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The impact of the National School Feeding Program on public schools in Ceará, Brazil

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Abstract

Purpose – This study evaluates the impact of the National School Feeding Program (PNAE) on academic performance in public schools, focusing on Portuguese language and mathematics exams from the Permanent System for the Assessment of Basic Education of Ceará (SPAECE) between 2008 and 2019.

Design/methodology/approach – We employ the generalized propensity score (GPS) methodology combined with a dose-response function to assess the impact of the program on the average student performance in these subjects at the school level, considering all educational stages in which SPAECE is administered.

Findings – Overall, the results indicate that larger transfers from PNAE to schools are, on average, associated with better academic outcomes. Furthermore, the marginal effects of additional transfers are positive but diminishing.

Originality/value – In addition to estimating PNAE transfers at the individual school level, a key contribution of this study is the application of the GPS methodology and dose-response function, which enables the identification of the differential impact of increased school meal funding on student performance. To the best of our knowledge, this is a novel result that enhances our understanding of both the importance and limitations of this type of resource transfer.

Keywords PNAE, School performance, Impact assessment, Dose-response function

Paper type Research paper

1. Introduction

The concept behind what is now known as the National School Feeding Program (PNAE) originated in the 1940s but failed to materialize due to a lack of financial resources. It was only in the 1950s that a structured, nationwide school meal program under public administration was implemented for the first time. Since 1979, this program has been officially known as PNAE.

JEL Classification — D04, C52, H52

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The program was established with the aim of, among other objectives, contributing to student growth and development, enhancing academic performance, and fostering healthy eating habits. One of its operational mechanisms involves providing meals that aim to meet students' nutritional needs during the school term [1]. Although it was designed to be universal, in practice, PNAE has primarily benefited nutritionally vulnerable students from low-income and low-education households. As such, it plays a crucial role in ensuring adequate nutrition for these students. According to Sturion, Silva, Ometto, Furtuoso, and Pipitone (2005), 46% of students in two municipalities from each geographic region of Brazil consumed school-provided meals daily, while 17% of those surveyed did not participate in the program.

Despite its importance, recent years have seen a weakening of key institutional support mechanisms for the program. Castro (2019) and Corrêa *et al.* (2020) highlighted the dissolution of the National Council for Food and Nutrition Security and the National Policy for Food and Nutrition Security. They also noted delays in the implementation of federal regulations during the COVID-19 pandemic. Additionally, Sidaner, Balaban, and Burlandy (2012) emphasized that improving access to healthy food requires local food production, as well as the integration of school meals and nutritional education into broader policies and programs. In recent years, the quality of school meals in Brazil has improved significantly, largely due to the increased availability of fruits and vegetables. However, national standards for menu composition have yet to be fully achieved. This shortfall is primarily attributed to persistent challenges such as conflicts of interest and the limited capacity of local producers to meet supply demands and comply with technical standards.

The weakening of a program that still struggles to fulfill its goal of providing healthy school meals is unfolding amid an economic crisis marked by the resurgence of hunger. Consequently, expanding direct benefit transfers that guarantee access to nutritious food is of utmost importance (Gupta, Seth, Abraham, & Pingali, 2021).

In terms of educational outcomes, Jomaa, Mcdonnell, and Probart (2011) emphasize that school feeding programs positively impact energy intake, micronutrient status, school enrollment, and attendance, when comparing participating children to non-participants. According to Rocha (2016), implementing public policies for school meals in basic education is critical, with PNAE being one of the oldest such initiatives in Brazil. Similarly, Gomes (2009) noted improvements in nutritional imbalances among public school students through PNAE and highlighted the importance of policymakers' focus on combating malnutrition. The consequences of malnutrition go beyond individual health and well-being, as it can hinder learning and the accumulation of human capital, ultimately affecting labor productivity and contributing to long-term inequality.

Ceará's education model has emerged as a benchmark for quality and effective management. Despite being one of the least developed states in Brazil, it has achieved remarkable results in assessments measuring the quality of basic education.

In a recent study by the World Bank, Loureiro, Cruz, Lautharte, and Evans (2020) argue that Ceará has developed a model of basic education capable of significantly reducing learning poverty—one that could be replicated in other states by following specific principles of management and efficiency. According to their findings, Ceará's education system experienced the most substantial improvement in the national quality index for elementary education between 2005 and 2017.

As a result of this successful experience in improving educational outcomes, the state has attracted significant attention from scholars in the field, even garnering interest from international education outlets such as the renowned magazine *The Economist* [2]. Thus, our study contributes to the literature by examining a potential explanatory factor for the region's improved school performance—one that has not yet been explored.

To date, no studies have evaluated the impact of the PNAE on academic performance; existing research has only investigated correlations with socioeconomic indicators. In light of this gap, the present study aims to assess the impact of the PNAE on student performance in Portuguese language and mathematics exams administered by the Ceará State Basic Education

Assessment System (SPAECE). Specifically, we evaluate the effect of the PNAE on the average academic performance of students in these subjects at the school level, considering all educational stages in which SPAECE is implemented.

Due to limitations in accessing data from periods prior to the implementation of the PNAE, we employ the Generalized Propensity Score (GPS) in conjunction with the Dose-Response Function (DRF) to estimate the program's impact. This methodological approach allows us to examine whether variations in treatment intensity (i.e. the amount of resources transferred) generate differential effects on the treated units.

In examining the educational impact of the PNAE, this study seeks to determine whether schools receiving greater allocations of program resources exhibit better academic performance than those receiving fewer resources. To this end, the GPS and DRF methodologies are appropriate, as they enable the estimation of the average effect of an intervention while accounting for treatment intensity – in this case, the estimated volume of PNAE resources transferred to each school.

Accordingly, this research contributes to the literature on the determinants of school performance by identifying the causal impact of the PNAE on the average academic achievement of schools in Ceará. Our analysis accounts for subject area – Portuguese or Mathematics – as well as educational stage, and explores the heterogeneity of program effects according to the amount of resources received by each school. To the best of our knowledge, this represents a novel contribution to the field.

Moreover, this is the first study to assess the impact of the PNAE on school performance using school-level data while accounting for different educational stages. Previous studies, such as Gomes (2020) and Ramos (2022), rely on municipal-level data and apply, respectively, Propensity Score Matching (PSM) and Regression Discontinuity Design (RDD). However, the way in which these methodologies were implemented does not allow for an analysis of potential heterogeneities in the program's effects stemming from variations in resource transfers across schools.

We hypothesize that schools receiving greater levels of resources would demonstrate improved performance relative to others. However, we also expect a threshold beyond which additional resources no longer yield significant improvements in outcomes. Consistent with this hypothesis, our results indicate that larger PNAE transfers are generally associated with higher average academic performance. Additionally, the marginal effects of increased allocations are positive but diminishing, regardless of the functional form assumed for the conditional expectation of the response variable.

The remainder of this paper is organized as follows: Section 2 presents a historical overview of the program and the related empirical literature; Section 3 details the methodology and empirical results; and Section 4 offers concluding remarks.

2. PNAE: history and empirical evidence

In 1965, the National School Feeding Program was formally established, marking the beginning of a collaborative effort involving various American organizations and the United Nations to provide essential resources. In 1979, the program was officially renamed the PNAE. From that point forward, it was implemented with funding sourced directly from the Ministry of Education (Félix, Souza, Santos, & Ramos, 2020).

The enactment of the 1988 Federal Constitution guaranteed the right to school meals for all elementary school students. A supplementary school feeding program was subsequently created, characterized primarily by the centralization of resources at the federal level. Beginning in 1994, under the administration of the National Fund for Educational Development (FNDE), the program began a process of decentralizing its resources to state and municipal governments. Since 2009, the program has been expanded to cover the entire public basic education system, mandating that at least 30% of its resources be used to purchase products from family farming enterprises [3].

With respect to financial resource allocation, the PNAE prioritizes agrarian reform settlements, traditional Indigenous communities, and Quilombola communities, particularly when procuring goods from family farmers (Fnde, 2017). Transfers are made on a per-student basis and are differentiated to more effectively address the specific needs of each beneficiary group (Fnde, 2021). Table 1, available in the Supplementary_file01, presents the per capita values allocated to each educational group for school food provision in all Brazilian public schools between 2008 and 2019.

It is worth noting that the per capita resources allocated to schools by educational group increased substantially between 2008 and 2019. Using 2008 as the base year and considering nominal terms, transfers to the daycare group rose by 386% over the period, while allocations to the preschool group increased by 141%. Transfers to Indigenous and Quilombola educational groups grew at a uniform rate of 45%. These are undeniably substantial growth rates.

Table 2, available in the Supplementary_file01, presents the PNAE transfer values – adjusted to 2020 prices – for the northeastern states of Brazil over the period from 2014 to 2020. Despite an average reduction of 7% in total allocations to these states during this period, the state of Ceará consistently ranked as the second-highest recipient of funds in the region. This pattern may help explain why Ceará has emerged as a national benchmark in terms of education quality and program management. According to Loureiro *et al.* (2020), Ceará's education system registered the most significant improvement in the national elementary school quality index between 2005 and 2017.

In the context of the right to adequate food, Pedraza *et al.* (2018) highlight the PNAE as an important strategy for promoting healthy eating. Currently managed by the FNDE, the program is popularly known as "school meals" (Fnde, 2017). The FNDE is responsible for disbursing federal PNAE funds to state education departments and municipal governments. These resources are distributed in up to ten annual installments, typically between February and November. The total amount allocated is determined based on the number of students enrolled in federal, state, municipal, and district schools, as reported in the previous year's School Census; the number of school days; and the per-student rates established in Article 47 of Resolution CD/FNDE No. 6/2020 (Fnde, 2021).

School feeding programs are widespread in developing countries; however, many of these initiatives are targeted and often make food provision conditional upon specific requirements, such as school attendance (Adelman, Gilligan, & Lehrer, 2008). In contrast, the PNAE is a more comprehensive program, characterized by its universal coverage. It allocates financial resources on a per-student basis without requiring direct contributions from families or students. While conditional programs might be expected to generate stronger impacts on educational outcomes, the PNAE also exerts influence over local food markets – both large-scale and small-scale – particularly since 2009, when the program mandated a minimum percentage of purchases from family farms. As such, it is essential to analyze the PNAE and other educational nutrition initiatives and evaluate their impacts on both educational and socioeconomic indicators.

Turning to the empirical literature, there remains a notable scarcity of studies examining the impact of school feeding programs such as the PNAE on academic achievement. In the context of Northeast Brazil, Gomes (2020) investigated the impact of the PNAE on the Basic Education Development Index (IDEB). The study employed a propensity score matching approach to assess the effects of the program in public schools across northeastern municipalities. The findings indicated that municipalities adhering to the PNAE's funding regulations experienced higher IDEB scores in elementary education. Specifically in Ceará, the state consistently ranked among the top recipients of PNAE funding in the Northeast between 2012 and 2016 and had the highest number of students benefiting from the program from 2009 to 2018.

Félix *et al.* (2020) analyzed the program's effect on agricultural GDP, focusing on the mandate that, since 2009, 30% of PNAE funds must be allocated to family farming. The authors used a panel data model for municipalities in Paraíba to measure this impact; however, the estimated coefficients for agricultural GDP were not statistically significant.

In the education sector, Viégas Serra and Gasparini (2022) aimed to assess the impact of the PNAE on improving the efficiency of educational service delivery in Brazilian municipalities. Initially, they employed a data envelopment analysis to construct a productivity index for elementary education services. In the second stage, a regression model was used to estimate the effects of PNAE transfers and other socioeconomic variables on this index. The results indicated that PNAE allocations positively contributed to improving the efficiency of educational service delivery.

Law No. 11,947/2009 established the mandatory allocation of at least 30% of PNAE resources for the purchase of food from family farming. At the municipal level, Ramos, Oliveira, Quintanilha, and Rodrigues (2022) examined the relationship between compliance with this law and the IDEB performance of Brazilian municipalities in 2017. Employing a regression discontinuity design, the authors identified a clear discontinuity at the 30% procurement threshold, demonstrating that medium-sized municipalities that complied with the PNAE procurement requirement had higher IDEB scores than those that did not.

In line with this perspective, Silva, Ciríaco, and Zen (2023) analyzed the impact of the changes introduced to the PNAE by Law No. 11,947/2009 on the quality of education. Their findings indicate that an increase in the share of purchases from family farms is positively associated with improvements in academic performance among elementary school students. Comparing the years 2013 and 2019—a period in which the procurement policy was consolidated—the authors observed statistically significant increases in average scores in both Portuguese and Mathematics in the Basic Education Assessment System (SAEB).

A decomposition of these results revealed that the PNAE was among the most relevant variables in explaining the observed improvements over time, reinforcing the program's multidimensional nature. In addition to promoting food security and adequate nutrition among students, the program strengthens family farming and contributes to greater educational equity.

Deus and Silva (2023) investigated the role of nutritionists in the implementation of the PNAE and its effects on academic performance, measured by proficiency scores in Portuguese and Mathematics in the 2019 SAEB. Using the Local Average Treatment Effect (LATE) methodology, the authors found that the presence of nutritionists was associated with an average increase of 12.3 points in Portuguese and 36.84 points in Mathematics scores. These effects were more pronounced among students from lower socioeconomic backgrounds, suggesting that the PNAE has a stronger impact on more vulnerable populations.

Their findings also indicated that the presence of nutritionists is associated with higher compliance with PNAE guidelines, including the procurement of food from family farms. This reinforces the importance of nutritionists not only in the technical execution of the program but also in the development of school menus and the promotion of healthy eating habits, which can improve students' nutritional status and, consequently, their academic outcomes.

Porrua and Colussi (2023) proposed an innovative model for evaluating the performance of Executing Entities (EEs) in managing the PNAE. Using a normative and quantitative approach, they analyzed 5,499 EEs across Brazil and revealed a concerning scenario: over half (52.43%) were classified as having "Poor" performance, while only 2.18% received a "Good" rating.

The most significant deficiencies were observed in the Family Farming dimension, where 71.3% of EEs failed to meet the minimum 30% direct procurement requirement, and in Menu Planning, where 50.2% of EEs did not perform acceptability tests and 41% failed to calculate the meal adherence index. Additionally, the lack of adequate infrastructure for the School Food Council (CAE) emerged as a critical issue, with 85.9% of EEs not ensuring sufficient financial support for the council's operations.

On a more positive note, the Food and Nutrition Education (EAN) subdimension stood out, with 64.8% of EEs incorporating educational activities into their schools' Political-

Pedagogical Projects. Moreover, the presence of a technically responsible nutritionist was nearly universal (98.7%), indicating progress in the program's technical structuring.

Internationally, many food assistance programs for impoverished populations are conditional on educational requirements. For instance, in 1993, Bangladesh launched the Food for Education program, which provided rice and wheat to poor families on the condition that their children attend elementary school. Ahmed and Del Ninno (2002) used a probit model to estimate the program's educational impacts. Their results indicated that as families received more grain, the probability of school enrollment and attendance among children increased. The study also found evidence of higher learning outcomes for students participating in the program compared to non-participants.

Similarly, Jacoby, Cueto, and Pollitt (1996), as well as Powell, Walker, Chang, and Grantham-Mcgregor (1998), also identified a positive association between food-for-education programs and increased school enrollment and attendance. However, these studies were based on data from students already enrolled in school, which introduces potential selection bias.

3. Methodological aspects

To assess the impact of PNAE transfers on academic performance, we use the GPS, following the estimation strategy outlined by Bia and Mattei (2008) and Guardabascio and Ventura (2014). The data used in the analysis are described below, followed by a presentation of the methodological strategy.

Before proceeding, we describe how PNAE expenditure was estimated. Due to the lack of publicly available information on PNAE allocations at the school level, expenditure was estimated based on decrees and resolutions published by the Ministry of Education (MEC) and/or FNDE, as well as enrollment data from the School Census. In every case, 200 school days were taken into account. Furthermore, all secondary classes were considered part of the regular education system. To minimize underestimation of allocations, classes for which the educational stage could not be identified were classified as elementary.

Finally, we excluded from the sample any schools that reported receiving no funding from the PNAE program. In summary, we estimate these allocations using the following equation:

$$PNAE = \left(\sum_{j=1}^{n} enrolled_{ijt-1} \times allocation_{ijt} \right) \times 200 \tag{1}$$

where *enrolled* denotes the number of students enrolled in school i in educational level j in year $t-1$; and *allocation* denotes the per-student transfer allocated to school i, educational level j, and period t, according to the values presented in Table 1, [4].

Based on Table 1 and Equation (1), we can assert that the amount of resources distributed to each school over time varies according to the number of students enrolled in the previous year, their corresponding educational stage, and their ethnicity – in the case of Indigenous and Quilombola students – without any direct relationship to the type of school (municipal, state, or federal).

Additionally, the transferred amounts may also be adjusted due to changes in MEC resolutions, which modify the per-student daily funding rate. In our estimates of annual PNAE transfers per school, we excluded students enrolled in Initial and Continuing Education (FIC, in Portuguese) courses, as well as those for whom it was not possible to determine the corresponding educational stage.

We plot the evolution of the estimated average real expenditures of the PNAE in Graph 1, available in the Supplementary_file01. We can see that the average transfer per school reached its peak in 2013, with approximately R$28,008,00 transferred.

To assess the accuracy of the estimated transfers at the school level, we aggregated our estimated funding allocations at the municipal level. This approach was chosen because PNAE expenditure data are publicly available at the municipal level for the period from 2011 to 2019, allowing for a comparative analysis.

In a dataset comprising 1,654 estimated values at the municipal level, we observed that only 1.63% of the cases resulted in exact matches. In the most frequently observed outcome, approximately 61% of the time, the estimates derived from Equation (1) tended to overestimate the amount transferred at the municipal level. Given that the simplifications made to estimate PNAE transfers at the school level would typically lead to an underestimation of expenditures, these results provide strong evidence that a significant number of municipalities may not be receiving the transfers as mandated by law.

Chart 1, available in the Supplementary_file01, outlines the key variables of interest, which measure academic performance across different educational stages, as well as the treatment variable, defined as the allocation provided by the PNAE to schools in the state of Ceará. Additionally, it includes the set of covariates used in the analysis, selected based on a comprehensive review of the empirical literature identifying the main determinants of academic performance.

Furthermore, regarding our outcome variable – the average SPAECE scores per school and educational stage – it is important to note that this exam is conducted on a census basis by the government of the state of Ceará. Specifically, SPAECE is administered to all students in all municipal and state public schools, and since 2007, it has been applied to the 2nd, 5th, and 9th grades of elementary school (ES), as well as the 3rd grade of secondary school (SS).

In this context, our sample includes all public schools in Ceará from 2008 to 2019 for which we estimated positive PNAE fund transfers. In the GPS and DRF estimations, we use subsamples disaggregated by educational stage and subject – Mathematics and Portuguese Language. Consequently, our subsamples consist of 6,470, 6,117, 3,511, and 677 schools for the 2nd, 5th, and 9th grades of ES, and the 3rd grade of SS, respectively.

3.1 Generalized propensity score and dose-response function

Consider a random sample of public schools indexed as $i = 1,2,...,N$. For each school i, we assume a potential set of outcomes $Y_i(t)$, where $t \in T =, t_1$, which is referred to as the DRF. Note that in the case under consideration, the treatment variable is defined over an interval on the real line, as opposed to the binary treatment case where $T = \{0, 1\}$. The variable $Y_i(t)$ represents the average SPAECE exam score of the *i-th* public school. The treatment variable T represents the PNAE financial resources allocated to each public school. Additionally, there is a vector of covariates X_i, and we aimed to calculate the DRF $\gamma(t) = E[Y_i(t)]$.

As the allocation of funds to schools is determined by the number of enrolled students, there are variations in the amounts received from the PNAE. Consequently, the GPS was used to assess whether these differences in funding allocation have led to heterogeneous effects on student performance on the SPAECE exam. Thus, the aim was to determine whether increased financial support has an impact on academic performance, using a DRF to analyze the effects. The underlying hypothesis of this study posited that schools receiving greater resources are better equipped to provide higher quality school meals. This, in turn, helps maintain better student nutrition and higher attendance rates, both of which contribute to improved performance on exams.

The GPS method was implemented in three stages. First, the propensity score $r(t,x)$ was estimated, which is the conditional density of the treatment given the covariates $f_{T \vee X}(t \vee x)$. In this work, the parameters were not estimated using a linear regression model, but through a generalized linear model (GLM) proposed by Mccullagh and Nelder (1989). This approach diverges from the linear regression model in that the distribution of T is specified from the exponential family, and furthermore, a non-identity transformation of the treatment mean is linearly related to the explanatory variables. These facts can be summarized in the following equations:

$$f(T) = c(T,\phi)exp\left\{\frac{T\theta - a(\theta)}{\phi}\right\} \tag{2}$$

$$g\{E(T)\} = \beta' X \tag{3}$$

where the choice of the family $a(\theta)$ is guided by the nature of the treatment variable [5]. On the other hand, $g(\cdot)$ is a monotonic and differentiable function called the link function, and its choice is defined by the functional form of the relationship between the treatment and the explanatory variables [6]. While this function determines how the mean is related to the covariates X, θ and φ represent the canonical parameter and dispersion parameter, respectively [7].

In this work, a normal distribution was assumed for the treatment of the covariates [8]. The GLM has the advantage of accommodating a heteroscedastic treatment, as it allows T to be a member of the exponential family. Using the GLM method, it is possible to estimate β by maximizing the following logarithmic version of a quasi-maximum likelihood function for T_i independently distributed:

$$l(\beta) \equiv \sum_{i=1}^{N} l_i(\beta) \equiv \sum_{i=1}^{N} logf(T_i;\,\beta) = \sum_{i=1}^{N} \left\{logc(T_i,\phi) + \frac{T_i\theta_i - a(\theta_i)}{\phi}\right\} \tag{4}$$

As the GPS represents the conditional density of the treatment given the covariates, it can be computed using the exponential density function evaluated at β given the covariates. Thus,

$$R = r(T,X) = f\left(\widehat{\beta}\right) \tag{5}$$

where the function f is defined as per Equation (2), [9]. A natural logarithm transformation was applied to both the treatment and outcome variables. To assess the validity of the normality assumption for the treatment conditional on the covariates, the Shapiro-Francia normality test was conducted.

Next, the expected outcome (Y_i) was estimated conditional on the treatment (T_i) and the GPS $(R = r(T,X))$, modeled as a flexible function of these two variables. This approach allows for second- and third-order polynomial approximations. Thus, we have

$$\varphi\{E(Y_i|T_i,R_i)\} = \lambda(T_i,R_i;\,\alpha) = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 R_i + \alpha_4 R_i^2 + \alpha_5 T_i R_i \tag{6.a}$$

or

$$\varphi\{E(Y_i|T_i,R_i)\} = \lambda(T_i,R_i;\,\alpha) = \alpha_0 + \alpha_1 T_i + \alpha_2 T_i^2 + \alpha_3 T_i^3 + \alpha_4 R_i + \alpha_5 R_i^2 + \alpha_6 R_i^3 + \alpha_7 T_i R_i \tag{6.b}$$

where $\varphi(.)$ is a link function that links the predictor $\lambda(T_i,R_i;\,\alpha)$ and the expected value, $E(Y_i|T_i,R_i)$.

Finally, the DRF was estimated from the average of the conditional expectation estimated using the GPS at each treatment level of interest. More specifically, to obtain an estimate of the entire DRF, the average potential outcome was estimated for each treatment level:

$$E\{\widehat{Y(t)}\} = \frac{1}{N}\sum_{i=1}^{N} \widehat{\gamma}\{t,\widehat{r}(t,X_i)\} = \frac{1}{N}\sum_{i=1}^{N} \varphi^{-1}\left[\widehat{\lambda}\{t,\widehat{r}(t,X_i);\,\widehat{\alpha}\}\right] \tag{7}$$

where $\widehat{\alpha}$ represents the vector of parameters estimated in the second stage. In addition, tests were conducted to assess the balancing property.

4. Analysis and discussion of results

Below are the estimated Dose-Response Functions (DRFs) for the following outcome variables: school performance on the SPAECE Portuguese Language exam for 2nd-, 5th-, and 9th-grade elementary classes; performance on the Mathematics exam for 5th- and 9th-grade elementary classes; and performance in both subjects for 3rd-grade secondary classes. In estimating the conditional expectation of the outcome given the treatment and the GPS, as defined in Equations (6.a) and (6.b), we consistently adopt a specification that includes second- and third-order terms in both the treatment and the GPS [10].

The treatment intervals were divided into four sub-intervals for each educational stage [11], based on the quartiles of the treatment distribution, in order to maintain a similar number of observations [12] in each quartile. In addition to the covariates discussed in the previous section, all estimations include a set of time dummy variables to capture the effects of common shocks potentially caused by curriculum changes or other educational reforms.

The results of the mean difference tests conducted before data balancing – which assess the balancing property [13] – are presented in Tables 4.a to 4.d, and post-balancing results are presented in Tables 5.a to 5.d of the supplementary document (Supplementary_file01). The estimates for the conditional expectation of the outcome given the treatment and the estimated GPS are shown in Tables 6 and 7 of the Supplementary_file01. These results indicate that the coefficients of the estimated DRF are statistically significant in most specifications, regardless of functional form. The balancing property was satisfied for each sub-interval in all cases at a significance level below 1%.

Before balancing, the absolute values of the *t*-statistics in the mean difference tests exceeded 1.96 in approximately 94.44, 88.89, 97.22, and 69.44% of cases for the 2nd, 5th, and 9th grades of elementary school and the 3rd grade of secondary school, respectively. After balancing, these percentages fell to 41.67, 44.44, 83.33, and 11.11%, respectively.

The Table 3 of the Supplementary_file01 presents the results of the Shapiro–Francia normality tests. In all cases, the null hypothesis of normality for the treatment distribution, conditional on the covariates, is not rejected at the 1% significance level. However, for the 3rd grade of secondary school, this hypothesis is rejected at the 5% level. Therefore, the results regarding the impact of PNAE on school performance for this group should be interpreted with caution, as the normality assumption may not hold.

Finally, the estimated dose-response curves were analyzed. In all reported figures, the DRF appears on the left, while the Average Treatment Effect (ATE) curve appears on the right. The ATE curve can be interpreted as the derivative of the DRF.

Figure 1 shows the impact curves of PNAE allocations on school performance in SPAECE-alpha, the Portuguese language proficiency test for 2nd-grade elementary classes. In all cases, there is a positive and decreasing impact of PNAE allocation on performance in the exam.

Therefore, the allocations transfers generate positive marginal effects on performance, but these become smaller and smaller as the transfers become larger. This happens until the DRF curves reach a peak, where the impact of the allocations is zero. After this peak, the effect is ambiguous, as it depends on the functional form chosen for the expectation of the outcome variable conditional on treatment and GPS, being negative in the quadratic case and close to zero in the cubic case.

The same exercise was repeated for the other stages of education, but now considering the effects on the mathematics proficiency test, which is only given to classes from the 5th grade of elementary onward. The results are shown in Figure 2. Similar to previous observations, it can be concluded that the PNAE allocation to schools has a positive and decreasing impact on

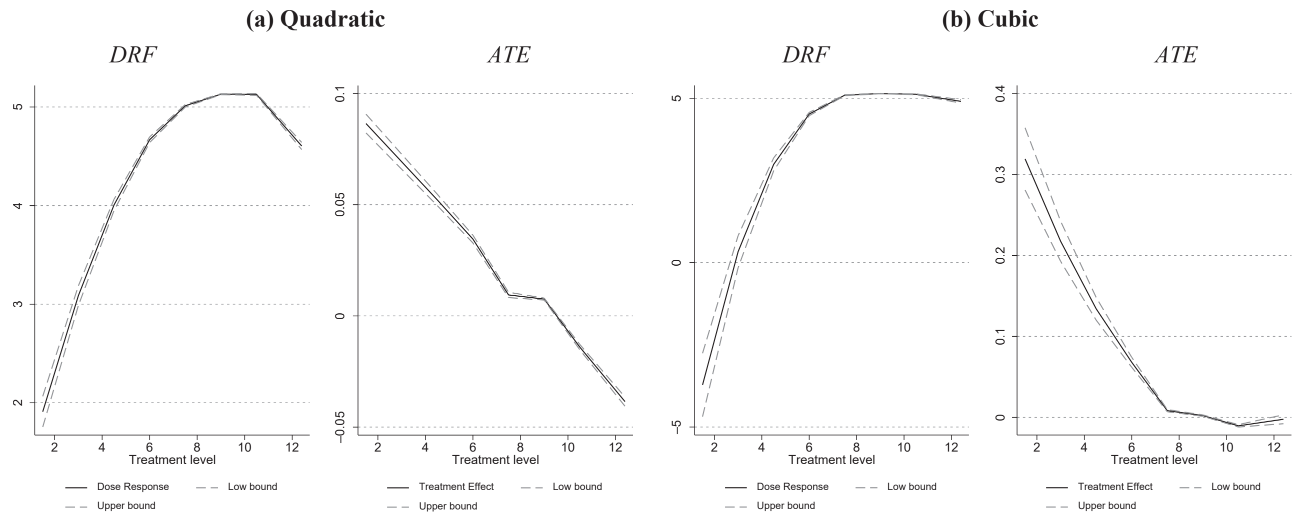

Figure 1. Dose-response function and treatment effect—proficiency exams in Portuguese language for 2nd-grade elementary school students. Note: The balancing property is satisfied for a level below 1%. The dashed lines indicate the 95% confidence interval based on 1,000 bootstrap samples. Source: Prepared by the authors

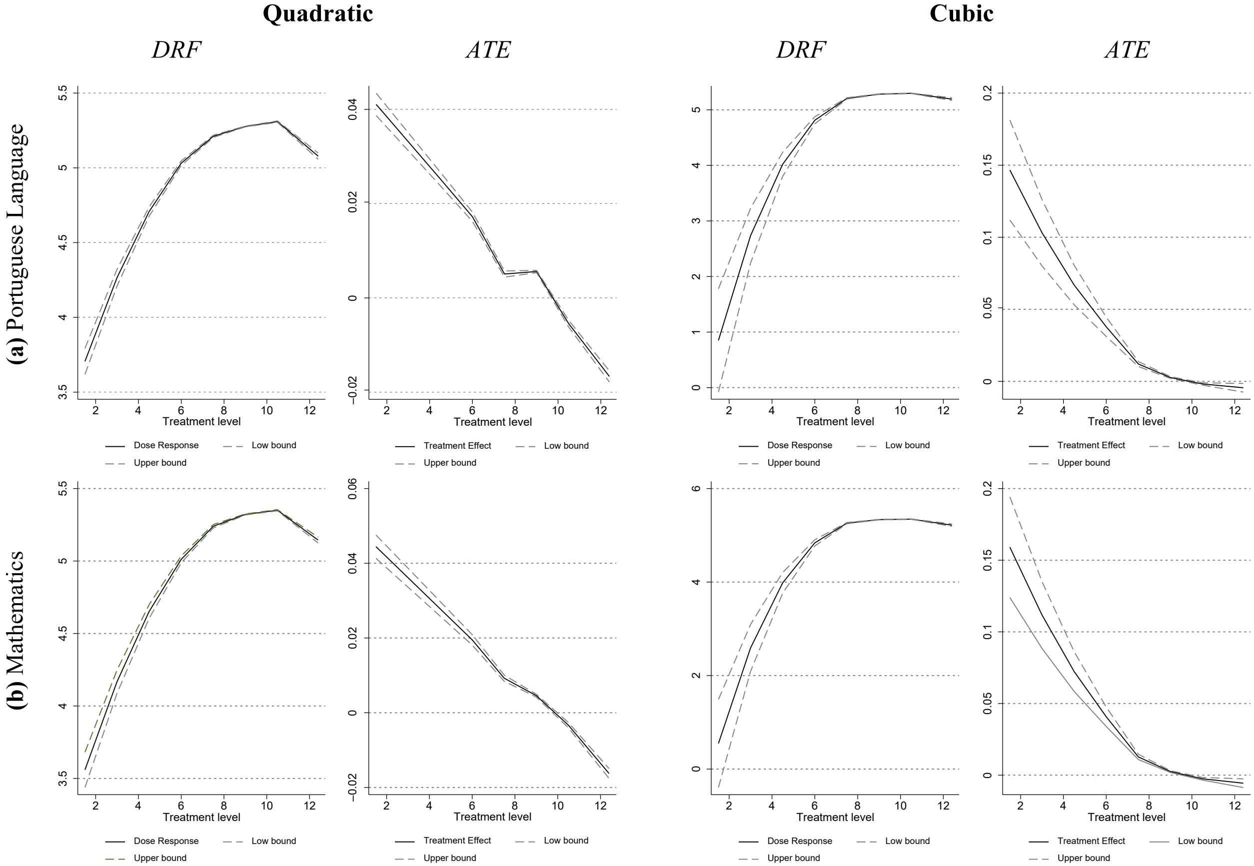

Figure 2. Dose-response function and treatment effect – Portuguese language and mathematics proficiency exams of 5th grade elementary school classes. Note: The balancing property is satisfied for a level below 1%. The dashed lines indicate the 95% confidence interval based on 1,000 bootstrap samples. Source: Prepared by the authors

performance on the Portuguese exam, and the same behavior is observed for the mathematics exam.

For students enrolled in the 9th grade of elementary school, this trend continues, as can be seen in Figure 3.

In other words, there is once again a positive and decreasing impact of the PNAE allocation on students' school performance on both tests. In this case, it should be noted that the confidence intervals are less aligned with the DRF and ATE in cases where up to third-order polynomials are applied for the treatment and GPS, when proficiency in Portuguese is the outcome variable.

Finally, for students in the 3rd grade of secondary, the results were similar to those reported above for both exams and the adopted functional form. We can therefore see behavior that corroborates the findings for the cases of the 2nd, 5th, and 9th grades of elementary, as shown in the graphs in Figure 4.

Based on the observed results, it can be concluded that increased allocations of PNAE resources per school are associated with improved student performance in Portuguese language and mathematics exams. However, this positive impact diminishes as allocations rise, eventually becoming negligible. Furthermore, the analysis of confidence interval adjustments suggests that a quadratic functional form for the conditional expectation of the response variable is more appropriate for evaluating the impact of PNAE allocations on school performance in the SPAECE.

In summary, we affirm that PNAE fund transfers exert a positive influence on academic performance, regardless of the educational stage or subject assessed. Moreover, the impact is more pronounced in schools that receive higher levels of funding compared to those with lower allocations. Nevertheless, the effect is diminishing, implying that the marginal gains in performance indicators decrease as the program's transfers increase.

Thus, the program's transfers appear to reach an average maximum impact on academic performance at approximately R$22,026.47 in most cases. This value corresponds to the estimated maximum of the DRFs and Treatment Effect curves presented in Figures 1–4. In other words, beyond this threshold, no significant effects of PNAE transfers are observed on the SPAECE performance of 2nd, 5th, and 9th-grade elementary school students, as well as 3rd-grade secondary school students.

It is important to emphasize that this result does not imply that PNAE transfers to schools should be reduced. Other relevant aspects – such as meal quality and nutritional value – must also be taken into account when defining appropriate funding levels.

To assess the robustness of the results, we repeated the empirical exercise using an alternative set of covariates to estimate the GPS. This specification included municipal fixed effects and a binary variable indicating whether the school's administrative dependence is municipal or state. The results showed no meaningful changes in the quadratic estimates of the conditional expectation of the response variable. However, greater uncertainty – reflected in wider confidence intervals – was observed in estimates based on the cubic functional form. Notably, the direction of the estimated effects remained unchanged. These results are presented in Figures 1.a – 4.a and Tables 6.a and 7.a of the supplementary document (Supplementary_file01).

Finally, additional estimations were performed to account for potential effects related to school size. Specifically, we added the number of students enrolled in each school to the set of covariates, which already included infrastructure-related variables that capture school characteristics. These estimations indicated that, with the exception of the quadratic DRFs for 3rd-grade secondary school, there were no significant changes in the direction or statistical significance of the estimated results. Therefore, it can be concluded that the main findings reported in this study are robust to alternative specifications of the covariate set. These results are presented in Figures 1b – 4b and Tables 6.b and 7.b of the supplementary document (Supplementary_file01).

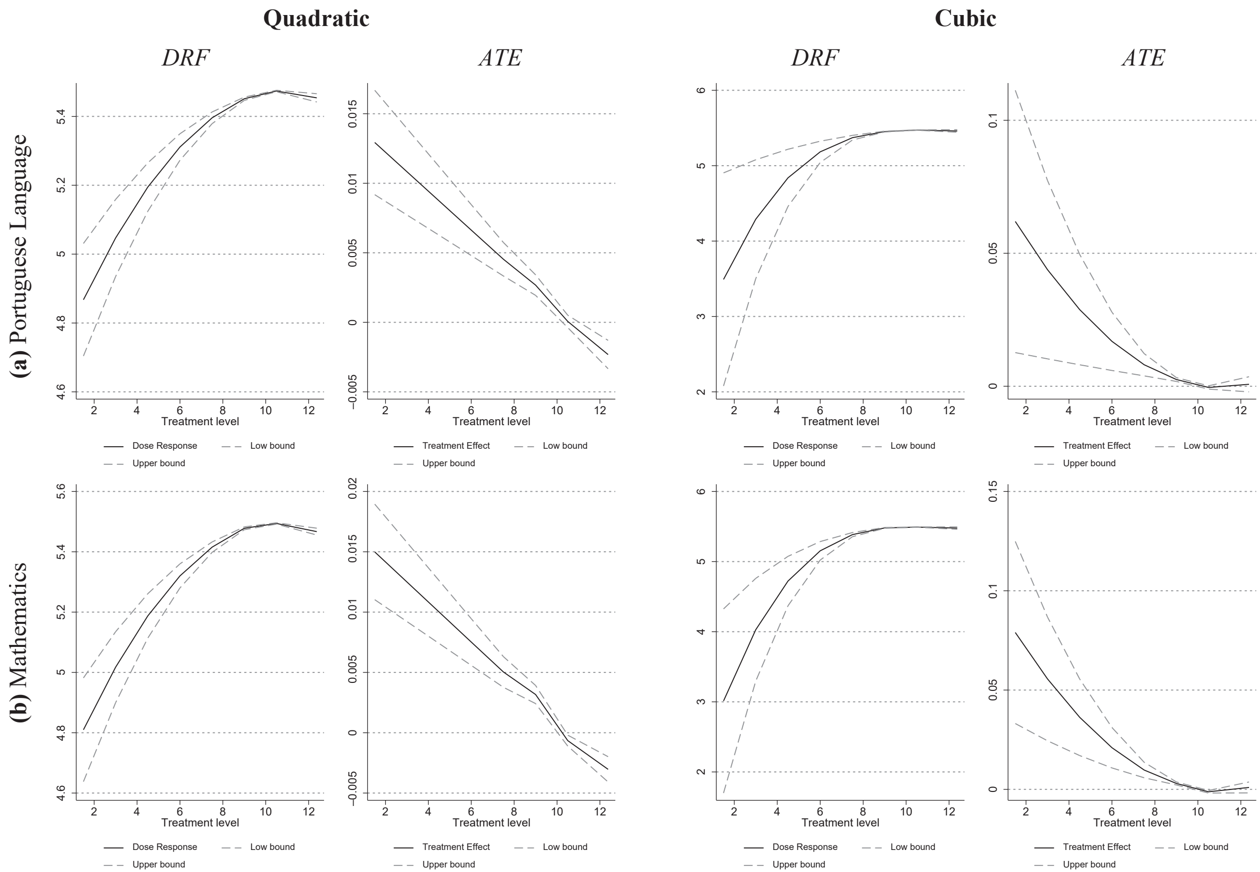

Figure 3. Dose-response function and treatment effect – Portuguese language and mathematics proficiency exams of 9th grade elementary school classes. Note: The balancing property is satisfied for a level below 1%. The dashed lines indicate the 95% confidence interval based on 1,000 bootstrap samples. Source: Prepared by the authors

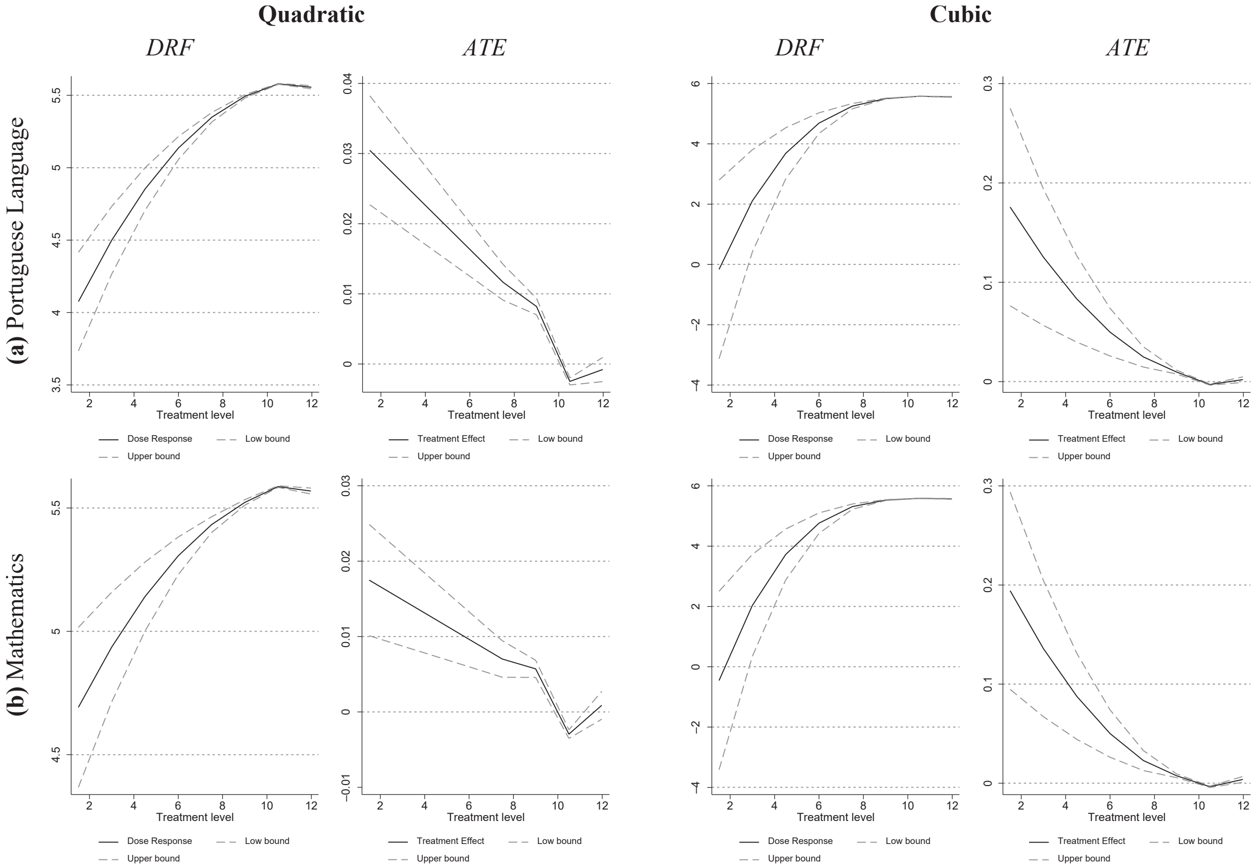

Figure 4. Dose-response function and treatment effect – Portuguese language and mathematics proficiency exams of 3rd grade secondary school classes. Note: The balancing property is satisfied for a level below 1%. The dashed lines indicate the 95% confidence interval based on 1,000 bootstrap samples. Source: Prepared by the authors

5. Conclusion

This study aimed to assess the impact of resource transfers from the PNAE to public schools in the state of Ceará on students' average performance in Portuguese Language and Mathematics exams. Under the hypothesis that increased funding allocations are associated with improved academic performance, the impact of the program was assessed using a GPS model and a DRF. This analysis was conducted for students in the 2nd, 5th, and 9th grades of ES, as well as those in the 3rd grade of SS.

For all grade levels and subjects, there was a positive but diminishing impact of estimated PNAE expenditures on academic performance. This result was graphically summarized by the dose-response curve, which had a concave shape. Furthermore, the DRF curve appeared to fit better to a quadratic model of the conditional expectation of the response variable, as the confidence intervals indicated a better fit in these cases. It is also important to highlight the robustness of the results, which remained consistent even when the covariate vector was adjusted to account for municipal fixed effects, school's administrative dependence, and the size of schools participating in the PNAE. These findings are consistent with those of Jacoby *et al.* (1996) and Powell *et al.* (1998), who identified a positive relationship between nutritional programs and school performance indicators.

Within the PNAE framework, the results of this article support the findings of Gomes (2020) and Viégas Serra and Gasparini (2022). The former identified a positive correlation between program expenditures and the IDEB at the municipal level, while the latter found similar evidence related to the efficiency of educational services in municipalities. To our knowledge, no previous studies have identified direct positive impacts of PNAE allocations on school performance in Brazil. However, since the results were based on estimated PNAE expenditures – which in most cases overestimate actual municipal-level allocations – these findings should be interpreted as an indication that PNAE transfers need to be better aligned with the standards established by MEC/FNDE.

As previously noted, our results suggest that there is an average maximum threshold – approximately R$22,026.47 – beyond which additional PNAE transfers no longer produce significant effects on academic performance. However, this figure should not be interpreted as a definitive cap for resource allocation, as factors such as the quality and nutritional value of meals must also be considered in determining appropriate funding levels.

Rather, this result suggests that there are limits to the extent to which school feeding programs can influence academic outcomes. Therefore, we argue that public policies aiming to improve school performance must also consider other influential factors, such as age, sex, race, and participation in the *Bolsa Família* cash transfer program (Rodrigues, Costa, Silva, Mariano, & Jesus Filho, 2020; Melo & Suzuki, 2021; Benevides & Soares, 2020; Park, Goodman, Hurwitz, & Smith, 2020), as well as elements related to physical infrastructure, geography, and administrative dependence (Hanushek, 2010; Rodrigues *et al.*, 2020; Benevides & Soares, 2020).

Furthermore, since the methodology employed allows for the identification of the ATE, and no evidence of endogeneity issues was found in the previous estimates, the results suggest that there is a ceiling to the PNAE's capacity to positively influence academic performance in Brazilian schools. Therefore, additional public policies aimed at improving student achievement should be implemented in conjunction with the PNAE in order to effectively enhance academic outcomes.

Future research should aim to track PNAE transfers at the individual school level to better estimate the effect of the program on actual school expenditures. Moreover, it is important to investigate in greater detail the mechanisms – such as improved attendance and enhanced nutrition – that may help explain the program's positive impact on school performance.

Notes

1. For more information, see: Food and Nutrition Education – Education Development Fund Portal.
2. For more information, see: What a Brazilian state can teach the world about education.

3. These guidelines were established by Law No. 11,947/2009.
4. The estimated transfers from the PNAE were adjusted for inflation using the Broad Consumer Price Index (IPCA, in Portuguese) for the Metropolitan Region of Fortaleza, with 2019 as the base year.
5. Regardless of the chosen distribution, the first and second moments of the distribution will be given by $E(T) = \dot{a}(\theta)$ and $Var(T) = \phi\ddot{a}(\theta)$, respectively.
6. In this research, an identity functional form was used for $g(.)$.
7. In most situations, the form of $c(T, \phi)$ is not of interest. For more information, see Chapter 3 of De Jong and Heller (2008).
8. Therefore, it is assumed that a follows a normal distribution, and an identity is adopted for $g(.)$, a choice that aligns with the findings of Guardabascio and Ventura (2013).
9. The linear specification was tested, and despite the poor fit of the confidence intervals, which introduces some uncertainty, no significant changes were observed in the direction of the effect of PNAE expenditures on school performance. These results are available on request.
10. For more information, see Guardabascio and Ventura (2014).
11. The intervals were divided into [5.3936, 8.6089], [8.6110, 9.3826], [9.3843, 9.9988] and [9.9993, 12.3814] for second grade of ES; [5.1705, 8.7765], [8.7792, 9.4712], [9.4713, 10.0732] and [10.0733, 12.3814] for fifth grade of ES; [6.4922, 9.3237], [9.3244, 9.8320], [9.8324, 10.3615] and [10.3617, 12.3814] for ninth grade of ES; and [7.0031, 10.1121], [10.1129, 10.4941], [10.4946, 10.8743] and [10.8754, 11.9797] for third grade of SS.
12. The number of observations in each of the groups was approximately 10,796, 10,771, 10,786 and 15,978 for the 2nd grade of ES, respectively; 10,139, 10,116, 10,102 and 14,896 for the 5th year of ES, respectively; 6,300, 6,298, 6,299 and 6,292 for the 9th year of ES, respectively; and 1,414, 1,413, 1,415 and 2033 for the third year of SS, respectively.
13. It involves examining whether the conditional mean of pre-treatment variables, given the GPS, remains consistent between units within a specific treatment interval and those in all other treatment intervals.

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Further reading

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Supplementary material

The supplementary material for this article can be found online.

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