a gift from church or a non-profit institution, or that either member of the household took from a business. Of the distinct food items acquired by households over the last 7 days (162.865), 90.1% were purchased or self-produced. Food items that either member of the household took from a business accounted for 5.36%, while food items that the household received from another household accounted for 3.82%. Food items received by the household from a social protection or nutrition program, or as a gift from church or a non-profit institution, accounted for the remaining $< 1\%$.

[8]In the analysis, we did not consider the consumption of alcoholic/non-alcoholic drinks, sweets, spices and condiments, and of foods consumed outside of home.

group was constructed by including all the vegetable varieties in fresh, frozen, or canned form; and the proteins group was constructed by including all fish/seafood, meat, poultry, eggs, soy and soy products, nuts, and seeds.[9]

For the purposes of our analysis, we converted each food item to its cup- (in case of fruits and vegetables) or ounce- (in case of protein foods) equivalents [17]. For fruits and vegetables, 1 cup-equivalent corresponds to 1 cup of vegetable or fruit, 1 cup of vegetable or fruit juice, 2 cups of leafy salad greens, and 0.5 cup of dried fruit or vegetable. For protein foods, 1 ounce-equivalent corresponds to approximately 1 ounce of lean meat, poultry, or fish/seafood, 1 egg, 1 tablespoon of peanut butter, and 0.5 ounce of nuts or seeds. We applied the Food Patterns Equivalents Ingredients Database (FPID) cup equivalent weights and, where appropriate, the FPID in combination with ARS Food Intakes Converted to Retail Commodities Database (FICRCD) conversion factors to estimate the amount of raw fruits and vegetables to be purchased in order to obtain one cup equivalent of raw (edible) portion of each food item [6; 5]. The weight/volume of the particular food item can vary significantly depending on whether it is consumed raw or prepared (boiled, cooked). Therefore, for each food item traditionally consumed in a cooked state (such as pumpkin, lentils, meats), we converted the raw amounts to cooked amounts using a yield factor [4; 16].[10] For the meats, we fixed the yield factor at 0.8.

Finally, the household's consumption matrix (X) was obtained by adding the household's apparent consumption of food items across each food group (sub-group).

2.4 Statistical analyses

Estimates of the NDI index (and the related measures) were calculated according to household's income quintiles and area of residence (rural or urban). Differences among groups were

[9]Meat and eggs represented by the far the most important constituents of the protein group, both in terms of volumes purchased and the relative expenditures. Soy-based products represent a small part of this group (in relative terms) as their consumption remains limited in Paraguay.

[10]We used internet resources to determine the yield factors for the food items that were not available in the manuals [4; 16].

analyzed using the χ^2 test. Where relevant, linear trends across income quintiles and areas were assessed. In all analyses, the data was weighted using the expansion factors provided in the EIG datasets. The analysis was performed in R^{TM} statistical software, version 3.4.3, using the package "survey" [11].

The EIG dataset contains detailed information on household income and expenditures. In this study, the monthly per capita household income was used to stratify households into 5 income quintiles (Q1-Q5). The corresponding income quintile thresholds were as follows: Q1: Gs. 0 to 353,992, Q2: Gs. 354,262 to 610,327, Q3: Gs. 610,784 to 930,532, Q4: Gs. 930,913 to 1,514,103, and Q5: Gs. 1,515,036 and more.[11]

The effects of household income on nutritional deprivation were estimated after statistically controlling for the effects of a number of potentially confounding factors. The factors include household size (0-4, 5-8, and 9 members or more), language spoken by the household head, education level of female and male household head (no education, primary or less, middle or less, and secondary or more), household's area of residence (rural/urban), and department. Table A5 in the Appendix provides a definition of each variable.

The effects of household economic status and other factors on nutritional deprivation were estimated using a multivariate logistic regression procedure. A number of alternative models were estimated to assess the relative significance of various confounding factors included in the analysis, as well as the robustness of the results. Results of multivariate analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs).

The final note concerns the construction of the dependent variable. For the estimation purposes, the NDI index was transformed into a binary variable. Given this transformation is dependent on the value of k, the logistic regression analysis was performed varying the parameter from $k = 4$ to $k = 6$. The results of the analysis for $k = 5$ and $k = 6$ were both quantitatively and qualitatively similar to those for $k = 4$ presented in the text.

[11] In terms of the distribution of households falling into each income quintile, about 1 in 6 (16.7%) belonged to Q1, while about 1 in 4 (26.4%) belonged to Q5. The remaining households were relatively equally split among the middle three income quintiles.

3 Results

3.1 Food group analysis

We start our analysis by considering 6 main food-groups (vegetables, fruits, grains, dairy, proteins and oils).[12]. The use of the NDI requires the definition of the weights w_d for each food group (2.1); in the analysis, each food group was considered to be as important as any other food group; therefore, each food group was assigned an equal weight ($w_d = 1/6$).

As a starting point, we analyze simple (population-level) headcount ratios; these *simple* ratios do not communicate the incidence of multidimensionaly deprived, but only the incidence of deprivation in each food group. The simple headcount ratios show that most Paraguayan households were deprived in dairy products (82%), followed by fruits (69%), proteins (56%) and vegetables (53%); only 25% of households were deprived in cereals (Table 1). More urban than rural households were deprived in vegetables (62% vs. 38%, $p < 0.001$), whereas more rural than urban households were deprived in grains (29% vs. 23%, $p < 0.001$) and proteins (60% vs. 54%, $p < 0.001$).

Table 1. Simple headcount ratios for basic food groups by income quintiles

		Area			Income Quintile						
Food Group	**Global**	**Rural**	**Urban**	***Diff***	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	***Diff***	***Trend***
Vegetables	0.53	0.38	0.62	***	0.40	0.48	0.54	0.58	0.61	***	***
Fruits	0.69	0.69	0.68		0.76	0.75	0.72	0.68	0.59	***	***
Cereals	0.25	0.29	0.23	***	0.30	0.25	0.21	0.23	0.28	***	
Dairy	0.82	0.82	0.82		0.93	0.88	0.82	0.80	0.72	***	***
Proteins	0.56	0.60	0.54	***	0.72	0.60	0.54	0.52	0.48	***	***
Oils	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00		

Diff (*difference test*): H_0: The deprivation proportion is the same in each group. H_a: At least one deprivation proportion is different from the others. Trend (*linear trend test*): H_0: No linear trend in the deprivation proportion across groups. H_a: Linear trend in the deprivation proportion across groups. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

The simple headcount ratios varied significantly with household economic status.[13] In particular, for fruits, dairy, and proteins, the simple incidence of deprivation declined monotonically with increasing income, while for vegetables, the simple incidence of deprivation

[12] An equivalent analysis based on food sub-groups can be found in 4; results of this analysis are referenced later in the text as necessary

[13] In order to evaluate the differences between the simple deprivation proportions across income quintiles, we tested the null hypothesis that the simple deprivation proportion was the same for each of the five income quintiles versus the alternative that at least one simple deprivation proportion was different from the others.

increased monotonically with increasing income (Table 1).[14] For example, 72% of Q1, 54% of Q3 and 48% of Q5 households were deprived in proteins. Similar findings were obtained when the analysis was carried out separately for rural and urban households, although no relationship was found between the incidence of deprivation and the level of income in vegetables group in urban areas (Appendix: Table A1).

Joint analysis of household's economic status and its area of residence shows that differences in simple incidence of deprivation between rural and urban households were most significant in lower income quintiles (Table 2). In particular, whereas the lowest income households (Q1-Q2) showed significant differences in four out of six food groups ($p < 0.05$), the middle income households (Q3) showed differences in three food groups, and the highest income households (Q4-Q5) in only one to two groups.

Table 2. Simple headcount ratios for basic food groups by income quintiles and rural/urban areas

	Q1		Q2		Q3		Q4		Q5	
Food Group	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
Vegetables	0.32	0.56***	0.35	0.60***	0.37	0.63***	0.47	0.63***	0.51	0.63***
Fruits	0.73	0.81**	0.71	0.78*	0.69	0.74	0.65	0.69	0.62	0.58
Cereals	0.34	0.22**	0.30	0.21**	0.21	0.21	0.27	0.22	0.31	0.27
Dairy	0.92	0.94	0.84	0.92***	0.75	0.87***	0.75	0.82**	0.70	0.72
Proteins	0.75	0.65**	0.60	0.59	0.49	0.57*	0.52	0.53	0.46	0.48
Oils	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Difference test: H_0: The deprivation proportion is the same in each group. H_a: The two deprivation proportions are different. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

Table 3 reports incidence of deprivation (headcount ratio) (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) for values of k ranging from zero to six. Recall that the value of k represents the minimum number of food-category deprivations necessary to be considered deprived. Thus, the lower the value of k, the higher the incidence of nutritionally deprived households; that is, the headcount ratio H tends to 1, or 100%.

The results show that every Paraguayan household was nutritionally deprived in at least one food group ($k = 1$, $H = 1$). This is, in fact, the oil group, as seen in Table 1. In

[14] In order to evaluate the existence of linear relationship between the simple deprivation proportion and the level of income, we tested the null hypothesis that there was no trend in the simple deprivation proportions versus the alternative that there was a linear trend in the simple deprivation proportions across income quintiles.

Table 3. Incidence of deprivation, intensity of deprivation and adjusted headcount ratio

	Global			Rural			Urban			*Diff*
k	H	A	M_0	H	A	M_0	H	A	M_0	
0	1.00	0.64	0.64	1.00	0.63	0.63	1.00	0.65	0.65	
1	1.00	0.64	0.64	1.00	0.63	0.63	1.00	0.65	0.65	
2	0.95	0.66	0.63	0.96	0.65	0.62	0.95	0.67	0.64	
3	0.83	0.71	0.59	0.84	0.70	0.58	0.83	0.73	0.60	
4	0.62	0.79	0.49	0.60	0.77	0.46	0.63	0.80	0.50	
5	0.35	0.88	0.31	0.30	0.88	0.27	0.38	0.88	0.33	**
6	0.10	1.00	0.10	0.08	1.00	0.08	0.11	1.00	0.11	

Incidence of deprivation (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) conditional on different values of k (minimum number of group deprivations), grouped by income quintiles (Q1-Q5) and rural/urban areas. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

this case, the intensity of deprivation is 0.64, implying that the same households were on average nutritionally deprived in almost 4 food groups (3.84). Similarly, just over three of every five households (62%) were inadequately nourished in at least four food groups. The corresponding intensity of deprivation was close to 5 food groups (4.74). There were mostly no differences in the incidences of deprivation for different values of k between urban and rural households.

Table 4 provides analysis of the percentage contribution of each food group to the incidence of deprivation. We find that, aside to Oils, Dairy and Fruits contributed the most to the incidence of deprivation relative to other food groups. Separating the rural and urban households, the differences in percentage contributions are - with the exception of vegetables - generally marginal. However, an interesting pattern is found at different income quintiles, with vegetables (proteins) contributing more (less) to the incidence of deprivation the higher the household income. This patterns is especially pronounced in case of vegetables in rural areas (Appendix: Table A2).

Table 4. Percentage Contribution of Food Groups to Incidence of Deprivation

		Area		Income Quintiles				
Food Group	**Global**	**Rural**	**Urban**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Vegetables	15.81	12.10	17.78	11.38	14.33	16.75	17.25	18.56
Fruits	18.24	18.68	18.01	18.98	19.09	18.59	18.37	16.64
Grains	8.04	9.40	7.31	8.66	7.50	6.71	7.57	9.32
Dairy	20.02	20.34	19.86	20.80	20.49	20.19	19.90	19.03
Proteins	16.75	17.90	16.14	18.78	17.36	16.56	15.95	15.49
Oils	21.14	21.58	20.90	21.40	21.23	21.20	20.96	20.96

Percentage contribution of food groups to incidence of deprivation (H) for $k = 4$. Source: Authors' calculations.

The incidence of deprivation decreased monotonically with the level of household income.

Moving from the lowest (Q1) to the highest income quintile (Q2), the proportion of households that were inadequately nourished decreased from 98% to 92% for $k = 2$, from 92% to 75% for $k = 3$, from 71% to 56% for $k = 4$, and from 38% to 32% for $k = 5$ (Table 5). Similar results were observed when the analysis was carried out separately for rural and urban households (Appendix: Table A3). Finally, joint analysis of economic status and household's area of residence shows that the latter generally played a limited role in the incidence of deprivation within income quintiles (Appendix: Table A4).

Table 5. Incidence and intensity of deprivation and adjusted headcount ratio

	Q1			**Q2**			**Q3**			**Q4**			**Q5**			Test
k	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	
0	1.00	0.68	0.68	1.00	0.66	0.66	1.00	0.64	0.64	1.00	0.64	0.64	1.00	0.61	0.61	
1	1.00	0.68	0.68	1.00	0.66	0.66	1.00	0.64	0.64	1.00	0.64	0.64	1.00	0.61	0.61	
2	0.98	0.69	0.68	0.98	0.67	0.66	0.96	0.66	0.63	0.94	0.66	0.63	0.92	0.65	0.60	***
3	0.92	0.71	0.66	0.88	0.71	0.62	0.84	0.71	0.59	0.81	0.72	0.58	0.75	0.72	0.54	***
4	0.71	0.78	0.55	0.64	0.79	0.50	0.60	0.78	0.47	0.60	0.80	0.48	0.56	0.80	0.45	***
5	0.38	0.87	0.34	0.36	0.88	0.32	0.35	0.87	0.30	0.36	0.88	0.32	0.32	0.89	0.29	**
6	0.09	1.00	0.09	0.10	1.00	0.10	0.08	1.00	0.08	0.11	1.00	0.11	0.11	1.00	0.11	

Incidence of deprivation (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) conditional on different values of k (minimum number of group deprivations), grouped by income quintiles (Q1-Q5) and rural/urban areas. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

Effect of household income on nutritional deprivation

The unadjusted odds of nutritional deprivation are more than two times higher among the lowest income (Q1) households than among the highest income (Q5) households (OR = 2.1; 95% CI: 1.72.7) (Table 6, Model 1). Similarly, Q2 households also face higher odds of nutritional deprivation than Q5 households, although the income effect is not as pronounced (OR = 1.4; 95% CI: 1.11.8). The middle income quintile households (Q3 and Q4) face similar risk of nutritional deprivation as Q5 households. The relationship remains largely unchanged when controlling for household size, language spoken by the household head, and the education level of female/male head of household (Model 2). Additionally controlling for household's residence (rural/urban) and the department, increases the effect of household income, especially for the lowest two income quintile households (Model 3). In other words, the poorest 40% of households are about two or more times as likely to be nutritionally

deprived as the richest 60% of households (Q1 households: OR = 2.7, 95% CI 1.93.8; Q2 households: OR = 1.9, 95% CI 1.4−2.5).

Effects of other factors and confounders

Among the control variables, household size has the strongest effect on the risk of nutritional deprivation, and this effect is independent of the household's income and other household characteristics (OR = 1.4; 95% CI: 1.1–1.8) (Table 6, Models 2-4). With household income and other factors controlled, households headed by Guaraní speakers (both monolingual and bilingual) are significantly less likely to be nutritionally deprived than households whose heads speak a language other than Spanish and/or Guaraní. Also, the adjusted prevalence of nutritional deprivation is significantly lower among households whose female head has some education than among households whose female head is uneducated, although this effect is relatively small. In contrast, the education level of the male head of household has no apparent effect on household's nutritional deprivation. Finally, the adjusted prevalence of nutritional deprivation is significantly lower among households from relatively less populated departments (Caaguazú: OR = 0.4, 95% CI 0.30.6, Itapúa: OR = 0.6, 95% CI 0.40.9; San Pedro: OR = 0.5, 95% CI 0.30.8).[15] Households residing in rural areas are marginally less likely to be nutritionally deprived than urban households (Model 3), but this effect largely disappears when departmental controls are included (Model 4).

Additional analyses

In the analyses above, the dependent variable (NDI) is constructed based on 6 food groups. The results of the regression analyses with the NDI constructed based on 13 food groups and sub-groups are similar to those obtained in the former case (Table B6 in the Appendix).

Finally, we also estimated the above regressions separately for urban and rural areas. The results are similar to those obtained in pooled analysis (Tables A6 and B7 in the Appendix).

[15] Asunción and the department of Central are the most populated regions of Paraguay.

In particular, household economic status continues to have a similar effect on nutritional deprivation as that found in pooled regressions, albeit somewhat less pronounced in rural areas. Household size continues to have the strongest effect on the risk of nutritional deprivation; in contrast to household's economic status, this effect is the strongest in rural areas.

Table 6. Odds-ratio estimates of the effects of household income and other household characteristics on nutritional deprivation for $k = 4$ and 6 food groups

	OR (95% CI)							
Variable	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
(Intercept)	1.4	1.2-1.6	3.0	1.6-5.7	3.3	1.8-6.3	3.9	2.0-7.7
Economic status								
5th quintile (richest)*	-	-	-	-	-	-	-	-
4th quintile	1.1	0.9-1.4	1.3	1.0-1.8	1.4	1-1.8	1.4	1.1-1.8
3rd quintile	1.1	0.9-1.4	1.1	0.8-1.5	1.1	0.8-1.5	1.2	0.8-1.6
2nd quintile	1.4	1.1-1.8	1.7	1.2-2.2	1.7	1.3-2.3	1.9	1.4-2.5
1st quintile (poorest)	2.1	1.7-2.7	2.1	1.5-2.8	2.3	1.7-3.3	2.7	1.9-3.8
Household size								
0-4*			-	-	-	-	-	-
5-8			1.8	1.5-2.1	1.8	1.5-2.1	1.7	1.4-2.1
>8			4.0	2.4-6.7	4.0	2.4-6.7	3.9	2.3-6.5
Language								
Spanish*			-	-	-	-	-	-
Guraní			0.6	0.4-0.8	0.7	0.5-0.9	0.7	0.5-1.0
Bilingual			0.6	0.5-0.8	0.6	0.5-0.8	0.6	0.5-0.8
Other			1.2	0.7-1.9	1.4	0.8-2.4	1.5	0.9-2.6
Male HH education level								
None*			-	-	-	-	-	-
Primary			1.0	0.6-1.6	1.0	0.6-1.6	1.0	0.7-1.6
Middle			1.0	0.6-1.6	0.9	0.6-1.5	0.9	0.6-1.5
Secondary or higher			1.0	0.6-1.7	0.9	0.5-1.6	0.9	0.5-1.6
Female HH education level								
None*			-	-	-	-	-	-
Primary			0.5	0.3-0.7	0.5	0.3-0.7	0.5	0.3-0.7
Middle			0.5	0.3-0.7	0.5	0.3-0.7	0.4	0.3-0.7
Secondary or higher			0.5	0.3-0.8	0.5	0.3-0.8	0.5	0.3-0.8
Area								
Urban*					-	-	-	-
Rural					0.7	0.5-0.8	0.8	0.7-1.0
Department								
Asunción*							-	-
San Pedro							0.5	0.3-0.8
Caaguazú							0.4	0.3-0.6
Itapúa							0.6	0.4-0.9
Alto Paraná							0.7	0.5-1.0
Central							0.9	0.7-1.3
Others							0.7	0.5-1.0

Pooled odds ratio estimates (OR) and the associated 95% confidence intervals (CI) from the multivariate logistic regression of NDI on household income and other household characteristics. * marks the reference group. Source: Authors' calculations. See Table A5 for variable definitions. Source: Authors' calculations.

4 Discussion

Lack of dietary diversity, particularly severe among poor populations, has become increasingly relevant in light of the recent shifts in global dietary and activity patterns [15]. For example, more diverse diets tend to be associated also with lower rates of overweight and obesity nutritional problems of rising magnitude in many parts of the world [14]. Increasing dietary diversity therefore constitutes an important strategy to improve nutrition and health.

This study takes a novel approach to measuring access to diverse diets by applying the recently proposed Nutritional Deprivation Index (NDI) to a nationally representative data of Paraguayan households. Building on the Alkire-Foster methodology traditionally applied in the multidimensional poverty measurement [1; 2], the NDI overcomes the main weaknesses of conventional dietary diversity indices in that it allows to measure both the incidence (or headcount) and the average deprivation share of the inadequately nourished [13]. Moreover, the NDI framework also incorporates individual-specific thresholds, allowing the consumption to vary by age, gender, and other factors.

As noted by Oldiges [13], the NDI framework has many attractive properties. From the policy perspective, perhaps the most useful property is one of manifold decompositions, making the framework ideal for targeting purposes. For example, the NDI framework allows to isolate population groups or regions that are not adequately nourished, while also identifying the specific food groups.

Results of this study showed that Paraguayan households were significantly deprived across most food groups, with significant differences existing between urban and rural households. The study also found that, with the exception of vegetables, the level of nutritional deprivation generally decreased in income. Results from the logistic regressions confirmed that poorer households were at a greater risk of being nutritionally deprived than higher income households. These findings contribute to a growing literature analyzing the association between household economic status and dietary diversity.[8]

The main shortcomings of our study are related mainly to the dataset used in the analysis.

The use of household-level consumption data does not allow to consider intra-household inequalities in food consumption, nor to precisely capture the person-specific differences. Furthermore, apparent consumption may differ substantially from the actual consumption. And finally, inquiry about the food items acquired by members of the household over a specific period of time is subject to reporting error due to poor recollection over long periods of time.

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Appendix A

Appendix A presents a number of additional results related to raw headcount deprivation ratios, contribution of food groups to incidence of deprivation, and incidence of deprivation, as well as the results of the multivariate logistic regressions of NDI on household income and other household characteristics, (for k=4 and 6 food groups), run separately for rural and urban areas.

Table A1. Raw headcount deprivation ratios for basic food groups by household area of residence and economic status

				Rural			p-value	
Food	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	***Diff***	***Trend***
Vegetables	0.38	0.32	0.35	0.37	0.47	0.51	***	***
Fruits	0.69	0.73	0.71	0.69	0.65	0.62	**	***
Grains	0.29	0.34	0.30	0.21	0.27	0.31	***	*
Dairy	0.82	0.92	0.84	0.75	0.75	0.70	***	***
Proteins	0.60	0.75	0.60	0.49	0.52	0.46	***	***
Oils	1.00	1.00	1.00	1.00	1.00	1.00		
				Urban			p-value	
Food	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	***Diff***	***Trend***
Vegetables	0.62	0.56	0.60	0.63	0.63	0.63		*
Fruits	0.68	0.81	0.78	0.74	0.69	0.58	***	***
Grains	0.23	0.22	0.21	0.21	0.22	0.27	**	**
Dairy	0.82	0.94	0.92	0.87	0.82	0.72	***	***
Proteins	0.54	0.65	0.59	0.57	0.53	0.48	***	***
Oils	1.00	1.00	1.00	1.00	1.00	1.00		

DF (*Difference test*): H_0: The deprivation proportion is the same in each group. H_a: At least one deprivation proportion is different from the others. TR (*Trend test*): H_0: No linear trend in the deprivation proportion across groups. H_a: Linear trend in the deprivation proportion across groups. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

Table A2. Percentage contribution of food groups to incidence of deprivation

				Rural		
Food	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Vegetables	12.10	9.18	11.26	13.96	15.36	16.49
Fruits	18.68	18.86	19.06	19.25	18.01	17.53
Grains	9.40	9.93	9.29	7.55	9.40	10.25
Dairy	20.34	20.91	20.24	20.38	20.00	19.17
Proteins	17.90	19.46	18.50	16.98	16.29	15.01
Oils	21.58	21.66	21.65	21.89	20.93	21.55
				Urban		
Food	**All**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**
Vegetables	17.78	15.69	16.58	17.87	17.83	19.00
Fruits	18.01	19.22	19.12	18.33	18.49	16.45
Grains	7.31	6.18	6.18	6.36	7.00	9.12
Dairy	19.86	20.59	20.68	20.11	19.87	19.00
Proteins	16.14	17.45	16.52	16.40	15.84	15.59
Oils	20.90	20.87	20.92	20.93	20.97	20.84

Percentage contribution of food groups to incidence of deprivation (H) for $k = 4$. Source: Authors' calculations.

Table A3. Incidence of deprivation, intensity of deprivation and adjusted headcount ratio by household area of residence and economic status

	Rural Area															
	Q1			**Q2**			**Q3**			**Q4**			**Q5**			
k	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	p-value
0	1.00	0.68	0.68	1.00	0.63	0.63	1.00	0.58	0.58	1.00	0.61	0.61	1.00	0.60	0.60	
1	1.00	0.68	0.68	1.00	0.63	0.63	1.00	0.58	0.58	1.00	0.61	0.61	1.00	0.60	0.60	
2	0.99	0.68	0.67	0.98	0.64	0.63	0.95	0.61	0.57	0.92	0.65	0.59	0.91	0.64	0.58	**
3	0.93	0.70	0.65	0.86	0.68	0.59	0.78	0.67	0.52	0.75	0.72	0.54	0.75	0.71	0.53	***
4	0.70	0.77	0.54	0.59	0.77	0.46	0.50	0.76	0.38	0.55	0.80	0.44	0.57	0.77	0.44	***
5	0.35	0.88	0.30	0.29	0.88	0.25	0.25	0.86	0.21	0.33	0.88	0.29	0.28	0.88	0.25	
6	0.09	1.00	0.09	0.08	1.00	0.08	0.04	1.00	0.04	0.10	1.00	0.10	0.08	1.00	0.08	
	Urban Area															
	Q1			**Q2**			**Q3**			**Q4**			**Q5**			
k	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	p-value
0	1.00	0.70	0.70	1.00	0.68	0.68	1.00	0.67	0.67	1.00	0.65	0.65	1.00	0.61	0.61	
1	1.00	0.70	0.70	1.00	0.68	0.68	1.00	0.67	0.67	1.00	0.65	0.65	1.00	0.61	0.61	
2	0.98	0.71	0.69	0.98	0.69	0.68	0.97	0.68	0.66	0.95	0.67	0.64	0.92	0.65	0.60	***
3	0.92	0.74	0.67	0.89	0.73	0.65	0.87	0.72	0.63	0.82	0.72	0.60	0.75	0.72	0.54	***
4	0.72	0.80	0.58	0.68	0.80	0.54	0.66	0.79	0.53	0.62	0.79	0.50	0.56	0.80	0.45	***
5	0.46	0.87	0.40	0.42	0.88	0.37	0.40	0.88	0.35	0.37	0.88	0.33	0.33	0.89	0.30	***
6	0.11	1.00	0.11	0.11	1.00	0.11	0.11	1.00	0.11	0.11	1.00	0.11	0.12	1.00	0.12	

Incidence of deprivation (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) conditional on different values of k (minimum number of group deprivations), grouped by income quintiles (Q1-Q5) and rural/urban areas. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

Table A4. Incidence of deprivation, intensity of deprivation and adjusted headcount ratio by household economic status and area of residence

	Q1						
	Urban			**Rural**			
k	H	A	M_0	H	A	M_0	*p-value*
0	1.00	0.70	0.70	1.00	0.68	0.68	
1	1.00	0.70	0.70	1.00	0.68	0.68	
2	0.98	0.71	0.69	0.99	0.68	0.67	
3	0.92	0.74	0.67	0.93	0.70	0.65	
4	0.72	0.80	0.58	0.70	0.77	0.54	
5	0.46	0.87	0.40	0.35	0.88	0.30	*
6	0.12	1.00	0.12	0.09	1.00	0.09	
	Q2						
	Urban			**Rural**			
k	H	A	M_0	H	A	M_0	***p-value***
0	1.00	0.68	0.68	1.00	0.63	0.63	
1	1.00	0.68	0.68	1.00	0.63	0.63	
2	0.98	0.69	0.68	0.98	0.64	0.63	
3	0.89	0.73	0.65	0.86	0.68	0.59	
4	0.68	0.80	0.54	0.59	0.77	0.46	*
5	0.42	0.88	0.37	0.29	0.88	0.25	***
6	0.11	1.00	0.11	0.08	1.00	0.08	
	Q3						
	Urban			**Rural**			
k	H	A	M_0	H	A	M_0	***p-value***
0	1.00	0.67	0.67	1.00	0.58	0.58	
1	1.00	0.67	0.67	1.00	0.58	0.58	
2	0.97	0.68	0.66	0.95	0.61	0.57	
3	0.87	0.72	0.63	0.78	0.67	0.52	**
4	0.66	0.79	0.53	0.50	0.76	0.38	***
5	0.40	0.88	0.35	0.25	0.86	0.21	*
6	0.10	1.00	0.10	0.04	1.00	0.04	*
	Q4						
	Urban			**Rural**			
k	H	A	M_0	H	A	M_0	***p-value***
0	1.00	0.65	0.65	1.00	0.61	0.61	
1	1.00	0.65	0.65	1.00	0.61	0.61	
2	0.95	0.67	0.64	0.92	0.65	0.59	
3	0.82	0.72	0.60	0.75	0.72	0.54	*
4	0.62	0.79	0.50	0.55	0.80	0.44	*
5	0.37	0.88	0.33	0.33	0.88	0.29	
6	0.11	1.00	0.11	0.10	1.00	0.10	
	Q5						
	Urban			**Rural**			
k	H	A	M_0	H	A	M_0	***p-value***
0	1.00	0.61	0.61	1.00	0.60	0.60	
1	1.00	0.61	0.61	1.00	0.60	0.60	
2	0.92	0.65	0.60	0.91	0.64	0.58	
3	0.75	0.72	0.54	0.75	0.71	0.53	
4	0.56	0.80	0.45	0.57	0.77	0.44	
5	0.33	0.89	0.30	0.29	0.88	0.25	
6	0.12	1.00	0.12	0.08	1.00	0.08	

Incidence of deprivation (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) conditional on different values of k (minimum number of group deprivations), grouped by income quintiles (Q1-Q5) and rural/urban areas. P-value shows the statistical significance of the difference between rural and urban headcount ratios: H_0: The deprivation proportion is the same in both groups. H_a: The two deprivation proportions are different: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

Table A5. Variable definitions

Variable Name	Definition
Income	Quintiles of monthly per capita household income
Household size	Indicator variable for number of members in a household: $0-4$, $5-8$, and >8 members of household
Maternal education	Indicator variable for maximum years of schooling achieved by any female adult (16+) household member: no education (ref.), primary education or less, middle education or less, secondary education and more
Paternal education	Indicator variable for maximum years of schooling achieved by any male adult (16+) household member: no education (ref.), primary education or less, secondary education or more
Head Spanish (ref.)	Indicator variable = 1 if head of the household speaks monolingual Spanish
Head Guaraní	Indicator variable = 1 if head of the household speaks monolingual Guaraní
Head bilingual	Indicator variable = 1 if head of the household speaks bilingual Spanish and Guaraní
Head other language	Indicator variable = 1 if head of the household speaks a language other than Spanish or Guarani
Area	Indicator variable: urban area (ref.) and rural area
Departments	Indicator variables for departments of Asunción (ref.), San Pedro, Caaguazú, Itapúa, Alto Paraná, Central, and Rest (a representative grouping of the remaining departments)

Table A6. Robustness analysis - urban and rural regressions: Odds-ratio estimates of the effects of household income and other household characteristics on nutritional deprivation for $k = 4$ and 6 food groups/sub-groups

	OR (95% CI)							
	Urban				Rural			
Variable	**Model 1**		**Model 2**		**Model 1**		**Model 2**	
(Intercept)	1.4	1.2-1.6	3.5	1.5-8.3	1.2	0.8-1.8	2.7	0.9-7.8
Economic status								
5th quintile (richest)*	-	-	-	-	-	-	-	-
4th quintile	1.2	1.0-1.6	1.5	1.1-2.0	0.9	0.6-1.5	1.2	0.6-2.1
3rd quintile	1.4	1.1-1.8	1.5	1.0-2.0	0.8	0.5-1.4	0.7	0.4-1.3
2nd quintile	1.7	1.3-2.3	2.3	1.6-3.3	1.2	0.8-2	1.1	0.6-1.9
1st quintile (poorest)	2.4	1.7-3.3	2.5	1.5-4.1	2.2	1.4-3.5	1.6	1-2.8
Household size								
0-4*			-	-	-	-	-	-
5-8			2.0	1.5-2.6			1.5	1.2-2.0
>8			3.0	1.5-6.2			5.2	2.5-10.8
Language								
Spanish*			-	-	-	-	-	-
Guraní			0.7	0.5-1.0			0.7	0.4-1.3
Bilingual			0.6	0.5-0.8			0.8	0.4-1.4
Other			0.6	0.2-1.6			1.9	0.9-3.7
Male HH education level								
None*			-	-	-	-	-	-
Primary			1.4	0.7-3.2			0.9	0.5-1.6
Middle			1.4	0.6-3.1			0.8	0.4-1.5
Secondary or higher			1.5	0.6-3.5			0.7	0.3-1.8
Female HH education level								
None*			-	-	-	-	-	-
Primary			0.2	0.1-0.5			0.6	0.4-1.0
Middle			0.3	0.1-0.5			0.6	0.3-1.0
Secondary or higher			0.3	0.1-0.7			0.3	0.1-0.6

Odds ratio estimates (OR) and the associated 95% confidence intervals (CI) from the multivariate logistic regression of NDI on household income and other household characteristics, run separately for rural and urban households. * marks the reference group. Source: Authors' calculations. See Table A5 for variable definitions. Source: Authors' calculations.

Appendix B

Appendix B extends the analysis of nutritional deprivation presented in 3.1 for six food groups by splitting some of the food group categories into sub-groups (see the description of the six food groups in Section 2.3). We considered a total of 13 (sub-)groups, including five vegetable sub-groups, two grains sub-groups (whole grains and refined grains), and three protein foods sub-groups (fish/seafood, meats and nuts/seeds). Fruits, dairy and oils groups remained a single item as before.

In particular, we classified the vegetable group into five sub-groups, including dark-green vegetables (e.g., broccoli, collard greens, kale, spinach), red and orange vegetables (e.g., carrots, pumpkin, red peppers, sweet potato, tomatoes), legumes (e.g., black beans, garbanzos, green soybeans, kidney beans, lentils, pinto beans, white beans), starchy vegetables (e.g., cassava, green lima beans, green peas, plantains, potatoes), and other vegetables (e.g., common lettuce, onion, cucumber, cabbage, celery, mushrooms, green peppers).[16] The grains group was classified into two sub-groups: whole grains and refined grains. Finally, the protein foods group was classified into three sub-groups: meats, eggs, soy and soy products, nuts, and seeds.

The food sub-group weights were assigned such that their sum equaled to that of the corresponding basic food group as in Section 3.1. For example, each of the 5 vegetable sub-groups were assigned weight 1/30, so that the total weight for the vegetable group was 1/6.

The analysis of population-level headcount ratios shows important food sub-group variation within the corresponding food groups. For example, whereas 53% of Paraguayan households were previously found to deprived in vegetables (Table 1), the sub-group analysis shows that only 46% of households were deprived in starches, but as many as 86% (87%) of households were deprived in green (red and orange) vegetables. Similarly, notable variation was found within grains and proteins sub-groups (Table B1). More rural than urban households were deprived in green vegetables (89% vs. 84%, $p < 0.001$), red and orange vegetables (91% vs. 85%, $p < 0.001$), whole grains (99% vs. 93%, $p < 0.001$), refined grains (12% vs. 9%, $p < 0.01$), and meats (43% vs. 35%, $p < 0.001$); more urban than rural households were deprived in legumes (86% vs. 74%, $p < 0.001$), starch (57% vs. 27%, $p < 0.001$), and nuts (96% vs. 91%, $p < 0.001$).

As in case of food groups, the raw incidences of deprivation across food sub-groups varied significantly with household income (Table B1). In general, the raw incidences of deprivation followed the same monotonic behavior as that observed for basic food groups. In some instances, however, their behavior was contrary to that a group: in particular, for green vegetables and red and orange vegetables, the raw incidence of deprivation declined monotonically with increase in income, and for nuts and seeds group, the raw incidence of deprivation increased monotonically with increase in income increase in income. Similar findings were obtained when the analysis was carried out separately for rural and urban households (Table B2).[17]

[16] Legumes (beans and peas) can be considered part of the protein group as well as the vegetable group; we included these as a separate group within the vegetables group.

[17] Table B3 complements these findings with a joint analysis of household's economic status and its area of residence, providing additional insight into the statistical significance of the differences between rural and

Table B1. Raw headcount deprivation ratios for basic food groups by household income quintiles

		Area		*p*-val	Income Quintile					*p*-val	
Food Group	**Global**	**Rural**	**Urban**	**Diff**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Diff**	**Trend**
Vegetables											
Greens	0.86	0.89	0.84	***	0.91	0.88	0.85	0.84	0.83	***	***
Red & Orange	0.87	0.91	0.85	***	0.95	0.91	0.89	0.86	0.80	***	***
Legumes	0.82	0.74	0.86	***	0.74	0.78	0.83	0.85	0.87	***	***
Starch	0.46	0.27	0.57	***	0.26	0.36	0.44	0.51	0.64	***	***
Other	0.60	0.67	0.56	***	0.76	0.69	0.61	0.54	0.47	***	***
Fruits											
Any	0.69	0.69	0.68		0.76	0.75	0.72	0.68	0.59	***	***
Grains											
Whole	0.95	0.99	0.93	***	0.99	0.99	0.97	0.94	0.89	***	***
Refined	0.10	0.12	0.09	**	0.11	0.08	0.06	0.07	0.15	***	***
Dairy											
Any	0.82	0.82	0.82		0.93	0.88	0.82	0.80	0.72	***	***
Proteins											
Seafood	0.94	0.94	0.94		0.96	0.95	0.94	0.94	0.91	***	***
Meats	0.38	0.43	0.35	***	0.57	0.38	0.33	0.33	0.32	***	***
Nuts	0.94	0.91	0.96	***	0.91	0.94	0.95	0.96	0.95	***	***
Oils											
Any	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00		

DF (*Difference test*): H_0: The deprivation proportion is the same in each group. H_a: At least one deprivation proportion is different from the others. TR (*Linear trend test*): H_0: No linear trend in the deprivation proportion across groups. H_a: Linear trend in the deprivation proportion across groups. Statistical significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ Source: Authors' calculations.

The analysis of incidence of deprivation (H) and intensity of deprivation (A) based on food sub-groups results in a less optimistic scenario for the Paraguayan households, as the likelihood of the household being deprived in a particular group increases with deeper classification.[18] However, the results are qualitatively similar to those found for the food groups (Tables B4 and B5).

urban households by income quintile.

[18]Note that, despite considering 13 food sub-groups, in terms of deprivation we still refer to the 6 basic food groups; as a result, a household may result either totally or only partially deprived for a given food category.

Table B2. Headcount deprivation ratio for each group/sub-group by income quintile

Rural Areas							
Food Group	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**DF**	**TR**
Vegetables							
Greens	0.92	0.88	0.86	0.87	0.89	*	*
Red & Orange	0.96	0.92	0.89	0.89	0.85	***	***
Legumes	0.70	0.71	0.75	0.80	0.80	**	***
Starch	0.18	0.24	0.27	0.35	0.45	***	***
Other	0.80	0.71	0.62	0.57	0.49	***	***
Fruits							
Any	0.73	0.71	0.69	0.65	0.62	**	***
Grains							
Whole	0.99	1.00	0.99	0.98	0.95	***	***
Refined	0.13	0.12	0.06	0.10	0.17	***	
Dairy							
Any	0.92	0.84	0.75	0.75	0.70	***	***
Proteins							
Seafood	0.97	0.94	0.92	0.93	0.91	**	***
Meats	0.60	0.42	0.29	0.35	0.32	***	***
Nuts	0.88	0.91	0.92	0.95	0.92	*	**
Oils							
Any	1.00	1.00	1.00	1.00	1.00		
Urban Areas							
Food Group	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**DF**	**TR**
Vegetables							
Greens	0.89	0.89	0.84	0.82	0.82	***	***
Red & Orange	0.91	0.91	0.89	0.85	0.8	***	***
Legumes	0.82	0.84	0.87	0.87	0.88	*	**
Starch	0.41	0.47	0.53	0.57	0.68	***	***
Other	0.66	0.67	0.60	0.53	0.47	***	***
Fruits							
Any	0.81	0.78	0.74	0.69	0.58	***	***
Grains							
Whole	0.98	0.97	0.96	0.93	0.88	***	***
Refined	0.06	0.05	0.06	0.07	0.15	***	***
Dairy							
Any	0.94	0.92	0.87	0.82	0.72	***	***
Proteins							
Seafood	0.96	0.96	0.95	0.95	0.91	***	***
Meats	0.51	0.35	0.35	0.33	0.32	***	***
Nuts	0.97	0.97	0.97	0.96	0.96		
Oils							
Any	1.00	1.00	1.00	1.00	1.00		

Headcount deprivation ratios for each food category by income quintile group (Q1-Q5) for rural and urban areas. *Test difference:* H_0: The deprivation proportion is the same in each group. H_a: At least one deprivation proportion is different from the others. *Test trend:* H_0: There is no linear trend in the deprivation proportion across groups. H_a: There is a linear trend in the deprivation proportion across groups. Statistically significance code: *** $p_{val} < 0.001$, ** $p_{val} < 0.01$, * $p_{val} < 0.05$.

Table B3. Headcount deprivation ratios for each food group by income quintiles and rural/urban areas

	Q1		Q2		Q3		Q4		Q5	
Food Group	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
Vegetables										
Greens	0.92	0.89	0.88	0.89	0.86	0.84	0.87	0.82	0.89	0.82**
Red & Orange	0.96	0.92*	0.91	0.91	0.89	0.89	0.89	0.84	0.84	0.80
Legumes	0.70	0.82***	0.71	0.84***	0.75	0.87***	0.80	0.87**	0.80	0.88***
Starch	0.18	0.41***	0.24	0.47***	0.27	0.53***	0.35	0.57***	0.45	0.68***
Other	0.81	0.66***	0.71	0.67	0.62	0.60	0.57	0.53	0.49	0.47
Fruits										
Any	0.73	0.81**	0.71	0.78*	0.69	0.74	0.65	0.69	0.62	0.58
Grains										
Whole	0.99	0.98	1.00	0.97**	0.99	0.96**	0.98	0.93**	0.95	0.88**
Refined	0.13	0.06**	0.12	0.05***	0.06	0.06	0.10	0.07	0.17	0.15
Dairy										
Any	0.92	0.94	0.84	0.92***	0.75	0.87***	0.75	0.82**	0.70	0.72
Proteins										
Seafood	0.97	0.96	0.94	0.96	0.92	0.95	0.93	0.95	0.91	0.91
Meats	0.61	0.51*	0.43	0.35*	0.29	0.35	0.35	0.33	0.32	0.32
Nuts	0.88	0.97***	0.91	0.97***	0.92	0.97**	0.95	0.96	0.92	0.96**
Oils										
Any	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

DF (*Difference test*): H_0: The deprivation proportion is the same in each group. H_a: The two deprivation proportions are different. Statistical significance: $* \ p < 0.05$, $** \ p < 0.01$, $*** \ p < 0.001$ Source: Authors' calculations.

Table B4. Incidence and intensity of deprivation and adjusted headcount ratio

	Global			Rural			Urban		
k	H	A	M_0	H	A	M_0	H	A	M_0
0	1.00	0.75	0.75	1.00	0.75	0.75	1.00	0.75	0.75
1	1.00	0.75	0.75	1.00	0.75	0.75	1.00	0.75	0.75
2	0.98	0.76	0.74	0.98	0.76	0.74	0.98	0.76	0.75
3	0.90	0.78	0.70	0.88	0.78	0.69	0.90	0.78	0.70
4	0.67	0.82	0.55	0.66	0.82	0.54	0.64	0.82	0.53
5	0.31	0.87	0.27	0.32	0.87	0.28	0.29	0.87	0.25
6	0.03	1.00	0.03	0.03	1.00	0.03	0.02	1.00	0.02

Incidence of deprivation (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) conditional on the value of k (minimum number of group deprivations), grouped by income quintiles (Q1-Q5) and rural/urban areas. DF (*Difference test*): H_0: The deprivation proportion is the same in each group. H_a: The two deprivation proportions are different. Statistical significance: $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$ Source: Authors' calculations.

Table B5. Incidence and intensity of deprivation and adjusted headcount ratio

Global																
	Q1			**Q2**			**Q3**			**Q4**			**Q5**			
k	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	Test
0	1.00	0.79	0.79	1.00	0.77	0.77	1.00	0.75	0.75	1.00	0.74	0.74	1.00	0.71	0.71	
1	1.00	0.79	0.79	1.00	0.77	0.77	1.00	0.76	0.75	1.00	0.74	0.74	1.00	0.71	0.71	
2	0.99	0.80	0.79	0.99	0.78	0.77	0.99	0.76	0.75	0.97	0.75	0.73	0.95	0.73	0.69	***
3	0.94	0.81	0.76	0.93	0.79	0.74	0.90	0.78	0.70	0.87	0.78	0.68	0.83	0.76	0.63	***
4	0.74	0.83	0.62	0.73	0.82	0.59	0.67	0.81	0.55	0.65	0.82	0.54	0.60	0.81	0.48	***
5	0.34	0.88	0.30	0.29	0.88	0.25	0.30	0.87	0.26	0.30	0.87	0.26	0.30	0.87	0.26	**
6	0.02	1.00	0.02	0.02	1.00	0.02	0.01	1.00	0.01	0.03	1.00	0.03	0.04	1.00	0.04	
Rural Area																
	Q1			**Q2**			**Q3**			**Q4**			**Q5**			
k	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	Test
0	1.00	0.79	0.79	1.00	0.76	0.76	1.00	0.73	0.73	1.00	0.73	0.73	1.00	0.71	0.71	
1	1.00	0.79	0.79	1.00	0.76	0.76	1.00	0.73	0.72	1.00	0.73	0.73	1.00	0.71	0.71	
2	0.99	0.79	0.79	0.98	0.76	0.75	0.97	0.73	0.71	0.97	0.74	0.71	0.96	0.73	0.70	
3	0.96	0.80	0.77	0.91	0.78	0.70	0.87	0.76	0.65	0.86	0.76	0.66	0.84	0.75	0.63	**
4	0.74	0.83	0.61	0.68	0.81	0.55	0.59	0.80	0.47	0.59	0.81	0.48	0.56	0.81	0.46	***
5	0.33	0.89	0.30	0.26	0.88	0.23	0.22	0.86	0.19	0.30	0.87	0.26	0.28	0.87	0.25	**
6	0.02	1.00	0.02	0.02	1.00	0.02	0.01	1.00	0.01	0.03	1.00	0.03	0.02	1.00	0.02	
Urban Area																
	Q1			**Q2**			**Q3**			**Q4**			**Q5**			
k	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	H	A	M_0	Test
0	1.00	0.80	0.80	1.00	0.79	0.79	1.00	0.77	0.77	1.00	0.75	0.75	1.00	0.71	0.71	
1	1.00	0.80	0.80	1.00	0.79	0.79	1.00	0.77	0.77	1.00	0.75	0.75	1.00	0.71	0.71	
2	0.99	0.81	0.80	0.98	0.79	0.78	0.99	0.77	0.76	0.99	0.75	0.74	0.96	0.72	0.70	***
3	0.94	0.82	0.77	0.93	0.80	0.75	0.92	0.79	0.72	0.89	0.78	0.69	0.84	0.76	0.63	***
4	0.75	0.85	0.63	0.73	0.83	0.61	0.68	0.83	0.56	0.65	0.82	0.54	0.61	0.81	0.49	***
5	0.38	0.89	0.34	0.34	0.88	0.30	0.33	0.88	0.30	0.28	0.88	0.25	0.29	0.88	0.25	**
6	0.01	1.00	0.01	0.02	1.00	0.02	0.02	1.00	0.02	0.02	1.00	0.02	0.05	1.00	0.05	*

Incidence of deprivation (H), intensity of deprivation (A) and adjusted headcount ratio (M_0) conditional on the value of k (minimum number of group deprivations), grouped by income quintiles (Q1-Q5) and rural/urban areas. DF (*Difference test*): H_0: The deprivation proportion is the same in each group. H_a: The two deprivation proportions are different. Statistical significance: $*$ $p < 0.05$, $**$ $p < 0.01$, $***$ $p < 0.001$ Source: Authors' calculations.

Table B6. Odds-ratio estimates of the effects of household income and other household characteristics on nutritional deprivation for $k = 4$ and 13 food groups/sub-groups

	OR (95% CI)							
Variable	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
(Intercept)	6.3	5.2-7.6	8.8	3.0-25.6	9.4	3.2-27.6	12.3	3.8-39.6
Economic status								
5th quintile (richest)*	-	-	-	-	-	-	-	-
4th quintile	1.3	1.0-1.6	1.3	1-1.7	1.3	1.0-1.7	1.3	1.0-1.8
3rd quintile	1.5	1.2-1.8	1.2	0.9-1.6	1.2	0.9-1.7	1.3	0.9-1.7
2nd quintile	2.3	1.8-2.9	2.0	1.5-2.8	2.2	1.6-3	2.3	1.7-3.2
1st quintile (poorest)	3.0	2.3-3.9	2.3	1.6-3.4	2.7	1.9-4	3.1	2.1-4.5
Household size								
0-4*			-	-	-	-	-	-
5-8			1.6	1.3-1.9	1.6	1.3-1.9	1.5	1.2-1.9
>8			3.5	1.9-6.7	3.5	1.8-6.6	3.4	1.8-6.6
Language								
Spanish*			-	-	-	-	-	-
Guraní			0.8	0.6-1.1	0.9	0.6-1.2	0.9	0.7-1.3
Bilingual			0.7	0.5-1	0.8	0.6-1	0.8	0.6-1
Others			1.2	0.7-2.1	1.5	0.8-2.8	1.4	0.7-2.7
Male HH education level								
None*			-	-	-	-	-	-
Primary			1.2	0.8-1.9	1.2	0.8-1.9	1.2	0.8-1.9
Middle			1.1	0.7-1.8	1.0	0.6-1.7	1.0	0.7-1.7
Secondary or higher			1.1	0.6-1.9	1.0	0.6-1.8	1.0	0.6-1.7
Female HH education level								
None*			-	-	-	-	-	-
Primary			0.5	0.3-0.8	0.5	0.3-0.8	0.5	0.3-0.8
Middle			0.4	0.3-0.8	0.4	0.3-0.7	0.4	0.2-0.7
Secondary or higher			0.4	0.2-0.6	0.4	0.2-0.6	0.4	0.2-0.6
Area								
Urban*					-	-	-	-
Rural					0.6	0.5-0.8	0.7	0.5-0.9
Department								
Asunción*							-	-
San Pedro							0.5	0.3-0.8
Caaguazú							0.5	0.3-0.8
Itapúa							0.6	0.4-1.0
Alto Paraná							0.9	0.6-1.4
Central							0.9	0.6-1.2
Others							0.8	0.6-1.2

Pooled odds ratio estimates (OR) and the associated 95% confidence intervals (CI) from the multivariate logistic regression of NDI on household income and other household characteristics. * marks the reference group. Source: Authors' calculations. See Table A5 for variable definitions. Source: Authors' calculations.

Table B7. Robustness analysis - urban and rural regressions: Odds-ratio estimates of the effects of household income and other household characteristics on nutritional deprivation for $k = 4$ and 13 food groups/sub-groups

	OR (95% CI)							
	Urban				Rural			
Variable	**Model 1**		**Model 2**		**Model 1**		**Model 2**	
(Intercept)	3.2	2.6-3.8	8.9	2.3-34.8	1.2	0.8-1.8	2.7	0.9-7.8
Economic status								
5th quintile (richest)*	-	-	-	-	-	-	-	-
4th quintile	1.6	1.2-2.1	1.6	1.1-2.3	0.9	0.6-1.5	1.2	0.6-2.1
3rd quintile	2.1	1.5-3.0	2	1.2-3.3	0.8	0.5-1.4	0.7	0.4-1.3
2nd quintile	3.0	2.0-4.3	3.9	2.4-6.4	1.2	0.8-2.0	1.1	0.6-1.9
1st quintile (poorest)	3.9	2.3-6.8	4.5	1.9-10.6	2.2	1.4-3.5	1.6	1.0-2.8
Household size								
0-4*			-	-	-	-	-	-
5-8			1.8	1.2-2.7			1.5	1.2-2
>8			1.7	0.6-4.9			5.2	2.5-10.8
Language								
Spanish*			-	-	-	-	-	-
Guraní			0.8	0.5-1.2			0.7	0.4-1.3
Bilingual			0.7	0.5-0.9			0.8	0.4-1.4
Others			0.5	0.1-2.0			1.9	0.9-3.7
Male HH education level								
None*			-	-	-	-	-	-
Primary			1.6	0.5-4.7			0.9	0.5-1.6
Middle			1.7	0.5-5.6			0.8	0.4-1.5
Secondary or higher			1.7	0.5-5.8			0.7	0.3-1.8
Female HH education level								
None*			-	-	-	-	-	-
Primary			0.3	0.1-1.1			0.6	0.4-1.0
Middle			0.2	0.1-0.8			0.6	0.3-1.0
Secondary or higher			0.2	0.1-0.9			0.3	0.1-0.6

Odds ratio estimates (OR) and the associated 95% confidence intervals (CI) from the multivariate logistic regression of NDI on household income and other household characteristics, run separately for rural and urban households. * marks the reference group. Source: Authors' calculations. See Table A5 for variable definitions. Source: Authors' calculations.

Este Proyecto es cofinanciado por el Consejo Nacional de Ciencia y Tecnología - CONACYT con recursos del FEEI