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Synergy between the work of nutritionists and purchases from family farming: impacts of the PNAE on school performance and children's nutritional status

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ABSTRACT

This article evaluates the impacts of the synergy between the work of nutritionists and purchases from family farming, in the PNAE, on SAEB 2019 scores and child nutritional status. Considering continuous treatment, the *Local Average Treatment Effect* approach was used, in addition to the Dose-Response Function (DRF). The impact of family farm purchases was greater in schools with nutritionists, compared to those without, and had an impact of 2.23 points in math and 1.34 in Portuguese. For severe obesity and obesity alone, the synergy had an impact on reducing obesity by 0.29 and 0.53 percentage points, respectively. Thus, the cost of increasing math and Portuguese proficiency by 1 point is R$45.00 and R$74.00, respectively. While to reduce obesity and severe obesity by 1 percentage point is R$344.00 and R$188.00. Finally, the FDR shows that the optimum level of purchases from family farming is 50%, showing that the minimum percentage, 30%, required by law is not ideal.

Palavras-chave: SAEB; nutritional status; PNAE.
JEL: I20, I29, C26

SUMMARY

1. INTRODUCTION

The accumulation of human capital through learning is one of the pillars of economic development. Despite this, the reality of the quality of education in Brazil is alarming. The average performance of Brazilian students in the Program for International Student Assessment 2022 (PISA) was practically stagnant compared to 2018. Since 2009, progress in math, reading and science has been minimal and not significant. In addition, the students at the top of the math proficiency distribution did worse in the last assessment (Brazil, 2023).

One of the main indicators related to variation in the quality of education is the socio--economic status of students, which involves their (in)food security. This relationship occurs because children's cognitive development is directly influenced by the nutritional quality they receive, and food insecurity and malnutrition have been identified as factors that contribute to learning difficulties and school absenteeism (Alaimo; Olson; Frongillo, 2001; Winicki; Jemison, 2003; JMT *et al*., 2011; Bernal *et al*., 2014; Naik; Itagi; Patil, 2015).

Since school is one of the environments most frequented by children and, consequently, is part of the process of accessing and promoting eating habits, interventions in this area should be encouraged (Papoutsi; Drichoutis; Naygra Jr., 2013; Azeredo *et al*., 2016). This makes schoolchildren an excellent target population for nutritional interventions. School feeding programs are a significant part of this. As one of the channels of influence on children's nutrition, school meals are an essential way to improve school results (Sorhaindo; Feinstein, 2006).

International experiences show how school feeding policies play a fundamental role in the student learning process, highlighting the *Feed Me Better* programs in the United Kingdom, the *School Breakfast Program* in the United States and the *Mid Day Meal Scheme* in India, with positive and significant effects on grades and school attendance, in addition to promoting healthier eating habits (Belot; James, 2011; Imberman; Kugler, 2014; Frisvold, 2015; Anderson *et al*., 2018; Cohen *et al*., 2021; Kaur, 2021).

In Brazil, school meals are a benefit of the National School Feeding Program (PNAE). Effectively created in 1955, the PNAE is one of the oldest Brazilian social programs in the area of food and nutrition. It is considered internationally to be one of the largest and most widely covered programmes when it comes to universalizing care for healthy and safe food for students. Managed by the National Fund for the Development of Education (FNDE), the Federal Government passes on, in a complementary manner, to the states or municipalities (school districts) responsible and to federal schools the monthly financial amounts for school meals to

cover the school days, according to the number of students enrolled (FNDE, 2024). Although it was created more than half a century ago, some changes have taken place over time, most notably in 2009, when it was ratified that nutritionists would be technically responsible for the PNAE, in addition to the purchase of food from family farming (AF), with a mandatory minimum percentage of 30% of the PNAE budget (Brasil, 2009).

These measures have been implemented as a way of offering healthier food. Family farming products are healthy because they offer fresher or minimally processed food. The partnership between family farming and the PNAE aims to considerably reduce the purchase of processed and ultra-processed foods for school meals and improve the nutritional content of school meals, with fresh fruit, vegetables and products offered to meet the nutritional needs of schoolchildren. In addition, the consumption of regionally produced food is encouraged, which favors local food habits and culture, as well as sustainability and diversification (Teo, 2017; Noll *et al*., 2019; Oliveira *et al*., 2021).

According to Law 11.947/2009, the purchase process can take place with the municipality waiving the bidding procedure through a public call, as long as the prices are compatible with those practiced in the local market and sales projects. Sales projects can be submitted by individual sellers, formal or informal groups. The law requires that family farms in the municipalities themselves be prioritized in the public call. In order for individual farmers and groups to take part in the process, they need to have a Declaration of Aptitude to Pronaf (DAP). The DAP is a document that identifies family farmers and grants them access to public programs and policies. Each DAP has a sales limit of up to R$20,000.00 (twenty thousand) per purchasing agency per year (Brasil, 2020).

In the case of nutritionists, they are responsible for formulating menus and supervising various stages in the production of school meals. In addition, they are obliged to take part in bidding processes and direct purchases from family farming, as well as promoting coordination with family farmers (Brasil, 2009; CFN, 2010).

In a survey carried out by Machado *et al.* (2018) , there was evidence of a high frequency of purchases of family farm products in municipalities with a high number of nutritionists responsible for school meals, indicating the importance of these professionals in incorporating foodstuffs from these producers. However, in a descriptive study on the joint relationship between the programs, Gallicchio *et al*. (2021) show some difficulties in the food procurement process, not favoring dietary diversity in the preparation of menus, which can lead to a low percentage. In general, the authors identified the insufficient number of nutritionists as an obs-

tacle to the functioning of the programs, and not all of them have access to local agricultural mapping, as well as low participation in the purchasing process. Porrua *et al*. (2020) also highlight problems in reconciling the formulation of menus with what is produced in the region, attributing this to the low level of coordination between nutrition professionals and farmers and organizations that support FA. All these points explain the lack of adherence to the partnership with FA, even with nutritionists available.

In view of the PNAE's objective of improving school performance through adequate nutrition for students, some national studies have sought to understand the relationship between school meals and the grades obtained by students in proficiency exams. Gomes *et al's* (2021) study evaluated the effect of meeting the minimum percentage of food purchases via school feeding on the Basic Education Development Index and pass, fail, dropout and age-grade distortion rates in the Northeast region. To do this, the authors used a binary treatment, showing that municipalities that complied with the 30% requirement had better results than those that did not. Exploring a discontinuity around the value specified in the law, Ramos *et al*. (2021) also verified the importance of meeting the established minimum and the scores obtained in standardized proficiency exams. Silva, Ciríaco and Zen (2024) , in a score decomposition analysis, showed how the PNAE, through participation in PA, has a positive influence on school results. However, a large part of the differences in grades is due to structural factors, which may be associated with a lower incidence of nutritional problems, as well as the adoption of more nutritious foods, something that is not observed by the researchers. With regard to the participation of nutritionists as those technically responsible for the food offered by the school, De Deus and Da Costa Silva (2023) can be cited, in which the importance of the participation of this professional for grades was verified in different contexts.

However, these studies do not evaluate the possible synergy between the participation of nutritionists and the acquisition of food from the PNAE on the learning of Brazilian children. By not exploring the joint importance of the programs, the evidence may be incurring an omission bias, in addition to not identifying how these programs may be acting together, in addition to separately. Thus, this article seeks to assess how the percentage of purchases of PA in the municipality, interacted with the existence of a nutrition professional in schools, contributes to the grades obtained by schoolchildren through proficiency tests. With this more refined analysis, it is possible to signal the extent to which municipalities that do not implement one of the programs may be less effective in delivering favorable results.

One of the treatments evaluated, the percentage of food purchases from FA, given that its

range of variation is in percentage terms, favors an analysis of dosage effects and an analysis of the marginal treatment effect, rather than specifying just one indicator of compliance with the Law or whether the policy is implemented. This is because municipalities that transfer less than 30% of their resources to the purchase of PS products are also beneficiaries of the policy, but the effects may be different along the distribution of percentages. In addition, in order to control for possible endogeneity, instrumental variables related to farmers' participation in the PNAE and other programs can be used, applying the *Local Average Treatment Effect* (LATE) approach. A similar strategy was applied in De Deus and Da Costa Silva (2023) in the case of schools with nutritionists, where a positive effect was found for the participation of these professionals, but without considering the effect of purchases of PA. In schools with such professionals, the percentage may be different. Regarding this synergistic relationship with the existence of a nutritionist in schools, this factor is measured in a binary way, and its possible endogeneity is controlled by means of instruments that represent the labor market of nutritionists.

Another contribution of this research is to analyze the effects of such programs on children's nutritional status, given that this is an important channel for transmitting effects. The aim is to verify the influence not only on performance, but also on children's health. In the observed literature, there is no record of evidence of how such programs also influence results in the formation of eating and health habits.

It is possible that the effects on school performance and nutritional status differ according to the context in which the school is located, so the study also analyzes rural areas, the semi-arid region, students in more vulnerable socio-economic situations, municipalities that meet the minimum requirement of 30% of products from FA, with Bolsa Família Program (PBF) coverage greater than 25% and fewer than 4 nutritionists. It also examines the interaction between the PNAE and other policies, such as the PBF, the Family Health Program (PSF) and Health at School (PSE).

Based on the estimates of the impact of the synergy between PA nutritionists, it was possible to analyze the cost-effectiveness of these two axes of the PNAE together. Each real invested per pupil is 0.45 and 0.74 effective in math and Portuguese, respectively. For severe obesity and obesity alone, it is 3.44 and 1.88 percentage points, respectively. This cost-effectiveness is low, given that the amount invested per elementary school pupil per school day is R$0.50. Considering that the transfer is made for 200 school days a year, the total amount is R$100.00/pupil. Thus, the cost of increasing math and Portuguese proficiency by 1 point is R$45.00 and R$74.00, respectively. While to reduce obesity and severe obesity by 1 percentage point is

R$344.00 and R$188.00.

The study makes useful suggestions for the design of the policy. Firstly, in terms of the minimum requirement of 30% of the purchase of PA and hiring a nutritionist to draw up the school's food menus. The results indicate that the optimum percentage of food purchases from family farming to increase student performance is between 50 and 60%. This evidence has important implications for changing the program's guidelines. To do so, it is clear that, in order to implement it, it is necessary to strengthen the links between the programs aimed at this public, so that family farmers, especially the less capitalized ones, have access to the PNAE market and there is an increase in supply.

Secondly, the evidence also helps to elucidate the changes that Bill 3.292 of 2020 may make to Law 11.947/09. It would not be efficient to return the mechanisms for promoting healthy eating with the approval of the bill, which advocates that at least 40% of milk consumption be in liquid form. Imposing this rigidity on the school menu disregards the autonomy of nutrition professionals as technically responsible and could hinder their work, the implementation of the program and regional food diversity. The bill also establishes the withdrawal of priority for the purchase of food from indigenous communities and agrarian settlements, which compromises the distributive economic character of the program, the inclusion of the most economically vulnerable producers, such as farmers in group B of Pronaf, predominantly in the Northeast region, and local economic development.

Finally, as the food offered by the PA can be considered healthy, this article also confirms the feasibility of increasing students' performance and improving their nutritional status through this type of food. In addition, the evidence also serves as a basis for municipal managers to motivate and strive to increase the percentage spent on PA foods, as well as hiring nutrition professionals, so that students in their municipality achieve higher educational results and better nutritional status. Above all, attention must be paid to the joint operation of the PNAE's axes, given that their impact is greater than in isolation.

To this end, the research is divided into five sections, in addition to this introduction. The next section presents the theoretical framework and the mechanism for transmitting the effect of the programs evaluated on learning. This is followed by the research methodology, with the database, variables and identification strategy. The fourth section sets out the evidence and discussion and concludes the study with the main considerations of the research.

2. THE RELATIONSHIP BETWEEN FOOD AND SCHOOL PERFORMANCE

The quality of school meals depends on school and municipal management, and its influence is modeled through the specification of a school production function, which relates inputs: family and school characteristics, with the results achieved by the students (Hanushek, 1979; 2010; 2020):

$$A_i = f(B_i, P_i, S_i, I_i) \quad (1)$$

where, for the i-th student, A_i is their school performance; B_i is a vector of family characteristics; P_i is a vector of class characteristics; S_i is a vector of school inputs; I_i are innate (unobservable) abilities.

School meals are part of the social space or public policies that support the school and are therefore an element of S_i. This element can act in different transmission channels for school performance and can act in different transmission channels for school performance. One of them is the reduction of the stigma surrounding free school meals, due to the fact that its access is universal, making family income less relevant and increasing participation in meals, which provides a more inclusive means of learning (Leos-Urbel et al., 2013). Studies show that food insecurity is associated with the deterioration of non-intellectual skills, such as behaviors that generate externalities. Therefore, as school feeding operates to reduce food insecurity, classroom distractions can be reduced by improving classroom behavior and thus effectively increasing teaching time, spilling over the spillover effects to those students who do not have modified nutritional intake (Alaimo et al., 2001; Lazear, 2001). Providing free and universal school meals increases families' available resources for other consumer goods which, in turn, can generate benefits for children and their performance at school (Cireno; Silva; Proença, 2013; Camargo; Pazello, 2014).

Since 2009, with the implementation of Law 11.947, there have been significant changes to the program, such as the inclusion of private schools in the eligible public, the request for nutritionists to be technically responsible for the meals and the obligation to purchase at least 30% of the resources in food from family farming or local rural family entrepreneurs (Brasil, 2009). The last two changes were a significant step towards healthier school meals. In the case of nutritionists, the support of a professional in food management makes it possible to control what is supplied, as well as being an important link in favoring the purchase of products from local farmers. These, in turn, can generate a constant supply of fresh, organic and healthy foods,

such as fruit and vegetables (Machado *et al*., 2018).

The mechanisms behind the provision of school meals on student performance include motivation to go to school (Pontili; Kassouf, 2007), especially for children who are socioeconomically vulnerable. In addition, better nutrition helps to reduce the incidence of illnesses, reducing absenteeism. Higher school attendance indirectly promotes higher performance, which in turn is directly affected by better a nutrition, as it allows for better concentration. The nutritional status of students, which is the result of the formation of consumption habits, can be considered an input in the school production function, and adequate nutrition is related to student effort and learning (Popkin; Lim-Yabanez, 1982; Cohen et al., 2021). Therefore, it is to be expected that government actions that influence healthier eating habits can be important factors to consider when analyzing school quality, highlighting the need to include inputs related to food and nutrition, not only in the short term, but also in the long term, as a mechanism for forming eating habits.

3. METHODOLOGY

3.1 Identification Strategy

The PNAE rules establish criteria to which managers need to comply. The quantity of Family Farming (FA) products offered, for example, which must meet the program's quality criteria, can be a limiting factor for the municipality to reach the minimum percentage required. As a result, the percentage of purchases from family farms varies greatly between municipalities. For example, 34.7% of municipalities did not reach the minimum of 30%, of which 10.3 did not purchase any FA products, while 8.3% purchased 100%. This means that the benefit is offered in different doses, making the effect heterogeneous. Circumventing this by specifying only an indicator of compliance with the Law or whether the policy is implemented does not favor the analysis, since municipalities that buy less than 30% of FA products are also beneficiaries of the policy, but the effects of the doses may be different throughout the distribution.

Therefore, given the percentage variation in PA purchases, their interaction with the participation of nutritionists in schools will have a continuous character in this analysis. Adopting the continuous treatment makes it possible to assess the dose effect of the different levels of acquisition of PA products with the work of nutritionists. The dose, in this case, captures the intensity of the value of the purchase of PA foods in schools with nutritionists and the effect this

variation has on school performance and children's nutritional status. Thus, using the intensity of the treatment increases the accuracy of the results rather than just relying on the binary treatment. Unlike the latter, which gives a value of zero to the control group and 1 to the treated group, the continuous treatment approach used here gives the control group a dose of zero and the treated group a dose of between zero and 100 (Cerulli, 2015), depending on the amount of food acquired from PA and its interaction with the presence of nutritionists in schools. Thus, in this study, the control group is made up of students from schools with PNAE, in which the municipalities purchase 0% of the products from PA and do not have nutrition professionals. While the treatment group is made up of students from schools with PNAE, where the municipalities buy more than 0% and have nutritionists.

In addition to the heterogeneity of the dosage effect of the purchases of PS, the hiring of a nutrition professional to draw up school menus, although mandatory by law, comes up against the decision and execution of the managers of the entities responsible and thus makes the process non-random. For these reasons, this analysis took an exogenous route to the treatments and potential results with the adoption of instrumental variables (VI) in the LATE approach, which allows the causal effect to be correctly estimated in the presence of heterogeneous effects and possible endogeneities. We used variables related to farmers' participation in the PNAE and which represent the labor market for nutritionists, as in De Deus and Da Costa Silva (2023). With more than one instrument, the LATE will be a weighted average of the VI estimators using the instruments separately.

The instruments used to estimate the relationship between treatment and school performance were the number of nutritionists per municipality, the average municipal salary for this category outside basic education and the number of Pronaf Aptitude Declarations (DAP) per municipality. To estimate the relationship between treatment and nutritional status, we used the average municipal salary for this category outside basic education and the number of DAPs per municipality. It was decided not to use the number of nutritionists per municipality in this specification, due to the possible direct influence of nutritionists outside the PNAE on children's nutritional status. To be valid, the instruments need to meet the conditions of independence, random allocation, exclusion and monotonicity. It is believed that the instruments meet these conditions for both the relationship with school performance and nutritional status.

It can be assumed that the instruments are as good as if they were randomly allocated, since they are independent of school performance, nutritional status and the interaction between purchases of PA and the work of nutritionists in the PNAE. This means that a variation in the

VI does not depend on a variation in the treatments. Or the producer does not depend on school performance to acquire the DAP, in the same way that the number of nutritionists per municipality and their salaries outside basic education are not a consequence of it. Similarly, for the producer to obtain DAP, he does not depend on the nutritional status of the children, just as the salaries of nutritionists outside basic education are not defined by the nutritional status of the students.

Although the treatments do not affect the variation in the instruments, the latter are relevant in explaining the variation in the treatments, which makes the existence of the first stage possible. For example, municipalities with farmers who have a DAP are more likely to participate in the PNAE sales process, since this document is necessary for their participation in the policy. Schools located in municipalities with a good number of nutritionists are more likely to have such professionals. On the other hand, the higher the salary offered in other activities, the less likely they are to be hired in schools, since agents are expected to be rational and seek the highest salaries. Therefore, since the influence is controlled by socio-economic characteristics, the correlation between this intervention and the salary offered is negative.

In addition to being independent, relevant and randomly allocated in this relationship of interest, the instruments meet the exclusion restriction of the structural equation. When the economic and demographic characteristics of the municipality are included, other channels that could divert the causal effect are controlled for, so the instruments only affect the results through the treatments: $Y_i(z,t,x)=Y_i(z^*,t,x)\ \forall\ t,x,z,z^*$. This means that, in the context of the vector of characteristics, X_i ,the potential results do not depend on the realization of the instruments (Pinto; Menezes Filho, 2017).

Furthermore, unlike the classical approach, in which treatment effects are homogeneous, LATE can determine the average treatment effect of a specific subpopulation when the treatment effect is heterogeneous, which is believed to be the case in this estimation (Imbens; Angrist, 1994). In this case, the instruments will act in the right directions. This means that when the number of establishments with DAP is favorable to contracting in the sales project, then municipalities will purchase food from FA. But when the number of DAPs is not favorable to the demand in the public call, then the executing entities will end up not buying. The same applies to hiring nutritionists. If the number of nutritionists in the municipality is favorable to their participation in schools and salaries outside basic education are less attractive, then it will be more likely that nutritionists will be hired in schools. This has the effect of compliers. Also according to Imbens and Angrist (1994), LATE identifies the average effect, assuming that there

are few non-compliers. Therefore, the executing entities that will not purchase family farming products, if the instruments are not favorable, are a small number that will not affect the true average effect. So, for monotonicity: $T_{z_i}(t) > T_{z_i}(0)$

Although LATE estimates the effect of the treatment locally for the portion of those who comply with the relationship between instruments and intervention, by using the instrument of the amount of DAP per municipality, it is reasonable to assume that it was possible to extrapolate the impact to other eligible populations, giving external validity to the analysis. This is because the DAP is the document required for producers to access PNAE sales calls. Thus, if the instrument works for the context analyzed, public school students, it will also be valid in the context of other eligible populations, such as philanthropic and community schools.

Once these conditions were met, the LATE was first estimated using Two-Stage Least Squares (2LS). The structural equation for school performance is given below:

$$y_{iem} = \alpha + \lambda X_{iem} + \beta_1 PNAE\_Nutri_e + \beta_2 PNAE\_AF_m + \tau PNAE\_Nutri_e * PNA \quad (2)$$

where y_{iem} represents the SAEB proficiency test score of student *i*, in school *e*, in municipality *m* in 2019; α is the constant; X_{iem} is a vector of covariates and λ its coefficient; $PNAE\_Nutri_e$ is a dummy indicating the role of a nutritionist in the PNAE; $PNAE\_AF_m$ is the percentage of purchases of PS for the PNAE, where β_1 and β_2 are their respective effects; $PNAE\_Nutri_e$ * $PNAE\_AF_m$ is the interaction between the treatments, and τ is the effect of interest. Finally, ε_{iem} is the random error term.

The structural equation for nutritional status, which was also estimated by MQ2E, is represented by:

$$EN_m = \delta + \gamma X_m + \rho_1 PNAE\_Nutri_m + \rho_2 PNAE\_AF_m + \mu PNAE\_Nutri_m * PNA \quad (3)$$

where EN_m is the percentage of children and adolescents in municipality *m* according to nutritional status (eutrophy, obesity and severe obesity) in 2019. δ is the intercept and v_m is the random error term. The other variables are defined as in the previous equation.

Finally, given the continuous nature of the treatment, the FDR and EMT were estimated, following the approach of Cerulli (2015), as it considers that what is important is not just whether or not the treatment is adopted, but the level of adoption and the heterogeneity of the impact. The methodology was therefore divided into two further subsections. The first goes

through the methodology used in the FDR and EMT. The second deals with the databases and variables.

3.2 Dose-Response Function and Marginal Effect of Treatment

The difference in the intensity of adoption of a treatment can interfere with the heterogeneity of the impact. This can occur in the relationships of interest, as the response of student proficiency or nutritional status can be different for each percentage of food consumed and presence of a nutritionist. The Dose-Response Function (DRF) makes it possible to assess this heterogeneity of impact at each level of adoption. According to Cerulli (2015), the DRF is equal to the average treatment effect (ATE), given a treatment level t, ATE(t), where t represents the continuous treatment variable. In this case, t is the percentage of food purchased from family farms per municipality, in the interaction with the nutritionist.

In summary, the FDR is the conditional expectation of variations in student proficiency and nutritional status, given the explanatory variables. The derivative of the FDR is therefore the marginal treatment effect (MTE), which shows how the effects of the policy interaction change the outcome variables as the percentage of treatment increases. The approach allows for the existence of endogeneity in the policy intervention, without causing damage to the estimation of the causal effect, by implementing the VI estimation method (Cerulli, 2015).

According to Cerulli (2015), these are two different and exclusive potential outcomes: y_{1i} and y_{0i}, indicating the outcome of the individual or municipality i, when it receives the treatment, w_1, and when it does not, w_0. Note that, in this case, the variable w is binary. We define $x_i = (x_{1i}, x_{2i}, x_{3i}, \ldots, x_{Mi})$ as the vector of M observable characteristics, where i=1,…, N. is N the total number of students or municipalities (in the case of the nutritional status sample), N_1 is the treated portion, and N_0 is the untreated portion. The equations for the two potential results are expressed as:

$$\{w = 1: y_1 = \mu_1 + g_1(x) + h(t) + e_1 \; w = 0: \quad y_0 = \mu_0 + g_0(x) + e_0 \quad (4)$$

Two response functions are assumed, $g_1(x_i)$ and $g_0(x_i)$, associated with the vector of variables x_i, respectively when individuals are treated or not; μ_1 and μ_0 are scalars; e_1 and e_0 are two random variables with zero mean and constant variance. The treatment t is within the interval [0, 100] and $h(t)$ is the function derived from t. From (4), the treatment effect can be defined.

Adjusting the expression in a regression approach and applying the VI method to restore the consistency of the estimators in the presence of endogeneity, Cerulli (2015) expresses the model as follows:

$$y_i = \mu_0 + x_i\delta_0 + w_i ATE + w_i(x_i - \bar{X})\delta + w_i T_{1i} + bw_i T_{2i} + cw_i T_{3i} + \eta_i \quad (5.1)$$

$$w_i^* = x_{w,i}\beta_w + \epsilon_{w,i} \quad (5.2)$$

$$t_i = x_{t,i}\beta_t + \epsilon_{t,i} \quad (5.3)$$

In which $T_{1i} = t_i - E(t_i)$, $T_{2i} = t_i^2 - E(t_i^2)$ e $T_{3i} = t_i^3 - E(t_i^3)$; w_i^*i* is the latent variable; t_i is observable only when w_i=*1 (e* t_i=t_i'*);* $x_{w,i}$ *and* $x_{t,i}$ are two sets of exogenous regressors that explain the treatment, while $\epsilon_{w,i}$, $\epsilon_{t,i}$ and η_i are error terms freely correlated with each other, with unconditional mean equal to zero. Equation (5.2) is the selection equation, which defines the regression explaining the treatment indicator w_i* with the vector of covariates, $x_{w,i}$, used as a criterion to define the treated and control groups. Equation (5.3) is the treatment level equation, which defines how the level of interaction is decided, considering only individuals eligible for treatment. And the vector $x_{t,i}$ are the exogenous covariates that determine the treatment level.

It can be seen that w_i, T_{1i}, T_{2i} and T_{3i} are endogenous variables, the last three being functions of the treatment level, *t*. Thus, the estimations have two endogenous variables: w_i*, the treatment variable in its binary form; and t_i', the variable in its continuous form. Thus, at least two instrumental variables are required, which are directly correlated with w_i* and t_i', but not with the outcome variables, to satisfy the exclusion restriction, and not correlated with the error terms, ensuring exogeneity.

Equations (5.2) and (5.3) were estimated using the Heckman model in two stages. The first stage consists of estimating w_i in $x_{w,i}$, using a *probit* with only N_1 observations. In the second stage, using Ordinary Least Squares (OLS), was estimated t_i' in $x_{t,i}$ with all N observations and using the Mills ratio obtained in the first stage. In this way, the estimates of w_i and t_i. With equations (5.2) and (5.3) calculated, equation (5.1) was estimated. To do this, MQ2E was applied and consistent estimators were obtained. Finally, the FDR was estimated by OLS.

3.3 Data bases and Variables

The sample cut out for the analysis of school performance is made up of students in public schools. This is because it contains a greater number of observations than the eligible private

schools. Imbens and Angrist (1994) state that the use of small samples in LATE can cause a loss of efficiency. In addition, leaving observations of private school students in the sample would confound the effect, as they have different individual and family characteristics from public school students, and perform better at school than the latter.

The variable that captures school performance is the Portuguese and math test scores of students in 5th grade in the public school system. As such, the dependent variable is at student level. The scores are calculated and standardized on proficiency scales in the SAEB 2019 exams, prepared by INEP. They range from zero to 375 and are applied in odd-numbered years to public and private schools registered in the School Census.

The other dependent variables, nutritional status, are from children aged between 7 and 10 and adolescents in the Food and Nutrition Surveillance System (SISVAN) sample. This sample mainly includes children from families benefiting from the Bolsa Família Program (PBF) grouped into municipalities. The measure of nutritional status used by SISVAN that best suits the analysis is the Body Mass Index (BMI) for age and gender. BMI relates an individual's weight and height, based on their age group and gender. Thus, a child or adolescent can be considered eutrophic when their BMI is adequate; obese when it is between the 97th and 99.9th percentiles; and severely obese when it is above the 99.9th percentile (Brasil, 2011). Table 1 describes the variables.

Table 1 - Descriptions of the variables used and their sources for 2019.

Variable	Description	Source
Proficiency_MT	Math test score.	SAEB
Proficiency_LP	Portuguese test score.	SAEB
Eutrophy	% of children and adolescents with adequate BMI.	SISVAN
Obesity	% of obese children and adolescents.	SISVAN
Severe Obesity	% of severely obese children and adolescents.	SISVAN
PNAE	1 = offers school meals; 0 = c.c.[1]	School Census
PNAE_AF	% of resources earmarked for family farming.	FNDE
PNAE_Nutri	1 = the school has a nutritionist; 0 = c.c.	School Census
PNAE_AF_Nutri	Interaction between % of family farming purchases and nutritionists.	
Instrument 1	Total number of nutritionists per municipality.	RAIS
Instrument 2	Average salary of nutritionists outside education.	RAIS
Instrument 3	Establishments with DAP in the municipality.	Agricultural Census
Municipality		
Region	Geographical region of the municipality.	SAEB
School location	1 = urban area; 0 = otherwise.	SAEB
Capital	1= municipality is a capital; 0 = c.c.	IBGE
Population	Municipal population.	IBGE
GDP	Current Gross Domestic Product.	IBGE
VAG	Added value of agriculture by municipality.	IBGE
Agro	1= Agricultural sector is strong; 0 = c.c.	IBGE
School		
Class size	Number of students per class.	School Census
Educ. Education	1 = school offers food education; 0 = c.c.	
ICGE	School Management Complexity Index.	
Dependency Adm.	1= Federal; 2= State; 3= Municipal.	
Teachers		
Education	Proportion of teachers with higher education.	INEP
Suitability	% of teachers with appropriate training for the position.	
Student		
INSE	Socioeconomic Indicator	SAEB

Source: Own elaboration based on the sources cited above.

Note: [1] otherwise.

The variable percentage of resources earmarked for PS is constructed by the FNDE for 2019 (FNDE, 2024). A cut-off was made if the school receives PNAE resources, collected from the 2019 School Census (INEP, 2019), so that only schools participating in the program were treated. Due to the complementary nature of the PNAE, some municipalities reported spending more than 100% on family farming. However, since the purpose of this study is to analyze only the effect of the program, those that reported more than 100% were given a value of 100. The variable for the participation of PNAE nutritionists was taken from the 2019 School Census, where it appears from 2019 onwards. It was decided not to use data from 2021, due to the Co-vid-19 pandemic, when students had remote classes and were not exposed to the program as they were in the classroom. Just as in the case of purchases of PS, we cut out whether the school with a nutritionist receives PNAE resources, in order to keep only the beneficiaries. After the interaction between the treatments, students from municipalities with positive values were as-

signed to the treated group, while the control group was made up of those with a value of zero.

The instrument for the amount of DAP per municipality is part of the 2017 Agricultural Census, carried out by the Brazilian Institute of Geography and Statistics (IBGE), the year in which the most recent data is found (IBGE, 2019). The use of this instrument in a period prior to the other data does not harm the analysis; on the contrary, considering the time lag of farmers' harvests in analyses of current periods can be advantageous. The other instruments, total number of nutritionists per municipality and average municipal salary of these professionals outside basic education, were found in the Annual Social Information Report (RAIS). As in De Deus and Da Costa Silva (2023), from the CBO (Brazilian Classification of Occupations), only professionals in the area were selected and, from the CNAE (National Classification of Economic Activities), those who are in the education sector, specifically working in basic education, were excluded. After these filters, the average salary offered in the municipality was calculated. Therefore, the estimation is based on cross-section data.

Given that the outcome variables are information on children and adolescents and knowing the relationship that school performance and nutritional status have with the socioeconomic and cultural profile of the student (INEP, 2015), the Socioeconomic Level Indicator (INSE) of basic education students in Brazil was included. In this way, we controlled for the influence of family *background* on proficiency, as well as on nutritional status. In addition, knowing that the municipality's income can affect the dependent and treatment variables, the municipal Gross Domestic Product (GDP), the Value Added of Agriculture and the indicator that the agricultural sector is the strongest in the municipality were also added. In addition to these, other variables were inserted, as described in Table 1.

4. RESULTS

The interaction between the work of nutritionists and purchases of FA under the PNAE is a strategy to improve the nutritional status of students and their school performance, through healthier foods from FA, compared to other sources, such as industrialized foods, and the preparation of the food menu directed by the nutritionist. In view of this, this section estimates the impact of this synergy on the SAEB scores for Portuguese and mathematics of 5th graders in public elementary schools and on the nutritional status of children and adolescents in Brazil.

Before analyzing the effects found, the validity and strength of the instruments must be assessed. It can be seen that the results of the tests in Table 1 were all in favor of the VI. For spe-

cifications 1 and 2, the hypothesis of overidentification was not rejected, demonstrating that the instruments are exogenous to the performance equation. For nutritional status specifications 3 to 5, the under-identification of the models was rejected and proves that the matrix is identified and, therefore, the instrument is relevant at the 5% statistical significance level. In addition, the Stock-Wright test, in robust inference, rejected the hypothesis that the instruments were weak. Thus, the instruments are influencing the treatments in the right direction and intensity.

Table 1, based on the interaction coefficient between the programs, shows that in schools with nutritionists, the return on PA purchases is 0.68 points higher in Portuguese and 1.35 points higher in mathematics. This indicates that the impact on math is greater than if the school has a nutrition professional or only receives PA products. The total impact is 2.23 points (0.88+1.35) for a 1 percentage point increase in PA purchases in schools with a nutritionist, while for Portuguese the impact is 1.34 points (0.66+0.68). The isolated effect of the presence of a nutritionist on school performance may show that the work of this professional alone is null, compared to joint implementation with the PA, implying that the work of the professional alone is less effective and that the purchase of quality food is necessary to complement their work. This evidence confirms the points made by Gallicchio *et al*. (2021) and Porrua *et al*. (2020) about the difficulties faced by programs due to the lack of nutritionists. Many professionals do not have access to local agricultural mapping, which results in low participation in the purchasing process and difficulties in aligning the formulation of menus with regional production. These problems are attributed to a lack of coordination between nutritionists, farmers and organizations that support PA.

With regard to nutritional status, Table 1 shows that the interaction was not statistically significant in affecting the percentage of children and adolescents with an adequate BMI for their age (eutrophy). This may have been limited by the size of the sample. However, it is possible to capture isolated effects of the programs, which are associated with a reduction in cases of eutrophy. On the other hand, for severe obesity and obesity alone, the two axes of the PNAE together have a significant impact on reducing the percentage of both. The total impact of a 1 percentage point increase in food purchases via PA, considering the work of nutritionists, is a reduction of 0.29 (0.35-0.59) and 0.53 (0.65-1.18) percentage points, respectively, although isolated, are not effective in reducing cases of obesity. However, the dynamic effect that was not captured and which is present in anthropometric measures must be taken into account. This is because the positive association between the nutritional status variables and the PNAE programs, via a contemporaneous relationship, may be capturing an attempt to reverse cases of

obesity by increasing the scope of the participation of nutritionists. One explanation is that the increase in the percentage occurred because obesity cases are high. Compared to the isolated effect of the two axes of the program, the synergy appears to be more effective and aimed at achieving the program's objectives.

Figures 1 and 2 illustrate the FDR and EMT for performance and nutritional status. It can be seen that the 20-30% interval is not statistically significant for the two scores, as the distribution cuts through zero at this point. Despite this point, the confidence interval for the other doses was significant. Both proficiencies show decreasing marginal returns, i.e. as the treatment dosage increases, the impact becomes smaller and smaller, but this does not mean that it is negative. This can be seen in the behavior of the EMT curve, which is concave. As a result, it can be seen that the optimum dosage point is in the range between 50 and 60% of PA purchases, given the participation of the nutritionist. It can be seen that, in this range, the dosage response is between 50 points in mathematics and around 200 points in Portuguese.

Table 1 - Effects of the synergy between purchases of PA and the work of nutritionists in the PNAE for children and adolescents in Brazil, 2019.

Variables	(1) Mathematics	(2) Portuguese	(3) Eutrophy	(4) Obesity	(5) Severe Obesity
PNAE_Nutritionist	-17,14	-8,13	-80,30*	55,54*	28,28*
	(12,06)	(8,50)	(43,54)	(29,61)	(15,85)
PNAE_AF	0,88***	0,66***	-0,67	0,65*	0,35*
	(0,09)	(0,06)	(0,56)	(0,38)	(0,21)
PNAE_Nutritionist x PNAE_AF	1,35***	0,68**	1,39	-1,18*	-0,59*
	(0,41)	(0,29)	(0,97)	(0,66)	(0,35)
Constant	144,60***	122,05***	107,69***	-21,94	-13,38
	(13,73)	(9,40)	(23,24)	(15,86)	(8,64)
Observations	1.528.296	1.528.296	10.784	10.784	10.784
Controls	Yes	Yes	Yes	Yes	Yes
Statistics χ^2	9.855	16.580	715	217	188
Tests					
Overidentification	0,33	1,9			
Sub-identification	51***	52***	4,34**	4,34**	4,34**
Strength of VIs	486***	318***	71***	71***	71***

Source: Survey results.

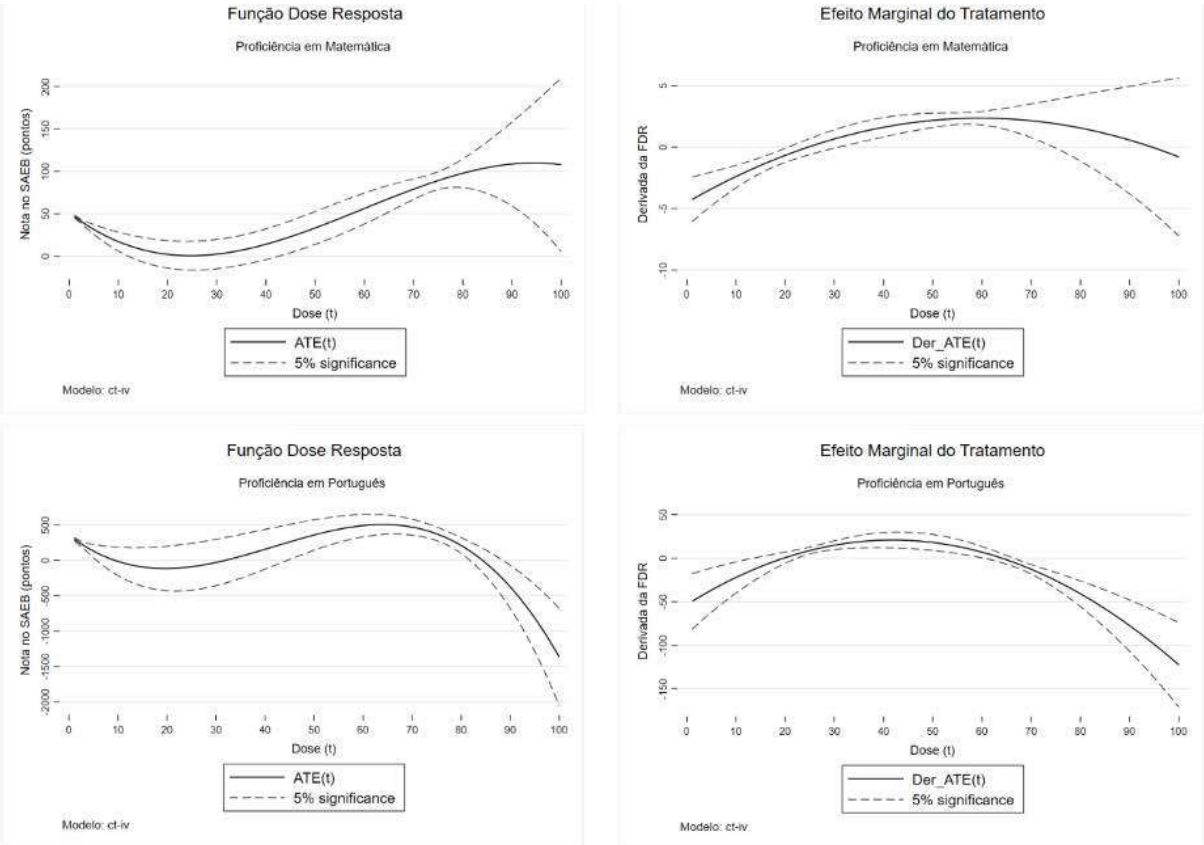
Note: Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Standard errors for Portuguese and mathematics were clustered by school. Overidentification test shows Hansen's J statistic. Identification Test shows Kleibergen-Paap LM statistic. Instrument Strength Test is a robust inference based on the LM statistic from Stock-Wright . Controls models 1 and 2: urban area indicator; capital indicator; state fixed effects; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; ICGE; school administrative dependency indicator; proportion of teachers with higher education; percentage of teachers with adequate training for the position; total number of students per class; school food education indicator. Model controls 3 to 5: urban area indicator; capital indicator; municipal population; current GDP; indicator of municipality with strong agricul-

tural sector; INSE; percentage of schools with food education, percentage of people with treated water at home.

With regard to nutritional status, although the EMT interval was not significant for severe obesity, the response to the initial 30% shows a reduction in the percentage of severe obesity. Similar behavior is observed in the confidence interval for eutrophy, although the 30% dosage increases the percentage of children and adolescents with adequate nutritional status. On the other hand, the FDR for obesity remained statistically significant throughout the distribution. Its yields proved to be decreasing, but always in the direction of reducing the percentage of childhood obesity.

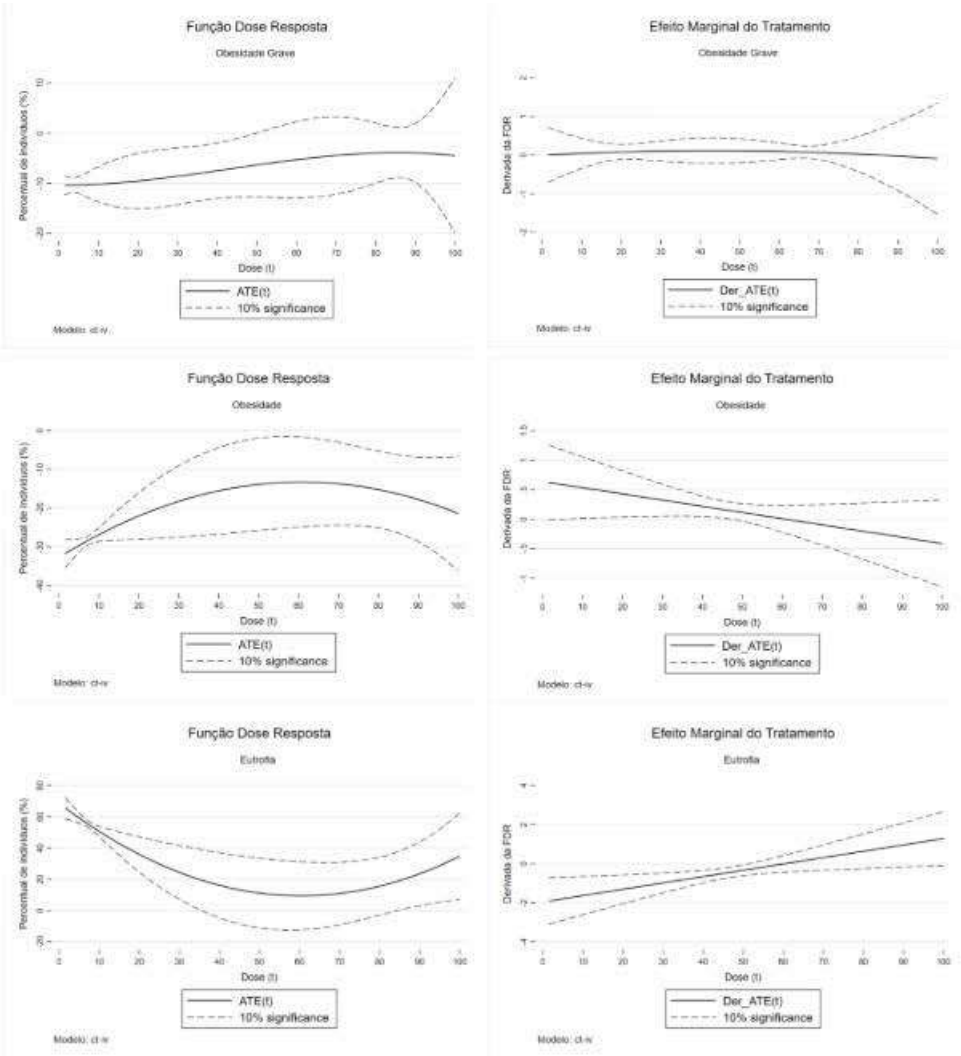
Based on these analyses, the graphs reveal the heterogeneity of the impact of the treatment, especially in relation to nutritional status. Evaluating the adoption of 30%, the purchase level required by the PNAE, seems an adequate measure. However, analysis of the FDR and EMT showed that the optimum level of adoption of the policy, with the presence of nutritionists, is between 50 and 60%, especially for school performance.

Figure 1 - Dose-Response Function and Marginal Effect of Treatment for 5th grade performance, 2019.



Source: Survey results.

Figure 2 - Dose-Response Function and Marginal Effect of Treatment for nutritional status, 2019.



Source: Survey results.

5. HETEROGENEOUS EFFECTS ANALYSIS

Table 2 shows the relationship between the synergy between PA and nutritionists and other policies. It can be seen that the inclusion of interaction with the Bolsa Família Program (PBF) does not alter the synergy between PA and nutritionists, either for proficiency in Portuguese or mathematics, something that for the Health at School Program (PSE) and Family Health Program (PSF) is not observed to be statistically significant, with the exception of the mathematics score for the latter.

Table 2 - Relation of the synergy between purchases from FA and the work of nutritionists in the PNAE with other public policies on Portuguese and mathematics, 2019.

Variables	(1) Total	(2) PBF	(3) PSF	(4) PSE
			Mathematics	
PNAE_Nutritionist x PNAE_AF	1,35***	1,46**	-0,70	0,70
	(0,41)	(0,62)	(0,56)	(0,44)
Politics		-5,30***	-0,09	39,12***
		(0,90)	(0,13)	(7,61)
PNAE_Nutritionist x PNAE_AF x Politics		-0,04	0,02**	4,54***
		(0,15)	(0,01)	(1,21)
			Portuguese	
PNAE_Nutritionist x PNAE_AF	0,68**	0,63	-1,69***	0,34
	(0,29)	(0,61)	(0,51)	(0,36)
Politics		-4,18***	0,04	40,97***
		(0,98)	(0,13)	(7,14)
PNAE_Nutritionist x PNAE_AF x Politics		0,11	0,03***	5,10***
		(0,14)	(0,01)	(1,19)
Observations		1.528.296	1.528.296	1.528.296
Controls		Yes	Yes	Yes

Source: Survey results.

Note: Robust standard errors clustered by school in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Controls: urban area indicator; capital indicator; state fixed effects; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; ICGE; school administrative dependency indicator; proportion of teachers with higher education; percentage of teachers with adequate training for the position; total number of pupils per class; school food education indicator.

As for the municipal coverage of the Family Health Program (PSF), it was found to be important in conjunction with the participation of a nutritionist in the school, especially for mathematics, with a complementary relationship in the students' health care, which translated into higher performance on average, although the greater coverage of the PSF alone was not enough to change the students' grades, given its statistical insignificance. With regard to its isolated effects, the PBF reduced scores in both Portuguese and math. However, for PSE, there was an average increase of 40 points in both proficiencies. In addition, it should be noted that the return of purchases of PS in the presence of nutritionists on both scores is high when municipal coverage of the PSF increases and when the PSE is present. This demonstrates the joint importance of the policies and their complementarity in student health care, which translates into higher proficiency, although greater FHP coverage alone is not enough to change student performance,

given its statistical insignificance.

Table 3 - Relation of the synergy between purchases from PA and the work of nutritionists in the PNAE with other public policies on nutritional status, 2019.

Variables	(1) Total	(2) PBF	(3) PSF	(4) PSE
			Eutrophy	
PNAE_Nutritionist x PNAE_AF	1,39	6,15	-15,03	82,72
	(0,97)	(11,95)	(23,55)	(486,61)
Politics		-4,23	4,37	-1.794.84
		(11,00)	(6,27)	(10.783)
PNAE_Nutritionist x PNAE_AF x Politics		0,04	0,19	-99,12
		(0,36)	(0,28)	(592,62)
			Obesity	
PNAE_Nutritionist x PNAE_AF	-1,18*	-3,10	9,70	-51,29
	(0,66)	(5,34)	(15,94)	(291,76)
Politics		2,23	-2,87	1.106.16
		(4,93)	(4,25)	(6.465)
PNAE_Nutritionist x PNAE_AF x Politics		0,33	-12,51	60,98
		(16,33)	(18,76)	(355,35)
			Severe Obesity	
PNAE_Nutritionist x PNAE_AF	-0,59*	-0,66	3,63	-16,97
	(0,35)	(2,64)	(6,86)	(94,88)
Politics		4,80	-111,62	364,31
		(244,12)	(183,32)	(2.102)
PNAE_Nutritionist x PNAE_AF x Politics		-4,72	-4,79	20,06
		(7,35)	(8,06)	(115,55)
Observations		1.528.296	1.528.296	1.528.296
Controls		Yes	Yes	Yes

Source: Survey results.

Note: Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Controls: urban area indicator; capital indicator; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; percentage of schools with food education, percentage of people with treated water at home.

Similarly, according to Table 3, the insertion of policies does not significantly alter the synergy effect, given the lack of statistical relevance. Furthermore, nothing can be inferred about the interaction of policies with the synergy of interest or even their isolated effects on child nutritional status. This may be due to the size of the sample and even the low power of variation in nutritional status that these policies can present when compared to the PNAE and its two axes of action.

In Table 4, the effects in the rural and semi-arid sub-samples are positive only in the context in which there is food from PA, with no statistical relevance in the interaction with the

presence of nutritionists. This can be explained by the predominance of family farmers in the northeast of the country and in rural areas. The non-significance of the interaction in these geographical contexts may be due to the lack of adequate sanitary conditions. Souza, Ramos and Borges (2015), evaluating the hygiene and sanitation situation in schools in the semi-arid northeast, found that all of them were not in line with ideal facilities. According to them, food handling facilities are a cause for concern, as they can compromise the hygienic safety of the food and, consequently, the health of the students. In relation to rural areas, Frutuoso (2023) points out that, in Paraíba, nutrition professionals have difficulties accessing schools in these areas. The author points out that their commitment may be hampered by low salaries, the lack of structure to work in and the large number of students they serve. According to her, there is a shortage of nutritionists in almost all municipalities and they face difficulties in mapping the production of food from family farming, in the purchasing process, which is an input for the professional in preparing the school menu. Silva et al. (2021) support the conclusions of Frutuoso (2023). They state that, in smaller towns, direct interaction between nutritionists and farmers is crucial for purchases, as menu planning is based on local cultures and seasonality. When analyzing all Brazilian municipalities, the authors note an increase in the number of entities that follow the policy's guidelines between 2011 and 2016, but there are still many municipalities, especially in poorer regions, that do not comply with these guidelines, affecting students who are more vulnerable to food insecurity. Gomes et al. (2021) indicate that the unviability of certain foods and drought are factors that hinder the implementation of the policy, which is corroborated by Gomes and Amorim (2018) in the context of Piauí.

Table 4 - Effects by sub-samples for the Portuguese and math scores of 5th grade students in the 2019 SAEB.

Variables	(1) Rural	(2) Semi-arid	(3) INSE	(4) AF>30	(5) PBF>25	(6) Nutri<4
			Mathematics			
PNAE_Nutritionist	8,93	75,02	-308,0**	-142,5***	107,88	-119,15*
	(186,26)	(63,02)	(138,72)	(22,89)	(72,29)	(67,65)
PNAE_AF	3,54***	3,37***	2,27***	0,08	0,31	1,15***
	(0,95)	(0,56)	(0,55)	(0,10)	(0,61)	(0,41)
PNAE_Nutritionist	0,11	-0,32	8,31**	3,01***	-2,44	2,98**
x PNAE_AF	(4,19)	(2,02)	(4,00)	(0,49)	(2,22)	(1,17)
			Portuguese			
PNAE_Nutritionist	-40,71	66,98	-222,6**	-104,4***	87,54	-160,21**
	(188,55)	(47,07)	(107,86)	(18,41)	(66,54)	(77,19)
PNAE_AF	3,51***	2,59***	2,14***	0,04	0,29	1,30***
	(0,99)	(0,44)	(0,43)	(0,08)	(0,62)	(0,46)
PNAE_Nutritionist	0,86	-0,64	5,70*	2,15***	-2,20	3,48***
x PNAE_AF	(4,24)	(1,50)	(3,11)	(0,39)	(2,17)	(1,34)
Observations	167.257	223.205	842.893	996.746	4.736	1.103.406
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Source: Survey results.

Note: Robust standard errors clustered by school in brackets. *** p<0.01, ** p<0.05, * p<0.1. Controls: urban area indicator; capital indicator; state fixed effects; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; ICGE; school administrative dependency indicator; proportion of teachers with higher education; percentage of teachers with adequate training for the position; total number of students per class; school food education indicator.

Students from lower socio-economic levels (INSE 1, 2, 3 and 4), who may be more socially and economically vulnerable, including to food insecurity, are the ones who have the greatest returns from consuming food from FA, given the work of the nutritionist. This means that the synergy of the policy benefited the lower socioeconomic class of the student population. Gomes et al. (2021) also verified this when they showed that school meals attract children living in poverty.

As expected, the return on purchases of PS, given the work of the nutritionist, is greater for students in municipalities that meet the minimum requirement of 30%, when compared to those that do not. This impact can be seen for both proficiencies. Similarly, students in municipalities with less than 4 nutritionists per 10,000 inhabitants is higher than the total effect. This shows that nutritionists are necessary for the policy to be effective.

Table 5 - Effects by sub-samples for the nutritional status of children and adolescents in Brazil in 2019.

Variables	(1) Rural	(2) Semi-arid	(3) INSE	(4) AF>30	(5) PBF>25	(6) Nutri<4
			Eutrophy			
PNAE_Nutritionist	-69,71	53,94	18,17	-73,63*	2.375,36	-90,02*
	(48,04)	(383,74)	(49,79)	(38,44)	(253.703)	(53,85)
PNAE_AF	-0,59	0,27	0,40	-0,40	23,05	-0,71
	(0,38)	(2,46)	(0,70)	(0,46)	(2.456,52)	(0,69)
PNAE_Nutritionist	0,89	-2,63	-0,88	0,99	-76,23	1,63
x PNAE_AF	(1,15)	(12,61)	(1,83)	(0,64)	(8.123)	(1,23)
			Obesity			
PNAE_Nutritionist	15,44	-33,01	-3,98	27,73	-703,90	52,92
	(32,77)	(164,13)	(30,26)	(21,75)	(76.028)	(33,96)
PNAE_AF	0,34	-0,27	0,15	0,45*	-6,93	0,61
	(0,23)	(1,05)	(0,42)	(0,25)	(736,13)	(0,43)
PNAE_Nutritionist	-0,13	1,32	0,32	-0,57	22,69	-1,09
x PNAE_AF	(0,82)	(5,41)	(1,07)	(0,36)	(2.434)	(0,77)
			Severe Obesity			
PNAE_Nutritionist	10,57	-40,09	-19,54	10,84	-703,90	52,92
	(12,45)	(162,49)	(22,16)	(14,91)	(76.028)	(33,96)
PNAE_AF	0,10	-0,30	-0,28	0,31*	-6,93	0,61
	(0,08)	(1,04)	(0,30)	(0,18)	(736,13)	(0,43)
PNAE_Nutritionist	-0,18	1,41	0,67	-0,26	22,69	-1,09
x PNAE_AF	(0,32)	(5,35)	(0,81)	(0,24)	(2.434)	(0,77)
Observations	1.734	2.462	2.332	7.072	100	8.694
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Source: Survey results.

Note: Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Controls: urban area indicator; capital indicator; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; percentage of schools with food education, percentage of people with treated water at home.

On the other hand, for municipalities where the percentage of BFP beneficiaries is higher than 25%, the observed effect was lower than the general average and was not statistically significant. This suggests that the treatment may not be generating the desired effect for this specific group.

As for the nutritional results in Table 5, no sub-sample had a significant effect when interacting with the PNAE. Only municipalities that comply with the PA policy had a positive effect precisely on this axis of the PNAE in question. This demonstrates the importance of municipalities complying with at least 30% of their purchases from PS, although this percentage is not optimal for achieving the best results in Portuguese and mathematics and in nutritional

status, as seen in the analysis of the dosage effect.

6. COST-EFFECTIVENESS ANALYSIS

In addition to evaluating the impact of the program on school performance and nutritional status, this study also carries out a cost-effectiveness analysis to shed light on the decision of policy managers regarding the allocation of public resources. When managers seek to improve student performance or the nutritional status of pupils, they face decisions about where and how to allocate the limited resources available.

Within the school environment, there are different strategies that can be adopted to improve these indicators, such as teacher salaries, full-time schools, starting school earlier, free school meals with mechanisms to promote healthy eating, among others (Akiba *et al*., 2012; Rosa; Martins; Carnoy, 2019; De Deus; Da Costa Silva, 2023; Rosa *et al*., 2022).

Initiatives that allocate more resources to teachers may be positive, but they are certainly more expensive than those directed at students and would possibly have no influence on their nutritional status. Jacob and Rockoff (2011) highlight both the need and the opportunity for more cost-effective policies; lower-cost policies with modest effects on student test scores can provide a better return than expensive policies with larger absolute effects.

Based on the estimates of the impact of the synergy between PA nutritionists, it was possible to analyze the cost- effectiveness of these two axes of the PNAE together. Each real invested per student has an effect on math and Portuguese of 0.45 and 0.74, respectively. For severe obesity and obesity alone, it is 3.44 and 1.88 percentage points, respectively. This cost-effectiveness is low, given that the amount invested per elementary school student per school day is R$0.50 (FNDE, 2024). Considering that the transfer is made for 200 school days a year, the total amount is R$100.00. Thus, 45 reais can increase 1 point in mathematics and 74 reais can increase 1 point in Portuguese per year, while the cost of reducing 1 percentage point of obesity and severe obesity is, respectively, 344 and 188 reais.

7. FINAL CONSIDERATIONS

This article sought to assess how the percentage of purchases from Family Farming in the municipality, interacted with the existence of a nutrition professional in schools, contributes to the grades obtained by schoolchildren, through proficiency tests, and to their nutritional status.

In order to identify the relationships of interest, instrumental variables were used to correct possible endogeneities in the treatment variables evaluated. With this more refined analysis, it was possible to signal the extent to which municipalities that do not implement one of the programs may be less effective in delivering favorable results.

The effect found for PA purchases was greater in schools where nutritionists worked, compared to those where they did not, and had an impact of 2.23 points for mathematics, while for Portuguese the impact was 1.34 points. This shows that the work of the professional alone is less effective and that the purchase of quality food is necessary to complement their work, and vice versa. In relation to nutritional status, the interaction was not statistically significant in affecting adequate child nutritional status. On the other hand, for severe obesity and obesity alone, the two axes of the PNAE together have a significant impact on reducing the percentage of both. The impact of this synergy is a reduction of 0.29 and 0.53 percentage points.

With regard to the literature, the study contributes, firstly, by providing evidence of the importance of school meals and, consequently, of the PNAE in increasing school performance, via food security. This evidence shows that the PNAE is a factor capable of acting on two vectors of the Brazilian School Production Function: school inputs, operating directly as a public policy; and, indirectly, in the family *background*, by influencing the food and nutritional security of students. It also contributes by evaluating the two axes that promote healthy eating in the PNAE and is the first study, to the authors' knowledge, to empirically analyze the influence of this synergy on the quality of education and children's nutritional health. In addition, the cost-effectiveness analysis calculated that each real invested per student is effective in math and Portuguese, as well as reducing cases of obesity. In view of the amount allocated per student over the course of the school year, the conclusion is that the cost is low, given the effectiveness of the programs.

As the food offered by PA can be considered healthy, this article also confirms the feasibility of increasing student performance and improving their nutritional status through this type of food. In addition, the evidence also serves as a basis for municipal managers to motivate and strive to increase the percentage spent on PA foods, as well as hiring nutrition professionals, so that the students in their municipality achieve higher educational results and better nutritional status. Above all, attention should be paid to the joint operation of the PNAE's axes, given that their impact is greater than in isolation.

The study provides useful suggestions for the design of the policy, in terms of the minimum requirement of 30% of purchases from FA and hiring a nutritionist to draw up the school's

food menus. The results indicate that the optimum percentage of food purchases from family farming to increase student performance is between 50 and 60%. This evidence has important implications for changing the program's guidelines. To this end, it is clear that, in order to implement it, it is necessary to strengthen the links between the programs aimed at this public, so that family farmers, especially the less capitalized ones, have access to the PNAE market and there is an increase in supply.

Given the relevance of the topic and the growing cases of obesity among children and young people, more research is needed to evaluate actions focused on improving the eating habits of this target audience, who are still in the process of building their preferences. As an indication for future studies, we suggest a dynamic analysis of the behavior of obesity cases in the light of the various programs aimed at feeding schoolchildren.

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APPENDIX

Table A1 - Estimation of reduced forms of school performance and nutritional status

Variables	(1) Performance	(2) Nutritional status
Nutritionists by municipality	0,02***	
	(0,00)	
Average salary for nutritionists	-0,0008***	-0,001***
	(0,00)	(0,00)
Establishments with DAP by municipality	0,06***	-0,006***
	(0,01)	(0,00)
Interaction between instruments	-0,00000009***	0,00005***
	(0,00)	(0,00)
Constant	6,15**	25,03***
	(2,84)	(2,59)
Observations	1.528.296	10.784
Controls	Yes	Yes
R^2	0,05	0,16
F-statistics	91.84	-

Source: Survey results.

Note: Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. Standard errors for performance were clustered by school. In model 2, DAP per municipality was relativized by the number of schools. Controls models 1 and 2: urban area indicator; capital indicator; state fixed effects; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; ICGE; school administrative dependency indicator; proportion of teachers with higher education; percentage of teachers with adequate training for the position; total number of students per class; school food education indicator. Model controls 3 to 5: urban area indicator; capital indicator; municipal population; current GDP; indicator of municipality with strong agricultural sector; INSE; percentage of schools with food education, percentage of people with treated water at home.