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Tese

Essays on economic development

Cíntia Amaral Pinto Cezar

Pelotas
2022

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Tese submetida ao Programa de Pós-graduação em Organizações e Mercados da Universidade Federal de Pelotas como requisito parcial para obtenção do título de Doutora em Economia Aplicada.

Orientador: Prof. Dr. Daniel de Abreu Pereira Uhr

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Summary

1. General introduction

This doctoral thesis applied two microeconometric techniques. We analyze the effect of the Conditional Income Transfer Program on child nutrition and the effect of sustainable technologies on electricity demand in Brazil. The first essay analyzes the effect of the Bolsa Família Program on the total food consumption of children in Brazil, using energy measurements in kilocalories, kilojoules and macronutrients (carbohydrates, proteins and lipids). We apply the ordinary least squares method for complex samples (Ordinary Least Square Survey). We proposed several subsample analyzes from the regions of Brazil and the urban area to test the robustness of the results. In the second essay, we identified the effect of sustainable technologies on electricity demand in Brazil and its implications for inequality in residential electricity consumption. We used the Inverse probability weight risk to identify the mean population-level treatment effect and the unconditional quantile treatment effect estimator for the analysis of heterogeneous treatment effects. We consider a correction to the sample data structure in both samples. We applied the placebo test and subsample samples to verify the robustness of the results. In both trials, we used the database of the Household Budget Survey (POF2017-2018) of the Brazilian Institute of Geography and Statistics.

The results of the first trial indicate that the “Bolsa Família” program positively affects the average consumption of macronutrients by children of beneficiary families, with these effects concentrated in the North and Northeast regions of Brazil, indicating that the PBF contributed to better food possibilities for low-income children. The results of the second essay show that the adoption of energy transition technology increases residential electricity consumption mainly in the higher quantiles of consumption distribution, imposing inequality in residential electricity consumption.

2. A study on the effect of the Brazilian conditional cash transfer program on child nutrition

Abstract

This article aims to identify the effect of the Brazilian conditional cash transfer program (Programa Bolsa Família - PBF) on the food condition of children in beneficiary families. We analyzed the effects of the BFP on the following outcome variables: (i) Energy in Kcal; (ii) Energy in KJ; (iii) Carbohydrates; (iv) Proteins; and (v) Lipids. We used microdata from the Household Budget Survey of the Brazilian Institute of Geography and Statistics (IBGE) for the period between 2017 and 2018. We applied the ordinary least squares method for complex samples (Ordinary Least Square Survey) and the matching methods (Propensity Score Weighting and Propensity Score Matching), adjusting for the complex data structure. We performed as robustness strategies: the placebo test, analysis for heterogeneous effects in the country's macro-regions and urban areas. The results show that the program positively affects the average consumption of macronutrients by children in beneficiary households, with these effects concentrated in the north and northeast regions of Brazil.

Keywords: Bolsa Família; macronutrients; propensity score matching

JEL: H53; I18; D60.

Resumo

Este artigo tem como objetivo identificar o efeito do programa brasileiro de transferência de renda condicionada (Programa Bolsa Família - PBF) na condição alimentar de crianças de famílias beneficiárias. Analisamos os efeitos do PBF nas seguintes variáveis de desfecho: (i) Energia em Kcal; (ii) Energia em KJ; (iii) Carboidratos; (iv) Proteínas; e (v) Lipídeos. Utilizamos microdados da Pesquisa de Orçamentos Familiares do Instituto Brasileiro de Geografia e Estatística (IBGE) para o período de 2017 a 2018. Aplicamos o método dos mínimos quadrados ordinários para amostras complexas (Ordinary Least Square Survey) e os métodos de pareamento (Propensity Score Weighting and Propensity Score Matching), ajustando para a estrutura de dados complexa. Realizamos como estratégias de robustez: o teste placebo e análise de efeitos heterogêneos nas macrorregiões do país e áreas urbanas. Os resultados mostram que o programa afeta positivamente o consumo médio de macronutrientes pelas crianças das famílias beneficiárias, com esses efeitos concentrados nas regiões Norte e Nordeste do Brasil.

Palavras-chave: Bolsa Família; macronutrientes; pareamento por escore de propensão

JEL: H53; I18; D60.

2.1. Introduction

In recent years, there has been a growing interest in applying cash transfer programs to improve beneficiaries' nutritional and health outcomes (Rasella et al., 2013; Shei et al., 2014). There is evidence of the impact of cash transfer programs - conditional or unconditional - on health (Angee Yaquelin and Mary Yesenia, 2019; Cooper et al., 2020; Ohrnberger et al., 2020; Oliosi et al., 2019; Owusu-Addo et al., 2018; Pega et al., 2017; Pescarini et al., 2020; Silva and Paes, 2018; Souza et al., 2021), on the fertility rate of women (Laszlo et al., 2019; Rocha, 2018), food security and nutritional status of families (Bhalla et al., 2018; Brugh et al., 2018; Carmo et al., 2016; Orsatto et al., 2020; Raghunathan et al., 2017) and food consumption (Carvalho et al., 2015; Costa et al., 2017; Kronebusch and Damon, 2019; Martins and Monteiro, 2016; Todd and Gregory, 2018).

Brazil's main income transfer program was called the "Bolsa Família" program (BFP) and lasted from 2004 to 2021. The program has been replaced by the *Auxílio Brasil* and *Alimenta Brasil* programs[1]. The Bolsa Família Program was formulated to unify other programs (Food Card, Food Grant, School Grant, and Auxílio Gás). After integrating these programs, the PBF differential was the increase in the number of beneficiaries and the increase in the average value of the benefit (Cabral et al., 2013). The literature suggests that the PBF stimulates the purchase of food by the beneficiaries (Almeida et al., 2016; Carmo et al., 2016; Carvalho et al., 2015; Costa et al., 2017; Martins and Monteiro, 2016). However, no studies still analyze the effect of the BFP on macronutrient intake by children from beneficiary families.

The objective of the article is to identify the effects of the BFP on child nutrition, mainly on the following outcome variables: (i) *Energy in Kcal*; (ii) *Energy in KJ*; (iii) *Carbohydrates*; (iv) *Proteins*; and (v) *Lipids*. We used data from the Household Budget Survey (POF) of the Brazilian Institute of Geography and Statistics (IBGE) for the period between 2017 and 2018. We corrected the estimates considering the complex sampling structure of the microdata

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[1] Programs instituted on December 29, 2021, based on Law No. 14,284. The Auxílio Brasil Program increased the value of the poverty and extreme poverty range (thus increasing the number of beneficiaries) and increased the value of existing benefits. It also instituted new benefits: Transition Compensatory Benefit, School Sports Aid, Junior Scientific Initiation Scholarship, Child Citizen Aid, Rural Productive Inclusion Aid and Urban Productive Inclusion Aid.

(Austin et al., 2018; DuGoff et al., 2014a). We propose the ordinary least squares method for complex samples (*Ordinary Least Squares Survey*) and the matching methods (*Propensity Score Matching and Propensity Score Weighting*) adjusting for the complex structure of the data. As a robustness analysis, we propose (i) the application of the placebo test, (ii) analysis of heterogeneous effects by regions, and (iii) analysis for urban areas in Brazil.

Studying the effect of conditional cash transfer programs on food measures for the children of beneficiaries is important for the academic literature and for guiding public policies. From an academic point of view, this article answers a gap in the literature regarding the effect of the cash transfer program on the macronutrient intake of children belonging to beneficiary families. In addition, the work results can be used as new parameters for future child food security policies, mainly aimed at the most vulnerable part of the population.

2.2. Literature Review

2.2.1. Income Transfers and Child Nutrition Programs

Cash Transfer Programs (PTR) are in place in numerous low- and middle-income countries (Bhalla et al., 2018; Cooper et al., 2020; Cruz et al., 2017; Garoma et al., 2017; Hanna and Olken, 2018; Millán et al., 2019; Moraes et al., 2018; Owusu-Addo et al., 2018; Owusu-Addo and Cross, 2014; Pase and Melo, 2017; Pega et al., 2017; Poirier, 2020) and in high-income countries (Loopstra, 2018), with the objective of State intervention in the fight against hunger (Walque et al., 2017). Income transfer programs presuppose the availability of discretionary resources, promoting the expansion of purchasing power and enabling families to allocate resources given their preferences.

The first Conditional Cash Transfer Programs (PTRC) were the "*Programa Prospera*" from Mexico and the "*Programa Bolsa Família*" from Brazil. These programs have been examples of other programs in Latin America, Africa, and the United States. (Aber and Rawlings, 2011; Fiszbein and Schady, 2009; Walque et al., 2017). Although the PTRCs have similar characteristics, there is a distinction in terms of requirements, conditions, benefits, goals, and payment methods. (Fiszbein and Schady, 2009; Miller et al., 2011; Walque et al., 2017). In general terms, the literature shows that PTRCs result in improvements in health, nutrition, school attendance and social cohesion, reducing poverty with low administrative level and costs (Barham et al., 2013; Barham and Maluccio, 2009; Barrientos and DeJong, 2006; Cecchini and Madariaga, 2011; Díaz and Saldarriaga, 2014; Fernald and Hidrobo, 2011; Gonzalez-Rozada and Pinto, 2011; Kronebusch and Damon, 2019; Lagarde et al., 2007; Llano, 2014; Maluccio, 2010; Millán et al., 2019; Molina Millán et al., 2020; Owusu-Addo and Cross, 2014; Poirier, 2020; Sánchez and Rodríguez, 2016; Sanchez Chico et al., 2020; Schady and Araujo, 2006; Walque et al., 2017).

Several articles have studied the effects of cash transfer programs on the health and nutrition of beneficiary families in Latin American countries (Attanasio and Mesnard, 2006; Kronebusch and Damon, 2019; León and Younger, 2007; Maluccio and Flores, 2004; Maluccio, 2010; Owusu-Addo and Cross, 2014; Saldivar-Frausto et al., 2022).

Kronebusch and Damon (2019) analyzed the "Programa Progresa" effects in Mexico on its participants' macro and micronutrient consumption levels. The authors used data from the "*Encuesta de Evaluación de Los Hogares*" (ENCEL) from the rural area of the country in the years 1998 (before the implementation of the program) and 1999 (after the implementation of the program). They used the difference analysis in difference and the transversal OLS. As a result, the authors found that beneficiary families increased their vitamin intake by 15% and their mineral intake by 7%. It was also found that treated families, on average, consumed 10.7% more protein and 19.7% more vitamins than control families. However, the results suggest that the program can double affect the nutrition indicators of its beneficiaries. The program has positive effects on increasing the consumption of macro and micronutrients, such as vitamin A, iron, and calcium. There is a positive effect for the consumption of processed carbohydrates in 23% and saturated fats in approximately 5%, factors capable of contributing to the expansion of overweight and obesity in the Mexican territory.

Saldivar-Frausto et al. (2022) analyzed the effects of the "*Prospera*" social inclusion program on food insecurity (FI) in Mexican families between 2012 and 2016, using data from the ENIGH-MCS and estimation by the difference-in-differences method. As a result, the authors found that food insecurity among all beneficiary households decreased by 8.0pp compared to non-beneficiary households during the study period. In beneficiary households with children, this decrease was 6.0pp. The study concluded that the "*Prospera*" program positively reduced AI at the household level through increased access to food, which generally improves nutritional outcomes in vulnerable Mexican populations.

For Brazil, several studies seek to identify the effects of the Bolsa Família Program both on the profile of food consumption and food insecurity (Almeida et al., 2016; Baptistella, 2012; Carvalho et al., 2015; Coelho and Melo, 2017; Costa et al., 2017; Cotta and Machado, 2013; Duarte et al., 2009a; Lignani et al., 2011; Lima et al., 2020; Martins and Monteiro, 2016; Orsatto et al., 2020; Palmeira et al., 2020) and on the health of the beneficiaries (Carmo et al., 2016; Chagas et al., 2013; Hoffmann, 2021; Moraes et al., 2018; Oliosi et al., 2019; Oliveira et al., 2011; Paes-Sousa et al., 2011; Paula et al., 2012; Pescarini et al., 2020; Pinho Neto and Berriel, 2017; Rasella et al., 2013; Rocha, 2018; Saldanha et al., 2014; Santos et al., 2021; Segall-Corrêa et al., 2008; Silva and Paes, 2018; Souza et al., 2021).

Martins and Monteiro (2016) analyzed the impact of the BFP on food consumption in low-income families based on data from the 2008 and 2009 Household Budget Surveys. The study used the *Propensity Score Matching* method. The results indicated that, compared to non-benefited families, beneficiary families have 6% higher food expenses and 9.4% higher total energy availability. The effects for specific groups of products were also measured, with a 7.3% higher expenditure on "*in natura*" or minimally processed foods and a 10.4% higher expenditure on culinary ingredients among the PBF families. The study found no statistically significant differences in spending and availability of processed and ultra-processed foods and beverages. In the group of "*in natura*" or minimally processed foods, expenditure and availability of meat, tubers, and vegetables were higher among PBF beneficiaries.

Duarte et al. (2009) analyzed the impact of the PBF on food expenditures in rural areas of Brazil. The data were obtained from a field survey carried out in 2005, and the *Propensity Score Matching* method was used. The results showed a positive relationship between the transfer of income from the program and the food consumption by beneficiary families in rural areas. Concerning total annual expenses, families in the treatment group have an average value of R$ 246 additional compared to those in the control group. It was also observed that 88% of the annual average received by beneficiary families (R$ 278) was used for food consumption.

Almeida et al. (2016) analyzed the effect of the BFP on the diversification of food consumption among families benefiting from the program in urban Brazil, including the nutritional properties of the consumption basket. Microdata from the Household Budget Survey (POF) for 2008-2009 was used. The empirical strategy was based on the *Propensity Score Matching* method. The Berry Index, which measures the level of food diversification of the households' consumption baskets included in the program, and the Healthy Diversification Index, which weights the Berry index by a factor that considers the "*health value*," was also used for the consumption basket. The results found that the PBF beneficiary families had a higher Berry index than the control families, with the program's effect being approximately 0.9%. However, the Healthy Diversification Index found that the difference between the indicators of the treated and control groups is not statistically different from zero, evidencing that the PBF does not generate impacts on diversification in the consumption of healthy foods.

Costa et al. (2017) evaluated the influence of the PBF on the nutritional consumption of adults in families, analyzing the impact on the consumption of calories from different food groups and the consumption of different nutrients (protein, carbohydrates, fiber, lipids, calcium, iron, zinc, and vitamins A and D). The authors used food consumption data from the POF (IBGE) from 2008 to 2009. The study used the *Propensity Score Matching* method. The estimated impacts showed that adult beneficiaries of the BFP have a daily consumption of about 135 calories higher than the intake of non-participating adults. Even so, the adult beneficiaries of the program had a daily average of 1.704 calories, which is lower than that recommended for Brazilian adults, which is 2.000 calories a day. They found that program beneficiaries had higher caloric intakes of cereals, fruits, vegetables, and vegetables (on average, 63 calories higher daily) and meat and other animal products (35 calories). In addition, BFP recipients had a higher average daily intake of protein, carbohydrates, fiber, lipids, calcium, iron, and zinc than the control group.

Coelho and Melo (2017) studied the impact of the PBF on diet quality in the state of Pernambuco. The authors used data from POF (IBGE) between 2008-2009. Using the Diet Quality Index (DQI) as a dependent variable, the *Propensity Score Matching* method was applied. The results show that the average IQD value for families included in the program exceeds by 9.05 the average value of families not participating. The results corroborate the effectiveness of the PBF in increasing the quality of the families' diet, mainly in terms of reducing fat and sodium and increasing the diversification of the diet, with the program's impact on the consumption of various food groups such as cereals, legumes, and fruits being remarkable.

Baptistella (2012) analyzes the effects and contribution of the BFP in terms of the food security of its beneficiaries. The authors used data from the 2008/2009 Household Budget Survey and the *Propensity Score Matching* method. As a result, it was found that the average value of annual expenses with food is R$146.74 higher among beneficiary families compared to non-beneficiaries. The most considerable expense of beneficiary families is consuming the following products: grains and cereals, poultry and eggs, meat, baked goods, vegetables, oils, and non-alcoholic beverages. The study also analyzed the average effect of treatment by macroregions and found that in the North and Northeast regions, the program's impact on household food consumption is 31.4% greater than in Brazil as a whole. However, in the South and Southeast regions, there was no significant difference between the consumption of families included in the PBF and those not included in the PBF.

2.2.2. The *Bolsa Família* Program - *BFP*

Conditional cash transfer programs in Brazil began in 1995, with pioneering municipal experiences in Campinas (SP) and the Federal District. At the federal level, these programs gained prominence from the Bolsa Escola (by the Ministry of Education), "*Bolsa Alimentação*" (by the Ministry of Health), and "*Auxílio Gás"* (by the Ministry of Mines and Energy) programs. In 2003, the Food Card Program was launched. These four national programs were aimed at a similar audience but managed by different ministries. It was then that in 2004 these programs (the so-called remaining programs) were unified, thus creating the Bolsa Família Program (PBF) (Moraes et al., 2018).

The Bolsa Família Program [2] (PBF) was a conditional direct income transfer program aimed to improve the lives of families in poverty and extreme poverty in Brazil. (Moraes et al., 2018). The program had the following objectives: to provide access for economically vulnerable families to the network of public services, such as health services, education, and

[2] Decree no. 5,209, of September 17, 2004

social assistance; contribute to the fight against hunger and promote food and nutrition security; assist families in poverty and extreme poverty in their development; fight poverty and inequality; and to encourage the promotion and implementation of social policies that help to overcome the poverty situation of the families served by the program, from the incentive to public authorities bodies and instances ("Manual do Pesquisador - Gestão do Programa Bolsa Família - Docsity," 2018).

The PBF worked from three central axes: direct income transfer, complementary programs, and conditionalities. The direct income transfer referred to financial assistance, which varied according to the families' socioeconomic status and composition. The complementary programs referred to expanding access to public services representing fundamental rights in health, education, and social assistance through the program's conditionalities. This axis aimed to allow families to break the intergenerational cycle of poverty reproduction. The third axis corresponded to the articulation of the program with other governmental actions and programs at the municipal, state, and federal levels to help families overcome situations of vulnerability and poverty.[3]

Bolsa Família paid monthly, preferentially to women, to help increase the family's well-being and female autonomy at home and in local communities. ("Manual do Pesquisador - Gestão do Programa Bolsa Família - Docsity," 2018). The amounts paid by the program were the sum of various types of benefits provided for in the program and varied according to monthly *per capita* income and family composition. The program had some benefits: the basic, the variable (which varied if the beneficiary household had pregnant women, young people, or children), and the benefit of overcoming extreme poverty. (Moraes et al., 2018). The program included families with a *per capita* income of up to R$85.00 per month (considered in extreme poverty) and families with per capita income between R$85.01 and R$170.00 per month (considered in a poverty situation). If they had pregnant women, nursing mothers, children and adolescents in their composition ("Manual do Pesquisador - Gestão do Programa Bolsa Família - Docsity," 2018)[4]. Concerning the conditionalities of the BFP, children and adolescents between 6 and 15 years of age should be enrolled and attend

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[3] Information was obtained from the website https://www.gov.br/cidadania/pt-br

[4] Values referring to the years of study of this work (2017-2018)

[6] Values referring to the years of study of this work (2017-2018)

at least 85% of their monthly school hours. Adolescents aged 16 and 17 should have, in addition to enrollment, at least 75% of monthly school attendance. In health, immunizing and monitoring the growth and development of children under seven years of age was necessary. Pregnant women should also go to consultations at the health unit and participate in prenatal care. ("Manual do Pesquisador - Gestão do Programa Bolsa Família - Docsity," 2018).

2.3. Data

We used data from the Household Budget Survey (POF) for 2017 and 2018 from the Brazilian Institute of Geography and Statistics (IBGE). The POF is a household survey carried out by sampling whose main objective is to obtain information about the Brazilian population's living conditions, financial structure, and nutritional status. The research has a complex stratification sampling plan, representing the Brazilian population. The food consumption questionnaire is intended for all individuals over ten years of age in the household. Thus, children aged between 10 and 18 years were identified by kinship to both the household reference person (*head of household*) and the spouse of the household reference person.

We constructed five outcome variables: (i) the variable *Energy in Kcal* corresponds to the household average of food consumed by children measured in kilocalories (Kcal); (ii) the variable *Energy in KJ* indicates the household average of food consumed by the children measured in kilojoules (Kj); (iii) the variable *Carbohydrates* indicates the average household amount of carbohydrates ingested by the children, measured in grams; (iv) the *Protein* variable comprises the average household amount of protein ingested by children, measured in grams; and (v) the *Lipids* variable indicates the average household amount of lipids ingested by children, measured in grams. The treatment variable (*Treated Household*) indicates whether the household receives the conditional income transfer from the Bolsa Família Program.

We created covariates for individuals in the household and households in general (Coelho and Melo, 2017; Duarte et al., 2009). The *Children's average education* variable assumes the value of the average of the children's years of schooling for each analyzed household. The *Average age of children* variable assumes the value of the average age of all children in the household. Regarding the characteristics of reference adults, we considered the average age of those responsible for the children, this value being contained in the variable *Average age of guardians*. We constructed variables indicative of race, sex, and marital status regarding household characteristics. The *White* covariate is binary and assumes the value of one if there is a white individual in the household and 0 otherwise. The binary variable *Couple of reference* receives a value of 1 if the heads of the household are married and 0 otherwise. Moreover, the binary variable *Female head of household* indicates whether the individual responsible for the household is female.

The *Per capita income* variable was constructed from information on total household income (any monetary gain received during the 12 months prior to the survey reference). It was divided by the value of the number of residents in the household.[5] Finally, we also considered variables covering geographic issues: we built *dummies* for each region of Brazil (North, North East, Midwest[6], Southeast, and South), *dummies* to indicate whether the household is contained in the urban area, and *dummies* for each unit of the federation.

Table 1 - Balance of covariates before matching

	Average Treated	Average Control	T-test	P-value
White	0,405	0,536	-10,033	0,000
Average age of children	10,618	8,290	7,613	0,000
Average age of guardians	41,260	49,740	-21,147	0,000
Children's average education	4,551	3,491	8,493	0,000
Reference couple	0,742	0,611	10,747	0,000
Per capita income	921,73	2120,72	-34,971	0,000
Female head of household	0,436	0,402	-12,641	0,000
Urban area	0,658	0,803	2,621	0,000
North	0,195	0,126	7,246	0,000
North East	0,536	0,296	19,106	0,000
Midwest	0,083	0,134	-6,281	0,000
Southeast	0,138	0,282	-13,625	0,000
South	0,047	0,162	-14,521	0,000

Notes: Due to space considerations, the *dummy* variables of federative units were omitted.

Table 1 contains information about the treated group and the control group. Note that both groups are statistically different, indicating attention to the econometric method.

[5] To mitigate the impact of possible measurement errors and outliers, 5% of the tails of the distribution were removed from the original sample.

[6] We excluded the Federal District from the sample.

Descriptive statistics of the variables that were used in the study are presented in Table 2. The Northeast region presents 26.49% of households as treated. The North region has 19.79% of the households belonging to the treated group. The Southeast and Midwest regions have similar data, with 7.93% and 8.07% of treaties, respectively. On the other hand, the southern region of Brazil contains only 4.56% of the households present as treated.

Table 2 - Descriptive statistics and characterization of variables

Variables	*Average*	*Standard Deviation*
Result Variables		
Energy in Kcal	2137,7	4758,3
Energy in KJ	8953,5	19981
Carbohydrates	285,13	637,08
Proteins	94,511	211,26
Lipids	71,723	169,67
Treatment Variable		
Treated domicile	0,131	0,337
Covariates of Individuals		
Children's middle ages	8,743	12,453
Children's average education	3,738	5,074
Middle ages of those responsible	47,582	17,183
Household Covariates		
White	0,561	0,496
Reference couple	0,631	0,482
Per capita income	2127,1	1815,9
Female head of household	0,385	0,486
Urban area	0,871	0,335
North	0,079	0,271
North East	0,257	0,437
Midwest	0,076	0,266
Southeast	0,428	0,494
South	0,158	0,364

Notes: Data based on POF for 2017 and 2018. Descriptive statistics were obtained considering the complex structure of the data. The variables of federative units were omitted for space considerations; all Brazilian states were considered.

2.4. Method

The econometric model has the following format:

$$Y_i = \alpha + \gamma T_i + \beta X_i + \varepsilon_i \quad (1)$$

where Y_i corresponds to the response variables on the consumption of kilocalories, kilojoules, and macronutrients (Carbohydrates, Proteins, and Lipids) by children; T_i is the binary variable that identifies participation in the Bolsa Família program; and X_i corresponds to the vector of covariates. The main observable characteristics present in the vector of covariates cover individual characteristics (race, average age and average schooling of children, and average age of guardians), household characteristics (reference couple, per capita income, female head of household), and demographic characteristics (federation unit of the household, macro-regions and urban area). And finally, ε_i represents the stochastic error term.

The first possible analysis is done by applying the ordinary least squares estimator considering the sampling plan of the database (*Ordinary Least Squares Survey)*. However, this analysis assumes no sample selection bias by treatment. In this way, the analysis will be reported as a comparison. As the participants themselves select themselves to participate in the Bolsa Família Program, the estimation of the causal relationship suffers from the so-called "treatment selection bias." If the selection hypothesis is due to observable characteristics (selection hypothesis on observable characteristics), then the matching method is suitable to mitigate this bias. Thus, we propose using Propensity Score Matching (PSM) methods, which approximate the treated sample to a group of individuals in the control group, similar to a randomization process. An individual would represent each component of the treated group in the control group through the propensity score value (*Propensity Score*).

In specific terms, we will use the *Propensity Score Weighting* (PSW) method, which considers the inverse probability of being treated to reweight the entire sample and identify the causal effect. This method is important because it reduces sample selection bias by treatment and does not lose sample data. Thus, the PSW method is more robust than the OLS-*Survey* but will also serve as a comparison. Finally, we propose using the *Propensity Score Matching* method with the *Nearest Neighbor* algorithm (Austin et al., 2018; DuGoff et al., 2014b; Ridgeway et al., 2015). We used the product of the propensity score and the weight of the POF complex sample to estimate the treatment effect to obtain estimates with less bias. Austin et al. (2018) suggest that the new sample weight should be used in the model after matching the nearest neighbor method (*Nearest Neighbour*).

2.5. Results

The balance of covariates and their respective differences in means after pairing the PSM model can be seen in Table 3. Note that, for most model variables, the two groups become comparable after pairing. The means of each variable became similar for the treated and control groups. However, the variables representing the *Per capita income* and the *Urban area* remained statistically different between both groups. However, compared to the balance of covariates before matching, shown in Table 1, it is possible to observe an approximation between both groups. Table 3 shows that the average age of those responsible is 41 years old, and the average schooling of children who receive the benefit is 4.5 years. In addition, 43.6% of these households have a female person as the head of the family. It is also possible to verify the proportion of households treated by each region of Brazil.

Table 3 - Balance of covariates for the PSM model

	Average Treated	Average Control	T-test	P-value
White	0,405	0,403	0,265	0,791
Average age of children	10,618	10,571	-0,144	0,885
Average age of guardians	41,260	41,464	-0,851	0,395
Children's average education	4,551	4,353	0,238	0,812
Reference couple	0,742	0,714	3,449	0,001
Per capita income	921,73	1006,99	-6,540	0,000
Female head of household	0,436	0,438	-0,300	0,764
Urban area	0,658	0,712	-5,947	0,000
North	0,195	0,190	0,656	0,512
North East	0,536	0,532	0,373	0,709
Midwest	0,083	0,087	-0,740	0,459
Southeast	0,138	0,143	-0,753	0,451
South	0,047	0,047	0,088	0,930

Notes: Due to space considerations, the *dummy* variables of federative units were omitted.

Table 4 presents the estimates of the effect of the BFP on the total sample of households. Three different models were estimated: *Ordinary Least Square Survey*, *Propensity Score Weighting*, and *Propensity Score Matching* (OLS, PSW, and PSM, respectively).

Table 4 - Effect of the Bolsa Família Program on energy and macronutrient variables

Variable	**OLS-Survey** (1)	**PSW** (2)	**PSM** (3)
Energy in Kcal	235,513**	389,603***	469,704***
	(113,558)	(86,694)	(123,694)
N	18.100	18.100	5.784
Energy in KJ	991,631**	1636,303***	1974,510***
	(477,623)	(364,333)	(520,149)
N	18.100	18.100	5.784
Carbohydrates	42,121**	52,770***	69,222***
	(17,558)	(12,668)	(18,944)
N	18.100	18.100	5.784
Proteins	7,386	16,854***	19,291***
	(4,495)	(3,820)	(4,948)
N	18.100	18.100	5.784
Lipids	3,724	11,325***	12,219***
	(3,297)	(2,790)	(3,659)
N	18.100	18.100	5.784

Notes: Control variables have been omitted for space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are the standard deviations of the coefficients.

The results suggest that the conditional cash transfer program "Bolsa Família" had a positive and significant effect on the levels of energy intake and the consumption of macronutrients in the children of the beneficiary families. Regarding the energy value, the PBF provided an average increase of 469 Kcal (p<1%) in the children's diet, this effect being similar to the measurement in kilojoules. Thus, children between 10 and 18 years old from the treated families had an average daily consumption of approximately 2607 calories, representing an increase of approximately 22% in calorie consumption compared to those in the control group (2137.7 calories). The average ideal consumption of calories depends on gender, age, weight, height, and the child's physical activity level. For girls, the ideal average consumption ranges from 1600 (9 to 13 years old sedentary) to 2400 (14 to 18 years old physically active). For boys, this average ranges from 1800 (9 to 13 sedentary years) to 3200 (14 to 18 physically active years) (Almeida and Fernandes, 2011). Thus, the results show that the PBF fights food insecurity and contributes to better food possibilities for low-income children.

Regarding macronutrients, we observed an increase of 69 grams (p<1%) in the consumption of carbohydrates, 19 grams (p<1%) in the consumption of proteins, and 12 grams (p<1%) in the consumption of lipids, representing an increase of approximately 24.28%, 20.41%, and 17.04%, respectively, in the average food consumption of children of beneficiary families. Thus, the average consumption of children in the treatment group was approximately 354 grams of carbohydrates, 114 grams of protein, and 84 grams of lipids. Macronutrients are responsible for providing energy for the body to function, and their consumption at adequate levels can prevent diseases such as obesity, type 2 diabetes, heart disease, and cancer. It is also noteworthy that fat is essential in the diet to promote the absorption of some vitamins and help build some tissues (NATIONAL RESEARCH COUNCIL, 2005). The results agree with the literature (Costa et al., 2017; Duarte et al., 2009b; Resende and Oliveira, 2008).

2.6. Robustness Analysis

2.6.1 Placebo Test

The placebo test is used to verify if the results found are due to randomness or if the results obtained were a type I error. For the implementation, we created the treatment variable with a mean and standard deviation similar to the original. Then, all the methods discussed above are performed, estimating new propensity scores using the same control covariates of the initial analysis. The balance of covariates for the placebo test can be found in the appendix (Table I). Table 5 presents the results. Columns 1, 2, and 3 present the models used in the test that converge to the models used in the original analysis, the only difference being the placebo treatment.

Table 5 - Placebo Test

Variable	**OLS (1)**	**PSW (2)**	**PSM (3)**
Energy in Kcal	95,953	84,942	34,045
	(141,261)	(137,046)	(187,486)
N	18.100	18.100	5.784
Energy in KJ	402,312	356,170	141,170
	(592,901)	(575,213)	(786,959)
N	18.100	18.100	5.784
Carbohydrates	15,919	14,909	5,672
	(18,287)	(17,825)	(24,495)
N	18.100	18.100	5.784

Proteins	-0,365	-1,115	-3,014
	(5,871)	(5,704)	(7,971)
N	18.100	18.100	5.784
Lipids	3,787	3,202	2,970
	(5,478)	(5,232)	(7,161)
N	18.100	18.100	5.784

Notes: Control variables have been omitted for space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are the standard deviations of the coefficients.

We can verify that there is no statistical significance in any of the estimates, both for the energy-dependent variables (in Kcal and KJ) and those representing the intake of macronutrients. Therefore, these results allow us to verify that the effects estimated in Table 4 are not due to type I errors.

2.6.2 Analysis of Heterogeneous Effects of Treatment

Table 6 presents the results of the estimations for each region of Brazil, with each dependent variable divided by a line and each region containing the same three previous methods. Observing the results, it is clear that the dependent variables present significant coefficients for the country's northern region. For the variable Energy in Kcal, there is an average increase of 497 Kcal ($p<1\%$). In the macronutrient variables, significant effects were also found. For proteins, lipids and carbohydrates, the results indicate an increase in average consumption of 16 ($p<10\%$) and 15 ($p<5\%$) and 71 ($p<1\%$) grams, respectively.

The Northeast region obtained statistically significant results in all dependent variables. For Energies, estimates indicate that PBF has a positive effect of 518 additional Kcal ($p<1\%$) on total food intake, and this result is extended to measure in kilojoules. Concerning macronutrients, positive effects of the treatment were also observed. For protein consumption, there was an increase of 22 grams ($p<1\%$) in the average intake, for carbohydrates, an additional 73 grams ($p<1\%$), and for lipids, an additional 12 grams ($p<1\%$).

However, the Midwest, Southeast, and South regions do not present significant results regarding the impact of the Bolsa Família Program on children's macronutrient intake. Therefore, these results indicate that the effects of the PBF are more intensified in regions with lower per capita income. It is also worth mentioning that the effects are predominant in less developed regions of the country, which is compatible with the results of Maluccio e

Flores (2004), Maluccio (2010), and Baptistella (2012), which also found more expressive effects of conditional cash transfer programs on the poorest.

Another sample was built that includes the urban area. The urban area concentrates more than 60% of the households treated in the sample. In Table 7, the results are presented. The effects are similar and have magnitudes consistent with those in Table 4. Regarding the energy-dependent variables measured in kilocalories and kilojoules, the results indicate an increase of 525 Kcal (p<1%) in the average diet of the beneficiary children, which is again similar to the measurements in kilojoules. Concerning macronutrients, expressive results were also found. The estimated additional average consumption was 17 grams (p<1%) for proteins, 87 grams (p<1%) for carbohydrates, and 11 grams (p<1%) for lipids.

We propose that other samples be constructed for each country region to complement the urban area analysis. The results are shown in Table 8. The main effects are concentrated in the North and Northeast regions. The highlight for the consumption of Proteins in urban areas of the Northeast with an additional 20 grams on average (p<1%) and also for the intake of carbohydrates with an additional 87 grams (p<1%). As for the North region, the estimation for carbohydrates is exalted, presenting a significant coefficient of 76 grams (p<1%) in feeding children living in treated households.

Table 6 - Regional Heterogeneous Effects

Variable	**North**			**North East**			**Midwest**			**Southeast**			**South**		
	OLS-Survey (1)	PSW (2)	PSM (3)	OLS-Survey (4)	PSW (5)	PSM (6)	OLS-Survey (7)	PSW (8)	PSM (9)	OLS-Survey (10)	PSW (11)	PSM (12)	OLS-Survey (13)	PSW (14)	PSM (15)
Energy Kcal	410.95**	487.22***	497.34***	279.24**	437.46***	518.42***	90.90	469.16	441.80	237.60	369.42	376.41	-28.73	73.47	91.71
	(174.57)	(168.14)	(183.20)	(133.18)	(110.62)	(139.29)	(371.60)	(300.50)	(372.42)	(300.32)	(274.11)	(334.91)	(182.85)	(172.23)	(233.29)
N	2477	2477	1130	6048	6048	3100	1934	1934	420	4689	4689	800	2605	2605	274
Energy KJ	1726.54**	2052.57***	2088.41***	1172.97**	1836.45***	2178.23***	389.02	1972.99	1855.60	1005.73	1554.73	1587.06	-122.02	303.95	380.90
	(732.68)	(705.30)	(768.70)	(559.43)	(464.67)	(585.12)	(1561.43)	(1262.19)	(1565.83)	(1264.07)	(1153.17)	(1409.97)	(767.50)	(721.90)	(979.28)
N	2477	2477	1130	6048	6048	3100	1934	1934	420	4689	4689	800	2605	2605	274
Carbohydrates	63.671***	68.295***	71.447***	39.087**	56.003***	73.106***	42.778	74.243*	67.046	54.794	61.534	72.567	2.610	4.133	11.879
	(22.56)	(22.77)	(24.34)	(19.19)	(15.65)	(20.18)	(54.26)	(43.40)	(57.13)	(48.20)	(42.82)	(51.18)	(26.24)	(21.80)	(32.89)
N	2477	2477	1130	6048	6048	3100	1934	1934	420	4689	4689	800	2605	2605	274
Proteins	13.794	15.682*	16.281*	12.488**	21.716***	22.690***	-12.501	13.547	12.747	4.260	11.838	6.174	-5.427	2.118	-1.937
	(8.61)	(8.62)	(9.20)	(5.60)	(5.08)	(5.89)	(15.90)	(13.13)	(14.23)	(11.38)	(10.71)	(14.31)	(8.18)	(9.19)	(11.71)
N	2477	2477	1130	6048	6048	3100	1934	1934	420	4689	4689	800	2605	2605	274
Lipids	11.817*	16.147***	15.948**	5.185	11.804***	12.904***	-1.269	14.869	15.721	1.707	9.615	8.021	0.707	6.100	5.752
	(6.29)	(6.00)	(6.55)	(4.15)	(3.67)	(4.24)	(11.65)	(9.43)	(11.15)	(8.14)	(7.81)	(9.58)	(6.73)	(7.21)	(8.54)
N	2477	2477	1130	6048	6048	3100	1934	1934	420	4689	4689	800	2605	2605	274

Notes: Control variables have been omitted for space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are the standard deviations of the coefficients.

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Table 7 - Results for urban área

Variable	OLS-Survey (1)	PSW (2)	PSM (3)
Energy in Kcal	288.441**	478.975***	525.763***
	(141.939)	(103.199)	(148.227)
N	14128	14128	3808
Energy in KJ	1216.283**	2013.700***	2214.332***
	(597.134)	(433.763)	(623.378)
N	14128	14128	3808
Carbohydrates	57.426***	74.718***	87.923***
	(22.218)	(15.012)	(22.665)
N	14128	14128	3808
Proteins	5.909	16.513***	17.580***
	(5.478)	(4.395)	(5.821)
N	14128	14128	3808
Lipids	4.593	13.242***	11.834***
	(4.035)	(3.368)	(4.490)
N	14128	14128	3808

Notes: Control variables have been omitted for space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are the standard deviations of the coefficients.

Table 8 - Regional Heterogeneous Effects for urban area

Variable	**North**			**North East**			**Midwest**			**Southeast**			**South**		
	OLS-Survey (1)	PSW (2)	PSM (3)	OLS-Survey (4)	PSW (5)	PSM (6)	OLS-Survey (7)	PSW (8)	PSM (9)	OLS-Survey (10)	PSW (11)	PSM (12)	OLS-Survey (13)	PSW	PSM
Energia Kcal	429.32*	568.14***	499.46*	384.75**	556.18***	514.95***	-58.28	367.11	494.33	307.69	502.40*	435.38	-56.34	157.47	212.37
	(219.26)	(199.35)	(286.18)	(168.55)	(138.64)	(196.69)	(384.92)	(319.40)	(441.84)	(339.61)	(281.79)	(405.59)	(212.58)	(179.30)	(257.72)
N	1786	1786	592	5009	5009	2238	1206	1206	204	3883	3883	550	1942	1942	176
Energia KJ	1799.22*	2380.65***	2097.73*	1619.80**	2339.57***	2168.78***	-237.94	1543.39	2080.48	1301.94	2116.16*	1836.73	-238.38	657.47	892.30
	(920.38)	(836.94)	(1200.18)	(708.26)	(582.64)	(826.30)	(1617.20)	(1340.31)	(1854.89)	(1429.53)	(1185.46)	(1706.84)	(891.80)	(751.32)	(1079.87)
N	1786	1786	592	5009	5009	2238	1206	1206	204	3883	3883	550	1942	1942	176
Carboidratos	67.39**	84.34***	76.06**	67.05***	86.42***	87.95***	21.06	56.10	85.68	68.51	86.31**	89.56	-1.28	12.25	34.86
	(27.79)	(25.38)	(36.39)	(24.85)	(19.89)	(28.45)	(55.14)	(42.96)	(57.42)	(54.69)	(43.89)	(60.15)	(30.56)	(23.22)	(34.40)
N	1786	1786	592	5009	5009	2238	1206	1206	204	3883	3883	550	1942	1942	176
Proteínas	15.08	19.07*	15.01	11.11*	21.26***	20.03***	-21.60	6.30	4.86	5.25	14.07	6.24	-7.81	5.53	2.59
	(10.55)	(9.79)	(13.35)	(6.72)	(5.91)	(7.56)	(16.60)	(14.40)	(21.42)	(12.78)	(11.13)	(18.01)	(9.46)	(9.02)	(11.55)
N	1786	1786	592	5009	5009	2238	1206	1206	204	3883	3883	550	1942	1942	176
Lipídios	12.81	18.53**	15.68	7.33	14.03***	9.03	-5.28	13.00	16.65	3.13	12.63	7.36	-0.10	10.05	8.33
	(8.03)	(7.37)	(10.77)	(5.11)	(4.64)	(6.47)	(12.35)	(10.46)	(15.25)	(9.11)	(8.09)	(12.28)	(7.86)	(7.57)	(10.37)
N	1786	1786	592	5009	5009	2238	1206	1206	204	3883	3883	550	1942	1942	176

Notes: Control variables have been omitted for space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are the standard deviations of the coefficients.

7. Final considerations

This article analyzed the effect of the BFP on children's total food consumption levels in Brazil. We analyze energy measures in kilocalories, kilojoules, and macronutrients (carbohydrates, proteins, and lipids). The study was carried out with POF microdata collected in 2017 and 2018, and we applied the ordinary least squares method for complex samples (*Ordinary Least Squares Survey*). The matching methods (*Propensity Score Weighting* and *Propensity Score Matching*) adjust for the data's complex structure. We proposed several subsamples analyses from the regions of Brazil and the urban area in order to test the robustness of the results.

The results suggest that the conditional cash transfer program "Bolsa Família" had a positive and significant effect on the levels of energy intake and the consumption of macronutrients in the children of the beneficiary families. Regarding the energy value, the BFP provided an average increase of 469 Kcal in the children's diet, this effect being similar to the measurement in kilojoules. The results indicate that children from the treated families had an average daily consumption of approximately 2607 calories, representing an increase of approximately 22% in calorie consumption compared to the control group (2137.7 calories). The results show that the PBF fought food insecurity and contributed to better food possibilities for low-income children. Regarding macronutrients, the increase in the consumption of carbohydrates (69 grams), proteins (19 grams), and lipids (12 grams) represented an increase of approximately 24.28%, 20.41%, and 17.04%, respectively, in the average food consumption of children of beneficiary families. Robustness tests were also performed to verify the magnitude of the main effects. In the regional analysis, it was found that the effects are significant in the North and Northeast regions of Brazil. It can be caused by the difference in the regions' development levels. They are the poorest and have the highest proportion of beneficiaries in the sample. The analysis for the urban area corroborates the same results, being statistically significant only for the two regions.

As a suggestion for future research, we can analyze how the additional income is applied within the consumption basket of families, that is, how families use this income between industrialized or non-industrialized food products. In addition, it is possible to verify the quality of food consumed by children between genders and ages, relating these conditions to schooling and access to employment. These analyses clarify the program's benefits in terms of food quality.

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Appendix

Tabela A 1 - Balance of covariates - Placebo test

	Average Treated	Average Control	T-test	P-value
White	0.526	0.529	-0.298	0.766
Average age of children	8.691	8.848	-0.681	0.496
Average age of guardians	48.736	48.679	0.180	0.858
Children's average education	3.679	3.701	-0.230	0.818
Reference couple	0.633	0.627	0.733	0.464
Per capita income	1928.173	1866.279	2.038	0.042
Female head of household	0.423	0.425	-0.263	0.792
Urban area	0.792	0.796	-0.458	0.647
North	0.138	0.136	0.270	0.787
North East	0.347	0.349	-0.195	0.845
Midwest	0.126	0.131	-0.896	0.370
Southeast	0.248	0.246	0.301	0.763
South	0.141	0.138	0.480	0.631
States	-	-	-	-

Notes: Due to space considerations, the *dummy* variables of federative units were omitted.

Tabela A 2 - Balance of covariates for urban area

	Average Treated	Average Control	T-test	P-value
White	0,412	0,418	-0,558	0,577
Average age of children	10,525	10,726	-0,817	0,414
Average age of guardians	41,037	40,547	1,619	0,106
Children's average education	4,540	4,466	-0,768	0,443
Reference couple	0,678	0,677	0,047	0,961
Per capita income	984,712	1032,472	-2,787	0,005
Female head of household	0,516	0,507	0,779	0,436
Urban area	-	-	-	-
North	0,156	0,160	-0,506	0,613
North East	0,588	0,579	0,791	0,429
Midwest	0,066	0,068	-0,368	0,713
Southeast	0,144	0,146	-0,196	0,845
South	0,046	0,047	-0,218	0,827
States	-	-	-	-

Notes: Due to space considerations, the *dummy* variables of federative units were omitted.

Tabela A 3 - Balance of covariates for the Regions of Brazil

	Total				Urban area			
Variáveis de controle	**Average Treated**	**Average Control**	**T-test**	**P-value**	**Average Treated**	**Average Control**	**T-test**	**P-value**
Panel A. North Region								
White	0.313	0.319	-0.272	0.786	0.307	0.287	0.751	0.453
Average age of children	10.697	10.285	0.989	0.323	10.878	10.365	0.901	0.368
Average age of guardians	40.595	40.892	-0.539	0.590	39.993	40.160	-0.225	0.822
Children's average education	4.761	4.469	1.601	0.110	5.113	4.649	1.760	0.080
Reference couple	0.807	0.777	1.778	0.076	0.760	0.740	0.810	0.418
Per capita income	818.657	911.887	-3.809	0.000	889.681	905.466	-0.418	0.676
Female head of household	0.374	0.396	-1.124	0.261	0.503	0.500	0.116	0.908
Urban area	0.524	0.628	-4.581	0.000	-	-	-	-
Panel B. Midwest Region								
White	0.386	0.357	0.843	0.400	0.343	0.304	0.818	0.415
Average age of children	10.310	10.457	-0.237	0.813	10.823	9.677	1.143	0.256
Average age of guardians	40.062	39.302	1.085	0.279	39.623	38.618	0.900	0.370
Children's average education	4.896	5.119	-0.767	0.444	4.801	4.675	0.284	0.777
Reference couple	0.819	0.819	0.000	1.000	0.706	0.726	-0.431	0.668
Per capita income	1232.928	1296.071	-1.034	0.303	1255.713	1265.889	-0.115	0.909
Female head of household	0.262	0.333	-2.204	0.028	0.441	0.363	1.514	0.133
Urban area	0.486	0.548	-1.738	0.084	-	-	-	-
Panel C. Southeast Region								
White	0.745	0.781	-0.959	0.339	0.727	0.716	0.238	0.813
Average age of children	7.978	8.015	-0.051	0.959	7.000	7.409	-0.460	0.646
Average age of guardians	39.303	37.780	1.470	0.144	36.932	35.227	1.272	0.207
Children's average education	3.527	3.372	0.480	0.632	3.025	3.335	-0.795	0.429
Reference couple	0.759	0.701	1.518	0.131	0.682	0.614	1.303	0.195
Per capita income	1121.012	1177.955	-0.904	0.368	1195.206	1222.977	-0.321	0.749
Female head of household	0.467	0.467	0.000	1.000	0.580	0.557	0.428	0.670
Urban area	0.642	0.650	-0.178	0.859	-	-	-	-
Panel D. South Region								
White	0.402	0.417	-1.240	0.215	0.415	0.426	-0.788	0.431
Average age of children	10.970	11.290	-1.122	0.262	10.848	11.228	-1.124	0.261
Average age of guardians	41.938	42.984	-3.099	0.002	41.925	41.990	-0.160	0.873
Children's average education	4.520	4.605	-0.760	0.448	4.544	4.694	-1.116	0.265
Reference couple	0.730	0.705	2.269	0.023	0.682	0.677	0.321	0.749
Per capita income	860.140	970.137	-7.239	0.000	926.447	987.463	-3.217	0.001
Female head of household	0.471	0.441	2.324	0.002	0.513	0.507	0.418	0.676
Urban area	0.722	0.784	-5.248	0.000	-	-	-	-
Panel E. North East Region								
White	0.402	0.417	-1.240	0.215	0.415	0.426	-0.788	0.431
Average age of children	10.970	11.290	-1.122	0.262	10.848	11.228	-1.124	0.261
Average age of guardians	41.938	42.984	-3.099	0.002	41.925	41.990	-0.160	0.873
Children's average education	4.520	4.605	-0.760	0.448	4.544	4.694	-1.116	0.265
Reference couple	0.730	0.705	2.269	0.023	0.682	0.677	0.321	0.749
Per capita income	860.140	970.137	-7.239	0.000	926.447	987.463	-3.217	0.001
Female head of household	0.471	0.441	2.324	0.002	0.513	0.507	0.418	0.676
Urban area	0.722	0.784	-5.248	0.000	-	-	-	-

Note: State dummies have been omitted from the table for space reasons, noting that they are included in all models.

3. Does adopting sustainable technologies increase residential electricity consumption inequality in emerging countries? An analysis of the Brazilian case

Abstract

We identify the effect of sustainable technologies on electricity demand in Brazil and its implications on residential electricity consumption inequality. We used the database of the Household Budget Survey (POF2017-2018) of the Brazilian Institute of Geography and Statistics. We use the Inverse Probability Weighting algorithm to identify the average treatment effect at the population level and the unconditional quantile treatment effect estimator for the heterogeneous treatment effects analysis. We considered the correction for the survey data structure in both analyses. We applied the placebo test and a subsample analysis to verify the robustness of the results. The results show that adopting energy transition technology increases residential electricity consumption mainly in the highest quantiles of consumption distribution, imposing inequality in residential electricity consumption.

Keywords: Sustainable Technologies Policy, Quantile Regression, Brazil.

JEL: C81, D11, Q41, Q48

Resumo

Identificamos o efeito de tecnologias sustentáveis na demanda de eletricidade no Brasil e suas implicações na desigualdade do consumo residencial de eletricidade. Utilizamos a base de dados da Pesquisa de Orçamentos Familiares (POF2017-2018) do Instituto Brasileiro de Geografia e Estatística. Usamos o algoritmo de Ponderação de Probabilidade Inversa para identificar o efeito médio do tratamento no nível da população e o estimador do efeito do tratamento quantílico incondicional para a análise dos efeitos do tratamento heterogêneo. Consideramos a correção para a estrutura de dados amostrais em ambas as análises. Aplicamos o teste placebo e análises em subamostras para verificar a robustez dos resultados. Os resultados mostram que a adoção da tecnologia de transição energética aumenta o consumo residencial de eletricidade principalmente nos quantis mais altos de distribuição do consumo, impondo desigualdade no consumo residencial de eletricidade.

Palavras-chave: Política de Tecnologias Sustentáveis, Regressão Quantílica, Brasil.

JEL: C81, D11, Q41, Q48

3.1. Introduction

The electric power generating sector is critical to worldwide economic growth and development. On the other hand, the energy sector is the most responsible for global greenhouse gas emissions, making it an essential topic in the climate debate (Antosiewicz et al., 2020; Guler, Çelebi, and Nathwani, 2018; Nikas et al., 2020). In numerous economies, the shift from fossil energy sources to renewable energy sources is a reality (Batinge, Musango, and Brent, 2019; Sareen & Haarstad, 2018; Warren, Christoff, and Green, 2016), and the incorporation of renewable energy-producing technology often centers the energy transition strategies (Li & Strachan, 2019; Sovacool et al., 2018; Tagliapietra et al., 2019). Developed and developing countries have invested in technological advancement to reduce their reliance on fossil fuels and transition to a more efficient energy matrix. Climate and energy policies at the national and local levels are critical in providing incentives and guidelines for this structural shift in society. Also, the literature shows progress in understanding the effects of poverty and energy inequality on quality of life, health, and education (Abbas et al., 2021; Acheampong, Erdiaw-Kwasie, and Abunyewah, 2021; Carley and Konisky, 2020; Nadimi & Tokimatsu. 2018; Sovacool, 2014; Zhang, Appau, and Kodom, 2021). However, an important aspect is still little explored in the literature: the possible generation of inequalities in energy consumption due to energy transition policies.

Measures encouraging renewable energy technologies have expanded alternative energy sources in developing countries like Brazil (ANEEL, 2013, 2016). The introduction of solar photovoltaic technology and changes in Brazil's energy regulatory system[7] is responsible for much of this growth (MME, 2015). This research aims to contribute to literature testing if adopting sustainable technologies impacts: (i) the population electricity consumption and (ii) population inequality in electricity consumption.

We used data from the Family Budget Survey (POF 2017-2018) conducted by the Brazilian Institute of Geography and Statistics (IBGE). The POF sampling plan has complex characteristics, so considering its sample weight allows inferences for the Brazilian population. To answer the first point, we propose using the Inverse Probability Weighting algorithm to identify the adoption of sustainable technologies' effect on electricity

[7] Ordinance of the Ministry of Mines and Energy number 538/2015.

consumption average at the population level. Furthermore, we propose the unconditional quantile treatment effect (UQTE) estimator by Firpo & Pinto (2016) to analyze heterogeneous treatment effects. In both analyzes, we considered the correction for the complex database proposed by (Dugoff, Schuler, and Stuart, 2014). The results show that adopting energy transition technology mainly increases residential electricity consumption in the highest consumption distribution quantiles. Lastly, we analyze the adoption of sustainable technologies' effect on measures of electricity inequality (inter-quantiles ratios, Gini inequality index, Absolute Gini inequality index, Atkin inequality index, and Lorenz inequality index). The results show that adopting energy transition technology increases inequality in residential electricity consumption in Brazil.

This paper is significant in energy economics because it breaks new ground in several aspects. It is the first study to examine the impact of renewable energy technology adoption on Brazil's unconditional distribution of residential electricity consumption. Furthermore, the work innovates using microdata from POF 2017-2018 with a complex sampling plan and methodologies not previously used to provide more reliable estimates of residential electricity demand in the Brazilian population. The findings are significant for national and international energy policies, as they can guide public residential electricity acquisition, generation, and poverty policies. Moreover, it aids in understanding the behavior of residential electricity demand during the expansion phase of the energy transition process.

In addition to this introduction, we present a literature review describing (i) sustainable technologies, energy poverty and inequality, and (ii) the energy transition in Brazil. Later, we present the database and the variables used. In section four, we describe the methods applied. In section five, we describe the findings. In section six, we present the robustness analysis. Finally, we conclude with policy considerations and final remarks.

3.2. Literature review

3.2.1. Sustainable Technologies, Energy Poverty, and Inequalities

The term "energy poverty" refers to a lack of access to safe and high-quality energy resources (such as electricity, gas, and oil) that meet a person's or family's basic needs

(Nussbaumer, Bazilian, and Modi, 2012; Zhang et al., 2021). To guarantee universal access to affordable, reliable, sustainable, and modern energy until 2030, the topic "energy poverty" was incorporated as one of the United Nations' Sustainable Development Objectives." Mohammadi & Ram (2012) show that energy and electricity consumption has a weak convergence trend (an inertia element) across countries and is especially weak between the first and last deciles. As a result, energy poverty is linked to issues like energy inequality and energy justice, affecting low-income countries' ability to improve their social, economic, and public health conditions (Xu & Chen, 2019). When conducted at the household level, this analysis links energy consumption to quality of life through lower infant mortality, longer life expectancy, and increased education, all of which are important for social development.

Nadimi & Tokimatsu (2018) create a quality-of-life index and relate it to the level of energy and electricity consumption per capita, indicating a positive relationship. The relationship between developing and low-income countries is deeper, particularly for the latter. The quality of life index takes into account the following factors: (i) infant mortality rate and life expectancy; (ii) average years of study; (iii) gross domestic product and gross national income; and (iv) improvements in access to water. Acheampong et al. (2021), who looked at low-income regions like South Asia, Latin America and the Caribbean, and Sub-Saharan Africa, found a similar result. In South Asia, Abbas et al. (2021) discover a link between energy poverty and domestic health problems: households with a high rate of energy poverty are more likely to have health problems, particularly among women, than households with lower levels of energy poverty. One of the mechanisms is poor air quality caused by the combustion of resources such as charcoal and wood for heating and cooking. In a sample of New York City residents, Hernández & Siegel (2019) found a link between respiratory problems, mental health issues, sleep problems, and energy insecurity. Using data from the China Family Panel Studies, Zhang et al. (2021) found that an increase in one standard deviation in energy poverty reduces 0.355 standard deviations in children's subjective wellbeing and indicates a reduction in academic performance. Awaworyi Churchill & Smyth (2021) found a similar result for Australia: an increase in energy poverty by one standard deviation reduces the general level of health between 0.099 and 0.296 standard deviations.

In this scenario, different income groups are unequally positioned in social and technological changes toward energy transition. Globally, deploying distributed generation systems policies based on solar and wind energy were adopted. However, they also have raised concerns about potential adverse effects (Miller, Iles, e Jones 2013; Ottinger 2013; Tarekegne 2020; Xu e Chen 2019). For example, with high start-up costs for low-carbon technologies, access to energy transition opportunities is limited for all demographic groups, especially with incentive policies that use asset tests as an eligibility criterion. This combination could inhibit low- and middle-income families from investing, resulting in a regressive effect on program access (Carley e Konisky 2020; Graff e Pirog 2019; Mitra e Buluswar 2015).

Furthermore, the literature presents evidence that rented properties represent barriers to adopting renewable technologies (Carley e Konisky 2020; Cayla, Maizi, e Marchand 2011; Langevin, Gurian, e Wen 2013; Sunter, Castellanos, e Kammen 2019; Xu e Chen 2019). Besides, few studies examine the changes in energy consumption behavior among different income groups following alternative technologies for energy services. Our research aims to see if adopting sustainable technologies has increased energy consumption inequality in Brazil.

3.2.2. The Energy Transition in Brazil

According to the National Energy Balance (EPE 2021), renewable energy accounts for 83.0 percent of Brazil's domestic electricity supply (the sum of national production and imports). Hydroelectric power has been the country's primary energy source for a decade and currently accounts for 64.9 percent of the domestic electricity supply (EPE 2021). However, due to the expected environmental restrictions on constructing new hydroelectric plants with large reservoirs, hydroelectric capacity in the following decades is expected to be lower than installed. It is common to activate coal-fired thermoelectric plants when rainfall is low, increasing the cost of producing electricity and posing a challenge to the Energy Transition. On the other hand, the high cost of electricity tariffs induced the deployment of renewable energy technologies by residential, commercial, and industrial sectors.

As Brazil has a great potential for solar energy, new regulations have expanded the energy self-generation market and the electricity generation sector (Sarruf e Piga 2006; Toniazzo et al. 2016). The National Electric Energy Agency (ANEEL) regulates the Brazilian electricity sector. ANEEL is an autarchy under a special Ministry of Mines and Energy regime. ANEEL's responsibility is to regulate the Federal Government's policies and guidelines for using and exploiting electric energy services by all economic agents in Brazilian territory (ANEEL 2021). In addition, the agency determines the rate and the system's quality and safety standards. Thus, it operates in the following modalities of regulation: (i) technical (which includes the generation, transmission, distribution, and sale of electricity), (ii) economic (which includes the definition of tariffs and market aspects), and (iii) development and energy efficiency projects.

In 2012, ANEEL regulation No. 482/2012 allowed Brazilian consumers to generate their electricity using renewable sources or qualified cogeneration and supply the surplus to the local distribution network, i.e., a net metering policy. The Normative Resolution No. 687/2015, published to revise Resolution No. 482/2012, reduced micro and mini-generation connections costs and time. Along with expanding the target audience, improving billing information, and ensuring that the electricity compensation system is compatible with general supply conditions (Normative Resolution No. 414/2010)[8]. In this scenario, the Brazilian government is heavily involved through two main strategies: subsidized credit policies and integrating alternative technologies into low-income housing construction programs. The National Bank for Economic and Social Development (BNDES) is a key player, providing credit for acquiring energy self-generation systems and sustainable technologies in Brazil. The BNDES was established in 1952 and is one of the world's largest development banks and the Brazilian government's primary tool for long-term financing and social impact investments for businesses, legal entities, and individuals (BNDES 2021f). Currently, the "*FINAME – Baixo Carbono*" credit line, operated by private commercial banks and other Brazilian regional development banks, finances the acquisition of decentralized power generation systems (BNDES 2021e, 2021a, 2021c, 2021b, 2021d).[9] According to the financing rules, the equipment purchased must be Brazilian. These funds can be obtained directly from the BNDES or through registered public or private financial institutions.

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[8] As of March 1, 2016, any renewable source, in addition to qualified cogeneration, could be used with distributed microgeneration referring to a generating plant with an installed capacity of up to 75 kilowatts (KW) and mini-generation referring to a plant with a power greater than 75 kW but less than or equal to 5 MW, both of which could be connected to the distribution network via consumer units.

[9] Other items financed are electric, hybrid and exclusively biofuel-powered buses and trucks, with the aim of reducing greenhouse gas emissions.

Bank of Brazil (BB) is another important institution influencing the market due to the Brazilian government's strategic interests (BB). BB is a public-private[10] financial institution responsible for implementing the Federal Government's credit policies. "*Pronaf–Eco"* and "*BB Crédito Energia Renovável"* are two of BB's current lines of credit for the adoption of sustainable technologies (BB 2021a, 2021b). The "*Pronaf–Eco"* credit line seeks to promote the adoption of sustainable and efficient technologies in family farming and finances up to R$200,000.00 for family farmers[11]. The credit line "*BB Crédito Energia Renovável*" is intended to acquire and install photovoltaic systems[12] acquired from suppliers with BB agreements.

The "*Minha Casa, Minha Vida*" program has built nearly 4 million housing units for low-income families. It has been one of the main drivers of domestic sustainable technology growth from 2009 to 2014. This growth is due to the program's encouragement of using solar water heaters and favorable loan terms for homes seeking energy efficiency within the program's scope (IRENA 2021; OIT 2013; SMP 2021). Similarly, the Goiana Housing Agency (AGEHAB) in Goiás State incorporates solar energy technologies into social interest housing programs in collaboration with city halls. For instance, the "*Cheque Mais Moradia*" program subsidizes the construction, renovation, and installation of up to two photovoltaic panels in social housing and solar water heater support (IRENA 2021; Osava 2019).

3.3. Data

The Family Budget Survey (*Pesquisa de Orçamento Familiar - POF*) analyzes the expenditure structures, income, and part of the wealth variation of families, providing a profile of the population's living conditions through the observation of household budgets. The information comes from a household sampling survey. The research sample disseminates results nationally and in urban and rural situations. The sample selection in the POF employs

[10] According to Article 4 of Law 13.303/2016, a mixed capital company is defined as "[...] an entity with legal personality of private law, with creation authorized by law, in the form of a joint stock company, whose shares with the right to vote belong in their majority to the Union, the States, the Federal District, the Municipalities or the indirect administration entity" (*República Federativa do Brasil*, 2016).

[11] Rural producers must submit the declaration of aptitude to the National Program for Strengthening Family Farming (*Programa Nacional de Fortalecimento da Agricultura Familiar*- PRONAF). The credit line has terms from 10 to 12 years and grace periods from 5 to 8 years, together with interest rates of 3% p.a. for ecological projects and 4.5% for forestry.

[12] With terms ranging from 2 to 60 months, with a grace period of 180 days, the hiring limits have a minimum value of R$5,000.00 and a maximum value of R$100,000.

a conglomerate sampling plan in two stages of selection, with statistical and geographic stratification in the first stage units. First stage selection units refer to sectors, and second stage units, on the other hand, correspond to permanent private households. The period of POF 2017-2018 began on July 11, 2017, and ended on July 9, 2018. Its reference date for compilation, analysis, and presentation of results was January 15, 2018. As the only consumption range in Brazil that does not have any tariff subsidy is those families that consume more than 220 kilowatts per hour (kW/h), we used it as a sample to analyze all households with consumption above 220 kWh per month.

The result variable used in this research was obtained from the POF 2017-2018 and derived from the household's final amount of electricity consumed in kilowatts per hour (kW/h). Thus, we propose using a treatment variable that indicates whether the home has alternative energy sources (generator, solar, and wind plate). We created a variable based on the residential electricity tariffs defined by the National Electric Energy Agency (ANEEL) for each state of the federation and each year of the POF 2017-2018 to adjust the sensitivity of the household to residential power costs. To control the sensitivity of the home to income, we constructed a variable that considers the total monthly gross income of the family unit. Moreover, the value of the electricity tariff and the household income were deflated to values on January 15, 2018. Finally, we apply the natural logarithm to the three variables.

Table 1 presents the descriptive statistics of all variables used considering the complex sampling plan of POF 2017-2018, with the expansion factor adjusted for January 15, 2018 (sample weight variable), considering geographic and statistical stratifications (variable of Stratum), and Primary sampling unit code (UPA Code). We have four groups of covariates, listed in Table 1. The first aims to regulate the architectural characteristics of the household (two discrete quantitative variables for the number of rooms and bathrooms in the home). The second group aims to control demand's specific characteristics through the number of electronic equipment in the house. The third group consists of binary variables seeking to maintain the status of the property and its type. The fourth group aims to exert control over the characteristics of the household's occupants (the average age of the household occupants, indicator variables for the individuals' race[13], the level of education of

[13] We considered those individuals who declared themselves to be white as white or yellow, and we considered as black those individuals who declared themselves as black or mixed-race.

the head of the household, and the average level of education of the reference couple) and to capture aspects related to work and family composition of the household occupants (a variable indicating whether the head of the household had a formal job and another whether the reference couple in the household had a formal job, a discrete variable for the number of children in the household).

Observing the descriptive statistics in Table 1, approximately 3% of the sample adopts some alternative energy source (such as generator, solar, and wind plant). The residential electricity consumption is approximately R$527.00 for the treated group against R$339.00 for the control group, and this difference is statistically different. As for household income, this variable is also statistically different between the two groups.

Table 9 – Descriptive Statistics and Balance of Variables

	Sample		Treated	Control	Difference
	Mean	**S.D.**	**Mean**	**Mean**	**p-value**
Treatment	0.027	0.161	-	-	-
kw/h	342.90	150.10	526.87	339.32	0.000
Tariff	0.52	0.06	0.55	0.51	0.000
Income	8615.96	12584.88	14766.01	8445.41	0.000
Group 1					
# Rooms	6.66	2.58	7.94	6.63	0.000
# Toilets	1.63	0.96	2.12	1.62	0.001
Group 2					
# Air conditioning	0.62	1.09	1.14	0.61	0.000
# Dishwasher	0.05	0.22	0.13	0.05	0.002
# Washing machine	0.80	0.48	0.78	0.80	0.743
# Iron	0.88	0.57	0.76	0.89	0.048
# Stereo	0.35	0.55	0.37	0.35	0.698
# TV´s	1.64	0.97	1.96	1.64	0.023
# Fans	1.72	1.40	1.22	1.74	0.000
# Computers	0.85	1.00	1.21	0.84	0.019
# Microwave	0.68	0.49	0.56	0.68	0.005
# Freezer´s	1.05	0.33	0.83	1.05	0.000
# Shower	1.04	0.92	1.04	1.04	0.986
Group 3					
Own	0.67	0.47	0.74	0.67	0.072
Rented	0.14	0.35	0.05	0.15	0.000
Funded	0.07	0.25	0.08	0.07	0.613
Given	0.12	0.32	0.13	0.11	0.581
Another condition.	0.01	0.09	0.01	0.01	0.635
House	0.88	0.33	0.83	0.88	0.230
Apartment.	0.12	0.33	0.17	0.12	0.228
Another type	0.0008	0.03	0.0007	0.0008	0.810
Group 4					
Average age of residence	34.36	14.31	34.89	34.34	0.647
Head’s average age	48.75	14.16	48.85	48.74	0.904

Couple’s average age	47.86	13.86	47.69	47.66	0.834
Race	0.72	0.45	0.71	0.72	0.696
Head’s education	9.83	4.73	9.68	9.83	0.768
Couple's education	9.87	4.40	9.87	9.87	0.994
Head’s Formal Work	0.95	0.22	0.94	0.95	0.762
Couple’s formal work	0.87	0.23	0.87	0.87	0.823
# Number of children	1.67	1.31	1.81	1.66	0.282

Source: Family Budget Survey 2017-2018 (POF 2017-2018), Brazilian Institute of Geography and Statistics (IBGE). The descriptive statistics of the federative units were not reported due to space limitations.

3.4. Method

This research test whether the adoption of sustainable technologies in the unconditional distribution affects residential electricity consumption in Brazil. We assess whether adopting sustainable technologies alters the distribution of residential electricity consumption in Brazil and whether this change affects the concentration of residential electricity consumption. We divide the analysis into two parts: (i) to verify whether there is an effect of renewable technologies on the average population distribution; and at different points of unconditional quantile distribution; and (ii) to verify whether the adoption of renewable technologies can generate inequality in the consumption of residential electricity for the Brazilian population. Consider the following linear relationship:

$$Y_i = \alpha + \beta T_i + \gamma X_i + \varepsilon_i \tag{1}$$

where Y_i represents residential electricity consumption in the natural logarithm of kWh for each household i. The variable T_i identifies those households that have adopted sustainable technologies. The treatment variable assumes the value 1 when using alternative energy sources (generator, solar, and wind board) and zero otherwise. Covariates X_i' are separated into four groups. The use of these variables seeks to mitigate the problem of confounding variables. Finally, the parameter ε_i is the stochastic term.

This first relationship aims to verify the effect of the adoption of technologies on the average residential electricity consumption. It is only possible to identify the effect if we eliminate the main sources of selection bias on the part of individuals. Consider the framework of potential results proposed by Rosenbaum and Rubin (1983), where for each household i, a couple of results are possible, $Y_i(0)$ and $Y_i(1)$ which are the results for the control and treated groups, respectively. As households cannot be in both conditions simultaneously, the causal effect cannot be estimated directly. The control group may not approach the counterfactual in the absence of randomization. To identify the effect of treatment with this possible mitigated bias, we need to find the average effect of treatment on treated (ATT). Assuming that the selection bias is due to observable characteristics. Then, the pairing method could perform the strategy of identifying the causal effect of treatment.

The observable selection hypothesis assumes that the vector of observable variables X_i contains all the information about the potential outcome. Thus, the potential results become independent of the treatment variable. The second hypothesis necessary to identify the effect of treatment on the mean is the hypothesis of common support, that is, that each household in the treatment group has at least one pair in the control group. The region of the vector function X_i which encompasses the characteristics of treated households and represents individuals in the untreated group. In formal terms, we have to $(Y_i(1), Y_i(0)) \perp T_i | X_i$ and as we increase the number of variables contained in the vector X_i, larger its dimension, and thus the possibility of pairing becomes more difficult. To deal with this, a function X_i can summarize all the information contained in the vector X_i and maintain the orthogonality of the treatment variable (Rosenbaum & Rubin 1983). That is, $(Y_i(1), Y_i(0)) \perp T_i | p(X_i)$. The causal effect of the adoption of sustainable technologies on the average consumption of electricity at home is given by:

$$\beta_{ATT} = E[Y|T = 1, p(X)] - E[Y|T = 0, p(X_i)] \tag{2}$$

Thus, econometric analysis takes place in two stages. First, the propensity score is estimated using the treatment variable as a dependent variable as a function of observable covariates. In the second stage, a regression of residential electricity consumption is estimated as a function of the treatment variable with the sample weighted by the propensity score. To perform the pairing, we used the Inverse Probability Weighting Algorithm, which randomly orders the observations, selects the first observation of the treated group, and performs the pairing with the observation of the control group with the closest propensity score. Since POF is a database with a complex sample structure, the propensity score weight methods are adequate in complex structures samples (DuGoff, Schuler, e Stuart 2014). That is, methods of propensity score with complex samples should combine the weights of the propensity score with the weights of the complex sample.

The average effects are of limited use when policymakers are concerned with the provision of public services and their distribution among different social strata and, more importantly, the outcomes of public policies in these groups. As a result, it is critical to examine the implications of policies for adopting sustainable technologies in various consumer groups. Quantile regression is an appropriate empirical strategy for identifying the effects at different points in the distribution (QR) (Koenker 2004; Koenker e Bassett 1978). If we were interested in finding the effect of conditional quantile treatment (CQR) assuming an exogenous treatment, we would use the estimator proposed by Koenker & Bassett (1978). If our interest were to estimate the conditional CQR considering the endogenous treatment, the estimator proposed by Abadie et al. (2002) could be used. However, we want to estimate unconditional QTE, that is, to identify the effect of treatment on unconditional population distribution. Thus, under the hypothesis of exogenous treatment, the estimators proposed by Firpo (2007) e Melly (2006). The unconditional QTE in the presence of endogenous treatment can be estimated through the estimators proposed by Frölich & Melly (2008) and Firpo & Pinto (2016).

Firpo & Pinto (2016) described that standard RIF regressions should not be used to estimate the effect of large changes in the distribution of the independent variables, particularly when considering categorical variables. Moreover, they use parametric or nonparametric strategies to obtain inverse probability weights to identify counterfactual distributions and the treatment effects. Firpo & Pinto (2016) call inequality treatment effects. In this line, the first analysis will be through the Propensity Score Matching adjusted for complex samples to verify the effect of the adoption of sustainable technologies in Brazil on the mean of the unconditional distribution. Subsequently, we applied the analysis of the unconditional quantile effects for the quantiles: Q05, Q10, Q25, Q50, Q75, Q90, and Q95, combining the estimator proposed by Firpo & Pinto (2016) and the adjusted complex sample weights (DuGoff et al. 2014).

Finally, we continue to use the same estimator; however, we tested whether there was a change in the distribution of residential electricity consumption to the following measures of inequality: inter-quantiles ratios Q90/Q05, Q90/10, Q95/Q05, Q95/Q10; Gini inequality index, Absolute Gini inequality index, Atkin inequality index, and Lorenz inequality index. If we find statistically significant and positive results for these measures, we will have evidence of inequality in electricity consumption. On the other hand, a negative and significant magnitude of the Lorenz inequality index indicates increased inequality.

3.5. Results

Table 2 presents the balances of the covariates after the weighting of each sample with the complex sample weights multiplied by the propensity scores as proposed by Dugoff et al. (2014). All covariates are comparable between the treated groups and controls for the three samples. They are statistically equal between the two groups at a significance level of at least 5%. Therefore, the treated and control groups are comparable in this sample.

Table 10 – Balance of Covariates

	Average Treated	Average Control	p-value
Tariff	0.55	0.55	0.781
Income	14766.01	13101.84	0.372
# Bathrooms	2.13	1.87	0.110
# Rooms	7.94	7.46	0.196
# Air-conditioners.	1.14	0.96	0.234
# Dishwashers	0.13	0.15	0.689
# Washing Machines	0.78	0.73	0.256
# Iron	0.76	0.73	0.688
# Stereo	0.37	0.34	0.471
# TV´s	1.96	1.79	0.280
# Fans	1.22	1.16	0.575
# Computers	1.21	1.01	0.200
# Microwaves	0.56	0.56	0.852
# Freezers	0.83	0.82	0.856
# Showers	1.04	0.94	0.467
Owned	0.74	0.74	0.951
Rented	0.05	0.04	0.857
Financed	0.08	0.07	0.687
Ceded	0.13	0.14	0.781
Other cond.	0.005	0.005	0.944
House	0.83	0.85	0.592
Apartment	0.17	0.15	0.578

Other type	0.001	0.001	0.409
Average age	34.89	32.93	0.119
Head's average age	48.84	48.14	0.421
Couple's average age	47.69	46.77	0.299
Race	0.71	0.71	0.938
Head's education	9.68	8.97	0.197
Couple's education	9.87	9.24	0.217
Head's formal work	0.94	0.96	0.466
Couple's formal work	0.87	0.87	0.986
# Number of children	1.81	1.99	0.248

Sources: POF2017-2018 (IBGE).

Table 3 presents the results for the treatment effect on different points of unconditional distribution of Brazilian residential electricity consumption. The first column shows the effect of the adoption of renewable technologies on the unconditional average. From column (2) to column (7), we have unconditional quantile effects (Q05, Q10, Q15, Q25, Q50, Q75, Q90, and Q95). As the treatment variable is indicative, the interpretation of the result is different, the coefficient is divided by 100, and the effect for the increase of 1 percentage point is analyzed. In the first column, the result shows that an increase of one percentage point in the adoption of sustainable technologies in Brazil increased, on average, the consumption of residential electricity by approximately 0.15%. When analyzing the possible heterogeneous effects of adoption for different points of consumption distribution, we noticed that the effect is significant to quantiles 0.25, 0.75, 0.90, and 0.95. It is important to note that the greatest heterogeneous effects occur in the 90 and 95 quantiles, which were approximately 0.27% and 0.37%, respectively.

Table 11 – The adoption of sustainable technologies

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Mean	**Q05**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**	**Q95**
Sus. Technologies	0.1495*** (0.0456)	-0.0069 (0.0269)	0.0183 (0.0487)	0.1034*** (0.0283)	0.0825 (0.0732)	0.2315*** (0.0813)	0.2680** (0.1085)	0.3744** (0.1630)
R-squared	0.3802	0.1475	0.1638	0.2261	0.3064	0.3359	0.1830	0.1866
N	41,749	41,749	41,749	41,749	41,749	41,749	41,749	41,749

Notes: Covariables were omitted by space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are linearized standard errors of the coefficients.

The results indicate that the adoption of renewable technologies positively affects the average population distribution. In other words, the adoption of sustainable technologies increases the average population consumption of residential electricity. Nevertheless, when analyzing different points of the consumption distribution, we realized that this displacement occurs at the highest points of the distribution of unconditional consumption. In economic terms, it is possible to argue that households with higher electricity consumption adopt modern technologies of energy self-generation as a strategy to increase electricity consumption. On the other hand, the adoption of self-generation technologies for households with lower consumption may indicate a strategy of replacing the electricity source by maintaining the same level of consumption.

We applied the analysis to different measures of inequality to assess the hypothesis that the adoption of renewable technologies generates inequality in the consumption of residential electricity for the Brazilian population. Table 4 presents the results in eight columns. From columns 1 to 4, we present inter-quantile residential electricity consumption (Q90/Q05; Q90/Q10; Q95/Q05; Q95/Q10). Moreover, in columns 5 to 8 are presented the results for the inequality measures of Gini, Absolute Gini, Atkinson, General Entropy, and Lorenz. Their complementarity justifies the application of such indices. For example, the Gini index has low sensitivity at the distribution's tails, and the inter-quantile ratios disregard the middle of the distribution (Foster et al. 2013; Sitthiyot e Holasut 2020). On the other hand, the Atkinson and General Entropy indices complement the others by adding consistency among subgroups to measure inequality and are suitable for policymaking (Foster et al. 2013; UN 2015).

The results in Table 4 show that the adoption of energy transition technologies increased the inequality of residential electricity consumption in all the analyzes conducted. The results presented in the first four columns show a statistically significant difference between the selected quantiles and the distribution's tails. Families that consumed more residential electricity and adopted sustainable technologies are farther away from families that consumed less residential electricity. Furthermore, columns 5 to 8 corroborate the hypothesis that the adoption of sustainable technologies in Brazil generated inequality in residential electricity consumption.

Table 12 – The adoption of sustainable technologies

	(1) Q90/05	(2) Q90/10	(3) Q95/05	(4) Q95/10	(5) Gini	(6) aGini	(7) Atkin	(8) Entropy	(9) Lorenz
Sus. Technologies	0.305*** (0.093)	0.282*** (0.102)	0.380** (0.164)	0.357** (0.170)	0.013*** (0.004)	0.096*** (0.024)	0.002*** (0.001)	0.002*** (0.000)	-0.009*** (0.003)
R-squared	0.144	0.132	0.168	0.157	0.197	0.23	0.180	0.176	0.202
N	41,749	41,749	41,749	41,749	41,749	41,749	41,749	41,749	41,749

Notes: Covariables were omitted by space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are linearized standard errors of the coefficients. Atkinson inequality index with inequality (entropy inequality index with sensitivity index 1); (Lorenz ordinate at 50th quantile).

3.6. Robustness analyzes

We present two empirical strategies to verify the robustness of the results found. We first propose the placebo test, which is a routine when using the propensity matching score method. This analysis verifies that the results were due to chance (Type I Error). We created a binary random treatment variable with mean and standard deviation similar to the original treatment variable to perform this analysis. This variable is named "Placebo Treatment". After creating the Placebo Treatment variable, we replicated the earlier analysis. Because the variable is random, we expect the results not to be consistent. Table I, in the appendix, shows a balance of the covariates for placebo treatment. Table II e III presents the results of the placebo test in the treatment. As expected, the variables are not statistically significant. Therefore, we are confident that the earlier results were not due to chance.

In the second robustness strategy, we propose an analysis for a population subsample. We propose a subsample removing 1% of both ends of the general consumption distribution (Robustness Sample). This analysis can be justified considering possible outliers values in the population sample. On the other hand, this type of analysis can be questioned because it can generate sample bias on the researcher's part. Table 5 presents the results for the treatment effect on different points of the unconditional distribution of Brazilian residential electricity consumption for the restricted sample. The table follows the same pattern as the table presented in the previous section. In the first column, the result indicates that an increase of one percentage point in the adoption of sustainable technologies in Brazil increased, on average, the consumption of residential electricity by approximately 0.06% for the restricted sample. When analyzing the possible heterogeneous effects of adoption for different points of consumption distribution, we noticed that the effect is significant in the quantiles 0.25, 0.90, and 0.95, following a pattern close to that found in the results section. In general terms, the results show that the adoption of renewable technologies positively affects the average consumption of residential electricity for the restricted sample. As found in the earlier analyses, when analyzing different points of the consumption distribution, we perceive that this displacement occurs in the highest points of the distribution of unconditional consumption.

Table 13 – Robustness - The adoption of sustainable technologies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Mean	**Q05**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**	**Q95**
Sus. Technologies	0.064* (0.0341)	-0.007 (0.0252)	0.036 (0.0365)	0.106*** (0.0260)	0.005 (0.0718)	0.057 (0.0866)	0.214*** (0.0683)	0.094** (0.0418)
R-squared	0.3866	0.1658	0.1694	0.2127	0.3080	0.4047	0.1407	0.1081
N	37,557	37,557	37,557	37,557	37,557	37,557	37,557	37,557

Notes: Covariables were omitted by space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are linearized standard errors of the coefficients.

As for the issues of inequality in residential electricity consumption, Table 6 presents the results in eight columns. From columns 1 to 4, we present inter-quantile residential electricity consumption (Q90/Q05; Q90/Q10; Q95/Q05; Q95/Q10). Moreover, in columns, 5 to 8 are presented the results for the previous measures of inequality (Gini, Absolute Gini, Atkin, Entropy, and Lorenz). The results corroborate the idea that the adoption of energy transition technologies for self-production increases the inequality of residential electricity consumption. The results presented in columns 1, 2, and 4 show a statistically significant distance between the distribution's tails. Furthermore, the results presented in columns 5, 7, 8, and 9 corroborate the hypothesis that adopting sustainable technologies generates inequality in residential electricity consumption considering the restricted sample.

Table 14 – Robustness - The adoption of sustainable technologies

	(1) Q90/05	(2) Q90/10	(3) Q95/05	(4) Q95/10	(5) Gini	(6) aGini	(7) Atkin	(8) Entropy	(9) Lorenz
Sus. Technologies	0.206** (0.081)	0.164** (0.081)	0.104* (0.056)	0.063 (0.057)	0.004** (0.001)	0.008 (0.011)	0.0004* (0.000)	0.0004* (0.000)	-0.003* (0.001)
R-squared	0.172	0.163	0.103	0.103	0.189	0.205	0.177	0.169	0.241
N	37,557	37,557	37,557	37,557	37,557	37,557	37,557	37,557	37,557

Notes: Covariables were omitted by space considerations. The symbols *, ** and *** stands for statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are linearized standard errors of the coefficients. Atkinson inequality index with inequality (entropy inequality index with sensitivity index 1); (Lorenz ordinate at 50th quantile).

3.7. Political Considerations

The power supply is a challenge for modern societies. A minimum level of electricity consumption (and from safe sources) is necessary to promote quality of life and adequate conditions for social development. In this sense, the expansion of distributed energy generation can generate systemic benefits by diversifying the energy matrix towards low-carbon energy sources, promoting resilience in peak demand and climatic adversities. Furthermore, adopting such technologies can generate essential gains in the household budget, especially for those who suffer from energy insecurity. Therefore, current movements toward the energy transition need to pay attention to the risk of reinforcing inequalities structures.

The adoption of sustainable technologies has been growing in recent years in Brazil. This adoption of distributed generation systems is subsidized by different channels, among which the governmental action stands out. The Brazilian government seeks to combine housing policies with energy self-generation technologies for low-income families. The federal program "*Minha Casa, Minha Vida*," which provides access to sustainable technologies for low-income households, stands out (IRENA 2021). The national electricity agency (ANEEL) discounts the electricity tariff for poor consumers, indigenous and *quilombolas*. Ordinary consumers consume more than 220 kW/h (ANEEL 2020). For these ordinary consumers, the adoption of sustainable technologies results from consumers' choice, which depends on their preferences regarding the environment and sustainable technologies, their investment ability, and whether the property's characteristics in which consumers live are suitable for installation equipment. Assuming that the property is suitable for installation and the heads of the household are interested in installing the equipment, the choice will fall on investment analysis and access to credit. The Brazilian federal government plays a crucial role in the electricity market, encouraging installing technologies from renewable sources through subsidized credit. The main financing agent of government policies is the National Bank for Economic and Social Development (BNDES) and its credit lines. In November 2021, *Caixa Econômica Federal* (the central public bank responsible for much of the real estate financing in Brazil) studied the launch of credit lines to expand the access of individuals to clean technologies with favorable interest rates (CNN Brasil 2021).

The empirical results show that the adoption of renewable technologies by ordinary consumers in Brazil generates an increase in electricity consumption, besides causing an effect of inequality in the consumption of residential electricity even controlling for distinct characteristics of both the property and income and characteristics of residents. It is essential to highlight that there is no possibility of identifying households that received the subsidy in the analyses. When considering the current Brazilian renewable electricity market context, there is a need to discuss the financing criteria of technologies to mitigate a possible indirect mechanism of income concentration. Therefore, so that the federal government of Brazil can continue to accelerate installing new self-generation technologies and expanding the energy matrix, the government could adopt at least two policies. First, more significant publicity of the credit lines explaining the current criteria and elucidating any doubts to stimulate the decision by installation. Secondly, review current credit subsidy policies to avoid possible regressive effects of the policy. For example, the government can expand credit lines within the financial system and redesign contractual criteria to adopt a conditional credit policy. One idea would be to distribute the available credit by consumption sub-bands for the last 12 months. Thus, the total amount of credit available for the investment can be divided into diverse consumption levels, avoiding consumption inequality and some regressive effect due to access to credit. In addition, it would be possible for the interest rate charged by the financing to be marginally different between the consumption levels. Finally, the policy could create a mechanism for randomizing access to public funding in case of excessive demand for credit.

3.8. Final Remarks

This research pioneered the study of the impact of the adoption of renewable energy technology on the unconditional distribution of residential electricity consumption in Brazil. The work innovated using microdata from the 2017-2018 POF with a complex sampling plan and methodologies not previously used. The results found provided reliable estimates of the adoption of sustainable technologies on the residential electricity demand of the Brazilian population. In strict terms, the results indicate that adopting sustainable technologies increases the average population consumption of residential electricity. However, it is consumers with higher consumption that shift the average. The results show that the adoption of energy transition technologies increased the inequality of residential electricity consumption in all the analyzes carried out.

Although the energy transition is essential from various perspectives, policymakers must be aware of how it is taking place. Public managers must pay particular attention to the potential mechanisms for generating electricity inequality and income concentration within the current socio-economic context. As a research suggestion, studies on the design of mechanisms for financing contracts for sustainable technologies in Brazil should be expanded to avoid any mechanism that concentrates income and creates inequalities. Furthermore, future research should empirically identify the effects of public financing on electricity inequality.

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Appendix

Tabela A 4 - Balance of Covariates

	Average Treated	Average Control	P-value
Tariff	0.52	0.52	0.962
Income	7187.45	7535.18	0.608
# Bathrooms	1.51	1.56	0.602
# Rooms	6.66	6.78	0.663
# Air-condic.	0.43	0.49	0.436
# Dishwasher	0.01	0.02	0.044
# Washing machines	0.73	0.80	0.207
# Iron	0.88	0.93	0.483
# Stereo	0.29	0.31	0.611
# TVs	1.42	1.48	0.384
# Fans	1.53	1.68	0.327
# Computers	0.66	0.70	0.646
# Microwave	0.59	0.60	0.862
# Freezers	1.01	1.02	0.405
# Shower	0.90	1.01	0.110
Own	0.60	0.66	0.255
Rented	0.20	0.16	0.446
Funded	0.11	0.07	0.289
Assigned	0.09	0.10	0.585
Another cond.	0.001	0.002	0.568
House	0.93	0.95	0.360

Apartment.	0.07	0.05	0.360
Another type	.	.	.
Average age	32.58	31.63	0.408
Head’s average age	49.65	48.61	0.472
Couple’s average age	49.59	47.73	0.194
Race	0.73	0.73	0.932
Head’s education	8.80	8.90	0.855
Couple's education	8.90	9.00	0.855
Head’s Formal Work	0.98	0.96	0.767
Couple’s Formal work	0.87	0.88	0.704
# Number of children	2.19	2.10	0.631

Sources: POF 2017-2018 (IBGE).

Tabela A 5 – Results for Placebo Treatment Effects

	(1) Mean	(2) Q05	(3) Q10	(4) Q25	(5) Q50	(6) Q75	(7) Q90	(8) Q95
Placebo Treatment	0.0105 (0.0252)	-0.0103 (0.0131)	0.0039 (0.0135)	-0.0037 (0.0250)	0.0090 (0.0276)	0.0555 (0.0433)	0.0894* (0.0484)	0.1112 (0.1391)
R-squared	0.2465	0.1552	0.1628	0.1694	0.1885	0.2070	0.1866	0.2160
N	41,742	41,742	41,742	41,742	41,742	41,742	41,742	41,742

Notes: Covariables were omitted by space considerations. The symbols *, ** and *** represent statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are linearized standard errors of the coefficients.

Tabela A 6 – Results for Placebo Treatment Effects

	(1) Q90/05	(2) Q90/10	(3) Q95/05	(4) Q95/10	(5) Gini	(6) aGini	(7) Atkin	(8) Entropy	(9) Lorenz
Placebo Treatment	0.1047 (0.0650)	0.0861 (0.0647)	0.1049 (0.1125)	0.0863 (0.1120)	0.0018 (0.0019)	0.0036 (0.0114)	0.0001 (0.0002)	0.0001 (0.0002)	-0.0013 (0.0014)
R-squared	0.2112	0.2091	0.1933	0.1934	0.2051	0.2093	0.1640	0.1591	0.2123
N	41,742	41,742	41,742	41,742	41,742	41,742	41,742	41,742	41,742

Notes: Covariables were omitted by space considerations. The symbols *, ** and *** stands for statistical significance of 10%, 5% and 1%, respectively. The values in parentheses are linearized standard errors of the coefficients. Atkinson inequality index with inequality (entropy inequality index with sensitivity index 1); (Lorenz ordinate at 50th quantile).

4. Final remarks

This thesis aimed to contribute to the literature on Conditional Income Transfer Programs and on renewable energies. In the first essay, we analyzed the effect of the “Bolsa Família” program on the food condition of children from beneficiary families, analyzing the effects of the PBF on the following outcome variables: (i) Energy in Kcal; (ii) Energy in KJ; (iii) Carbohydrates; (iv) Proteins; and (v) Lipids. In the second essay, we identified the effect of sustainable technologies on electricity demand in Brazil and its implications for inequality in residential electricity consumption. In both essays we used data from the Household Budget Survey (POF2017-2018) from the Brazilian Institute of Geography and Statistics.

In the first trial, we used the ordinary least squares method for complex samples (Ordinary Least Squares Survey) and pairing methods (Propensity Score Matching and Propensity Score Weighting) to identify the effects of the “Bolsa Família” program on child nutrition. As a robustness analysis, we propose (i) application of the placebo test, (ii) analysis of heterogeneous effects by regions and (iii) analysis for urban areas in Brazil. The results show that the “Bolsa Família” program provided an average increase of 469 Kcal in the children's diet, an effect similar to that measured in kilojoules. The results indicate that children from the treated families had an average daily consumption of approximately 2,607 calories, representing an increase of approximately 22% in caloric consumption compared to the control group (2,137.7 calories). Regarding macronutrients, the increase in the consumption of carbohydrates (69 grams), proteins (19 grams) and lipids (12 grams) represented an increase of approximately 24.28%, 20.41% and 17.04%, respectively, in the average food consumption of children of beneficiary families.

In the second essay, we analyze the effect of sustainable technologies on electricity demand in Brazil and its implications for inequality in residential electricity consumption using the Inverse Probability Weighting algorithm to identify the average effect of treatment at the population level and the estimator of the effect of unconditional quantile treatment for the analysis of heterogeneous treatment effects. We also considered the correction for the sample data structure in both analyzes and applied the placebo test and subsample analyzes to verify the robustness of the results. The empirical results show that the adoption of renewable technologies by common consumers in Brazil generates an increase in electricity consumption, in addition to causing an effect of inequality in residential electricity consumption, even controlling for different characteristics of both the property and income and characteristics. of the residents.