Climate Events and Academic Performance: Evidence from Brazil*

Juliano da Costa da Silva
PhD student at Federal University of Juiz de Fora
E-mail: jcs.julianodasilva@gmail.com

Flávia Chein
Professor at Federal University of Juiz de Fora
E-mail: flavia.chein@ufjf.br

ENABER Area: - Meio ambiente, recursos naturais e sustentabilidade

Abstract

This paper investigates the short-term effects of climatological events, particularly droughts, on the academic performance of children and teenagers. Using data from the National Civil Defense in Brazil, we exploit cross-sectional and time variation in the occurrence of extreme climate events. Our estimates using the Chaisemartin approach indicate a positive effect of climatological disasters on mathematics performance in the 5^{th} grade of elementary school, particularly in subsample 2, which corresponds to municipalities exposed to disasters during the period preceding the application of the Prova Brasil exam. Under this condition, treated municipalities showed an average increase of 3.82 points in math scores compared to control municipalities. This significant effect corresponds to a 0.15 standard deviation increase relative to the overall distribution of scores. Still, it is restricted to the exam edition that coincides temporally with the disaster. Additionally, improvements were observed in related educational indicators, such as higher promotion rates and lower failure rates, which reinforces the robustness of the proficiency test results

Keywords: Extreme Climate Events; Student Performance; Child Labor.

JEL Code: I1, I2, Q5

*The authors are grateful to CAPES, FAPEMIG, and CNPq for financial support

Resumo

Este artigo investiga os efeitos de curto prazo de eventos climatológicos, particularmente as secas, sobre o desempenho acadêmico de crianças e adolescentes. Utilizando dados da Defesa Civil Nacional no Brasil, exploramos variações seccionais e temporais na ocorrência de eventos climáticos extremos. Nossas estimativas, utilizando a abordagem de Chaisemartin, indicam um efeito positivo dos desastres climatológicos sobre o desempenho em matemática no 5º ano do ensino fundamental, particularmente na subamostra 2, que corresponde aos municípios expostos a desastres durante o período que antecede a aplicação da prova Brasil. Sob essa condição, os municípios tratados apresentaram um aumento médio de 3,82 pontos nas notas de matemática em comparação aos municípios de controle. Esse efeito significativo corresponde a um aumento de 0,15 desvio-padrão em relação à distribuição geral das notas. Ainda assim, ele é restrito à edição da prova que coincide temporalmente com o desastre. Adicionalmente, foram observadas melhorias em indicadores educacionais relacionados, como maiores taxas de promoção e menores taxas de reprovação, o que reforça a robustez dos resultados do teste de proficiência.

Palavras Chaves: Eventos Climáticos Extremos; Desempenho Estudantil; Trabalho Infantil.

1 Introduction

Global warming and climate change have become a growing concern on a worldwide scale, accompanied by an increasing frequency and intensity of natural disasters associated with these changes. In Brazil, the intensification of extreme weather events is already alarming. Given the importance of education for the country's development and economic growth, it becomes essential to understand how these disasters affect educational performance.

According to the Intergovernmental Panel on Climate Change IPCC (2022)[1], the number of natural disasters is expected to increase in the coming years. Based on information from the World Meteorological Organization OMM (2018)[2], in partnership with the United Nations Office for Disaster Risk Reduction (UNDRR[3]), between 1970 and 2019, natural disasters accounted for 50% of all historically recorded disasters. During this period, they were responsible for 45% of all deaths attributed to natural disasters and 74% of the associated economic losses. More than 11,000 natural disasters were reported as a result of climate-related events, resulting in over 2 million deaths and economic losses amounting to USD 3.47 trillion, with 91% of deaths occurring in developing countries.

In Brazil, according to data from the Digital Atlas of Natural Disasters in Brazil Atlas Digital (2024) from the National Secretariat for Protection and Civil Defense, between 2011 and 2019, 22,133 natural disasters were recorded. During this period, approximately 3.26 million people were displaced or left homeless, over 720,000 individuals were injured or fell ill, 1,897 deaths were recorded, and more than 116 million people were affected. Most of these disasters are associated with climate change, with climatological events accounting for 52.05% of occurrences, followed by hydrological events, which represent 24.03% of the records. In financial terms, the economic losses resulting from natural disasters in Brazil were estimated at approximately BRL 45.89 billion in material damage. In the public sector, the loss was about BRL 33.35 billion, while the private sector accumulated losses of approximately BRL 196.95 billion.

[1]IPCC: International Panel on Climate Change

[2]WMO: World Meteorological Organization

[3]UNDRR: United Nations Office for Disaster Risk Reduction

Climatological disasters are closely tied to the climatic conditions of a specific region and can manifest as extreme variations in humidity, prolonged droughts, and dry spells. These events significantly impacted the private sector, generating estimated losses of BRL 133.85 billion. In the public sector, the losses were approximately BRL 18.27 billion. In addition, BRL 262.8 million in material damages were reported, along with 110 deaths and approximately 25,000 displaced or homeless individuals, totaling around 72 million people affected between 2011 and 2019 (Atlas Digital, 2024).

Therefore, these impacts, encompassing both human and economic dimensions, have implications for human capital and education. The effects on human capital and education can arise directly or indirectly, whether through health damages, changes in family composition (due to the loss of family members), or economic damages that affect the availability of resources to be allocated to education Alderman et al. (2006); Hoddinott and Kinsey (2001). Moreover, damage to school infrastructure caused by natural disasters can also compromise educational performance (Baez et al., 2010; Baez and Santos, 2007; Stein et al., 2003).

The study by Nguyen and Minh Pham (2018) examines the impact of droughts, floods, and hailstorms on education by comparing results across four countries from different continents: Ethiopia, India, Peru, and Vietnam. These countries differ in their levels of investment in health, education, and culture. Exposure to floods negatively affected student pass rates in Ethiopia, India, and Vietnam, reducing the chances of passing by 3.4%, 3.8%, and 1.8%, respectively. In Vietnam, in addition to pass rates, floods also negatively affected enrollment rates, performance in Mathematics, and scores on the Peabody Picture Vocabulary Test (PPVT)[4]. In Peru, however, none of the analyzed natural disasters showed significant effects on educational indicators.

The literature generally suggests that natural disasters tend to reduce investments in education and human capital López (2009); Pörtner (2008); Sigurdsen et al. (2011); Yamauchi et al. (2009). However, some studies present theoretical arguments pointing to the possibility of increased investment in certain contexts Ferreira and Schady (2009); López (2009); Rush (2018); Shah and Steinberg (2017); Skidmore and Toya (2002). This may occur due to the renewal of school infrastructure and a reduction in child labor in some post-disaster scenarios. Thus, although the negative effect of disasters on education and human capital is the most common hypothesis, new theoretical approaches suggest that under specific circumstances, these events may lead to positive effects.

In India, school-age children's exposure to drought is associated with better performance in Mathematics tests and increased school attendance compared to non-exposed children. This phenomenon may be explained by the lower likelihood of mothers and children engaging in work activities during drought periods, which allows greater dedication to studies (Shah and Steinberg, 2017).

In Indonesia, it was observed that the higher the proportion of the population affected by disasters, the greater the number of enrollments in primary schools. One possible explanation for this phenomenon relates to the type of disaster. In the case of droughts, which affect a large portion of the population, there is a reduction in alternative work opportunities for primary school students, especially in the agricultural sector. This situation makes families more likely to enroll their children in school. Furthermore, the results indicate that damage to crops and irrigation is also associated with increased school enrollment for children (Rush, 2018).

In this context, the present article aims to analyze the effect of climatological natural disasters on education at the municipal level. Information on natural disasters and their impact on Brazilian municipalities was provided by the Secretariat for Protection and Civil Defense (SEDEC). To measure educational performance indicators, we use microdata from the Prova Brasil (Inep) for

[4]PPVT: Peabody Picture Vocabulary Test

the years 2013, 2015, 2017, and 2019.

The empirical strategy adopted to isolate the effect of climatological disasters consisted of classifying as "treated" municipalities that experienced only climatological disasters, while municipalities that did not face natural disasters during the analyzed period served as the control group. To assess the effect of these disasters, the method proposed by de Chaisemartin and D'Haultfœuille (2024) was employed, which introduced the DID_ℓ estimator. This estimator compares the evolution of outcomes between groups that switch from "untreated" to "treated" status for the first time (Switchers) and groups that have not yet changed their treatment status (Non-Switchers), for the ℓ-th period after the initial switch.

Therefore, this article is motivated by the aim of providing evidence that contributes to ensuring continuous access to education for children during and after natural disasters. Additionally, it seeks to offer insights that promote more inclusive public policies for affected municipalities. This study also aims to enrich the existing literature, given the scarcity of evidence on the contemporary effects of natural disasters on education. By investigating the impacts of climate events on academic performance in the Brazilian context, this work contributes new evidence to the literature, exploring the occurrence of extreme weather events across different regions and periods.

2 Methodology

2.1 Data

2.1.1 Educational Data

The educational data used in this study come from the Prova Brasil, a standardized nationwide assessment conducted, administered, and disseminated by the National Institute for Educational Studies and Research Anísio Teixeira (INEP). Since 2007, the assessments have been administered biennially to 5^{th} and 9^{th} grade classes in public schools with a minimum enrollment of 20 students in these grades. This evaluation, promoted by the Brazilian Federal Government, aims to identify the cognitive skills of students throughout the national territory.

For the results of the schools participating in the SAEB to be published, it is essential to meet the following criteria: (i) record a minimum of 10 students present at the time of the assessment; (ii) achieve a participation rate of at least 80% of enrolled students, according to the data reported by the school in the Basic Education Census, also conducted by INEP.

The tests aim to evaluate skills in the Portuguese language and mathematics through proficiency tests, as well as to collect information about the students' home, family, school environment, and institutional infrastructure. INEP, in partnership with SAEB, administers a set of questionnaires addressed to students, teachers, and principals to obtain a comprehensive overview of the educational context.

In this research, we use data from the 2013, 2015, 2017, and 2019 editions of Prova Brasil. The data were aggregated at the municipal level, considering the average standardized scores in proficiency tests in Mathematics and Portuguese Language. Standardization involves transforming students' proficiencies into a unified SAEB scale, with a mean of 250 points, a standard deviation of 50, and a range of 0 to 500 points. Table 1 below presents the classification of student proficiency levels as established by SAEB, based on the scores obtained in the Mathematics and Portuguese Language tests. Students are distributed across 10 levels, ranging from 0 to 9.

Table 1: Student stratification by proficiency levels on the SAEB scale

	5th Grade of Elementary School	9th Grade of Elementary School
Level 0	From 0 to 124 points	From 0 to 199 points
Level 1	From 125 to 149 points	From 200 to 224 points
Level 2	From 150 to 174 points	From 225 to 249 points
Level 3	From 175 to 199 points	From 250 to 274 points
Level 4	From 200 to 224 points	From 275 to 299 points
Level 5	From 225 to 249 points	From 300 to 324 points
Level 6	From 250 to 274 points	From 325 to 349 points
Level 7	From 275 to 299 points	From 350 to 374 points
Level 8	From 300 to 324 points	From 375 to 399 points
Level 9	325 points or more	400 points or more

Source: Own elaboration based on SAEB data.

Additionally, variables such as the total number of enrolled students, the number of participants in each edition of Prova Brasil, and information regarding child labor status, defined as engagement in activities outside the home for at least one hour, were included. The test administration dates are presented below:

Table 2: Prova Brasil Test Administration Dates

Prova Brasil Edition	Test Administration Dates
2013	2013/11/11 to 2013/11/21
2015	2015/11/03 to 2015/11/13
2017	2017/10/23 to 2017/11/03
2019	2019/10/21 to 2019/11/01

Source: Own elaboration based on SAEB data.

To obtain municipal-level information on pass rates, data from the Basic Education Development Index (IDEB) made available by INEP were used. IDEB is calculated in the same years as the Prova Brasil, as its computation combines school pass rates, derived from the School Census, with the average performance scores obtained in SAEB. Consequently, pass rates from public schools referring to students in the fifth and ninth grades of elementary school were considered. Furthermore, to collect information about school infrastructure, data from the School Census corresponding to the years of the aforementioned Prova Brasil editions were utilized.

2.1.2 Climatological Disaster Data

Data on natural disasters were provided by the Secretariat of Protection and Civil Defense (SEDEC). In the 1990s, the National Civil Defense Information System (SINDEC) primarily relied on two instruments: the Preliminary Disaster Notification document (NOPRED) and the Damage Assessment Form (AVADAN). These instruments aimed to provide detailed information regarding the characteristics of the disasters that occurred, as well as the damage caused.

However, through a Cooperation Agreement between the National Secretariat of Protection and Civil Defense and the Center for Studies and Research in Engineering and Civil Defense (CEPED), carried out between 2010 and 2012, previously recorded data were digitized and entered into the Integrated Disaster Information System (S2ID), to centralize all disaster-related information in a single system. Additionally, since the publication of Normative Instruction

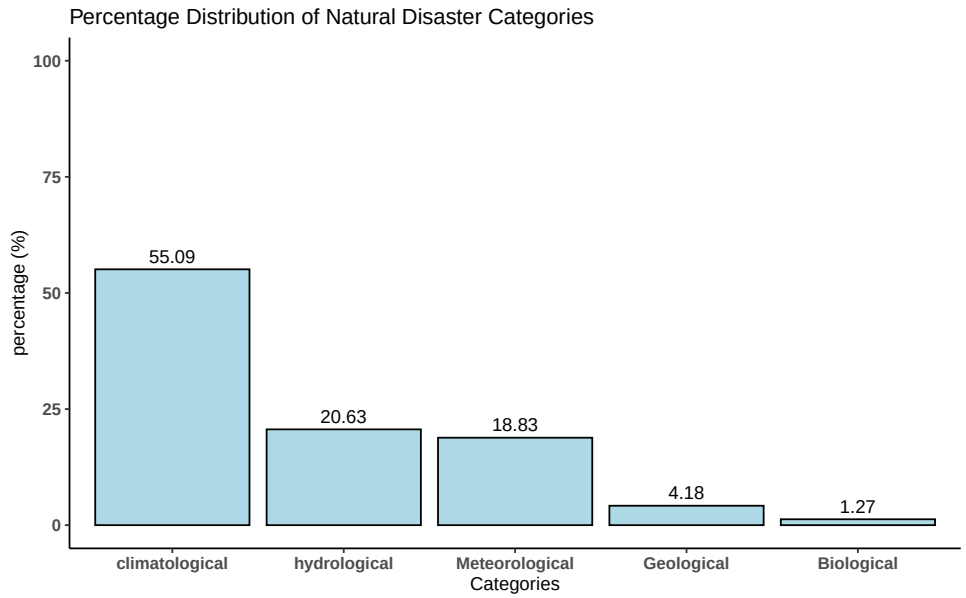
No. 01, dated 2012/08/24[5], records began to be made through a single document, the Disaster Information Form (FIDE).

The FIDE aims to define each step and the criteria for declaring an emergency or a state of public calamity, as well as to regulate the federal recognition of abnormal situations declared by federative entities. The form is structured to include detailed information on the identification of the affected municipality, disaster classification, date of occurrence, affected area (classified by types of land use), a description of the causes and effects of the disaster, as well as human, material, and environmental damages, economic losses (both public and private), and the reporting institution responsible for the record.

In Brazil, most natural disasters are directly related to variations in rainfall and temperature, reflecting the complex interaction between the country's climatic and geographic factors. According to the typology adopted by the National Secretariat of Protection and Civil Defense (SEDEC), events are divided into five categories: climatological (drought, dry spells, among others), hydrological (floods, flash floods, among others), meteorological (storms, extreme temperatures, among others), geological (erosion, earthquakes, among others), and biological (epidemics and infestations/pests)[6].

According to the Digital Atlas of Disasters in Brazil Atlas Digital (2024), between 2011 and 2019, 52.05% of the occurrences were climatological in nature, followed by 24.03% of hydrological events. Records of other categories, including meteorological, geological, and biological, account for approximately 24%. Thus, climatological and hydrological disasters represent about 77.81% of natural disaster occurrences in Brazil.

Figure 1: Distribution of Natural Disasters in Brazil (2011–2019)



Source: Author's elaboration based on the Digital Atlas of Disasters in Brazil.

This study will focus on analyzing the damages caused by the most frequent disasters in

[5] https://cnm.org.br/cms/images/stories/Links/09062014_Instrucao_normativa_de_01_de_agosto_de_2012.pdf, accessed on 2024/10/15

[6] For more details on the Brazilian Disaster Classification and Coding System (Cobrade): https://www.defesacivil.rs.gov.br/upload/arquivos/202105/04095316-cobrade-classificacao-e-codificacao-brasileira-de-desastres.pdf, accessed on 2024/10/15.

Brazil: climatological disasters. Below are the definitions, classifications, and examples of the most common climatological disasters in Brazil:

Climatological disasters are related to the climatic conditions of a specific region, which can range from extreme humidity to prolonged droughts. The main examples include:

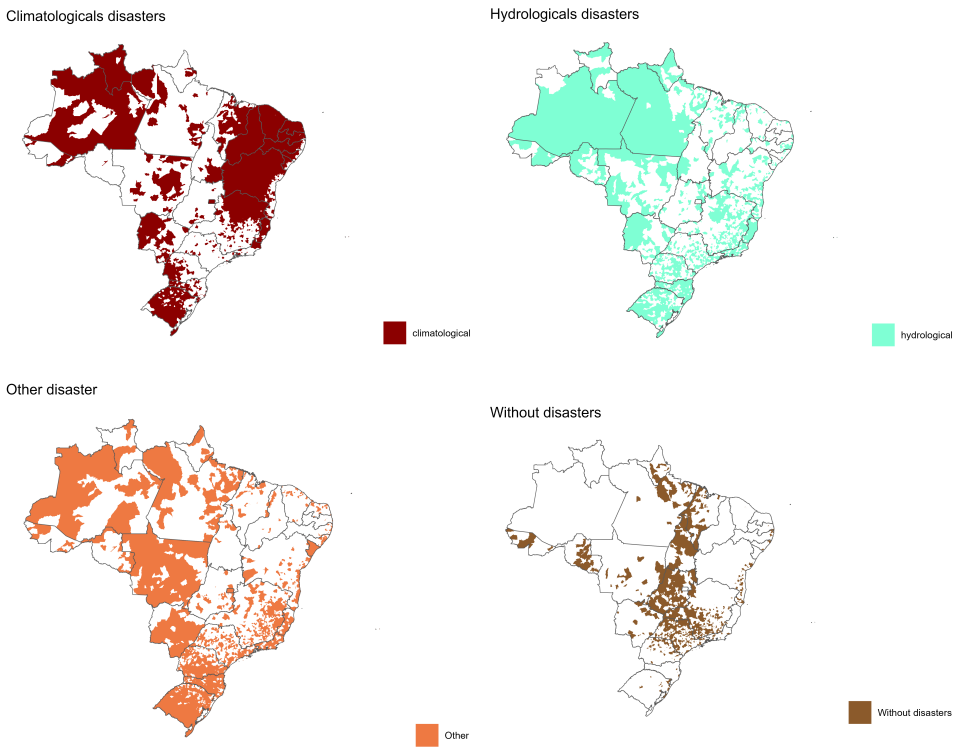
I. Drought: A prolonged period of low precipitation or absence of rainfall, in which the soil moisture loss exceeds its replenishment. This phenomenon has a direct impact on agriculture, livestock, and water resources in a region.

II. Dry spell: Although a dry spell is conceptualized as a prolonged drought, its effect is even more severe. The lack of precipitation for a sufficiently long period results in hydrological imbalances, with profound impacts on water supply, agricultural production, and population provisioning.

To isolate the effect of climatological disasters on education, municipalities that experienced only climatological disasters will be considered as the treated group. In contrast, municipalities that never experienced disasters will form the control group (Non-switchers). For this purpose, natural disasters that occurred between 2011/01/19 and 2019/10/20 are considered.

The following section presents four municipal-level thematic maps of Brazil, highlighting municipalities that experienced at least one occurrence within the analyzed period. The first map depicts climatological disasters, the second shows hydrological disasters, the third illustrates regions affected by other types of disasters (meteorological, geological, and biological), and the fourth represents municipalities with no recorded natural disaster occurrences during the analyzed period.

Figure 2: Thematic Maps Showing the Distribution of Municipalities by Disaster Occurrence and Their Respective Types



Source: Author's elaboration based on the Digital Atlas of Disasters in Brazil.

The period of climatological events considered for defining the treated municipalities in this study was delimited between the end date of the Prova Brasil exam and the first day of application of the subsequent edition. Thus, disasters included in this research occurred within this interval. If any disaster happened during the Prova Brasil exam administration, the affected municipalities will be excluded from the analysis to avoid confounding effects in the results.

To ensure consistency of the analysis, municipalities that experienced disasters between January 19, 2011, and November 21, 2013, were excluded, as they could not be considered treated in the first Prova Brasil edition analyzed, which is the 2013 edition.

Table 3: Definition of Treated and Control Groups

Groups	**Treatment Period**	**Specific Dates**
2015	0	2013/11/22 to 2014/12/31
	1	2015/01/01 to 2015/11/02
2017	2	2015/11/14 to 2016/12/31
	3	2017/01/01 to 2017/10/22
2019	4	2017/11/04 to 2018/12/31
	5	2019/01/01 to 2019/10/20
Control	Never Treated	2011/01/19 to 2019/10/20

Source: Author's elaboration based on SAEB data and the Digital Atlas of Disasters in Brazil.

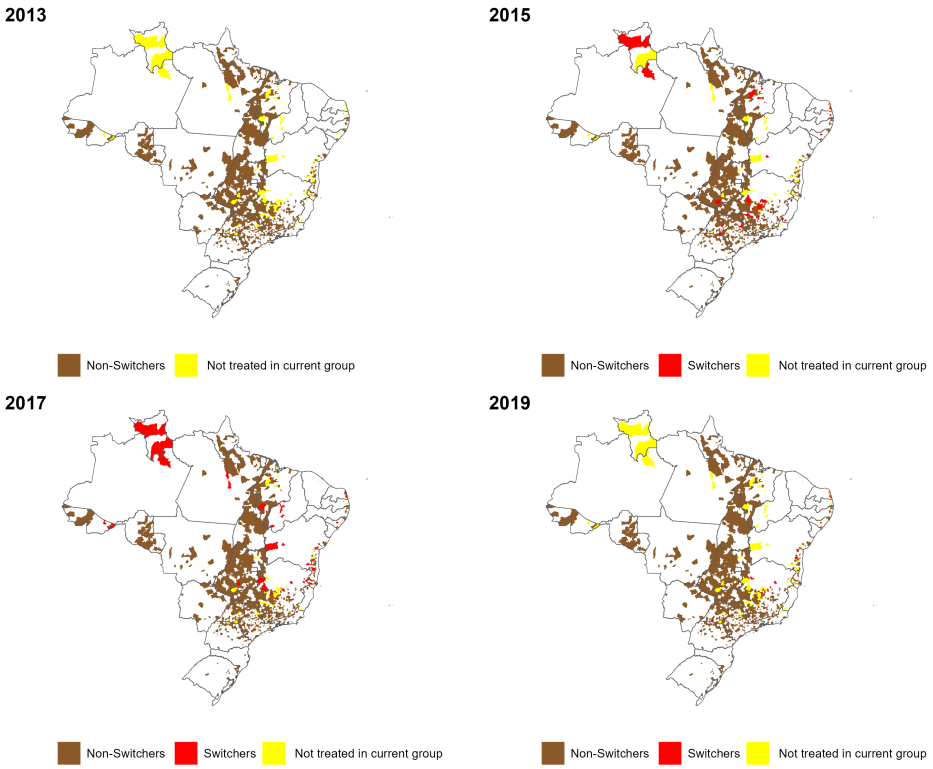
Thus, the sample was created with the treated group consisting of municipalities that experienced only climatological disasters, and the control group composed of municipalities that did not experience any natural disasters during the analyzed period. A total of 118 municipalities were identified as having suffered exclusively climatological disasters during the study period, constituting the specific treated group for the sample.

On the other hand, 1,375 municipalities did not register any natural disaster occurrences during the analyzed period, forming the control group. Therefore, the analyzed sample comprises 1,493 municipalities, while 4,077 municipalities were omitted from the analysis through the identification strategy described above.

"Switchers" refers to municipalities that received treatment during the specific period defined for each group in Table 3. The term "Not Treated in Current Group" applies to municipalities that were treated at some point during the analyzed period but not within the specific time interval of the current group under consideration. The control group, known as "Non-Switchers," includes municipalities with no recorded disaster occurrences during the study period from January 19, 2011, to October 20, 2019.

This categorization enables the isolation of the effects of extreme climatological events, ensuring a more precise and robust analysis of the impacts of these extreme events on Brazilian education. The exclusion of municipalities that experienced more than one type of natural disaster aims to avoid confounding effects, thereby ensuring that the results clearly and reliably reflect the specific consequences of each disaster category.

Figure 3: Thematic Maps Showing the Classification of Municipalities According to the Identification Strategy



Source: Author's elaboration based on SAEB data and the Digital Atlas of Disasters in Brazil.

2.2 Empirical Strategy

The method employed in this research follows the approach proposed by de Chaisemartin and D'Haultfœuille (2024), which is based on the estimation of difference-in-differences. The DID_ℓ estimator compares the evolution of outcomes between groups that transition from untreated to treated status (*Switchers*) and those that have not yet changed status (*Non-Switchers*) in the ℓ-th period following the initial change. To support the validity of the parallel trends assumption, placebo estimators will be assessed. Under the assumption of parallel trends, the estimator is consistent and robust to treatment effect heterogeneity.

One advantage of this estimator over that proposed by Callaway and Sant'Anna (2021) is its applicability in settings where treatment adoption varies over time, allowing for multiple treatment status transitions across groups. Moreover, compared to the method proposed by Sun and Abraham (2021), its key advantage lies in the use of not-yet-treated groups as the control group.

Based on the estimator of de Chaisemartin and D'Haultfœuille (2024), let $Y_{g,t}$ represent the outcome (SAEB test scores in Portuguese and Mathematics), and $D_1, ..., D_t$ indicate treatment status over time. Let F_g denote the first period in which municipality g transitions from control to treatment. The expected difference between the actual outcome of group g in period $F_g - 1 + \ell$ and the counterfactual outcome that would have been observed had g remained untreated between period 1 and period $F_g - 1 + \ell$, is defined as:

$$\delta_{(g,\ell)} = \mathbb{E}\left(Y_{g,F_g-1+\ell} - Y_{g,F_g-1+\ell}(D_{g,1}, \ldots, D_{g,1})\right) \tag{1}$$

To estimate $\delta_{g,\ell}$, the authors propose a DID_ℓ estimator that compares the change in outcomes between periods $F_g - 1$ and $F_g - 1 + \ell$ for group g, with the change observed in groups whose treatment status has not yet changed in the same period. This estimator accommodates group-varying effects, enabling a more accurate analysis of treatment effect heterogeneity.

To isolate the effect of climatological disasters on educational performance, only municipalities that experienced exclusively this type of disaster during the analyzed period were considered as treated. Municipalities that never faced natural disasters composed the control group. Those who experienced more than one type of disaster were excluded from the analysis.

The research design follows the estimator proposed by de Chaisemartin and D'Haultfœuille (2024), which is suitable for situations in which the frequency of treatment exceeds that of the outcome. This is the case for natural disasters, which are recorded annually, while the Portuguese and Mathematics assessments from Prova Brasil occur only every two years. To address this asymmetry, the dataset was divided into two subsamples:

I. First subsample: Includes all groups and periods in which the treatment status remained constant from the beginning until the observation of the outcome (Non-Switchers). Additionally, it includes only the groups that switched from untreated to treated exactly in the year of the Prova Brasil application, i.e., the odd-numbered periods presented in Table 2.

II. Second subsample: Also composed of Non-Switchers, but includes only the groups that switched from untreated to treated in the year prior to the Prova Brasil application, corresponding to the even-numbered periods in Table 2.

This approach allows the identification of treatment effects both in the year when the proficiency tests were administered and in the preceding periods. As such, it enables a comprehensive analysis of the effects of climatological and hydrological disasters on educational performance across all relevant periods.

3 Results

3.1 Descriptive Statistics

To understand the behavior of the climatological sample in education, a descriptive analysis was conducted based on data provided by Inep (SAEB) and SEDEC (Digital Atlas of Disasters). This analysis investigates the relationship between the treatment groups and the control group.

Regarding the educational performance of treated municipalities and the control group, the analyzed indicators include test scores in Mathematics and Portuguese proficiency, the distribution of students across proficiency levels as previously defined, and the rates of promotion, failure, and age-grade distortion. For analysis, treated municipalities are classified into two categories: switchers and not-yet-treated. Switchers correspond to municipalities that were exposed to treatment during the specific period defined for each group in Table 3. Not-yet-treated municipalities are those that were treated at some point during the analyzed period but not within the particular time interval for the group in question.

In the 2013 edition of Prova Brasil, which marks the beginning of the analysis, only municipalities in the control group and the not-yet-treated show results, as no municipality had been treated by then. Conversely, in the 2019 edition, results include switchers and the control group, since by that time all treated municipalities in the sample had already been exposed to treatment. Therefore, there are no records for not-yet-treated municipalities, as all municipalities affected by disasters had been treated within the analyzed interval.

This approach enables the examination of the evolution of educational indicators over time and the evaluation of the impact of treatment exposure on students' academic performance in affected municipalities.

Table 4 presents the results for educational indicators for the 5th grade of elementary school in the climatological sample, following the same structure as the previous table. It is observed that for Mathematics proficiency scores in 2015, switchers perform better than the not-yet-treated. Specifically, the average difference relative to the control group was -9.91 points for switchers and -14.09 points for not-yet-treated. However, in 2017, this pattern reversed, with the not-yet-treated averaging higher scores than the switchers.

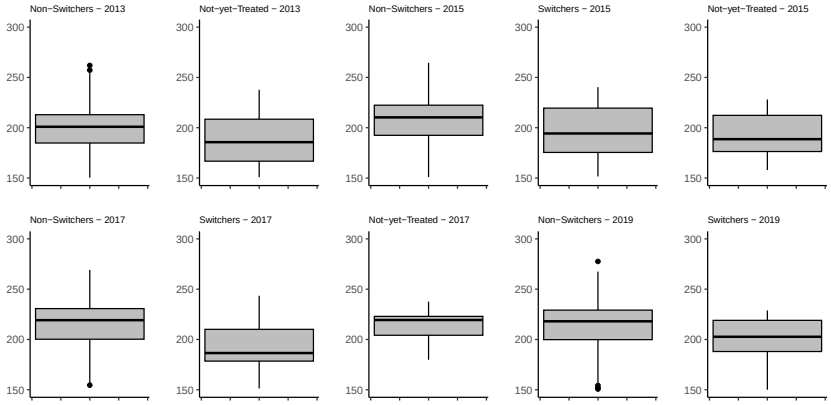
Table 4: Descriptive Statistics of Educational Indicators for 5th Grade - Climatological Sample

	2013			2015					2017					2019		
Variable	Mean Not-yet-treated (2)	Mean Non-Switchers (3)	Diff (5) (2) – (3)	Mean Switchers (1)	Mean Not-yet-treated (2)	Mean Non-Switchers (3)	Diff (4) (1) – (3)	Diff (5) (2) – (3)	Mean Switchers (1)	Mean Not-yet-treated (2)	Mean Non-Switchers (3)	Diff (4) (1) – (3)	Diff (5) (2) – (3)	Mean Switchers (1)	Mean Non-Switchers (3)	Diff (4) (1) – (3)
Math Proficiency	184.62	196.39	-11.77***	197.02	192.84	206.93	-9.91***	-14.09***	195.26	212.46	214.68	-19.42***	-2.22	201.54	213.71	-12.17***
Portuguese Proficiency	201.06	215.67	-14.61***	211.87	204.31	221.39	-9.52***	-17.08***	205.04	223.55	226.58	-21.54***	-3.03	215.04	229.53	-14.49***
Age-Grade Distortion Rate	29.47	21.00	8.47***	22.00	29.10	18.77	3.23*	10.33***	27.92	17.53	16.26	11.66***	1.27	21.24	14.70	6.54**
Promotion Rate	89.88	93.86	-3.98***	91.22	88.88	94.14	-2.92***	-5.26***	87.03	93.29	94.43	-7.4***	-1.14	90.04	95.37	-5.33***
Failure Rate	7.99	5.24	2.75***	7.36	8.95	5.08	2.28**	3.87***	10.94	6.01	4.89	6.05***	1.12	8.69	4.12	4.57***
Dropout Rate	2.13	0.90	1.23***	1.42	2.17	0.79	0.63***	1.38***	2.03	0.70	0.68	1.35***	0.02	1.27	0.51	0.76**
Math Level 0	0.10	0.06	0.04***	0.05	0.05	0.03	0.02***	0.02***	0.06	0.02	0.03	0.03***	-0.01	0.07	0.03	0.04***
Math Level 1	0.19	0.13	0.06***	0.14	0.14	0.09	0.05***	0.05***	0.14	0.08	0.08	0.06***	0.00	0.12	0.08	0.04***
Math Level 2	0.19	0.17	0.02***	0.18	0.19	0.15	0.03**	0.04***	0.18	0.16	0.13	0.05***	0.03	0.15	0.12	0.03
Math Level 3	0.17	0.18	-0.01*	0.18	0.20	0.18	0.00	0.02***	0.18	0.15	0.16	0.02***	-0.01	0.16	0.16	0.00
Math Level 4	0.13	0.17	-0.04***	0.15	0.17	0.19	-0.04***	-0.02**	0.16	0.20	0.18	-0.02***	0.02	0.17	0.18	-0.01
Math Level 5	0.10	0.13	-0.03***	0.14	0.12	0.16	-0.02*	-0.04***	0.13	0.17	0.17	-0.04***	0.00	0.14	0.17	-0.03**
Math Level 6	0.07	0.09	-0.02***	0.09	0.08	0.11	-0.02***	-0.03***	0.09	0.11	0.13	-0.04***	-0.02	0.11	0.13	-0.02
Math Level 7	0.04	0.05	-0.01***	0.05	0.03	0.05	0.00	-0.02***	0.04	0.08	0.07	-0.03***	0.01	0.06	0.07	-0.01*
Math Level 8	0.01	0.02	-0.01***	0.02	0.01	0.02	0.00*	-0.01***	0.02	0.03	0.03	-0.01***	0.00	0.02	0.04	-0.02***
Math Level 9	0.00	0.00	0.00**	0.01	0.01	0.01	0.00*	0.00**	0.00	0.01	0.01	-0.01***	0.00	0.01	0.01	0.00
Portuguese Level 0	0.07	0.04	0.03***	0.00	0.00	0.00	0.00	0.00**	0.02	0.01	0.01	0.01***	0.00	0.02	0.01	0.01
Portuguese Level 1	0.10	0.07	0.03***	0.08	0.08	0.05	0.03***	0.03***	0.09	0.04	0.05	0.04***	-0.01	0.07	0.04	0.03***
Portuguese Level 2	0.17	0.13	0.04***	0.17	0.19	0.13	0.04***	0.06***	0.17	0.13	0.10	0.07***	0.03	0.13	0.09	0.04**
Portuguese Level 3	0.18	0.17	0.01***	0.21	0.23	0.18	0.03**	0.05***	0.21	0.15	0.15	0.06***	0.00	0.18	0.15	0.03**
Portuguese Level 4	0.15	0.17	-0.02***	0.18	0.20	0.19	-0.01*	0.01	0.18	0.20	0.18	0.00	0.02	0.19	0.18	0.01
Portuguese Level 5	0.12	0.16	-0.04***	0.14	0.13	0.17	-0.03***	-0.04***	0.15	0.18	0.19	-0.04***	-0.01	0.17	0.19	-0.02
Portuguese Level 6	0.09	0.12	-0.03***	0.10	0.08	0.14	-0.04***	-0.06***	0.11	0.16	0.16	-0.05***	0.00	0.12	0.15	-0.03**
Portuguese Level 7	0.06	0.08	-0.02***	0.07	0.05	0.09	-0.02	-0.04***	0.05	0.09	0.10	-0.05***	-0.01	0.08	0.11	-0.03**
Portuguese Level 8	0.03	0.04	-0.01***	0.03	0.02	0.04	-0.01	-0.02***	0.02	0.04	0.05	-0.03***	-0.01	0.03	0.05	-0.02***
Portuguese Level 9	0.02	0.02	0.00***	0.01	0.01	0.01	0.00	0.00***	0.01	0.01	0.02	-0.01***	-0.01	0.01	0.03	-0.02***

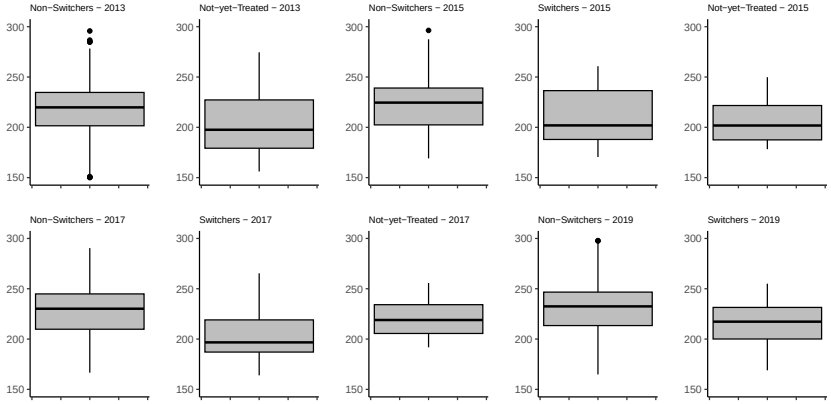
Source: Own elaboration based on SAEB data and the Digital Atlas of Disasters in Brazil. Statistical Significance: *** = 1%, ** = 5%, and * = 10%.

Figure 4: Distribution of 5th Grade Scores – Climatological Sample (Box-Plot)

Panel A – Portuguese Proficiency Test



Panel B – Mathematics Proficiency Test



Source: Own elaboration based on SAEB data and the Digital Atlas of Disasters in Brazil.

This dynamic is also observed in the results of the Portuguese proficiency tests, indicating a similar trend between the two subjects. In 2015, the treated-active municipalities (Switchers) had, on average, better performance than the treated-inactive ones (Not-yet-Treated). However, in 2017, the treated-inactive municipalities outperformed the active ones. In all evaluated periods, the control group (Non-Switchers) showed higher average scores.

Figure 5 complements the results through boxplot graphs, with Panel A representing the Portuguese proficiency tests and Panel B representing the Mathematics proficiency tests. In Panel A, for the year 2017, the median of the treated-inactive municipalities is higher than that of the control group, although the latter displays a higher average due to larger values in the upper quartiles. In this context, the treated-inactive municipalities perform better than the treated-active ones across all evaluated parameters.

In contrast, in the year 2015, both in Panel A and Panel B, the treated-active municipalities exhibit better performance than the treated-inactive ones, evidenced by a higher median. These results reinforce the shift in dynamics between the treated municipalities over time, highlighting the complexity of the impact of natural disasters on educational performance. The Approval, Dropout, Age-Grade Distortion, and Failure rates follow the same pattern as the test scores, with treated-active municipalities performing better in 2015 and treated-inactive ones in 2017.

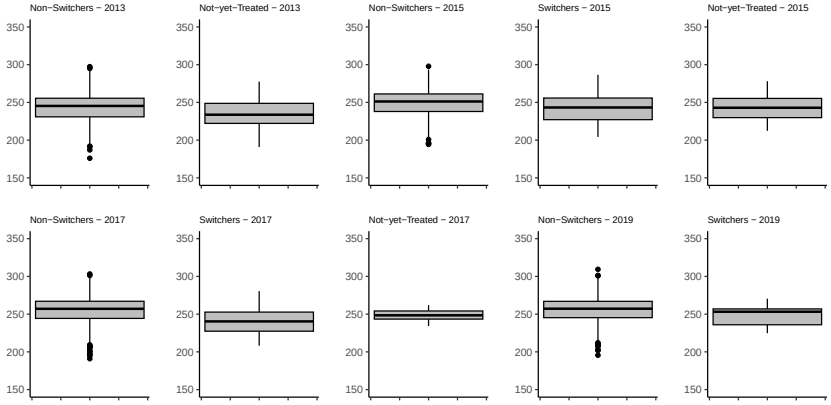
Table 5: Descriptive Statistics of Educational Indicators for 9th Grade – Climatological Sample

	2013			2015					2017					2019		
Variable	Mean Not-yet-Treated (2)	Mean Non-Switchers (3)	Diff (5) (2) – (3)	Mean Switchers (1)	Mean Not-yet-Treated (2)	Mean Non-Switchers (3)	Diff (4) (1) – (3)	Diff (5) (2) – (3)	Mean Switchers (1)	Mean Not-yet-Treated (2)	Mean Non-Switchers (3)	Diff (4) (1) – (3)	Diff (5) (2) – (3)	Mean Switchers (1)	Mean Non-Switchers (3)	Diff (4) (1) – (3)
Math Proficiency	234.59	243.37	-8.78***	242.47	242.60	249.44	-6.97***	-6.84***	241.59	247.62	255.04	-13.45***	-7.42**	247.72	255.74	-8.02***
Portuguese Proficiency	240.45	250.61	-10.16***	246.47	245.51	254.46	-7.99***	-8.95***	240.19	248.05	255.94	-15.75***	-7.89*	252.75	260.60	-7.85**
Age-grade Distortion Rate	30.02	23.76	6.26***	27.34	31.66	22.95	4.39	8.71***	34.11	26.13	22.97	11.14***	3.16	23.50	20.22	3.28
Approval Rate	87.25	90.76	-3.51***	86.56	87.75	90.07	-3.51	-2.32***	85.07	90.39	90.55	-5.48***	-0.16	87.04	93.13	-6.09***
Failure Rate	7.91	5.91	2.00***	8.96	7.85	6.60	2.36	1.25*	8.82	6.87	6.42	2.4***	0.45	10.84	5.03	5.81***
Dropout Rate	4.84	3.33	1.51***	4.48	4.41	3.32	1.16	1.09**	6.11	2.74	3.04	3.07***	-0.30	2.12	1.84	0.28
Math Level 0	0.26	0.21	0.05***	0.21	0.19	0.17	0.04***	0.02**	0.21	0.17	0.14	0.07***	0.03	0.18	0.15	0.03*
Math Level 1	0.18	0.15	0.03***	0.16	0.17	0.14	0.02**	0.03***	0.17	0.15	0.13	0.04***	0.02	0.15	0.13	0.02*
Math Level 2	0.18	0.19	-0.01	0.18	0.20	0.18	0.00	0.02**	0.19	0.20	0.17	0.02***	0.03*	0.17	0.17	0.00
Math Level 3	0.17	0.18	-0.01**	0.18	0.19	0.19	-0.01*	0.00	0.18	0.18	0.20	-0.02*	-0.02	0.21	0.19	0.02
Math Level 4	0.12	0.14	-0.02***	0.14	0.13	0.16	-0.02	-0.03***	0.14	0.19	0.18	-0.04***	0.01	0.15	0.17	-0.02***
Math Level 5	0.06	0.08	-0.02***	0.08	0.08	0.10	-0.02***	-0.02***	0.08	0.10	0.12	-0.04***	-0.02	0.10	0.12	-0.02*
Math Level 6	0.02	0.04	-0.02***	0.03	0.03	0.04	-0.01	-0.01***	0.03	0.02	0.05	-0.02***	-0.03***	0.04	0.06	-0.02*
Math Level 7	0.01	0.01	0.00***	0.01	0.01	0.01	0.00*	0.00	0.01	0.01	0.02	-0.01***	-0.01***	0.01	0.02	-0.01
Math Level 8	0.00	0.00	0.00	0.00	0.00	0.00	0.00***	0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00***
Math Level 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portuguese Level 0	0.22	0.17	0.05***	0.15	0.15	0.12	0.03**	0.03**	0.20	0.12	0.13	0.07***	-0.01	0.14	0.12	0.02
Portuguese Level 1	0.17	0.14	0.03***	0.20	0.19	0.16	0.04***	0.03***	0.17	0.20	0.14	0.03***	0.06**	0.14	0.12	0.02*
Portuguese Level 2	0.19	0.18	0.01***	0.20	0.22	0.20	0.00	0.02***	0.22	0.23	0.19	0.03***	0.04**	0.18	0.17	0.01
Portuguese Level 3	0.19	0.19	0.00	0.19	0.19	0.19	0.00	0.00	0.18	0.17	0.19	-0.01***	-0.02	0.18	0.19	-0.01
Portuguese Level 4	0.12	0.16	-0.04***	0.14	0.14	0.16	-0.02*	-0.02**	0.12	0.15	0.16	-0.04***	-0.01	0.18	0.19	-0.01
Portuguese Level 5	0.07	0.09	-0.02***	0.08	0.07	0.10	-0.02***	-0.03***	0.07	0.08	0.11	-0.04***	-0.03**	0.11	0.13	-0.02*
Portuguese Level 6	0.03	0.04	-0.01***	0.03	0.03	0.05	-0.02***	-0.02***	0.03	0.03	0.05	-0.02***	-0.02**	0.05	0.06	-0.01
Portuguese Level 7	0.01	0.02	-0.01***	0.01	0.01	0.02	-0.01***	-0.01***	0.01	0.01	0.02	-0.01***	-0.01	0.01	0.02	-0.01***
Portuguese Level 8	0.00	0.00	0.00***	0.00	0.00	0.00	0.00*	0.00***	0.00	0.00	0.01	-0.01***	-0.01***	0.00	0.01	-0.01***
Portuguese Level 9	0.00	0.00	0.00	0.00	0.00	0.00	0.00***	0.00	0.00	0.00	0.00	0.00	0.00***	0.00	0.00	0.00

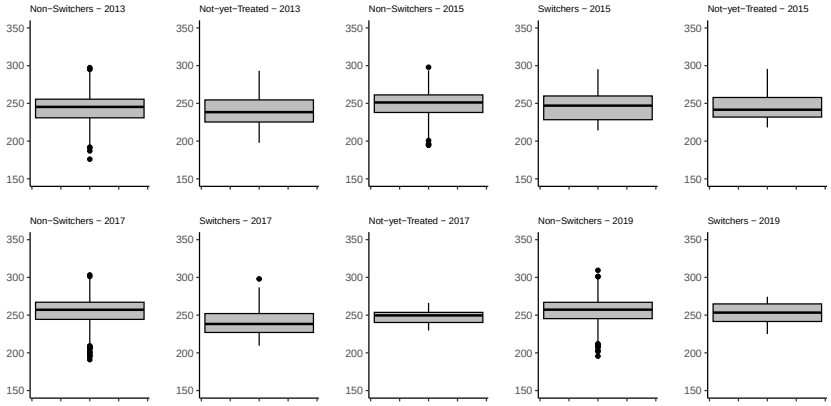
Source: Own elaboration based on SAEB data and the Digital Atlas of Disasters in Brazil. Statistical Significance: *** = 1%, ** = 5%, and * = 10%.

Figure 5: Distribution of 9th Grade Scores – Climatological Sample (Box-Plot)

Panel A Portuguese Proficiency Test



Panel B Mathematics Proficiency Test



Fonte: Own elaboration based on SAEB data and the Digital Atlas of Disasters in Brazil.

Table 5 follows the same structure as Table 6, now analyzing educational indicators for 9th[th] grade students in the sample restricted to climatological events. For the Mathematics and Portuguese proficiency tests, municipalities classified as non-switchers and not-yet-treated

show a similar upward trend over time. In contrast, the switchers exhibit a deterioration in test performance, particularly in the year 2017. Figure 4 reinforces this pattern: all groups follow comparable trajectories throughout the analyzed periods, except for the switchers in Panel A, who consistently perform worse than both the non-switchers and the not-yet-treated — a pattern that becomes especially evident in 2017 and is not observed in the other years.

3.2 Main Results

This section presents the estimation results using the method proposed by De Chaisemartin and D'Haultfoeuille (2024), as discussed in the previous section. The outcomes are the Portuguese and Mathematics scores of 5th and 9th-grade elementary school students.

Table 7 and Figure 6 present the estimates for the Portuguese and Mathematics proficiency tests administered to 5th and 9th graders in elementary education.

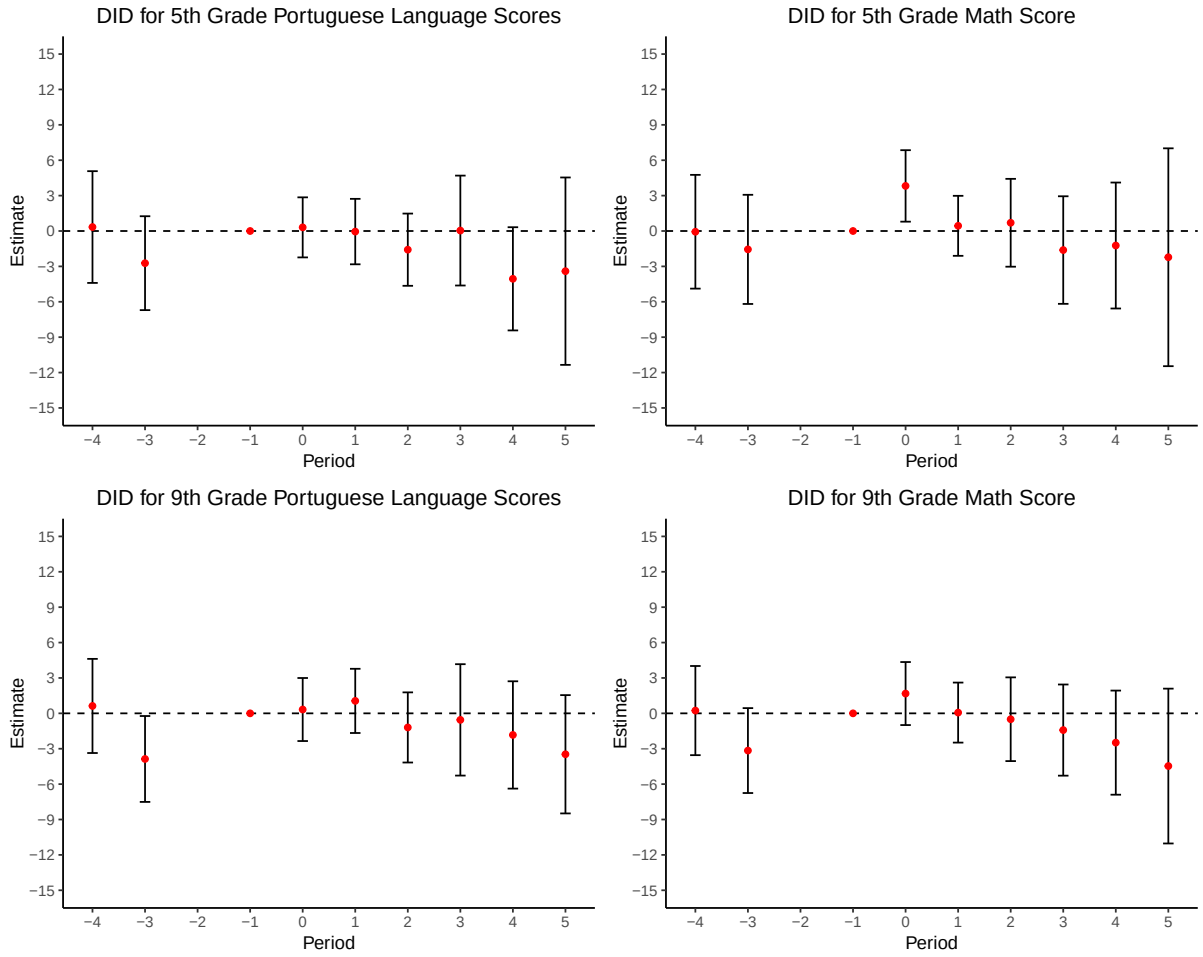
Table 6: Estimation Results for the Climatological Disaster Sample

	5th Grade				**9th Grade**			
Period	**N**	**Switchers**	**Portuguese**	**Mathematics**	**N**	**Switchers**	**Portuguese**	**Mathematics**
-4	2640	34	0.34	-0.06	2647	34	0.63	0.23
			(0.890)	(0.980)			(0.758)	(0.903)
-3	2628	22	-2.73	-1.56	2634	21	-3.87**	-3.15*
			(0.179)	(0.509)			(0.037)	(0.085)
0	4110	69	0.30	3.82**	4120	71	0.32	1.68
			(0.812)	(0.013)			(0.812)	(0.219)
1	4113	45	-0.05	0.44	4120	45	1.05	0.06
			(0.972)	(0.735)			(0.448)	(0.961)
2	2737	56	-1.58	0.70	2730	55	-1.20	-0.50
			(0.311)	(0.714)			(0.431)	(0.783)
3	2734	28	0.04	-1.62	2727	28	-0.55	-1.42
			(0.987)	(0.487)			(0.817)	(0.472)
4	1409	47	-4.05*	-1.23	1375	44	-1.83	-2.48
			(0.070)	(0.652)			(0.430)	(0.270)
5	1402	10	-3.40	-2.22	1368	10	-3.47	-4.47
			(0.401)	(0.472)			(0.175)	(0.182)

Source: Author's calculations based on data from SAEB and the Digital Atlas of Disasters in Brazil.

Notes: N = Total Observations; Statistical significance: *** = 1%, ** = 5%, * = 10%. Values in parentheses are p-values. Estimation performed using 10,000 bootstrap replications.

Figure 6: Estimation Results of DID for the Climatological Disaster Sample



Source: Author's calculations based on data from SAEB and the Digital Atlas of Disasters in Brazil. Confidence intervals based on a 5% level of significance. Estimation performed using 10,000 bootstrap replications.

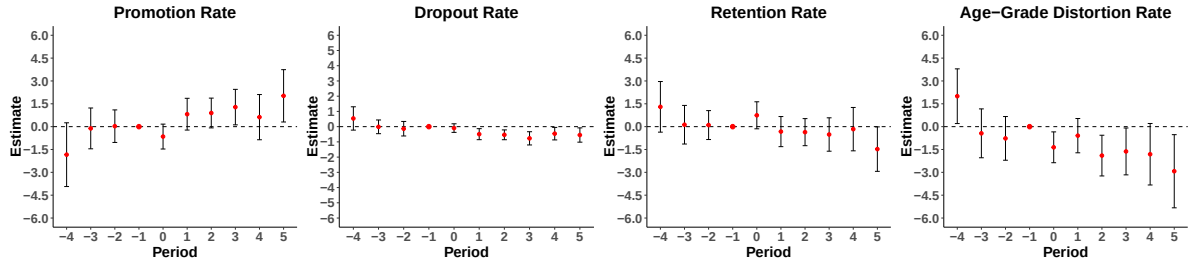
It is observed that only the Mathematics test for the 5th grade showed a statistically significant effect of 0.15 standard deviations relative to the overall distribution of mathematics scores, demonstrating an immediate increase in period 0, indicative of a direct impact of climatological disasters. Thus, municipalities affected by climatological disasters recorded a significant increase in the average Mathematics scores for the 5th grade compared to untreated municipalities.

This result is consistent with the findings of Shah and Steinberg (2017), which indicate that school-aged children exposed to climatological disasters perform better on Mathematics tests. The proposed explanation suggests that during years with climatological shocks, both mothers and children tend to be less involved in labor market activities, leading to increased time available for studying.

In contrast, no significant effects were found for Portuguese test scores for 9th grade Mathematics performance, suggesting that the positive effect is specific to 5th grade Mathematics.

Figure 7 presents the results for other outcomes, namely dropout rates, promotion rates, age-grade distortion, and failure rates for the 5th grade of elementary education.

Figure 7: Results for Climatological Disaster Sample – 5th Grade



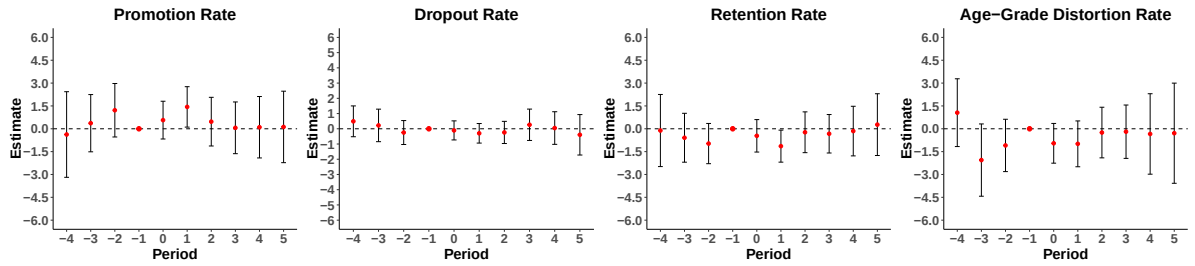
Source: Author's elaboration based on SAEB and Digital Atlas of Disasters in Brazil. Confidence intervals based on 5% level of significance. Estimation performed using 1,000 bootstrap replications.

A larger variation is observed in the promotion rate. This effect is statistically significant at the 5% level for municipalities affected by climatological events in periods 3 and 5 after the disaster, with an average increase of 1.3 and 2 percentage points, respectively. This corresponds to an increase of 0.18 and 0.28 standard deviations, respectively, compared to the control group, indicating a substantial effect on promotion rates.

Estimates also indicate a reduction in the dropout rate of approximately 0.42 percentage points for the 5th grade, which translates into a 0.26 standard deviation decrease relative to the general distribution of dropout rates, suggesting an improvement in academic outcomes after treatment. For age-grade distortion, no significant effect was found, likely due to the absence of a parallel pre-treatment trend, which limits the validity of the identification strategy.

These results demonstrate an improvement in academic performance for the 5th grade, consistent with the findings from Figure 5, which showed gains in Mathematics. A potential explanation for this effect lies in the reduced labor market participation of children and their mothers, which may have allowed more time to be devoted to academic activities, as well as greater parental involvement in the school environment.

Figure 8: Results for Climatological Disaster Sample – 9th Grade



Source: Author's elaboration based on SAEB and Digital Atlas of Disasters in Brazil. Confidence intervals based on 5% significance. Estimation performed using 1,000 bootstrap replications.

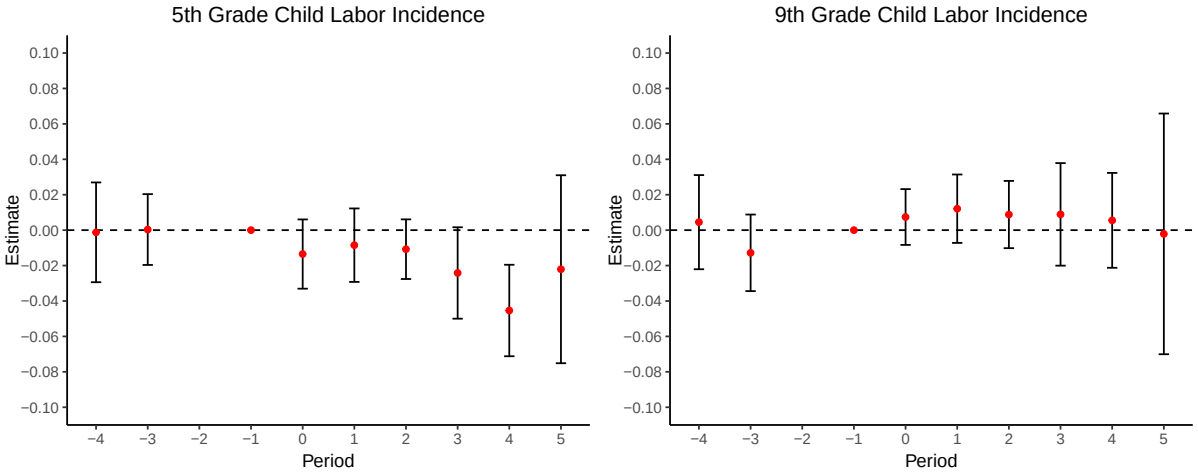
Figure 8 reports the same outcomes as previously discussed. A greater variation is observed in the promotion rate for the treated group, with an increase of approximately 1.4 percentage points in period 1, which is statistically significant. Similarly, a 1.14 percentage point reduction in the failure rate was observed in period 1. This corresponds to a 0.19 standard deviation reduction in the overall distribution, indicating a meaningful decline in grade repetition for treated municipalities.

3.3 Mechanism

As evidenced in the literature, particularly in the studies by Rush (2018) and Shah and Steinberg (2017), climatological disasters can have a positive impact on Mathematics scores among school-aged children by reducing opportunities for child labor. In the context of the main results of this paper, a significant increase in Mathematics scores for 5th grade students was observed in municipalities affected by climatological disasters. To investigate the underlying mechanism of this effect, we propose analyzing the percentage of children working outside of school at the municipal level as an alternative outcome. The hypothesis is that a reduction in child labor opportunities resulting from climatological disasters may have contributed to the observed increase in Mathematics scores.

To test this hypothesis, we estimate the results for the climatological disaster sample using a survey question in the student questionnaire that asks whether the student works at least one hour outside the home. We use this as a proxy for child labor and compare the percentage of working children in treated municipalities with that of the control group. The estimation is based on a Difference-in-Differences (DiD) approach, as described in the methodology section, adapted for this alternative outcome.

Figure 9: Estimation of the Child Labor Mechanism with Treatment as Climatological Disasters



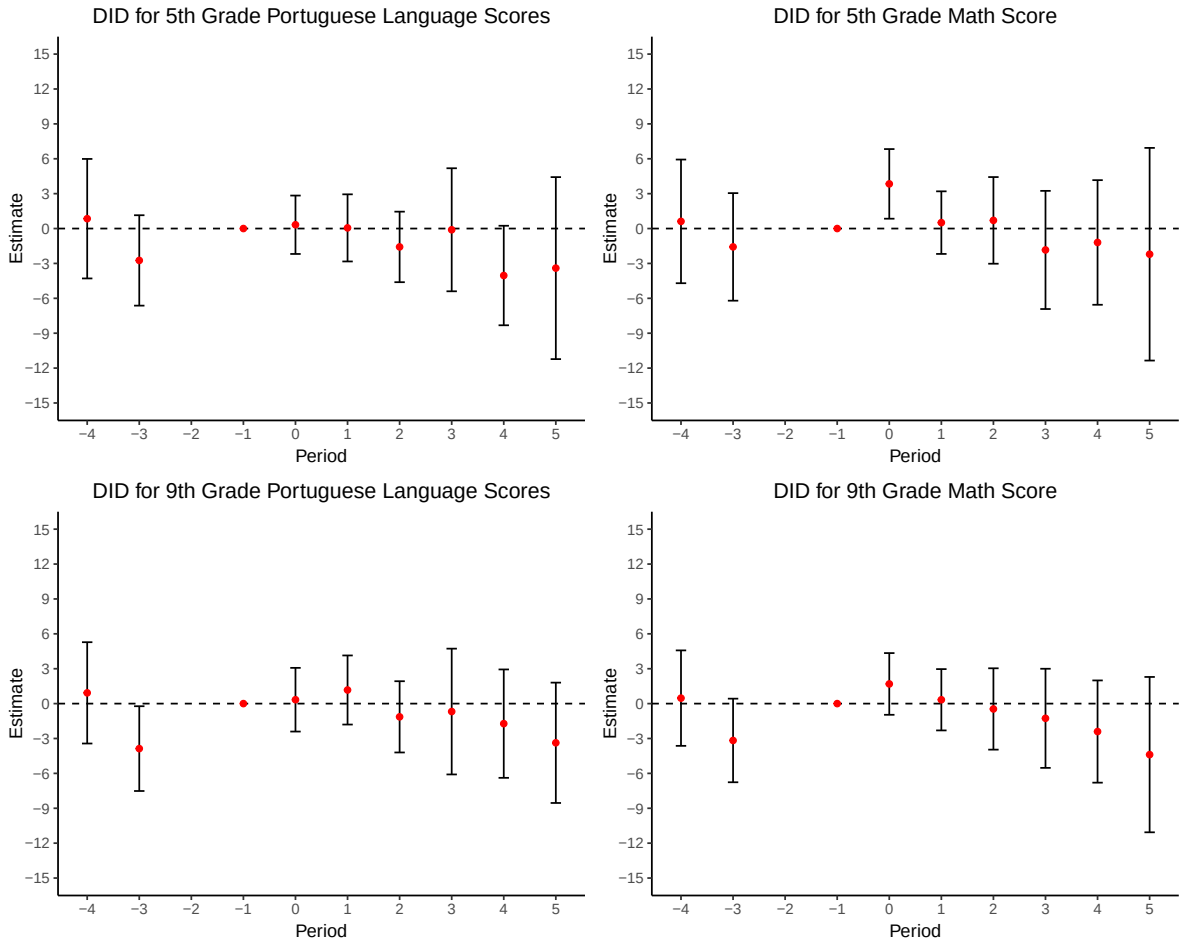
Source: Author's elaboration based on data from SAEB and the Digital Atlas of Disasters in Brazil. Confidence intervals based on 5% significance level. Estimation performed using 1000 bootstrap replications.

In Figure 9, we observe that municipalities affected by climatological disasters experienced a statistically significant reduction in child labor among 5th grade students, at a 10% significance level. On average, this reduction amounts to approximately 1.5 percentage points compared to municipalities not affected by such disasters, corresponding to a decrease of 0.15 standard deviations. Notably, this decline occurs simultaneously with the increase in Mathematics test scores, as previously shown (Figure 6). The literature suggests that this improvement in academic performance is a result of the decline in labor opportunities for children. Furthermore, four periods after the treatment, the reduction in child labor becomes even more pronounced, reaching a 5% significance level, with a total decrease of 4.7 percentage points for 5th grade students, indicating a cumulative effect over time throughout the period analyzed.

3.4 Heterogeneity Test

To explore the heterogeneity of the results, we exclude municipalities with a population exceeding 100,000 inhabitants. This restriction resulted in the omission of 39 municipalities, yielding a restricted sample of 1,468 municipalities. This methodological strategy allows us to assess whether the estimated effects vary according to municipal size.

Figure 10: Difference-in-Differences Estimation Results for Climatological Disasters Restricted to Municipalities with Fewer than 100,000 Inhabitants



Source: Author's elaboration based on data from SAEB and the Digital Atlas of Disasters in Brazil. Confidence intervals based on 5% significance level. Estimation performed using 1000 bootstrap replications.

As observed in Figure 6 with the full sample, the analysis using the restricted sample reveals that for early grades (5^{th} grade), there is a significant increase in Mathematics scores at the time of treatment, replicating the previous results. However, for 9^{th} grade students, no statistically significant effects are identified, consistent with the earlier findings. Regarding the Portuguese proficiency test for 5^{th} grade students, the restricted sample also shows no significant effects, similar to the general sample, highlighting some heterogeneity in the estimated impacts.

4 Conclusion

This study investigates the contemporary effect of extreme climatological events on academic performance in Brazilian elementary education. The research contributes to the literature by

examining the impact of climatological disasters on education in the country, employing a recent and innovative methodology.

The results indicate a positive effect of climatological disasters on mathematics performance in the 5th grade of elementary school, particularly in subsample 2, which corresponds to municipalities exposed to disasters during the period preceding the application of the Prova Brasil exam. Under this condition, treated municipalities showed an average increase of 3.82 points in math scores compared to control municipalities. This significant effect corresponds to a 0.15 standard deviation increase relative to the overall distribution of scores. Still, it is restricted to the exam edition that coincides temporally with the disaster. Additionally, improvements were observed in related educational indicators, such as higher promotion rates and lower failure rates, which reinforces the robustness of the proficiency test results.

A plausible interpretation for the positive effect observed in math scores is linked to the reduction of child labor incidence in municipalities affected by climatological disasters. Empirical evidence indicates that following these events, there was a 1.5 percentage point decrease in the child labor rate, corresponding to a reduction of approximately 0.15 standard deviations. This effect is statistically significant at the 10

While educational gains appear to occur immediately, the reduction in child labor tends to present cumulative effects over time. Thus, the findings suggest that one of the underlying mechanisms for improved school performance may be related to the decrease in child labor resulting from climatological disasters.

These results underscore the importance of public policies that focus on monitoring child labor and enhancing access to education. Measures such as financial aid to vulnerable families and school feeding programs can reduce the need for child labor, promoting a more favorable learning environment.

Finally, this research contributes to the existing literature by offering a new perspective on the contemporary effects of natural disasters on Brazilian education, a field that remains underexplored in the country. However, the study presents some limitations. It was not possible to track the same individuals over time, which necessitated analyzing at the municipal level.

References

Alderman, Harold, John Hoddinott, and Bill Kinsey, "Long term consequences of early childhood malnutrition," *Oxford economic papers*, 2006, *58* (3), 450–474. Publisher: Oxford University Press.

Atlas Digital, *Atlas Digital de Desastres no Brasil*, Brasília: Ministério da Integração e do Desenvolvimento Regional (MIDR), 2024. Acesso em: 21 out. 2024.

Baez, Javier, Alejandro de la Fuente, and Indhira Vanessa Santos, "Do Natural Disasters Affect Human Capital? An Assessment Based on Existing Empirical Evidence," September 2010.

Baez, Javier Eduardo and Indhira Vanessa Santos, "Children's vulnerability to weather shocks: A natural disaster as a natural experiment," *Social science research network, New York*, 2007, pp. 1–28.

Callaway, Brantly and Pedro H. C. Sant'Anna, "Difference-in-Differences with multiple time periods," *Journal of Econometrics*, December 2021, *225* (2), 200–230.

de Chaisemartin, Clément and Xavier D'Haultfœuille, "Difference-in-Differences Estimators of Intertemporal Treatment Effects," *The Review of Economics and Statistics*, February 2024, pp. 1–45.

Ferreira, Francisco H. G. and Norbert Schady, "Aggregate Economic Shocks, Child Schooling, and Child Health," *The World Bank Research Observer*, August 2009, *24* (2), 147–181.

Hoddinott, John and Bill Kinsey, "Child Growth in the Time of Drought," *Oxford Bulletin of Economics and Statistics*, September 2001, *63* (4), 409–436.

IPCC, *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Intergovernmental Panel on Climate Change (IPCC), 2022. Acesso em: 24 ago. 2024.

López, Ramón, "Natural disasters and the dynamics of intangible assets," *World Bank Policy Research Working Paper*, 2009, (4874).

Nguyen, Cuong Viet and Nguyet Minh Pham, "The impact of natural disasters on children's education: Comparative evidence from Ethiopia, India, Peru, and Vietnam," *Review of Development Economics*, November 2018, *22* (4), 1561–1589.

OMM, "Climate and weather related disasters surge five-fold over 50 years, but early warnings save lives - WMO report," United Nations News 2018. Acesso em: 20 ago. 2024.

Pörtner, Claus C., "Gone with the wind? Hurricane risk, fertility and education," *Hurricane Risk, Fertility and Education (February 2008)*, 2008.

Rush, J. V., "The Impact of Natural Disasters on Education in Indonesia," *Economics of Disasters and Climate Change*, July 2018, *2* (2), 137–158.

Shah, Manisha and Bryce Millett Steinberg, "Drought of Opportunities: Contemporaneous and Long-Term Impacts of Rainfall Shocks on Human Capital," *Journal of Political Economy*, April 2017, *125* (2), 527–561.

Sigurdsen, Parama, Samantha Berger, and Jody Heymann, "The Effects of Economic Crises on Families Caring for Children: Understanding and Reducing Long-term Consequences," *Development Policy Review*, September 2011, *29* (5), 547–564.

Skidmore, Mark and Hideki Toya, "DO NATURAL DISASTERS PROMOTE LONG-RUN GROWTH?," *Economic Inquiry*, October 2002, *40* (4), 664–687.

Stein, Aryeh D., Huiman X. Barnhart, Morgen Hickey, Usha Ramakrishnan, Dirk G. Schroeder, and Reynaldo Martorell, "Prospective study of protein-energy supplementation early in life and of growth in the subsequent generation in Guatemala," *The American journal of clinical nutrition*, 2003, *78* (1), 162–167. Publisher: Elsevier.

Sun, Liyang and Sarah Abraham, "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects," *Journal of Econometrics*, December 2021, *225* (2), 175–199.

Yamauchi, Futoshi, Yisehac Yohannes, and Agnes R. Quisumbing, "Risks, Ex-Ante Actions and Public Assistance: Impacts of Natural Disasters on Child Schooling in Bangladesh, Ethiopia and Malawi," April 2009.