IMPACTS OF MALNUTRITION ON LABOR PRODUCTIVITY: EMPIRICAL EVIDENCES IN RURAL BRAZIL

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RESUMO

Neste artigo investigam-se os impactos da subnutrição sobre a produtividade do trabalho, analisando a armadilha da pobreza nutricional (APN). Verifica-se o efeito da ingestão de micronutrientes (ferro e vitaminas A, B1 e B2) e de calorias sobre as rendas dos chefes de famílias para os setores agrícola, não agrícola, conta-própria e outros empregos. Utiliza-se uma variação do método de Durbin e McFadden (1984) para correção de viés de seleção baseado em modelos *logit multinomiais*. Os dados foram provenientes das Pesquisas de Orçamento Familiar/IBGE de 2002-2003 e 2008-2009 para a área rural do Brasil. Os resultados demonstram que embora as deficiências de micronutrientes ainda persistam como problemas de saúde pública no Brasil, ocorreu uma melhora no período analisado.

Palavras-chave: Armadilha da pobreza nutricional, privação de calorias e micronutrientes, Modelo Logit Multinomial

Classificação JEL: C24, I32, J43

Área ANPEC: Área 13 **-** Economia do Trabalho

ABSTRACT

This article studies the impacts of malnutrition on labor productivity, analyzing the Nutrition-Based Poverty Trap (NPT). We verify the effects of micronutrient and calorie intake (iron and vitamins A, B1 and B2) on the incomes of household heads for the agricultural, non-agricultural, independent and other employments sectors. We applied a variation of the Durbin and McFadden (1984) methods for the correction of the selection bias based on the *multinomial logit* data, obtained from the Family Budget Research/IBGE carried out from 2002-2003 and 2008-2009 in rural Brazil. Results suggest that although micronutrient deficiencies still persist as a public health problem in Brazil, there was an improvement during the analyzed period of time.

Keywords: nutrition-based poverty trap, calorie and micronutrient deprivation, multinomial logit model.

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1 INTRODUCTION

A considerable amount of the recent literature on economic development has been concerned about wellbeing determinants included in the millennium goals. One of the key elements to comply with such goals is the reduction of malnutrition. With this perspective, the main proposal of this study is to investigate the impacts of malnutrition on labor productivity in densely populated countries, where labor demand is often lower than labor offer. As a consequence, the lack of opportunities in the labor market results in low wages. In this context, the poor are doubly affected: they don´t receive any profits from assets, as they don´t have them, and they also have a restricted access to working opportunities.

Micronutrients and wage categories may suggest that a policy aimed at increasing nutritional intake by the malnourished population sector may lead to a growth in salary revenues. This would demonstrate the importance of a policy to grant nutritional supplements to the deprived population. The crucial question to be answered is if an improvement in nutrient intake could have any significant effects on rural income and therefore, on the possibility to break this trap, as well as on the reduction of poverty in rural Brazil. Consequently, the main focus of the public policies should be on raising awareness on nutritional implications. This would highlight the importance of a direct nutritional supplements policy, besides the inclusion of policies to directly reduce poverty.

The effects of nutritional intake on labor productivity and on wage levels have been an important research area for health economists and nutritionists. The hypothesis of efficient wages shows that in developing countries such as Brazil, which suffer from particularly low nutritional levels, workers are physically incapable of performing hard physical work, which results in low productivity and low wages, low purchase power and consequently, low nutritional levels, completing a vicious cycle of misery. This cycle also diminishes the chances of these workers to escape the Nutrition-Based Poverty Trap. (NPT).

Among the papers that empirically test the existence of a NPT we can mention those of Strauss (1986), Thomas and Strauss (1997), Deolalik (1988), Barret (2002) and Jha, Gaiha and Sharma (2009). There are also other studies that analyze the effects of micronutrient and calorie deficiency in workers' productivity, such as Stamoulis, Pingaly and Shetty in 2004. As for the national production however, there is no economics literature on the importance of quantifying micronutrient and calorie deficiency in the nutrition-based poverty trap development and consequently on the impact of this deprivation in labor productivity. With this in mind, this article aims mainly at analyzing the poverty trap with regards to nutrition, verifying the effect of micronutrients intake (iron and vitamins A, B1 and B2) and calories on the income of family heads. Seeking to comply with these goals, we apply a variation o the Durbin –Mcfadden method (1984) to correct the selection bias based on *multinomial logit* models, in agreement with Bourguignon, Fournier and Gurgand (2004). The main goal is to foresee the probabilities of an individual to participate in the labor market and use them as income determinants to verify the existence of the nutrition-based poverty trap (NPT). The database is created based on the Family Budget Research (FBD) 2002-2003 and 2008-2009 for rural Brazil.

The rest of this paper is organized in seven sections. Sections 2 and 3 review specialized literature on nutrition deprivation and on the nutrition-based poverty trap. The fourth section introduces a methodology that corrects the selection bias problem based on multinomial logit models. The fifth section introduces the database and the econometric models to be estimated. The sixth and seventh sections analyze estimated results and draw the final conclusions.

2 THEORETICAL AND EMPIRICAL ASPECTS OF NUTRITIONAL DEPRIVATION AND THE NUTRITION-BASED POVERTY TRAP

The pioneering works that relate wages, nutrition and productivity at work expressed by the initial hypothesis of an efficiency wage were developed by Leibenstein (1957), Mirrlees (1975) and Stiglitz (1976) among others. They advocate that productivity has a non-linear dependency on nutrition and that an increase in worker calorie intake generates marginal productivity gains and consequently, higher wages.

The hypothesis of efficiency wage models based on nutrition according to Mirrleees (1975) is that high wages may increase worker productivity as with higher wages, they may buy more food, becoming better nourished and therefore, more productive at work.

According to Leibenstein (1957), worker productivity is determined by the salary, as it enables for the purchase of food, which supplies the energy that allows the worker to become more productive at work. With this same perspective, Stiglitz's theoretical essay (1976) describes the productivity dependence of workers on the nutritional contents of their eating habits, which means that the consumption of more nutritive foods has a positive impact on productivity and therefore, on wages. On the other hand, the study developed by Ahmed *et al (*2007) corroborated that there was a significant reduction in calorie deprivation in India from 1997 to 2003.

There is a specific international literature that empirically tests the existence of the NPT. Using data from rural families in Sierra Leone, from May 1974 to April 1975, Strauss (1986) quantified the effects of nutritional patterns measured through the caloric intake in the annual agricultural production and in the labor productivity. He found that calorie intake had significant and important effects on the agricultural production. He concluded that an adequate calorie intake exerted a positive correlation with family productivity.

In a research based on the impact of four health indicators (height, body mass index, calorie intake per capita and protein intake) developed for Brazilian workers' wages in urban areas, Thomas and Strauss (1997) using a database provided by the National Studies on Family Expenses (ENDEF) between August 1974 and August 1975, verified that these four indicators had a positive and significant effect on wages. Such fact was due to an improvement in the health and nutrition situation of the urban poor.

Contrary to this however, Deolalik (1988) applying a regression panel data of fixed effects of an adequacy of wages and rural agricultural production in Southern India from 1976 to 1978, discovered that calorie intake does not affect wages or productivity, suggesting that the human body can adapt to short-term calorie intake deficits. However, he found out that height and weight does affect wages and productivity and that such results suggest that malnutrition is an important determinant of productivity and wages.

By analyzing rural data from India from 1966 to 1969, Swamy (1997) proved that wages based on the efficiency wage modes based on nutrition are rigid, as when they decrease they also reduce the workers activity and increase the cost per labor efficiency unit. In a theoretical study, Barret (2002) discovered that micronutrient deficiency reduces physical and cognitive activity, thus affecting work productivity. Such deficiency also indirectly decreases productivity by increasing worker susceptibility to disease and infections.

Using data from the World Bank from 1994 to 1996, Horton and Ross (2003) showed that iron deficiency in ten developing countries such as Honduras, Bangladesh, Nicaragua and Bolivia among others is related to a number of functional consequences with economic implications, such as mental deterioration in children and low productivity in adult work. Likewise, Lorch (2001) proved that vitamin A deficiency (carotene) is a serious malnutrition that weakens the immunologic system and may lead to blindness.

Micronutrient deficiency may also provoke a deep impact on worker productivity and performance, as advocated by the study developed by Lukaski (2004). Specifically, a deficiency in Vitamin B may cause weakness, reduced stamina, loss of weight and body mass, whereas a deficiency in vitamin B2 may lead to alterations in the skin, the mucous membrane and the nervous system. Vitamin A deficiency may cause loss of appetite and increased susceptibility to infections while iron deficiency is a common cause of anemia, cognitive deterioration and abnormalities in the immunologic system. Therefore, it is important to examine the effects of micronutrient and calorie deficiency in workers' productivity, in which the specialized literature has been focused on. (LAKDAWALLA, PHILIPSON and BHATTACHARYA, 2005).

In an analysis of micronutrient deficiency, Lakdawalla, Philipson, and Bhattacharya (2005) adopted data from the National Health and Nutrition Examination Survey III (NHANES) which contains demographic features, laboratorial analysis with blood samples and nutritional information collected from families from 1988 to 1994 in the USA. They estimated linear probability models and discovered that nutritional deficiencies (vitamins A and C, folic acid and anemia) vary according to food prices, as lower costs improve nutrition and obesity is the adverse effect of economic growth.

The existent gap in specialized literature on nutrition, poverty and wages is the negligence of the impact of micronutrient deprivation on labor productivity, in other words, the possibility of the existence of NPT related to micronutrient deficiency. An important contribution in this sense was made by Weinberg (2003) who adopted the two-stage least square estimation method (2SLS) and analyzed the impact of iron deficiency in labor productivity in rural India from July 1992 to June 1994. However, this author does not model the impact of micronutrient deficiency applying the nutrition-based poverty trap.

Seeking to fill that gap, Jha, Gaiha and Sharma (2009) tested the existence of the nutrition-based poverty trap (NPT) for four micronutrients and calorie intake (carotene, iron, riboflavin and thiamine) for rural India from January to June 1994 for three different wage levels (plantation, harvest and others) in male and female workers. They used the Heckman sample (1976, 1979) and verified the existence of NPT in ten cases, which proves that micronutrient deficiency has a significant impact on agricultural worker productivity, mainly on females.

In the national literature we should highlight Castro's work (1932.1946) as one of the pioneers in the topic of hunger, poverty, malnutrition and infant mortality, as he analyzed nutrition needs based on data on the metabolism of the Brazilian population.

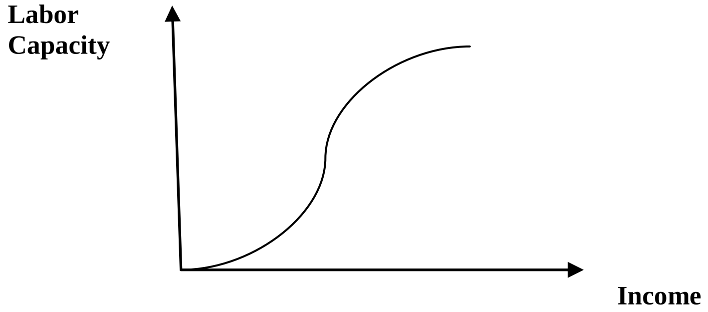
The referred author performed an economics study on nutrition patterns of the Recife working class, highlighting the living conditions of this population sector, which are narrated in his book *The Physiological Problem of Nutrition in Brazil (*1932). He concluded that most workers lived in famine and died of hunger, as the wages they were paid were insufficient to select food according to the calories they provide and the amount they needed. In his work *The Geography of Famine* (1946), the referred author introduced the problem of malnutrition and feeding deficiency by demonstrating that Brazilians suffered from nutritional deficiency (in proteins, mineral salts and vitamins) diversified in the most widespread areas of the national territory.

At a national level, there is no economics literature on the importance of quantifying the micronutrient and calorie deficiency and the progress of the nutrition-based poverty trap and consequently, the impact of such deprivation on labor productivity. This paper seeks to fill that gap.

3 NUTRITION-BASED POVERTY TRAP

The capacity curve is related to the labor capacity an individual can achieve for a given task and the quantity of energy necessary to perform a certain task. The stylized version of the relation between labor capacity and nutrition, according to Jha, Gaiha and Sharma (2009) is shown in Figure 1. It is assumed that income is a synonym of nutrition in the sense that all income is converted into nutrition, which means that the money earned by the poor is entirely spent on food.

Figure 1- Capacity Curve



Source: Jha, Gaiha and Sharma (2009)

For much lower income levels, all the energy from food intake goes to the *resting metabolism*, which is the minimum calorie quantity that the body needs to keep working properly (breathing, body temperature, etc). According to FAO (Food and Agriculture Organization) data from 2001, the minimum amount of energy for a Brazilian “reference man” with a weight of 65 kilos would be of 1,900 kcal per person a day. During this stage, little energy is allocated to work, so the capacity curve in this area is next to zero. When the resting metabolism is filled, the additional energy is sent to fill the energy required to perform physical work. As from a certain income level, the labor capacity quickly improves due to the growth in the required energy to perform work.

When all the human body energy obtained from food intake is satisfied, the capacity to work increases at decreasing rates, due to the natural limit imposed by the human body. In other words, for very low income levels, we have the well- known decreasing scale returns factor. The non-linear graphic represented by a convex and a concave region represents the possibility of the existence of involuntary unemployment and the consequent persistence of poverty.

The labor market is a mechanism of income and opportunity generation to acquire good health and nutrition. According to Dadgupta and Ray (1986) the labor market movement can be affected by a malnutrition problem, as it affects the capacity of the human body to perform tasks that generate income. Poverty may lead to malnutrition and the latter provokes low productivity. Consequently, a large part of the population may be prisoner of a poverty trap due to the malnutrition problem.

4 SELECTION BIAS CORRECTIONS BASED ON MULTINOMIAL LOGIT MODELS

Among the different sample selection modalities, there is one that appears when the dependent variable is observed solely for a defined population subgroup such as the income variable that is only noticed in individuals with a strictly positive labor day. In the simplest cases, in which the observation of the variable of interest is determined by a binary variable, the problem of endogenous selection may be easily solved through the procedure proposed by Heckman (1979) which consists of a two-stage regression on the system:

$$y_1 = x_1\beta_1 + u_1 \quad (1a)$$

$$y_2 = 1[x_2\delta_2 + v_2 > 0] \quad (1b)$$

In which (1a) is the equation that explains the variable of interest with regards to a vector of observable behavior x_1 and a disturbance u_1, called structural equation; (1b) is the equation that explains the binary variable y_2 through the observable behavior vector x_2 and the non-observable characteristics v_2, called selection equation; (x_1, x_2) are always observable and the variable y_1 is only observed when $y_2 = 1$.

According to Heckman (1979), consistent estimators for β_1 and γ_1 may be obtained through the regression of Ordinary Least Squares (OLS) of y_{i1} on x_{i1} and $\hat{\lambda} \equiv \lambda(x_{i2}, \hat{\delta}_2)$, being the last one an estimator of δ_2 obtained through the previous estimation of a *probit* for (1b), in which $\lambda(\cdot)$ is the inverse *Mills* ratio such that $\lambda(x_2\delta_2) \equiv \frac{\phi(x_2\delta_2)}{\Phi(x_2\delta_2)}$ [1],

In more complex models however, the selection takes place through a discrete choice multinomial process. According to Bourguignon, Fournier and Gurgand (2004), the configuration problem is as follows:

$$y_1 = x\beta_1 + u_1 \qquad (2a)$$

$$y_j^* = z\gamma_j + \eta_{j,}, \qquad j = 1.\ 2...., M \qquad (2b)$$

Where disturbances u_1 satisfy $E(u_1/x, z) = 0$ and $V(u_1/x, z) = \sigma^2$; *j* represents a category variable that describes the agent choice among the M alternatives based on "utilities" y_j^* o; vectors *z* and *x* contain the variables that explain alternatives and the variable of interest respectively, without loss of generality. It is assumed that the variable y_1 is observed only if the category 1 is selected, which happens when $y_1^* > \max_{j\neq 1}(y_j^*)$. This condition equals to $\varepsilon_1 < 0$ if we define $\varepsilon_1 = \max_{j\neq 1}(y_j^* - y_1^*) = \max_{j\neq 1}(z\gamma_j + \eta_j - z\gamma_1 - \eta_1)$. As demonstrated by McFadden (1973) and assuming that (η_j) are independent and identically distributed through the Gumbel distribution, this specification leads to the *multinomial logit* model, with the response probability $P(\varepsilon_1 < 0/z) = \frac{\exp(z\gamma_1)}{\sum_j \exp(z\gamma_j)}$.

Therefore, based on the above equation, consistent estimators for (γ_j)'s may be easily obtained through maximum likelihood. However, the problem continues to be how to estimate the vector for β_1 parameters, considering that disturbances u_1 may not be independent from all the (η_j)'s, in such a way that this may introduce some correlation among explanatory variables and the disturbances term in the equation of interest (2nd). Consequently, OLS estimators for β_1 are inconsistent.

Generalizing on the Heckman process (1979), Bourguignon, Fournier and Gurgand (2004) demonstrated that the selection bias correction may be based on the u_1 conditional median such that $E(u_1/\varepsilon_1 < 0, \Gamma) = \int\int_{-\infty}^{0} \frac{u_1 f(u_1, \varepsilon_1/\Gamma)}{P(\varepsilon_1 < 0/\Gamma)} d\varepsilon_1 du_1 = \lambda(\Gamma)$, where, $\Gamma \equiv \{z\gamma_1, z\gamma_2, ..., z\gamma_M\}$ and $f(u_1, \varepsilon_1/\Gamma)$ is the joint conditional density of u_1 and ε_1.

They also concluded that as relations among the M components of Γ and the corresponding M probabilities may be inverted, there is an unique μ function that may be replaced by λ in such a way that $E(u_1/\varepsilon_1 < 0, \Gamma) = \mu(P_1, ..., P_M)$.

Thus, consistent estimators for β_1 may be obtained through one of the two following regressions: $y_1 = x_1\beta_1 + \mu(P_1, ..., P_M) + w_1$ ou $y_1 = x_1\beta_1 + \lambda(\Gamma) + w_1$ where w_1 is the independent residual of the average regression.

However, as the estimation of a large number of parameters becomes necessary when we have a vast choice of alternatives, restrictions on $\mu(P_1, ..., P_M)$ or likewise, on $\lambda(\Gamma)$, must be imposed in order to keep the problem within control and it is exactly in that respect that bias correction methods proposed in literature differ.

[1] $\phi(\cdot)$ e $\Phi(\cdot)$ are the density function and the normal standard of accumulated distribution function respectively.

In the method proposed by Durbin and Mc Fadden (1984), we accept the hypothesis of linear disturbances, expressed through the u_1 average conditional to (η_j)'s through

$$E(u_1/\eta_1,...,\eta_M) = \sigma \sum_{j=1,..M} r_j \left(\eta_j - E(\eta_j)\right) \text{ com } \sum_{j=1...M} r_j = 0 \qquad (3)$$

This means that $E(u_1/\eta_1...\eta_M) = \sigma \sum_{j=2...M} r_j(\eta_j - \eta_1)$. Based on this condition and on the multinomial logit model, Durbin and McFadden (1984) obtained that $E\left(\eta_j - \eta_1 \Big/ y_1^* > \max_{s\neq 1}(y_s^*), \Gamma\right) = \dfrac{P_j \ln(P_j)}{1-P_j} + \ln(P_1), \forall j > 1$. Consequently, they proposed that the model described in (2a) and (2b) could be estimated through the OLS by the following equation:

$$y_1 = x_1\beta_1 + \sigma \sum_{j=2...M} r_j \left(\frac{P_j \ln(P_j)}{1-P_j} + \ln(P_1)\right) + w_1 \qquad (4)$$

When analyzing such procedure, Bourguignon, Fournier and Gurgand (2004) noticed that the hypothesis (3) imposed a specific kind of linearity between entre u_1 and the *Gumbel* distributions of (η_j)'s, thus restricting the distribution types permitted for u_1. They suggested a hypothesis variation that could turn u_1 linear in a set of normal distributions, allowing u_1 to be normal with: $E(u_1/\eta_1...\eta_M) = \sigma \sum_{j=1...M} r_j^* \eta_j^*$ [2] in which r_j^* are correlations between u_1 and standardized normal variables $\eta_j^* = J(\eta_j) = \Phi^{-1}(G(\eta_j))$, j = 1....M,[3]. Considering a sample selection, the authors derived the following conditional logits: $E\left(\eta_1^* \big/ y_1^* > \max_{s\neq}(y_s^*), \Gamma\right) = m(P_1)$ and $E\left(\eta_j^* \big/ y_1^* > \max_{s\neq}(y_s^*), \Gamma\right) = m(P_j)P_j/(P_j - 1)$ where $m(P_j) = \int J(v - \log P_j) g(v) dv$, $\forall j$ .With this, they concluded that after the hypothesis alteration, the regression equation (4) could be expressed as:

$$y_1 = x_1\beta_1 + \sigma\left[r_1^* m(P_1) + \sum_{j=2...M} r_j^* m(P_j) \frac{P_j}{(P_j - 1)}\right] + w_1 \qquad (5)$$

According to equation (5), the factors or variables that correct the selection bias are defined as $m_0 = m(P_1)$ and $m_j = m(P_{j+1})\dfrac{P_{j+1}}{(P_{j+1} - 1)}$ for *j=1.2....,M-1* in which σr_1^*, σr_2^*, σr_3^*, ..., σr_M^* are the respective parameters to be estimated.

By applying Monte-Carlo experiments to compare bias correction methods performances based on multinomial *logit* models (MLM), the authors verified that most of the times the method proposed by Dubin and McFadden (1984) was preferable to both the most commonly used Lee method (1983), and to the semi-parametric alternative proposed by Dahl (2002). Experiments showed that the Durbin - McFadden performance model (1984) is fairly sensitive to the imposed normalization restriction and that the suggested variation, however usually less robust than the original version, boasts higher performance when the normalization hypothesis is violated. Besides, it seems to be more capable of capturing intensely non-linear selection terms. Finally, through

[2] Please note that (3) is a special case of (4) for $J(\eta_j) = \eta_j - E(\eta_j)$ and a normalization on the correlations, as Dubin and McFadden (1984) normalized errors whereas in (4) this normalization does not happen due to a non-linear J transformation.

[3] Observe that for each j, Bourguignon *et al*. (2004) assumed that expected values of u1 and η_j^* are linearly related, which is maintained through the classic hypothesis in which u_1 is normal and (u_1, η_j^*) is bi-varied normal for any J alternative.

Monte-Carlo simulations, they concluded that the selection bias correction based on the *multinomial logit* model provides corrections that are good enough for the selection equation, even when the independence hypothesis of irrelevant alternatives (IIA) is violated.

5 DATABASE DESCRIPTIONS AND ANALYSIS

The database used was the Family Budget Research (FBR) 2002-2003 and 2008-2009 supplied by IBGE (Brazilian Institute of Geography and Statistics) for all rural Brazil states. From this database, variables related to the category "family reference person", who corresponds to the household head, were obtained. The variable average rainfall was built based on information provided by INMET (National Meteorology Institute).

Initially, we use a multinomial logit model in which the dependent and explanatory variables are discriminated in Chart 1. This model estimates the marginal effects of response probabilities of working in the agricultural sector (*P(ocup = 0))*, of working in the non-agricultural sector (*P(ocup = 1))*, of working independently *P(ocup = 2))* and of working in other employments (*P(ocup = 3))*. The estimated results shall allow us to verify in which form explanatory variables affect personal occupational decisions in the labor market.

Additionally, these response probabilities shall be used to set factors or variables that correct the selection bias problem in the estimation of the income equation (5) as demonstrated in the previous section. In this second stage, the estimation of the income equation shall allow to verify the hypothesis of NPT existence.

Chart 1. Description of variables for the Multinomial Logit

Dependent Variable	Description	Situation
Ocup	Occupational decision	0 if working in the agricultural sector 1 if working in the non-agricultural sector 2 if working independently 3 if working in other employments
Explanatory variables per family profile		
Idche	Age of family	Numeric
Idcheq	Square age of family head	Numeric
adultm	Nº adult men in the family	Numeric
tamfam	Nº de family components	Numeric
adultf	Nº de adult women in the family	Numeric
Dsexo	Sex *Dummy* of family head	0 sif female, 1 if male
Pluv	Average rainfall	Numeric
Litoral	Localization *Dummy*	0 if state is not located on the coast 1 if state is located on the coast

Source: Data elaborated by the authors based on FBR data (2002-2003) and (2008-2009).

With these patterns, we estimated four income regressions using equation (5) in which dependent variables are the income of the *agricultural, non-agricultural, independent and other employment* sectors. The agricultural sector is composed of producers working in agricultural exploitation, farmers, mixed production entrepreneurs, tenants, marsh dwellers, rural workers, foremen, farmers, temporary rural employees and trainees.

The non-agricultural sector is composed of the extractive industry workers, civil construction and the textile, electronics and mechanics, iron and steel, food and drinks, tobacco, timber and real estate sectors; the military, the police, the fire brigade, public powers and corporate managers, technicians, salesmen, services providers, professors and public services employees.

The independent sector includes people who exploit their own undertakings, alone or with partners and without any employees, regardless of having or not a non-remunerated aid from a member of the family unit in their residence. It also includes the following industry sectors: trades, automotive, domestic services and repairs, oil retail traders, construction and other services. The "other employments" sector refers to the following categories: employers (a person who works exploiting his own business having at least one employee regardless of having or not the aid of a non-remunerated worker from the family unit where he resides) and workers producing for their own consumption.

Besides the factors that correct the selection bias, the other explanatory variables used in the equation estimation (5) are described in Chart 2.

The choice of micronutrients was made based on their relevance in the Brazilian diet according to ANVISA (National Sanitary Control Agency). Average food prices were selected based on their importance in the Brazilian family budget: cereals and beans are the main items consumed, edible oil and sugar are intermediary goods and milk is a relatively luxury item for the poor.

Charta 2. Description of variables for the second stage regression

Dependent Variable	**Description**
	Agricultural sector income
	Non-agricultural sector income
	Independent sector income
	Other employments income
Explanatory variables of family profiles	
idche	Age of family head;
idcheq	Square age of family head
adultm	Nº of male adults in the family
adultf	Nº de female adults in the family
tamfam	Nº de family members
anest	Average schooling years of family head
Dsexo	Sex *Dummy* of family head. 0 if female, 1 if male
Other Explanatory Variables	
calorie	Amount of calories *per capita* consumed by the family head
calorieq	Amount of square calories *per capita* consumed by family head
vitamB1	Amount of vitamin B1 *per capita* consumed by family head
vitamB1q	Amount of square vitamin B1*per capita* consumed by family head
vitamB2	Amount of vitamin B2 *per capita* consumed by family head
vitamB2q	Amount of square vitamin B2 *per capita* consumed by family head
vitamA	Amount of vitamin *per capita* consumed by family head
vitamAq	Amount of square vitamin A *per capita* consumed by family head
ferro	Amount of iron per capita consumed by family head
ferroq	Amount of square iron per capita consumed by family head
pcer	Average price of cereals (rice, oat, wheat, rye, and by products)
poleo	Average price of edible oil
pacuc	Average price of sugar
pfeij	Average price of beans
pleit	Average price of milk
pluv	Average rainfall
litoral	Localization *Dummy*: 0 if state is not located on the coast, 1 if it is.

Source: Data elaborated by the authors based on FBR (2002-2003) and (2008-2009).

The explanatory variables for family profiles are commonly used in literature, such as the case of the household head age, average years of schooling, household head gender, the number of male and female adults, etc. Another explanatory variable used was the average rainfall, which is directly related to rural activities, as it can provoke from higher productivity to partial or total losses in a given harvest, thus affecting the search for employment in the sector. The control variable "localization of state in coastal areas or not" reflects the effects of the level of growth or economic stagnation. According to the specialized literature, this variable also affects the search for employment (JHA, GAIHA AND SHARMA, 2009).

It is important to highlight that the Family Budget Research – FBR, allows to indirectly evaluate food consumption tendencies though estimates of expenses made with the purchase of foods for household consumption and their market prices. However, this research has some limitations, once it does not permit to access information on individual consumption patterns.

Therefore, in order to establish the participation of each micronutrient in the total of foods consumed for each family and the total calorie intake per capita, we use a Food Nutrition Table provided by the IBGE. Studies on food consumption standards in Brazil are still scarce. The FBRs of 2002-2003 and 2008-2009 are the only nationwide ones that include urban areas (Brazilian states and greater regions) and rural areas (Brazil and greater regions) available in the country.

6 RESULTS ANALYSIS

6.1 Results for Brazil using the FBR 2002-2003

6.1.1 Multinomial logit results:

Table 1 introduces marginal effects obtained from the multinomial logit model estimated according to the specifications described in Chart 1.

Table 1: Marginal effects for family head samples in rural Brazil (2002-2003).

	P(ocup=0)			P(ocup=1)			P(ocup=2)			P(ocup=3)		
variable	**dy/dx**	**Dp**	**P>|z|**	**dy/dx**	**Dp**	**P>|z|**	**dy/dx**	**Dp**	**P>|z|**	**dy/dx**	**Dp**	**P>|z|**
idche	-0.0156	0.002	0.0000	0.0099	0.003	0.0000	0.0073	0.003	0.0090	-0.0016	0.002	0.3080
idcheq	0.0001	0.000	0.0000	-0.0002	0.000	0.0000	0.0000	0.000	0.8650	0.0001	0.000	0.0000
adultm	-0.0141	0.009	0.1050	0.0123	0.007	0.0990	0.0018	0.009	0.8460	-0.0001	0.004	0.9860
adultf	-0.0356	0.010	0.0000	0.0450	0.008	0.0000	-0.0076	0.011	0.4910	-0.0018	0.005	0.7310
tamfam	-0.0022	0.003	0.4640	-0.0199	0.003	0.0000	0.0158	0.004	0.0000	0.0063	0.002	0.0010
Dsexo*	0.1901	0.011	0.0000	-0.1726	0.019	0.0000	0.1171	0.020	0.0000	-0.1346	0.017	0.0000
pluv	1.42E-06	0.000	0.0000	-1.12E-06	0.000	0.0000	-2.43E-07	0.000	0.4200	-6.45E-08	0.000	0.7600
litoral	-0.0632	0.010	0.0000	-0.0068	0.009	0.4410	0.0334	0.012	0.0050	0.0366	0.006	0.0000

(*) *dummy* variable and dy/dx represents a discrete change in the dummy variable from 0 to 1. Obs.: the significance level adopted was 5%.
Source: results obtained by the authors from NBR research 2002-2003.

Results suggest that the higher the age, the greater the probability of working in the non-agricultural and independent sectors. Provided we acknowledge that age represents years of experience, negative and significant square age values for the agricultural and non-agricultural sectors characterize a concave relation between experience and the increase in the probability of working in these sectors. In other words, more experience means higher chances of working in these sectors until a certain limit, from which opportunities tend to start diminishing. In the agricultural and non-agricultural sectors, the number of female adults in the family contributes to decrease the chances of being employed in 3.6% in the first sector and 4.5% in the second one. The number of male adults in the family does not affect employment chances in either sector.

The family size collaborates to decrease employment chances in the non-agricultural sector in 1.99%, however increasing in 1.6% and 0.63% in the independent and other employment sectors respectively. The male family head suffers a decrease of 17.3% and 13.5% in their employment opportunities in the non-agricultural and other employments sectors respectively when compared to females, however increasing in 19.01% and 11.71% their chances of being employed in the agricultural and independent sectors.

The average rainfall suggests a higher probability of working in agriculture and a lower chance for the non-agricultural sector. Finally, individuals who live in states located on the coast, have a higher chance of being employed in the independent and other employment sectors and a lower chance of working in the agricultural sector. Such variables have implications in the search for employment, as in general, coastal states have a better infrastructure and easier access to the labor market.

6.1.2 Nutrition-Based Poverty Trap Estimation Results (NPT).

The results estimated in the model (5) to verify the hypothesis of NPT existence for the four sectors are entered in Tables A1 and A5. A positive and statistically significant sign of the estimated coefficient for a particular nutrient *per capita* variable and a negative and significant sign of the coefficient for that same square variable suggest the existence of NPT for that specific nutrient. For the estimated coefficient significant effects, we consider significance levels of 5% and

10%. In rural Brazil, according to Table A1, we observe the phenomenon of nutrition-based poverty trap for the case of calories in the agricultural, independent and other employment categories. According to data provided in Tables A2 and A3, we perceive that the nutrition-based poverty trap phenomenon is present for vitamins B1 and B2 in the agricultural, independent and other employment sectors, as the coefficients for these variables were positive and statistically significant. In table A4 we verify that workers in the non-agricultural, independent and other employments sectors are subject to the poverty trap with regards to vitamin A. As for nutrient iron, we can see that Table 5 shows that the agricultural, independent and other employments sectors are also subject to the poverty trap.

With regards to the other determinants, the estimated coefficient for the variable of average years of schooling was positive and significant in all regressions. This is a standard result observed in most empirical studies that correlate income and education. The coefficients for the price of sugar and oil obtained a negative and significant result for the regressions of vitamin B2 and iron (agricultural sector in Tables A3 and A5). As for the calorie regressions (agricultural sector in Table A1) the oil coefficient presented the same result. Nutritional deficiencies vary with food prices, as lower prices improve nutrition. For the other regressions, the price variable expressed a result that contradicted expectations.

The family profile variables, such as the number of male adults, showed a positive and significant result for the regressions of calories, vitamin B1, B2 and A and iron for the agricultural, independent and other employment categories, as shown in Tables A, A2, A3, A4 and A5 respectively. Results entered in Tables A1, A5, A2 and A4 suggest that the female adult variable boasted positive and significant results for the regressions of calories, iron and vitamins B1 and A for the independent sector and for vitamin B2 in the agricultural sector (Table A3). This means that a higher number of adults in the family working in these sectors will result in higher income for household heads. The family head age exerted a negative effect on income for the agricultural sector and this square variable had a positive impact on vitamin B2 regressions (agricultural sector, Table A3). This seems to suggest that workers in their initial stage of their labor lives earn less than after they reach a certain age and achieve some work experience.

The estimated coefficient for the coastal area variable was positive and significant in the regressions for calories, vitamins B1, B2 and A for the other employments category, as demonstrated by results shown on Tables A1, A2, A3 and A4. However, results from tables A3 and A5 show that the variable localization presented a negative and significant coefficient for the Vitamin B2 and iron regressions in the agricultural sector. This proves that agricultural workers located in coastal states tend to earn lower wages than workers in the other employments sector, possibly due to the fact that coastal states are more dynamic in economic terms. The average rainfall variable did not show any statistical significance for the agricultural sector in any of the analyzed regressions. In most of the studied regressions, some of the estimated coefficients for the variables m0, m1, m2 and m3 were statistically significant, thus showing that the selections bias correction was really necessary.

6.2 Results for Brazil using the FBR 2008-2009

6.2.1 Multinomial Logit model Results

Table 2 below shows the marginal effects obtained through the *multinomial logit* model estimated according to the specifications described in Chart 1.

Table 2: marginal effects for family head samples in rural Brazil (2008-2009).

	P(ocup=0)			P(ocup=1)			P(ocup=2)			P(ocup=3)		
variable	**dy/dx**	**Dp**	**P>|z|**	**dy/dx**	**Dp**	**P>|z|**	**dy/dx**	**Dp**	**P>|z|**	**dy/dx**	**Dp**	**P>|z|**
Idche	-0.0105	0.004	0.0090	0.0029	0.004	0.4860	0.0058	0.004	0.1420	0.0018	0.002	0.24000
Idcheq	0.0001	0.000	0.1570	-7.90E-05	0.000	0.0670	0.0000	0.000	0.7820	8.32E-06	0.000	0.54900
Adultm	0.0675	0.015	0.0000	0.0171	0.016	0.2810	-0.0655	0.016	0.0000	-0.0192	0.007	0.00400
Adultf	-0.0492	0.019	0.0080	0.1255	0.019	0.0000	-0.0796	0.020	0.0000	0.0033	0.007	0.61100
tamfam	0.0036	0.007	0.6220	-0.0349	0.008	0.0000	0.0313	0.008	0.0000	0.0001	0.003	0.98600
Dsexo*	0.0699	0.028	0.0130	-0.1106	0.031	0.0000	0.0478	0.029	0.0950	-0.0072	0.012	0.53500
Pluv	1.83E-06	0.000	0.0010	-4.27E-07	0.000	0.4610	-6.22E-07	0.000	0.2620	-7.80E-07	0.000	0.00400
litoral	-0.0571	0.021	0.0070	0.0308	0.021	0.1480	0.0174	0.022	0.4250	0.0089	0.009	0.29600

(*) D*ummy* variable and dy/dx represents a discrete change in the *dummy* variable from 0 to 1. Obs.: the significance level adopted was 5%,.
Source: results obtained by the authors based on data from POF 2008-2009.

According to the results entered in this table, in the agricultural sector, as an individual gets older, employment chances diminish. In this sector, age reduces employment opportunities in 1.05%. This shows that the older the age, the lower the chance to work in the farming sector, perhaps because agricultural activities demand more physical effort. This same result is not verified in other sectors. Still, in this area, the number of male adults in the family contributes to the chance of being employed in 6.75%. On the other hand, the number of female adults in the family contributes to reducing employment opportunities in 4.92% and 7.96% for the independent sector. This shows that female labor is associated to activities that demand less physical effort. On the other hand, in the non-agricultural sector the possibility for women to be employed growths in 12.55%.

The family size variable negatively affects employment chances in the non-agricultural sector in 3.49%, however increasing 3.13% in the independent sector. If compared to the female household head, the male head suffers a reduction of 11.06% in his chances to be employed in the non-farming sector and an increase of 6.99% in the farming sector. The average rainfall suggests a higher chance of working in agriculture and a lower chance of working in the non-agricultural and other employments categories. The coastal variable demonstrates that individuals located in coastal states have a lower probability of being employed in the farming sector, once coastal states in Brazil have a more developed economic infrastructure.

6.2.2 Nutrition-based Poverty Trap (NPT) Estimation Results

According to the results obtained from Tables A6 to A10, only the non-agricultural sector is subject to the poverty trap with regards to calories. In this same sector, the poverty trap is also verified for the the iron micronutrient, according to results entered in Table A10. Analyzing results from Table A7, we corroborate that the poverty trap is present in the non-agricultural and independent sectors with regards to the vitamin B1 nutrient as well. In the farming sector, we noticed the poverty trap phenomenon for the vitamin B2 and iron nutrients, as shown in Table A8 and A10 respectively. Table A9 shows that workers in other employments are subject to the poverty trap related to a vitamin A deficiency. As for the other determinants, again, the average schooling years was positively correlated to income in all regressions and the average rainfall did not present any statistical significance in any of the studied sectors through all analyzed regressions. The price of oil showed a negative and significant result for the regressions of calories, iron, and vitamins B1 and A (independent sector, Table A8). The number of female adults in the family presented a positive and significant coefficient for the vitamin B2 regression in the agricultural sector, as expressed by the results in Table A8. Some estimated coefficients of variables 0, m1, m2 and m3 were statistically significant in several regressions, thus suggesting the need to correct the selection bias.

6.3 Summary of Results for the Nutrition-based Poverty Trap

Table 3: Nutritional Poverty Trap for family head samples in rural Brazil

	Micronutrients and calories	
Sectors	**2002-2003**	**2008-2009**
Agricultural	Calories, vitamins B1 and B2, iron	Iron and vitamin B2
Non-agricultural	Vitamin A	Calories, vitamin B1 and iron
Independent	Calories, vitamins B1, B2 and A, iron	Vitamin B1
Other Employments	Calories, vitamins B, B2 and A, iron	----

Source: results obtained by the authors based on date provided by POFs 2002-2003 and 2008-2009.

For rural Brazil, in the 2002-2003 period, the existence of NPT was verified for calories, iron and vitamins B1, B2 and A for workers in the independent and other employments categories. Employees of the agricultural sector obtained the same result, except for vitamin A. Workers in the non-agricultural sector are subject to the poverty trap only with regards to vitamin A. In the period from 2008 to 2009, NPT was proved for workers in the agricultural sector but only for iron and vitamin 2. Non-agricultural sector workers suffered the poverty trap for calories, vitamin B1 and iron. Self-employed workers suffered NPT related to vitamin B and workers in other employments did not suffer from NPT for calories or the other analyzed nutrients.

7 FINAL CONSIDERATIONS

The main goal of this study was to verify the existence of the nutrition-based poverty trap (NPT) analyzing the effects of micronutrient intake (calories, iron and vitamins A, B1 and B2) on income in rural Brazil, correcting the problem of endogeneity between these variables. Although micronutrient deficiencies still persist as a public health problem in Brazil, it is worth highlighting that there has been an NPT reduction in the studied period for most workers in the analyzed sectors, except for non-agricultural employees. The improvement in food consumption patterns in the Brazilian population is probably originated in the economic and social transformations that resulted in a reduction of poverty and malnutrition. Such facts suggest that the increase in family income among the poorest and the reduction of essential food prices would be effective ways to increase the intake of key nutrients in the diet of Brazilian families. These results agree with economics literature, which highlights that nutritional policies are essential for the reduction of extreme poverty and the acceleration of economic growth, as specialized economy and nutrition studies remark that healthy workers in better nutritional state are more productive at work.

Besides these public policies, it is worth mentioning the National Policy for Nutrition and Feeding, approved in 1999 by the Ministry of Health, which has as its main objective the promotion of food and nutrition safety for the Brazilian population. The Ministry of Health, Nutrition and Public Health Programs that seeks to reduce micronutrient deficiencies in the Brazilian population include vitamin A supplements, as well as ferrous sulphate for risk groups (babies, children and pregnant women); the fortification of foods such as wheat flower and corn with iron and folic acid and the addition of salt iodide for human consumption, as regulated by the National Agency of Sanitary Control (Anvisa) through the Fome Zero Project and the program to reduce iron deficiency anemia in Brazil, signed together with the food industry.

With regards to the explanatory variables that affect the occupational decision of agents in the labor market, we can infer that the older the age, the higher the probability of working outside the agricultural sector and in self-employment. This evidence confirms the traditional literature argument that older people have more difficulty getting jobs. Education measured through years of schooling strongly contributes to the increase in income in the four sectors analyzed: agricultural, non-agricultural, independent and other employments.

In this context, we remark the need for long-term national public policies that consider nutritional aspects and involve multiple initiatives such as raising more awareness among the target populations, the regularity of food intake research, employment and income policies focused on the low-end income sector, reduction of food prices and support to the food farming industry and nutritional education initiatives.

We can therefore highlight the relevance of this study in the sense of offering a contribution to the economics and nutrition literature by quantifying the micronutrient and calorie deficiency in the progress of the nutrition-based poverty trap, and as a consequence, the impact of such deprivation in labor productivity, which emphasizes the importance of nutritional policies aimed at breaking this trap and reducing poverty in the rural areas of Brazil.

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APPENDIX

REGRESSIONS RESULTS USING A POF 2002-2003

TableA1. 2nd stage regression for the selection bias correction for family head samples - quantity of per capita calories per income category in rural Brazil (2002-2003)

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
calorie	2.10E-04	0.0000	9.94E-05	0.5220	1.18E-04	0.0000	2.00E-04	0.0000
caloriesq	-1.23E-11	0.0710	0.00	0.9000	-3.62E-12	0.2580	-2.84E-11	0.0030
anest	66.59	0.0000	270.36	0.0000	70.39	0.0000	31.21	0.0000
pcer	146.49	0.0000	48.99	0.5480	95.62	0.0020	15.65	0.7340
pfeij	19.28	0.8110	156.89	0.3750	-2.83	0.9560	96.08	0.0670
poleo	-177.09	0.0750	-97.09	0.7410	-131.78	0.1240	172.27	0.1670
pacuc	-83.37	0.1420	254.75	0.0220	85.53	0.0090	123.02	0.0270
pleit	443.73	0.0000	211.56	0.2760	133.11	0.0430	65.06	0.3790
idche	-75.50	0.1670	5.29	0.9440	-0.09	0.9970	1.29	0.9230
idcheq	1.05	0.0290	0.94	0.5300	0.04	0.8070	-0.02	0.7550
adultm	225.56	0.0010	50.66	0.6280	92.43	0.0010	93.06	0.0000
adultf	-60.69	0.5510	112.94	0.6480	175.10	0.0000	26.20	0.3780
tamfam	22.87	0.6850	166.34	0.3990	8.00	0.7310	7.27	0.6070
rain	0.00	0.8460	0.01	0.2790	0.00	0.1340	-0.00	0.3700
coast	-251.34	0.2620	205.53	0.6650	18.05	0.8520	306.74	0.0010
_m0	-1284.24	0.2180	-3055.95	0.5330	-2459.09	0.1420	446.86	0.6960
_m1	-5223.85	0.0160	-1651.54	0.5310	-2394.49	0.1040	516.26	0.5010
_m2	-6063.85	0.0950	-1165.98	0.7640	-1333.35	0.0600	-1.56	0.9980
_m3	-3204.35	0.4290	2784.75	0.4130	-2983.08	0.044	-26.459	0.931
_cons	-2691.80	0.011	-3889.5	0.027	-1483.1	0.389	-872.23	0.25
	Nºobs.= 1875	$R^2 = 0.12$	Nºobs.= 1736	$R^2 = 0.27$	Nºobs.=3953	$R^2 = 0.09$	N ºobs.=914	$R^2 = 0.21$

Source: Results obtained by the authors based on data from POF 2002-2003.

Table A2. 2nd stage regression for the selection bias correction for family head samples - quantity of vitamin B1 per capita per income category in rural Brazil (2002-2003)

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
vitamB1	0.06	0.0400	0.02	0.7300	0.06	0.0020	0.18	0.0000
vitamB1q	-1.49E-06	0.0410	5.71E-08	0.9870	-1.20E-06	0.0620	-1.00E-05	0.0000
anest	54.30	0.0000	270.27	0.0000	69.88	0.0000	31.36	0.0000
pcer	163.64	0.0000	41.54	0.6110	85.40	0.0060	22.49	0.6200
pfeij	53.42	0.5300	150.75	0.3930	0.55	0.9910	95.48	0.0650
poleo	-130.55	0.1570	-107.88	0.7130	-130.92	0.1270	143.45	0.2400
pacuc	-66.81	0.2760	258.40	0.0200	89.86	0.0060	88.15	0.1130
pleit	429.97	0.0010	210.08	0.2790	135.23	0.0400	25.30	0.7280
idche	-86.94	0.1210	5.20	0.9440	0.78	0.9740	-0.94	0.9430
idcheq	1.12	0.0230	0.96	0.5190	0.04	0.8160	-0.01	0.8920
adultm	226.82	0.0010	53.48	0.6080	92.12	0.0010	92.76	0.0000
adultf	-74.93	0.4710	100.84	0.6830	170.81	0.0000	22.83	0.4390
tamfam	0.31	0.9960	163.50	0.4070	1.53	0.9480	1.67	0.9050
pluv	-0.00	0.7690	0.01	0.2690	0.00	0.0920	-0.00	0.4280
litoral	-202.21	0.3860	191.46	0.6860	0.75	0.9940	255.99	0.0040
_m0	-1072.48	0.3100	-3058.10	0.5330	-2529.13	0.1320	631.28	0.5810
_m1	-4690.03	0.0360	-1674.83	0.5240	-2411.54	0.1020	649.10	0.3970
_m2	-6444.13	0.0870	-1169.23	0.7630	-1354.93	0.0570	-10.61	0.9860
_m3	-2858.12	0.4940	2874.91	0.3970	-3030.3	0.041	11.56	0.97
_cons	-2576.51	0.016	-3756.78	0.032	-1437.22	0.405	-489.18	0.515
	Nºobs.= 1797	$R^2 = 0.10$	Nºobs.= 1736	$R^2 = 0.27$	Nºobs.=3953	$R^2 = 0.09$	N ºobs.=914	$R^2 = 0.21$

Source results obtained by the authors based on data from POF 2002-2003.

Table A3. 2nd stage regression for the selection bias correction for family head samples - quantity of B2 vitamin per capita per income category in rural Brazil (2002-2003)

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
vitamB2	0.09	0.0010	0.06	0.4510	0.10	0.0000	0.21	0.0000
vitamB2q	-3.12e-06	0.0030	0.00	0.7340	-3.21E-06	0.0020	-1.49E-05	0.0000
anest	64.90	0.0000	269.63	0.0000	68.70	0.0000	30.31	0.0000
pcer	155.21	0.0000	40.34	0.6210	86.87	0.0050	21.75	0.6340
pfeij	26.86	0.7290	150.81	0.3930	11.59	0.8200	92.97	0.0740
poleo	-213.90	0.0300	-105.58	0.7190	-129.87	0.1290	150.49	0.2230
pacuc	-114.79	0.0340	257.79	0.0210	77.07	0.0190	89.02	0.1120
pleit	425.58	0.0000	212.69	0.2730	135.03	0.0400	41.84	0.5670
idche	-109.68	0.0250	4.83	0.9480	0.18	0.9940	0.93	0.9440
idcheq	1.30	0.0050	0.96	0.5220	0.04	0.8130	-0.02	0.7680
adultm	210.71	0.0010	53.62	0.6070	92.80	0.0010	95.27	0.0000
adultf	-74.42	0.4530	102.10	0.6790	170.80	0.0000	13.11	0.6580
tamfam	-11.63	0.8160	163.78	0.4050	4.22	0.8560	4.99	0.7210
pluv	0.00	0.9980	0.01	0.2660	0.00	0.0880	-0.00	0.5610
litoral	-391.75	0.0340	190.09	0.6880	6.12	0.9500	262.89	0.0040
_m0	-996.43	0.3250	-3028.17	0.5360	-2607.64	0.1200	510.04	0.6550
_m1	-5209.94	0.0110	-1665.75	0.5260	-2458.08	0.0960	557.44	0.4660
_m2	-7895.39	0.0090	-1209.39	0.7550	-1395.10	0.0500	38.57	0.9480
_m3	-3391.20	0.3500	2851.02	0.4010	-3148.04	0.034	-26.621	0.931
_cons	-2435.29	0.012	-3778.22	0.031	-1484.81	0.388	-585.07	0.437
	Nºobs.= 1916	$R^2 = 0.12$	Nºobs.= 1736	$R^2 = 0.27$	Nºobs.=3953	$R^2 = 0.09$	N obs.=914	$R^2 = 0.20$

Source: results obtained by the authors based on data from POF 2002-2003.

Table A4. 2nd stage regression for the selection bias correction for family head samples - quantity of vitamin A per capita per income category in rural Brazil (2002-2003)

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
vitamA	4.68E-05	0.5290	7.93E-04	0.0440	4.25E-04	0.0000	0.0004	0.0000
vitamAq	-1.32E-12	0.5290	-2.33E-10	0.0660	-3.64E-11	0.0000	-7.96E-11	0.0010
anest	59.86	0.0000	267.35	0.0000	68.62	0.0000	31.5568	0.0000
pcer	125.66	0.0010	50.22	0.5370	92.49	0.0030	10.3883	0.8220
pfeij	18.58	0.8310	151.39	0.3900	-8.03	0.8740	93.5672	0.0760
poleo	-164.75	0.0790	-98.72	0.7360	-128.76	0.1320	173.4329	0.1650
pacuc	-32.23	0.5960	252.44	0.0230	94.07	0.0040	127.0358	0.0230
pleit	439.78	0.0010	218.17	0.2600	155.30	0.0180	71.5468	0.3310
idche	-65.13	0.2430	8.96	0.9040	3.17	0.8960	5.1568	0.7000
idcheq	0.94	0.0520	0.83	0.5770	0.03	0.8830	-0.0539	0.5260
adultm	245.63	0.0000	50.17	0.6290	98.97	0.0000	97.7041	0.0000
adultf	-69.88	0.4880	110.49	0.6530	171.76	0.0000	19.6510	0.5110
tamfam	3.23	0.9550	152.32	0.4370	3.51	0.8810	-0.2206	0.9870
pluv	0.00	0.8940	0.01	0.2880	0.00	0.0600	-0.0016	0.4570
litoral	-238.72	0.2980	168.34	0.7210	12.73	0.8960	308.3382	0.0010
_m0	-1297.57	0.2130	-2607.94	0.5920	-2817.13	0.0960	397.1644	0.7310
_m1	-4955.01	0.0260	-1412.65	0.5900	-2566.24	0.0840	565.2173	0.4640
_m2	-5836.78	0.1190	-1184.37	0.7580	-1372.77	0.0560	163.7285	0.7820
_m3	-3428.90	0.4000	2822.62	0.4020	-3240.95	0.03	-34.93929	0.91
_cons	-2609.35	0.014	-3838.37	0.027	-1746.82	0.314	-787.88	0.301
	Nºobs.= 1807	$R^2 = 0.09$	Nºobs.= 1736	$R^2 = 0.26$	Nº obs.=3953	$R^2 = 0.09$	Nºobs.=914	$R^2 = 0.19$

Source: results obtained by the authors based on data from POF 2002-2003.

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Table A5. 2nd stage regression for the selection bias correction for family head samples - quantity of iron per capita per income category in rural Brazil (2002-2003)

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
ferro	0.019	0.0000	0.01	0.3910	0.01	0.0000	0.03	0.0000
ferroq	-7.69E-08	0.0000	-1.13E-07	0.5370	-7.60E-08	0.0280	-2.41E-07	0.0020
anest	58.61	0.0000	269.90	0.0000	69.31	0.0000	31.99	0.0000
pcer	145.40	0.0000	43.81	0.5910	88.60	0.0040	24.12	0.5950
pfeij	20.79	0.7830	154.94	0.3810	11.40	0.8240	100.20	0.0530
poleo	-239.82	0.0230	-109.03	0.7100	-135.90	0.1130	170.40	0.1660
pacuc	-108.97	0.0310	253.93	0.0220	81.61	0.0130	87.79	0.1120
pleit	472.86	0.0000	204.31	0.2930	127.59	0.0530	12.06	0.8690
idche	-83.05	0.0910	3.98	0.9580	0.90	0.9700	-2.31	0.8600
idcheq	1.03	0.0190	0.98	0.5130	0.04	0.8420	-0.01	0.9440
adultm	227.31	0.0000	50.87	0.6260	91.01	0.0010	89.67	0.0000
adultf	-36.28	0.7070	102.06	0.6790	171.75	0.0000	29.75	0.3110
tamfam	-9.30	0.8560	166.14	0.3990	4.02	0.8630	4.75	0.7320
pluv	0.00	0.8030	0.01	0.2630	0.00	0.1170	-0.00	0.3730
litoral	-410.08	0.0430	192.91	0.6840	3.47	0.9710	266.61	0.0030
_m0	-1178.94	0.2350	-3091.39	0.5280	-2537.67	0.1300	302.00	0.7880
_m1	-4702.08	0.0280	-1696.91	0.5190	-2393.89	0.1040	473.05	0.5300
_m2	-6661.64	0.0450	-1186.60	0.7600	-1345.94	0.0580	-184.38	0.7500
_m3	-3826.95	0.3050	2871.01	0.3980	-3057.71	0.039	-110.56	0.714
_cons	-2179.68	0.035	-3760.23	0.032	-1455.11	0.398	-603.59	0.419
	Nºobs.= 2014	$R^2 = 0.12$	Nºobs.= 1736	$R^2 = 0.27$	Nº obs.=3953	$R^2 = 0.09$	Nºobs.=914	$R^2 = 0.22$

Source: results obtained by the authors based on data from POF 2002-2003.

REGRESSIONS RESULTS USING POF 2008-2009

Table A6. 2nd stage regression for the selection bias correction for family head samples - quantity of per capita calories per income category in rural Brazil (2008-2009).

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
caloria1	0.00	0.4540	0.01	0.0280	0.00	0.8820	0.00	0.0280
caloria1q	-3.77e-10	0.7030	-6.69e-09	0.1100	6.72E-10	0.7390	2.79E-09	0.1100
anest	20.26	0.0000	52.81	0.0000	20.62	0.0140	290.52	0.0000
pcer	505.35	0.0250	1926.02	0.0040	-63.21	0.8770	-1124.76	0.0040
pfeij	179.17	0.0010	298.65	0.0350	9.69	0.9190	219.11	0.0350
poleo	-142.41	0.3900	197.89	0.7030	-934.47	0.0030	-1713.01	0.7030
pacuc	954.81	0.0020	2755.49	0.0010	431.16	0.4480	4017.02	0.0010
pleit	-1596.02	0.0000	-2617.17	0.0020	-1079.36	0.0260	-3108.91	0.0020
idche	70.74	0.4100	204.04	0.1400	70.56	0.5260	282.56	0.1400
idcheq	-0.30	0.3610	-0.59	0.5060	0.11	0.8210	-1.82	0.5060
adultm	-288.61	0.7260	-1008.91	0.4280	-687.72	0.5000	-817.79	0.4280
adultf	719.20	0.0720	-355.42	0.5910	61.11	0.9030	-1867.70	0.5910
tamfam	-62.98	0.7650	310.20	0.3570	125.88	0.6300	541.28	0.3570
pluv	0.00	0.6740	0.01	0.6330	0.01	0.6920	0.01	0.6330
litoral	290.48	0.4570	601.77	0.3530	162.04	0.7440	-1050.89	0.3530
_m0	-2149.01	0.3800	-15224.02	0.1530	-11603.81	0.2380	-11808.30	0.1530
_m1	2372.08	0.5150	-2844.43	0.3720	-6889.20	0.2180	-10965.77	0.3720
_m2	1742.76	0.8310	5411.17	0.6520	-473.29	0.8870	4682.85	0.6520
_m3	786.96	0.9050	2392.66	0.8090	-1038.84	0.819	-3998.05	0.8090
_cons	1133.7	0.64	-15001.21	0.004	-4761.53	0.679	1265.04	0.004
	Nºobs.= 557	$R^2 = 0.22$	Nºobs.= 828	$R^2 = 0.06$	Nºobs.=857	$R^2 = 0.07$	Nºobs.=85	$R^2 = 0.37$

Fonte: Resultados obtidos pelos autores a partir dos dados da POF 2008-2009.

Table A7. 2nd stage regression for the selection bias correction for family head samples – quantity of B1 vitamin per capita per income category in rural Brazil (2008-2009).

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
vitamB1	0.96	0.2160	8.93	0.0050	4.12	0.0180	6.56	0.3650
vitamB1q	-0.00	0.4990	-0.01	0.0940	-6.06E-03	0.0520	-1.00E-03	0.9320
anest	19.10	0.0000	50.38	0.0000	20.09	0.0160	334.70	0.0080
pcer	508.03	0.0260	1947.12	0.0040	-153.03	0.7070	-604.09	0.8150
pfeij	186.15	0.0010	313.19	0.0260	5.84	0.9510	447.12	0.3530
poleo	-125.64	0.4690	39.36	0.9400	-931.58	0.0030	-1100.10	0.3560
pacuc	956.84	0.0020	2672.67	0.0020	258.87	0.6490	1179.54	0.7180
pleit	-1606.19	0.0000	-2540.61	0.0020	-929.41	0.0550	-1684.00	0.5960
idche	61.57	0.4800	209.51	0.1340	79.68	0.4750	350.30	0.3140
idcheq	-0.25	0.4490	-0.50	0.5720	0.10	0.8370	-1.52	0.3660
adultm	-238.19	0.7750	-1174.09	0.3610	-794.06	0.4340	-1185.31	0.7210
adultf	708.24	0.0800	-457.40	0.4930	-14.09	0.9770	-2811.70	0.0780
tamfam	-62.87	0.7670	378.60	0.2660	162.11	0.5320	744.92	0.3390
pluv	0.01	0.6470	0.01	0.5920	0.01	0.6310	-0.01	0.8680
litoral	281.38	0.4750	601.57	0.3570	195.11	0.6930	-410.28	0.8190
_m0	-2130.15	0.3830	-16335.58	0.1290	-12052.94	0.2180	-3874.04	0.9140
_m1	2249.98	0.5390	-3080.27	0.3360	-6947.60	0.2100	-12024.30	0.5520
_m2	1435.27	0.8620	6196.90	0.6100	-83.61	0.9800	10667.96	0.5610
_m3	-536.80	0.9410	2965.88	0.7660	-708.15	0.875	81.48	0.993
_cons	976.35	0.693	-14896.75	0.005	-5723.16	0.618	-8728.18	0.811
	Nºobs.= 555	$R^2 = 0.22$	Nºobs.= 828	$R^2 = 0.07$	Nºobs.=857	$R^2 = 0.07$	Nºobs.=88	$R^2 = 0.36$

Source: results obtained by the authors based on data from POF 2008-2009.

Table A8. 2nd stage regression for the selection bias correction for family head samples - quantity of B2 vitamin per capita per income category in rural Brazil (2008-2009).

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
vitamB2	1.98	0.0030	0.06	0.4510	1.86	0.1120	-5.34	0.2820
vitamB2q	-0.00	0.0110	0.00	0.7340	-1.30E-03	0.3880	1.54E-02	0.0080
anest	26.88	0.0000	269.63	0.0000	19.90	0.0180	314.98	0.0060
pcer	339.70	0.1550	40.34	0.6210	-123.08	0.7630	-3477.80	0.1110
pfeij	232.08	0.0000	150.81	0.3930	-3.89	0.9670	345.07	0.4310
poleo	-361.28	0.0400	-105.58	0.7190	-959.74	0.0020	-1045.96	0.3600
pacuc	530.68	0.0980	257.79	0.0210	322.69	0.5710	-2173.14	0.4010
pleit	-1553.22	0.0000	212.69	0.2730	-920.61	0.0600	1523.44	0.5570
idche	45.03	0.6140	4.83	0.9480	71.45	0.5220	390.64	0.2250
idcheq	-0.07	0.8270	0.96	0.5220	0.12	0.8030	-0.87	0.5180
adultm	-314.55	0.7120	53.62	0.6070	-726.69	0.4760	-2237.12	0.4610
adultf	875.58	0.0350	102.10	0.6790	22.91	0.9630	-1385.86	0.3310
tamfam	-55.04	0.8030	163.78	0.4050	145.87	0.5750	508.51	0.4650
pluv	0.02	0.2030	0.01	0.2660	0.01	0.6620	0.01	0.8450
litoral	299.89	0.4540	190.09	0.6880	158.26	0.7490	524.13	0.7600
_m0	-4545.35	0.0660	-3028.17	0.5360	-11873.13	0.2270	-30226.91	0.3590
_m1	848.36	0.8110	-1665.75	0.5260	-7051.63	0.2070	-15431.14	0.3760
_m2	1137.04	0.8950	-1209.39	0.7550	-412.50	0.9010	11676.97	0.4700
_m3	-14892.76	0.0230	2851.02	0.4010	-1015.50	0.823	135.61	0.986
_cons	2503.44	0.32	-3778.22	0.031	-5050.51	0.661	-14631.18	0.641
	Nºobs.= 558	$R^2 = 0.43$	Nºobs.= 1736	$R^2 = 0.28$	Nºobs.=857	$R^2 = 0.07$	Nº obs.=88	$R^2 = 0.46$

Source: results obtained by the authors based on data from POF 2008-2009.

Table A9. 2nd stage regression for the selection bias correction for family head samples – quantity of vitamin A per capita per income category in rural Brazil (2008-2009).

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
vitamA	0.00	0.7270	0.00	0.6090	0.00	0.6840	0.03	0.0100
vitamAq	0.00	0.4880	0.00	0.6860	-3.45E-11	0.9550	-7.05E-08	0.0180
Anest	20.29	0.0000	52.82	0.0000	20.88	0.0140	310.34	0.0600
pcer	523.66	0.0210	1838.84	0.0060	-56.01	0.8930	-532.03	0.8330
pfeij	222.54	0.0000	287.79	0.0430	12.48	0.8970	556.83	0.2830
poleo	-173.24	0.3230	216.87	0.6760	-949.64	0.0030	-1911.65	0.1670
pacuc	990.10	0.0010	2704.86	0.0020	439.79	0.4450	402.61	0.8950
pleit	-1643.01	0.0000	-2544.94	0.0020	-1082.63	0.0280	-1238.38	0.6860
idche	45.24	0.5830	190.01	0.1620	59.72	0.5770	481.52	0.2350
idcheq	-0.26	0.3960	-0.64	0.4650	0.01	0.9850	-2.10	0.3590
adultm	-60.26	0.9380	-747.86	0.5490	-462.93	0.6350	-2161.39	0.5750
adultf	479.40	0.1980	-116.10	0.8570	184.59	0.6990	-1409.13	0.3760
tamfam	-12.57	0.9490	155.70	0.6350	45.46	0.8540	592.73	0.5080
pluv	0.01	0.4660	0.00	0.8130	0.00	0.8130	0.03	0.7720
litoral	122.10	0.7460	530.07	0.4070	78.38	0.8700	609.81	0.7500
_m0	-3240.22	0.1450	-13337.04	0.2030	-9571.95	0.3110	-21954.08	0.5940
_m1	-2567.34	0.4380	-2201.55	0.4830	-5578.33	0.3010	3023.19	0.9050
_m2	-1428.77	0.8550	3853.36	0.7430	-901.52	0.7770	25791.96	0.2300
_m3	-8208.03	0.2200	2505.33	0.7980	-1285.92	0.771	2316.90	0.832
_cons	-1124.40	0.634	-13365.4	0.01	-2329.55	0.833	-10043.68	0.819
	Nºobs.= 569	$R^2 = 0.21$	Nº obs.= 828	$R^2 = 0.054$	Nº obs.=857	$R^2 = 0.07$	Nº obs.=85	$R^2 = 0.29$

Source results obtained by the authors based on data from POF 2008-2009.

Table 10. 2nd stage regression for the selection bias correction for family head samples - quantity of iron per capita per income category in rural Brazil (2008-2009).

Variable	Agricultural Income		Non-Agricultural income		Self-employment Income		Other Employments Income	
	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p	Coef.	Value-p
ferro	0.22	0.0190	0.81	0.0200	0.09	0.5880	1.95	0.1080
ferroq	-2.94E-05	0.0650	-1.42E-04	0.0560	-1.01E-05	0.7420	-2.76E-04	0.1780
anest	18.98	0.0000	53.73	0.0000	20.85	0.0130	350.67	0.0050
pcer	436.27	0.0620	1848.01	0.0060	-75.22	0.8550	-888.50	0.7410
pfeij	201.20	0.0000	275.30	0.0530	2.52	0.9790	243.30	0.6550
poleo	-235.41	0.1790	154.15	0.7670	-929.01	0.0030	-1757.26	0.2290
pacuc	884.51	0.0060	2605.69	0.0030	372.81	0.5220	1685.27	0.6260
pleit	-1643.93	0.0000	-2432.59	0.0040	-1017.58	0.0400	-2471.59	0.4590
idche	97.44	0.2600	205.85	0.1380	64.98	0.5510	13.24	0.9740
idcheq	-0.11	0.7350	-0.59	0.5080	0.07	0.8880	-0.48	0.7820
adultm	-726.21	0.3800	-1015.69	0.4270	-586.21	0.5570	666.21	0.8590
adultf	167.14	0.6620	-307.46	0.6430	118.99	0.8080	-2730.07	0.1210
tamfam	190.79	0.3570	288.65	0.3940	87.89	0.7310	689.75	0.4090
pluv	0.02	0.1590	631.83	0.3320	0.00	0.7460	0.02	0.7840
litoral	392.10	0.3230	0.01	0.6500	129.14	0.7910	-1544.24	0.4820
_m0	-5279.46	0.0240	-14975.58	0.1610	-10553.72	0.2740	4330.98	0.9050
_m1	-5542.58	0.0950	-2600.19	0.4170	-6149.46	0.2630	-14162.02	0.5060
_m2	2586.92	0.7560	5791.23	0.6300	-647.46	0.8420	-912.62	0.9560
_m3	-4535.12	0.4910	2872.69	0.7730	-1001.06	0.823	-6818.673	0.519
_cons	-569.77	0.818	-14400.69	0.006	-3566.12	0.752	15465.12	0.726
	Nºobs.= 563	$R^2 = 0.24$	Nºobs.= 828	$R^2 = 0.06$	Nº obs.=857	$R^2 = 0.07$	Nº obs.=83	$R^2 = 0.47$

Source: results obtained by the authors based on date from POF 2008-2009.