

Drought of Learning: Can private sanitation systems exacerbate the impact of droughts on student learning?

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This paper examines the impact of droughts on educational performance, highlighting the exacerbating role of private water provision and limited service coverage. Using a balanced panel of 5,570 Brazilian municipalities from 2004 to 2021, we investigate the relationship between drought exposure, water provision characteristics, and student learning outcomes. To capture distinct mechanisms, we distinguish between short-term droughts, which primarily affect agricultural production, and long-term droughts, which deplete water stocks in reservoirs, rivers, and lakes and thus constrain sanitation services. Our findings indicate that severe droughts adversely affect educational outcomes and that these effects are significantly stronger in municipalities with privately operated sanitation systems. This result aligns with theoretical predictions from incomplete contracts models (Hart et al., 1997), which predict that private providers are less likely to undertake precautionary investments in water resilience. Overall, while private provision tends to enhance efficiency, public systems demonstrate greater resilience to extreme droughts, with meaningful implications for education and public policy.

1 Introduction

Reliable water supply is associated with a wide range of positive social outcomes. Children with access to piped water perform better in school and are less likely to be hospitalized or suffer from water-related diseases (Briscoe et al., 1986; Cvjetanovic, 1986; Esrey et al., 1985; Galiani et al., 2005; Scriptore Moreira et al., 2024). Not surprisingly, a substantial body of literature has examined how different governance arrangements for sanitation services – whether public, private, or hybrid – affect social outcomes (Galiani et al., 2005; Inoue, 2020;

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Saiani and de Azevedo, 2018; Chaves and Costa, 2025). Grounded in the literature on the scope of government (Hart et al., 1997; Williamson, 1999; Mahoney et al., 2009; Luo and Kaul, 2019), empirical evidence generally favors private provision, which tends to exhibit superior performance even in cases where operations have subsequently reverted to public management (Hailu et al., 2012).

Nevertheless, the literature on sanitation service provision has not yet explored the heterogeneous effects of water supply under extreme weather conditions. Severe droughts, for example, directly influence both the costs and quality of water provision. Because private operators often face stronger incentives to reduce costs – sometimes at the expense of precautionary measures – different modes of provision are expected to respond unevenly to water shortages, particularly when these are substantially lower water levels in reservoirs, rivers, and lakes. This paper addresses this gap by examining how water supply characteristics (e.g., access and mode of provision) perform under extreme weather conditions and their impacts on educational outcomes. Using municipal-level data for 5,570 Brazilian cities from 2004 to 2021, this study provides novel empirical evidence on the interplay between droughts, water governance, and learning outcomes.

Because droughts may affect learning through multiple channels, we employ two measures of drought to better identify the role of water supply characteristics. Short-term droughts (measured over a one-year window) are likely to influence agricultural production, with relatively limited effects on water supply. In contrast, long-term droughts (measured over a five-year window) are associated with the depletion of water stocks in reservoirs, rivers, and lakes, generating substantial adverse impacts on sanitation services that depend on these sources. We find that severe droughts not only directly affect learning outcomes but that their effects are significantly more detrimental when sanitation services are privately provided. This result is consistent with an adaptation of (Hart et al., 1997) incomplete contracts model, which predicts that private operators are less likely to invest in precautionary measures – such as expanding reservoir capacity or promoting water conservation. Overall, our findings suggest that while private provision of water services tends to be more efficient on average, public provision exhibits greater resilience to severe long-term droughts, with an indirect relevant impact on educational outcomes.

Droughts rank among the most disruptive natural hazards, with direct consequences on learning (Cunha et al., 2019; De Alwis and Noy, 2019). The effects of droughts on educational outcomes have been studied within the broader contexts of climate change and socioeconomic development. Prior research shows that extreme weather events pose significant risks to human capital accumulation, particularly in regions characterized by fragile infrastructure and limited institutional capacity (Ferreira and Schady, 2009; Zamand and Hyder, 2016;

Joshi, 2019).

The literature identifies multiple pathways through which climate variability and weather shocks influence educational outcomes (Thamtanajit, 2020; Delprato and Shephard, 2024; Kearney et al., 2024; Venegas Marin et al., 2024), with droughts being especially consequential (Prentice et al., 2024). One prominent mechanism involves the economic instability caused by droughts, which constrains household investment in education (Shah and Steinberg, 2017; Joshi, 2019; Nordstrom and Cotton, 2020; Palacios and Rojas-Velásquez, 2023). Studies in rural areas – where livelihoods depend heavily on agriculture – find that prolonged droughts increase dropout rates as children are withdrawn from school to assist with household labor or water collection (Arceo-Gómez et al., 2020; Branco and Feres, 2018). Conversely, some evidence suggests that households increase educational investments following rainfall shocks, as the opportunity cost of children’s time declines (Zimmermann, 2020). Moreover, climate shocks have been linked to declines in cognitive development and academic achievement; for instance, income uncertainty arising from rainfall variability in Brazil has been shown to impair students’ cognitive functioning and decision-making abilities (Lichand and Mani, 2020).

Another important pathway concerns the strain that droughts impose on public infrastructure and services (Vins et al., 2015; Salvador et al., 2023). Research from Sri Lanka and Vietnam demonstrates that water scarcity exacerbates health risks – raising the incidence of water-related diseases and malnutrition – which in turn contribute to higher absenteeism and reduced academic performance (Lohmann and Lechtenfeld, 2015; De Alwis and Noy, 2019; Gust, 2024). Similarly, studies from India and Kenya reveal that early-life exposure to extreme droughts produces persistent learning deficits and slower grade progression (Zimmermann, 2020; Nübler et al., 2021).

Despite these insights, the role of water service governance in mediating the educational impacts of droughts remains insufficiently studied. While there is general agreement that adequate water infrastructure can mitigate some adverse drought effects, the effectiveness of different governance models has received limited empirical attention.

The remainder of this paper is organized as follows. The next section provides contextual information on sanitation services and droughts in Brazil. Section 3 outlines the hypotheses regarding the moderating role of water provision characteristics in the relationship between droughts and educational outcomes. Sections 4 and 5 describe the data and empirical strategy, respectively. Section 6 presents and discusses the main results, followed by the conclusions and policy implications. Robustness checks are provided in the Appendix.

2 Background information on sanitation services in Brazil

The coverage of water and sewage collection services is a pressing issue in Brazil. According to the National Information System on Sanitation (SNIS), water utilities were available to 84.2% of the Brazilian population in 2021, indicating that around 32 million people had no access to potable water. The situation is even more concerning for sewage collection, as only 55.8% of the Brazilian population had access to this service in the same year, meaning that almost 90 million people lacked an adequate sewer system in their households.

In addition, the provision of sanitation services in Brazil is characterized by considerable inequalities, particularly between urban and rural areas and across regions. Urban areas exhibit higher coverage rates, with nearly universal access to piped water in major cities, whereas rural areas lag significantly, with coverage rates often below 50% (IBGE, 2017). Moreover, the regional disparity is particularly pronounced between the North and Southeast regions, as piped water is limited to 60% of the population in the former, while it is available to 91.5% of citizens in the latter.

The lack of piped water and sewage collection is closely associated with the prevalence of sanitation-related diseases in children, including diarrhea, parasitic infections, and soil-transmitted helminthiasis. Globally, poor sanitation is a leading cause of diarrheal diseases (Prüss-Ustün et al., 2019), which remain one of the primary contributors to child mortality. In Brazil, these impacts are particularly severe in regions with low sanitation coverage, such as the North and Northeast, where higher rates of child morbidity and mortality from sanitation-related diseases are consistently reported (IBGE, 2017). These illnesses have cascading effects, including malnutrition, impaired physical growth, and cognitive delays (WHO et al., 2003).

Consequently, sanitation-related diseases not only affect children’s health but also their educational performance. Frequent bouts of illness lead to increased school absences, which hinder instructional time and academic achievement (WHO et al., 2019). Chronic malnutrition, often stemming from repeated diarrheal episodes, further impairs cognitive development, making it difficult for children to focus, retain information, and perform well in school (Victora et al., 2008).

Nonetheless, the adverse effects of poor sanitation on educational performance are potentially exacerbated during drought periods. In regions without adequate piped water and sewage systems, droughts can lead to contamination of alternative water sources (such as wells and the water table) by untreated sewage. This contamination increases the risk of disease outbreaks, which results in school absences and poor academic performance. Furthermore, the impact on children’s educational development may be compounded by the

need to assist their families in securing water. Activities such as water collection require significant time and effort, contributing to higher rates of absenteeism and school dropouts.

Water services in Brazil may be provided under public or private governance arrangements. Public provision takes two main forms: state-owned companies operating at the state level and local public companies owned and managed by municipalities. Private governance occurs through three primary arrangements: long-term concessions (typically lasting around 30 years), public–private partnerships (PPPs), and the full privatization of public sanitation companies, whereby concession contracts include all assets previously owned by a state-owned provider. Under all private arrangements, firms retain residual claims over profits and operate under public regulation. As established by the Brazilian Constitution, the choice of governance mode is a municipal prerogative, initiated by the mayor and ratified by the city council.

State-level public provision was the dominant model, serving 69.5% of Brazilian municipalities in 2017. Its prevalence reflects historical and institutional factors. During the 1970s, a national effort to expand sanitation coverage led to the creation of state-owned sanitation companies, supported by federal funding. At that time, states held primary responsibility for sanitation policy, and private provision was virtually nonexistent. Although the 1988 Constitution transferred responsibility for sanitation services to municipalities, it allowed them to delegate service provision to state-owned companies without competitive bidding (CERI, 2019). This institutional arrangement persisted until the enactment of Law No. 14,026 in 2020, which sought to foster private investment through mandatory competitive procedures—changes that fall outside the time frame of this study.

Local public provision, adopted by approximately 25% of municipalities in 2017, involves the establishment of municipal companies fully controlled by local governments. Compared to state-level providers, municipal companies operate under closer local oversight, potentially reducing conflicts of interest and enabling more responsive service delivery (Shleifer, 1998). However, this mode places the financial burden of service provision entirely on municipalities, which may lack the fiscal capacity to sustain investments in infrastructure and service quality. In this sense, the performance of local-public providers is closely tied to the municipal financial health and government capabilities.

Private provision remained relatively limited, covering only 5.5% of municipalities in 2017. Its low prevalence is largely attributable to the legal and contractual complexity of private arrangements, which require competitive bidding processes and detailed long-term contracts. Furthermore, political considerations frequently influenced concessions, as state-level control offered opportunities for governments to align public service provision with political objectives (Saiani and Azevedo, 2014). To illustrate the evolution of private participation, Figure 1

presents the number of privatizations in the sanitation sector between 1994 and 2023.

Empirical evidence highlights the potential benefits of private provision, as studies have shown that transitioning from public to private providers often results in improved service quality and efficiency (Galiani et al., 2005; Barrera-Orsorio et al., 2009; Saiani and de Azevedo, 2018). In Brazil, private providers tend to outperform public suppliers on average in terms of service quality indicators. However, there is considerable variation within public provision, and some municipal or state providers achieve results that rival or even surpass those of private operators, as shown in Figure 2. This variability underscores the importance of local factors – such as population density, geographic aspects, and fiscal capacity – in shaping service performance. As a result, municipalities must carefully evaluate their characteristics when selecting a provision mode, as no single arrangement presents superior outcomes across all contexts.

Despite evidence favoring private provision in certain scenarios, its performance under adverse conditions, such as drought periods, remains uncertain. Private providers often face a trade-off between cost efficiency and service quality, which may encourage cost-cutting measures that compromise reliability and resilience (Hart et al., 1997). Investments in precautionary measures to cope with extreme and unanticipated weather conditions are likely to be neglected by private operators since they are costly, and extreme natural events are a sufficient motive for the revision of the terms of concession contracts.

3 Hypotheses

We examine two key features of water supply—water service coverage and the governance arrangement of sanitation services—and assess how they moderate the effects of droughts on student learning outcomes. For each of these features, we formulate testable hypotheses, which are developed in the following sections.

3.1 Water services coverage and school performance

Drought periods strain already limited water resources, making it difficult for families to prioritize hygiene practices such as handwashing, bathing, and cleaning. This lapse in hygiene facilitates the transmission of waterborne and sanitation-related diseases, such as diarrhea, dysentery, and skin infections. For children, these diseases not only cause physical suffering, but also lead to frequent school absences and a diminished ability to focus and perform academically when in school (WHO et al., 2003; Prüss-Ustün et al., 2019).

In areas lacking sewage and piped water systems, droughts exacerbate the contamination

of alternative water sources, such as wells and the water table. As water levels drop, the concentration of pollutants in these sources rises, increasing the risk of exposure to harmful pathogens. Moreover, untreated sewage from pit latrines or open defecation often seeps into groundwater, further compounding the problem. Contaminated water sources during droughts become a major channel for the spread of diseases such as gastrointestinal infections and parasitic infestations, which are directly linked to increased absenteeism and poorer educational outcomes (Hutton et al., 2007; WHO and UNCF, 2021).

However, drought periods adversely affect children’s education through other pathways beyond the increased incidence of sanitation-related diseases. A significant factor is the need for children to assist their families in the collection of water, a task that often involves walking long distances to retrieve water from rivers, wells, or other sources. This activity consumes time and energy that would otherwise be devoted to attending school or studying. Consequently, as children prioritize immediate family needs over their education, the demands of water collection may lead to chronic absenteeism and, in severe cases, school dropouts (Sorenson et al., 2011).

In addition, stress and anxiety associated with water scarcity can alter cognitive functions critical to learning. The constant concern about water availability diverts cognitive resources, reducing attention spans and decreasing concentration levels in the classroom (Lichand and Mani, 2020). This mental burden can lead to lower academic performance as students struggle to fully engage in their studies.

Thus, to test the potential moderating effects of a comprehensive water supply on educational results, the first hypothesis proposed by this study is as follows.

H1: Higher water coverage mitigates the adverse effects of droughts on school performance.

By creating a complex interplay of health and environmental factors that disproportionately impact children, droughts can deepen the adverse effects of poor sanitation on educational development. The scarcity of water amplifies the challenges associated with maintaining proper hygiene, leading to an increased prevalence of sanitation-related diseases. This, in turn, has consequences on school attendance and academic performance, as repeated exposure to such illnesses has a cumulative effect on cognitive development. In addition, the need to fetch water in areas without piped infrastructure, combined with the psychological stress caused by water scarcity, significantly disrupts children’s ability to regularly attend classes and sustain academic progress, ultimately contributing to poor educational outcomes. In this sense, higher coverage of water services may lessen the negative impacts of droughts on learning.

3.2 Private provision of water services and school performance

The provision of water services by private entities often involves a delicate balance between cost efficiency and service quality. According to the seminal framework developed by [Hart et al. \(1997\)](#), private providers have strong incentives to minimize costs to maximize profitability. Although such profit-driven measures may lead to reduced operational expenses, they can also compromise the reliability and resilience of service delivery, particularly in contexts where maintaining quality is costly. This trade-off becomes especially critical during periods of resource scarcity, such as droughts, when water is harder and more expensive to source and distribute.

Droughts present a unique stress test for water utilities, as constrained availability increases the logistical and financial challenges of maintaining adequate supply. To address the challenges posed by severe droughts, water utilities may adopt precautionary measures aimed at mitigating the risks and consequences of water shortages. Such measures include investments in additional reservoir capacity, anticipatory demand rationing, and the reduction of water pressure in distribution systems to limit leakages. While these interventions entail significant costs - whether in the form of capital expenditures or foregone revenue - they enhance the resilience of water supply systems under extreme drought conditions.

Conventional normative models concerning the scope of government intervention (e.g., privatization versus public provision) typically do not account for actions designed to address random extreme events such as severe droughts. The incomplete contracts framework of [Hart et al. \(1997\)](#) is deterministic in nature, and [Williamson \(1999\)](#) focuses primarily on transaction characteristics requiring probity, largely independent of risk considerations. Nonetheless, these frameworks can be extended to analyze precautionary investments that mitigate the consequences of stochastic extreme events. Such measures are generally costly and largely non-contractible, as their effects become observable only after rare occurrences, and courts often treat extreme weather events as force majeure, thereby exempting providers from liability.

Following the logic of [Hart et al. \(1997\)](#), we expect private water companies to exhibit weaker incentives to undertake precautionary measures against severe droughts. Consequently, during such periods, the quality of sanitation services is likely to deteriorate more under private provision than under public provision.

Hence, the second hypothesis to be tested by the present work is the following.

H2: Private provision of water utilities leads to poorer school performance during severe droughts.

By increasing the likelihood of service disruptions and inequities, private providers can

amplify the adverse effects of water scarcity on children, resulting in worse educational outcomes. When water availability becomes unreliable, children are more likely to experience the cascading effects of inadequate hygiene, such as increased exposure to waterborne and sanitation-related diseases. These illnesses often result in frequent school absences, as well as physical and cognitive impairments that affect their ability to fully engage in learning activities.

4 Data

Using municipal data from all 5,570 Brazilian cities spanning 2004 to 2021, this study evaluates the impact of droughts on the academic development of basic education students in light of disparities in sanitation provision. The dataset includes information on educational indicators, drought measures, and variables that characterize sanitation services, along with demographic, socioeconomic, and fiscal variables.

4.1 School outcomes

To assess the impact of drought periods on school development, we examine a combination of performance and attendance indicators, offering a comprehensive view of educational outcomes. The analysis focuses on data from Brazil’s public education system, as students from low-income households are disproportionately affected by the adverse consequences of droughts, including disruptions on water access, water-related diseases, and additional household responsibilities.

The Brazilian public education system is organized into three levels: Elementary 1, Elementary 2, and High School. Public schools serve most of the students. In 2023, according to the National Education Census, 80.7% of students in Elementary 1 and 83.5% in Elementary 2 attended public schools. Elementary education (Stages 1 and 2) is evaluated through SAEB, a national assessment administered every two years, along with additional indicators, such as dropout rates, grade-retention rates, and school infrastructure, compiled by the Ministry of Education and published in the National Education Census.

Performance indicators include three main covariates: the Basic Education Assessment System (SAEB), the Basic Education Development Index (IDEB), and the Approval Rate (AR). Together, these metrics provide robust information on academic proficiency and student progression, shedding light on how drought-related disruptions can influence education.

SAEB evaluates students’ proficiency in Portuguese (reading and comprehension) and Mathematics (numerical and problem-solving skills). Administered periodically to students

in the 5th and 9th grades, the results are presented on a standardized scale ranging from 0 to 500 points, further categorized into proficiency levels. This diagnostic tool enables a detailed assessment of educational quality at the municipal level. By examining SAEB scores, this study seeks to determine whether stressors associated with drought periods adversely affect student learning outcomes.

Encompassing SAEB, IDEB offers a broader perspective on educational quality in Brazil. This composite index combines SAEB performance scores with the Flow Index, which measures school efficiency in terms of approval, failure, and dropout rates. IDEB scores range from 0 to 10, with higher values signifying better results. The inclusion of IDEB allows for the investigation of whether drought-related disruptions correlate with declines not only in academic performance but also in school retention and flow efficiency.

Adding to these metrics, the Approval Rate measures the percentage of students who successfully advance to the next grade level at the end of the academic year. High approval rates often reflect supportive learning environments that facilitate student progression. In contrast, lower rates indicate systemic challenges, such as increased absenteeism or inadequate teaching resources, which could be exacerbated by environmental stressors such as droughts.

Dropout Rate (DR) quantifies the percentage of students who leave school before completing the academic year. It is a fundamental measure of educational retention and is often related to socioeconomic vulnerabilities and family stressors, both of which tend to intensify during droughts. For instance, families facing economic pressures during water scarcity may require children to contribute to household labor or water collection, leading to increased dropout rates and interrupted education.

Furthermore, the division of educational outcomes between elementary 1 (E1), encompassing 1st to 5th grades, and elementary 2 (E2), including 6th to 9th grades, allows a more nuanced understanding of how drought and water service characteristics affect scholars at different stages of their academic journey. E1 students are typically more vulnerable to external disruptions, such as sanitation-related diseases and water scarcity, which can significantly affect their attendance and foundational learning. Conversely, E2 students face more complex educational demands, including higher cognitive requirements and subject-specific instruction, which can amplify the effects of environmental stressors on academic performance.

This division provides insights into whether the impacts of droughts and water governance vary by educational stage, revealing potential differences in resilience, vulnerability, or response mechanisms across these groups. For example, younger students in E1 may be more affected by frequent absenteeism due to waterborne diseases, while E2 students might experience greater academic setbacks due to disrupted school environments or increased household

responsibilities, such as fetching water. This stratification enhances the interpretation of results, enabling targeted policy recommendations to address the distinct needs of scholars in these two critical phases of basic education.

In summary, the analysis of performance and attendance metrics for E1 and E2 students provides a refined understanding of how drought conditions affect both the quality and accessibility of education in Brazil. By examining these indicators, the study aims to uncover the pathways through which drought periods influence educational outcomes, particularly for vulnerable students.

4.2 Water and sewage services measures

To examine the heterogeneity in the provision of water services, we collect data from the Brazilian Association of Private Companies of Water and Sewage Services (ABCON) and the National Information System on Sanitation (SNIS).

To explore the heterogeneity associated with access to water services, we include a dummy variable indicating whether the municipal mean coverage of water utilities is above the national median. This variable captures disparities in infrastructure, which become particularly critical during droughts. Municipalities with water coverage above the national median are less likely to face compounded vulnerabilities, as more developed infrastructure ensures greater access to reliable water supplies. This improved access potentially contributes to lower rates of school absenteeism and better academic performance among students. By examining this variable, the analysis aims to determine whether better water supply mitigates educational challenges associated with droughts, offering insights into the role of water systems in building resilience within affected communities.

In addition, we incorporate a dummy variable indicating whether the water services in a municipality are delivered by a private provider. This variable enables to examine how different modes of water supply cope with severe droughts. The assumption driving this inclusion is that private providers, motivated by profit-maximizing strategies, may implement cost-cutting measures. These strategies, while profitable, could increase the risk of water shortages during droughts, when maintaining a stable water supply becomes increasingly expensive. Such disruptions in service provision are expected to contribute to poorer educational outcomes during periods of environmental stress.

Figure 4 shows municipalities with privatized sanitation services across the country.

4.3 Drought measures

Droughts have multiple dimensions ([Dai, 2013](#); [Trenberth et al., 2014](#)). They can be short-term, such as agricultural droughts and meteorological droughts, which typically last up to one year, or long-term, such as hydrological droughts, which impact river streamflow and water storage and are characterized by periods exceeding one year ([Dai, 2011](#)). Understanding that the different dimensions of droughts can trigger varied effects, we have decided to proceed with our analysis using two definitions of droughts: the impact of short-term droughts and the impact of long-term droughts. In the following, we describe how each of these measures was computed.

To construct our drought measure, we follow the work [Vicente-Serrano et al. \(2010\)](#), which highlights the importance of incorporating information about global warming when studying water availability. Specifically, the increase in temperature has influenced the rise in potential evapotranspiration, leading to a reduction in water availability in the environment. We use the Standardized Precipitation-Evapotranspiration Index (SPEI), a widely used indicator that accounts for the balance between precipitation and potential evapotranspiration.

Using the 12-month SPEI for each municipality in Brazil, we employ this index to create measures of both short-term and long-term droughts. For short-term droughts, we consider a municipality to be experiencing a drought if its SPEI value is below -1. This threshold indicates that the balance between precipitation and evapotranspiration over a one-year period in the municipality is approximately one standard deviation below its historical mean. This short-term measure is commonly used in studies on the impacts of droughts and is typically referred to as a type of "severe" aridity ([Boffa et al., 2024](#)). For the purposes of this work, we divide SPEI12 into three drought categories: values above zero are classified as low aridity, values between 0 and -2 are classified as moderate aridity, and values below -2 are classified as severe aridity. Given the focus on assessing the impact of extreme climate conditions, the analysis prioritizes the short-term severe drought category. To do this, an indicator variable is constructed, taking the value one if $\text{SPEI12} < -2$. This approach isolates the effects of severe droughts, allowing for a targeted evaluation of their implications on the variables of interest.

For long-term drought measures, we adopt the definition proposed by [Brito et al. \(2018\)](#). In this framework, we analyze a five-year window and define a drought as one that begins in a specific month when the SPEI12 value drops below -1. The drought is considered to end in the month when the SPEI12 value returns to zero. The severity of a long-term drought can be calculated as the absolute value of the integral of the monthly SPEI12 values for a municipality while the drought occurs within the 5-year window. This approach captures the cumulative impact of the drought on the municipality throughout the period. Using this

method, we create a variable that designates the impact of long-term droughts, identifying a municipality as having experienced significant long-term drought impact if its severity value exceeds the historical mean. In addition, to assess the long-term most adverse effects of droughts, the variable is divided into quartiles, with the highest one representing "severe drought". An indicator variable is then defined, taking the value of 1 if the severity of the drought falls within the fourth quartile of its distribution.

The primary source of data for this analysis is the Climate Research Unit Time Series (CRU TS) v. 4.08, which provides monthly grid-level data for the period 1901-2023. The raw data sets are transformed from their original grid-level resolution (1x1 degree) into municipality-level data. Transformation of data from the grid into aggregates at the municipality level is performed using routines that extract monthly data and spatially average them to produce measures at the municipality level.

4.4 Additional variables

To control for additional factors that can influence school performance, we also incorporate a set of demographic and fiscal characteristics of Brazilian municipalities. These control variables account for key differences such as population size, income and educational levels, and municipal expenditure on public services. By including these covariates, we isolate the specific effects of water governance and infrastructure coverage on educational outcomes, mitigating confounding influences from broader socioeconomic or fiscal disparities.

This comprehensive approach improves the robustness of the findings, offering a nuanced understanding of how water supply features intersect with educational performance, particularly under environmental stress conditions.

Finally, Table 1 offers a structured overview of the covariates used in the analysis, alongside their respective data sources. This detailed summary encompasses dependent, explanatory, and control variables, as well as their measurement criteria. By outlining the origins and construction of each variable, this figure ensures clarity in the analytical framework and supports the replicability of the findings.

4.5 Descriptive statistics

Table 2 presents descriptive statistics for the main variables used in the study. The variables analyzed include educational outcomes, drought conditions, and characteristics of water services in Brazilian municipalities from 2004 to 2021. This summary establishes the context for the subsequent analysis, linking the challenges of water scarcity and service delivery to their effects on educational indicators.

IDEB scores for elementary 1 (E1) and elementary 2 (E2) students reveal notable disparities in averages and variability. The mean IDEB score for E1 is 4.92, with a broader distribution (standard deviation of 1.19), while the mean for E2 is 4.07, with a smaller variation (standard deviation of 0.87). These differences could indicate that younger students in E1 might experience conditions more conducive to educational performance, potentially benefiting from institutional support or less exposure to disruptions. In contrast, the lower mean and narrower variability in E2 may reflect the increasing academic demands or adversities faced by older students, which could include environmental stressors.

The SAEB values align with the patterns observed in IDEB scores. The mean SAEB score for E1 is slightly higher at 5.38 compared to 4.78 for E2, suggesting relatively stronger achievement in the earlier grades. These statistics could indicate that older students in E2 face additional hurdles, potentially related to the more complex educational requirements and external factors.

Approval rates show similar trends for E1 (mean of 0.91) and E2 (mean of 0.84), reflecting a high level of progression for early stages. However, dropout rates differ significantly between the educational levels, with E1 having a mean of 1.35% compared to a much higher 4.32% in E2. The maximum dropout rate for E2 reaches 100%, indicating extreme cases of educational disruption. This sharp contrast suggests that older students are more vulnerable to socio-environmental stressors, such as water scarcity, which may force them out of school to support their families in managing drought-related challenges.

Turning to the drought measures, the SPEI12 variable presents a mean of -0.22 , indicating moderately dry conditions during the study period, with extreme droughts reaching a minimum of -11.06 . These statistics highlight the frequent occurrence of short-term droughts, which are expected to disrupt education through water shortages, sanitation-related illnesses, and increased stress on school operations.

Moreover, the long-term severe drought measure exhibits a mean value of 14 and a substantial standard deviation of 22.47, reflecting significant variability in drought conditions. Some regions experienced extreme severe drought, with a maximum value of 432.37. This heterogeneity in water scarcity underscores the varying levels of vulnerability among municipalities, supporting the analysis of how governance and infrastructure of water services can mediate the impacts of droughts on educational outcomes.

Lastly, the water service coverage presents an average of 68%. This, coupled with the wide range (0% to 100%), highlights the disparities among municipalities between 2004 and 2021. Cities with coverage below the median are especially prone to the impacts of droughts, as limited access to water services worsens sanitation problems and disrupts school attendance (Jalan and Ravallion, 2003). In contrast, municipalities with above-median coverage are

better equipped to withstand these problems, potentially buffering the negative educational effects of droughts.

Therefore, the differences observed in educational indicators, drought measures, and water service coverage reinforce the need to address infrastructure deficiencies and governance issues to mitigate drought impacts. These statistics provide a foundation for the empirical analysis, emphasizing the importance of understanding how municipal-level heterogeneity influences the relationship between environmental stressors and learning.

5 Econometric Approach

To evaluate the impact of drought periods on the educational performance of elementary school students, we apply an econometric framework grounded in panel data linear regressions. The analysis examines how variations in coverage levels and governance of water services influence educational outcomes, with particular attention to the interaction between drought intensity and key explanatory variables. This approach allows for a detailed investigation into the mechanisms through which droughts and water supply disparities affect student performance.

The first specification incorporates the heterogeneity related to water services coverage. It is expressed as:

$$y_{it} = \alpha_1 \text{Drought}_{it} + \alpha_2 \text{WAM}_{it} + \alpha_3 \text{Drought}_{it} \times \text{WAM}_{it} + \alpha_4 \text{C}_{it} + \kappa_i + \tau_t + \mu_{it},$$

where y_{it} represents one of the educational outcomes for municipality i in year t . Drought_{it} denotes a measure of drought intensity, while WAM_{it} is a dummy variable indicating whether the average coverage of water services in municipality i exceeds the national median. The interaction term ($\text{Drought}_{it} \times \text{WAM}_{it}$) evaluates whether limited water coverage amplifies the adverse effects of droughts. In addition, C_{it} represents a matrix of control variables capturing municipal characteristics such as population size, income level, and public expenditures. Municipality fixed effects (κ_i) and year fixed effects (τ_t) control for unobserved heterogeneity and temporal shocks, while μ_{it} is the error term.

The second specification captures the interplay between drought conditions and private water provision. The general form of this model is as follows.

$$y_{it} = \beta_1 \text{Drought}_{it} + \beta_2 \text{Private}_{it} + \beta_3 \text{Drought}_{it} \times \text{Private}_{it} + \beta_4 \text{C}_{it} + \kappa_i + \tau_t + \varepsilon_{it},$$

in which Private_{it} is a dummy variable indicating whether water services are provided by private entities, whereas the interaction term ($\text{Drought}_{it} \times \text{Private}_{it}$) identifies whether private

provision exacerbates the impacts of droughts on the dependent variable. As in the first model, this specification includes control variables, fixed effects, and an error term (ε_{it}).

This econometric approach exploits the exogeneity of droughts, treating them as natural experiments due to their unpredictability. This strengthens causal inference, ensuring the estimated relationships between droughts, water utility characteristics, and educational outcomes are not confounded by endogeneity or reverse causality. The inclusion of interaction terms provides a deeper understanding of heterogeneity, allowing for a nuanced analysis of how infrastructure levels and institutional arrangements mediate the effects of drought periods.

We employ two distinct measures of drought to more precisely identify the mechanisms underlying our main findings. Short-term severe drought may influence water availability, rural income, and consequently the opportunity cost of schooling. In contrast, long-term severe droughts primarily affect the stock of water by drying up or substantially reducing the levels of rivers, lakes, and reservoirs. The occurrence of these extreme climatic events enables us to assess the resilience of water supply systems and, indirectly, the extent to which precautionary measures are adopted to mitigate the impacts of long-term severe droughts.

The results of these models offer valuable policy insights. If the interaction term involving above-median water coverage is significant, it would underscore the need to expand the infrastructure of water services, particularly in underserved areas, to improve resilience against climate variability.

Similarly, if the interaction with private provision is significant, it would indicate that private providers may be less prone to ensure service resilience during droughts, potentially worsening educational outcomes. This would highlight the need for regulatory frameworks to mitigate risks associated with cost-cutting measures that undermine supply reliability.

By isolating the pathways through which droughts affect education, this study contributes to identifying critical vulnerabilities in water governance and infrastructure. The findings have far-reaching implications, emphasizing the importance of addressing inequities in resource distribution and strengthening adaptive strategies to mitigate the adverse effects of climate variability.

6 Results and Discussion

This section presents the empirical results of the analysis, examining how characteristics of water supply, specifically levels of water coverage and private provision, interact with long-term severe droughts to influence educational outcomes. Guided by the hypotheses that private provision of water utilities and lower water coverage lead to poorer school performance

during drought periods, the analysis employs panel data linear regressions to estimate the effects of droughts on four key educational indicators. The assessment investigates whether water supply features exacerbate or mitigate the adverse impacts of droughts on learning outcomes.

6.1 Preferred model for assessing educational impacts of droughts

Tables 3 to 6 illustrate the regression results for the IDEB indicator across various model specifications. These specifications progressively incorporate different combinations of control variables and fixed effects, culminating in the preferred specification with full controls and fixed effects for both municipality and year.

The preferred model is identified based on IDEB, as it is the most comprehensive indicator considered in this study, integrating both student performance through standardized test scores and school efficiency through grade progression metrics. Unlike other indicators, IDEB captures the dual impact of droughts on learning outcomes and student retention, providing a holistic perspective on how the education system responds to environmental stressors.

The baseline specification (columns 1 and 2 of Tables 3 to 6) excludes fixed effects and includes only the drought variable and its interaction terms with water supply features. Columns 3 to 6 introduce controls for demographic, socioeconomic, and fiscal characteristics but still lack fixed effects. These specifications yield coefficients that are likely biased due to the omission of unobserved heterogeneity across municipalities and over time. The coefficients for the drought measures are positive in these models for both elementary 1 (E1) and elementary 2 (E2), potentially reflecting confounding effects from omitted variables.

Columns 7 and 8 incorporate year fixed effects to account for time-varying shocks, such as national economic trends or education policies. The inclusion of year-fixed effects reduces the magnitude or even inverts the sign of the drought coefficients, suggesting that some of the variations in IDEB scores are attributable to temporal shocks rather than drought conditions alone.

In columns 9 and 10, municipality fixed effects are added, addressing time-invariant characteristics specific to each municipality, such as geography or long-standing institutional differences. These adjustments further reduce the magnitude of the coefficients and, in some cases, reverse their direction, highlighting the importance of municipal features in shaping the impact of droughts on educational outcomes.

The final specification (columns 11 and 12) includes both municipality and year fixed effects alongside a comprehensive set of control variables. This specification provides the most robust estimates, accounting for confounding factors and unobserved heterogeneity. Here, the coefficients for the drought variables are consistently negative and significant for

both E1 and E2, confirming the literature findings about the adverse effects of droughts on educational performance. Thus, this preferred specification is used for the remainder of the analysis, aligning with best practices in panel data econometrics to ensure reliable results.

6.2 Impacts of droughts and water supply features on educational indicators

To explore how water governance interacts with extreme drought conditions, this section analyzes two dimensions of water supply – service coverage and private provision – and two measures of droughts, one for short-term severe drought and one for long-term severe drought.

6.2.1 Short-term Droughts and Water Coverage

Focusing on access to water services, Table 7 evaluates the effects of short-term severe drought, above-median water coverage, and their interaction on four educational indicators: IDEB, SAEB, Approval Rate (AR), and Dropout Rate (DR). Short-term severe drought consistently shows a detrimental effect across most indicators, confirming its adverse short-term impact on educational outcomes. For example, short-term severe drought decreases IDEB-E2 by 0.102 points and SAEB-E2 by 0.066 points, highlighting the challenges posed by drought periods.

Water coverage above the national median shows a protective effect, as reflected by the positive coefficients for IDEB, SAEB, and AR-E1, and the negative coefficients for DR. For instance, IDEB-E1 increases by 0.047 points, while DR-E1 decreases by 0.162 points in municipalities with better infrastructure, underscoring the importance of adequate water access to improve educational performance and efficiency.

Despite these benefits, the interaction term between short-term severe drought and above-median water coverage is negative for most performance indicators. This suggests that, contrary to our expectations, extreme weather conditions reduce the advantage of having access to water services in periods of regular weather. Table 8 provides additional evidence by presenting the linear combination of short-term severe drought and the interaction term. These coefficients capture the total effect of droughts in municipalities with water coverage above the national median. According to the results, short-term droughts undermine all educational indicators in municipalities with higher water coverage.

These findings provide evidence against the first research hypothesis, contradicting the idea that wide coverage of water services mitigates the negative impact of droughts on education - which highlights the pervasive effect of short-term water scarcity.

6.2.2 Long-term Droughts and Water Coverage

Table 9 extends the analysis to explore the effects of long-term droughts and water service coverage on educational outcomes. The results indicate that long-term severe drought has a significant negative impact on SAEB-E1, reducing this indicator by 0.061 points under prolonged drought conditions. This finding highlights the cumulative toll that extended water shortages can take on educational systems, as ongoing resource constraints impair learning environments.

Nonetheless, the analysis reveals a puzzling effect for other indicators – AR and DR – which appear to improve under persistent drought conditions. This unexpected result may suggest underlying compensatory mechanisms, such as increased resource reallocation to priority areas, shifts in student engagement patterns, or changes in household behaviors during prolonged droughts. Further investigation is warranted to unpack the drivers behind these counterintuitive findings.

The coefficient for water above median remains positive and significant for performance indicators, and negative for the attendance indicator, reaffirming that higher water coverage is associated with better educational outcomes. For example, IDEB-E1 increases by 0.063 points in municipalities with above-median water coverage, reflecting the importance of accessible and hygienic water supplies in maintaining educational development.

The interaction term, however, is negative for all performance indicators and positive for DR. These results indicate that while high water coverage mitigates some challenges, it cannot fully offset the compounded effects of long-term droughts. Table 10 reinforces such findings, showing that prolonged droughts have a predominantly negative effect on performance indicators even in municipalities with coverage of water services above the national median. In this sense, water scarcity erodes learning outcomes over time, even in areas with well-developed infrastructure systems.

6.2.3 Short-term Droughts and Private Provision of Water Services

Table 11 examines the effects of short-term severe drought, private provision, and their interaction on the four educational indicators. Short-term severe drought consistently shows negative and statistically significant coefficients across most indicators, confirming that short-term droughts reduce educational performance (e.g., lower IDEB and SAEB scores) and efficiency (e.g., higher dropout rates). For instance, IDEB-E1 decreases by 0.097 points, while SAEB-E1 falls by 0.077 points under short-term severe drought. These results align with the already documented findings that drought conditions negatively affect education due to water scarcity and related stressors.

Regarding private provision, the analysis reveals a positive coefficient for IDEB and AR, indicating a modest improvement in these educational indicators under private water governance during non-drought periods. Furthermore, for SAEB and DR, private provision exhibits a targeted impact on specific educational groups (E1 or E2). Specifically, it increases SAEB scores for E1 and reduces dropout rates for E2. These results suggest that private provision of water services has the potential to enhance educational outcomes when adverse conditions such as droughts are absent.

Although the interaction coefficients between private provision and drought are positive for all indicators, they lack statistical significance. These findings align with the existing literature that associates privatization of sanitation services with enhanced water service quality, as evidenced by improvements in health outcomes ([Galiani et al., 2005](#); [Saiani and de Azevedo, 2018](#)).

In summary, we find no evidence that the mode of sanitation service provision moderates the impact of short-term droughts on student outcomes. Because such conditions are insufficient to deplete water stocks, the previous estimations do not yet reflect the potential absence of precautionary behavior expected under private provision. This issue is further investigated through the estimations based on severe (long-term) droughts.

Table 12 complements this analysis by presenting the coefficients for the linear combination of short-term severe drought and the interaction term. The results indicate that droughts can negatively influence educational outcomes, as evidenced by the negative and statistically significant coefficients for IDEB-E2, SAEB-E2, and AR-E2. These findings reinforce that the private provision of water services does not mitigate the adverse effects of short-term severe drought (short term droughts) on educational indicators, particularly for certain metrics and educational groups.

6.2.4 Long-term Droughts and Private Provision of Water Services

To compare the effects of short- and long-term droughts, Table 13 evaluates the impacts of long-term drought measures on the same educational indicators, alongside private provision and their interaction.

The results indicate that long-term severe drought has significant negative effects on IDEB and SAEB, particularly for elementary 1 (E1) students. For example, long-term severe drought reduces IDEB-E1 by 0.027 points and SAEB-E1 by 0.068 points, underscoring the detrimental impact of prolonged water scarcity on educational performance. However, the coefficients for the other indicators present a puzzling outcome, as they show a favorable relationship between long-term droughts and educational performance, which remains challenging to explain.

Private provision positively affects IDEB and AR for both E1 and E2, reflecting better water management under stable conditions. Notably, its effects are positive for SAEB-E1 and negative for DR-E2, suggesting that private water provision supports school performance and efficiency in certain contexts.

Nevertheless, the interaction term reverses the positive effect of private provision, negatively impacting most indicators. This finding supports the hypothesis that private providers of sanitation services are less likely to adopt precautionary measures to cope with long-term severe droughts—those associated with the depletion of reservoirs. The results further emphasize the relationship between privatization and the resilience of water provision, a dimension that remains largely overlooked in the literature on the scope of government (Hart et al., 1997; Williamson, 1998).

To bring additional evidence to these findings, Table 14 presents the estimates for the linear combination of long-term severe drought and the interaction term. The results show that the total effect of droughts in municipalities with private water governance is negative for most indicators, worsening IDEB and SAEB scores, and AR. However, inconsistent findings for DR remain unresolved, representing a persistent puzzle.

6.3 Discussion and Policy Implications

The findings presented in Tables 7 to 14 do not corroborate the first research hypothesis, while they provide evidence supporting the second hypothesis.

Firstly, the findings highlight the critical role of droughts in educational performance. Municipalities experience markedly worse results during drought periods, as indicated by the negative coefficients for short-term severe drought and long-term severe drought.

Regarding the coverage of water services, municipalities with above-median coverage demonstrate a degree of resilience, as improved water access positively impacts performance indicators and reduces dropouts. However, this protective effect has limitations, as the interaction coefficients reveal that high water coverage cannot fully mitigate the adverse effects of droughts.

These results underscore the urgent need to expand water access and invest in infrastructure as a strategy to reduce educational disparities. Yet, the uncertain effect of such improvements under drought conditions suggests that infrastructure development must be complemented by broader adaptive measures, such as drought contingency planning, equitable water distribution systems, and education-focused support programs during crises. Addressing these gaps is crucial to achieving sustainable advances in both water security and educational outcomes.

Secondly, the results demonstrate that private provision of water utilities exacerbates the

adverse impacts of droughts on educational outcomes during long periods of water scarcity. This aligns with the second hypothesis, underscoring the limitations private providers face in maintaining service quality and resilience during water scarcity. The findings suggest that cost-efficiency pressures and insufficient incentives for private operators to prioritize reliability during crises contribute to this failure.

Therefore, these outcomes emphasize the need for robust regulatory frameworks that ensure private service providers adopt measures to safeguard access and equity, particularly under adverse environmental conditions. Policies that foster infrastructure investments, promote transparency, and enforce accountability during crises are crucial to improve the resilience of privately managed water systems. Without such mechanisms, the broad social and educational implications of droughts may persist, disproportionately affecting vulnerable populations.

7 Conclusion

By investigating the interplay between droughts, water governance, and educational outcomes in Brazil, this study sheds light on the vulnerabilities of public services to environmental stressors. Using municipal-level data of Brazilian cities from 2004 to 2021, we provide evidence that droughts adversely affect educational performance, particularly in municipalities with private water provision. These findings suggest that private operators, driven by cost-efficiency priorities, may lack incentives to invest in the reliability and resilience of water services, undermining their ability to respond effectively to crises.

Our results also demonstrate the critical role of water service coverage in shaping educational outcomes. While high coverage levels contribute to better education indicators under normal weather conditions, their mitigating effect during droughts is limited. This shows that infrastructure alone is insufficient to address the compounded challenges of water scarcity, emphasizing the need for robust governance and adaptive policies.

These findings present significant implications for policy and practice. First, the exacerbating effects of private provision during drought periods call for revisiting regulatory frameworks to guarantee that private operators are held accountable for maintaining service reliability under adverse conditions. Second, investment in infrastructure should be complemented by measures to improve the responsive capacity of water services, such as diversification of water sources, improved storage systems, and proactive drought management strategies. Lastly, education systems need targeted interventions to support vulnerable students during environmental crises, ensuring that temporary disruptions do not lead to long-term declines in academic performance or dropouts.

As climate change intensifies the frequency and severity of droughts, the results underscore the urgency of integrating resilience into both water governance and educational planning. By addressing the interconnected challenges of water scarcity and educational progress, policymakers can help build more equitable and sustainable systems to minimize the impacts of future environmental stressors.

References

- Alwis, Diana De and Ilan Noy**, “The cost of being under the weather: Droughts, floods, and health-care costs in Sri Lanka,” *Asian Development Review*, 2019, *36* (2), 185–214.
- Arceo-Gómez, Eva O, Danae Hernández-Cortés, and Alejandro López-Feldman**, “Droughts and rural households’ wellbeing: evidence from Mexico,” *Climatic Change*, 2020, *162* (3), 1197–1212.
- Barrera-Osorio, Felipe, Mauricio Olivera, and Carlos Ospino**, “Does society win or lose as a result of privatization? The case of water sector privatization in Colombia,” *Economica*, 2009, *76* (304), 649–674.
- Boffa, Federico, Francisco Cavalcanti, Christian Fons-Rosen, and Amedeo Pioletto**, “Drought-Reliefs and Partisanship,” *Oxford Bulletin of Economics and Statistics*, 2024, *86* (2), 187–208.
- Branco, Danyelle and Jose Gustavo Feres**, “Drought Shocks and School Performance in Brazilian Rural Schools,” Technical Report, Anpec 2018.
- Briscoe, John, Richard G Feachem, and M Mujibur Rahaman**, *Evaluating health impact: water supply, sanitation, and hygiene education*, IDRC, Ottawa, ON, CA, 1986.
- Brito, S. S. B., A. P. M. A. Cunha, C. C. Cunningham, R. C. Alvalá, J. A. Marengo, and M. A. Carvalho**, “Frequency, duration and severity of drought in the Semiarid Northeast Brazil region,” *International Journal of Climatology*, 2018, *38* (2), 517–529.
- CERI, FGV** –, “Análise dos Contratos de Programa,” 2019.
- Chaves, Rodrigo França and Adriano Borges Costa**, “Private ownership of water and wastewater systems: Assessing health impacts,” *Utilities Policy*, 2025, *95*, 101903.

- Cunha, Ana Paula MA, Marcelo Zeri, Karinne Deusdará Leal, Lidianne Costa, Luz Adriana Cuartas, José Antônio Marengo, Javier Tomasella, Rita Marcia Vieira, Alexandre Augusto Barbosa, Christopher Cunningham et al., “Extreme drought events over Brazil from 2011 to 2019,” *Atmosphere*, 2019, 10 (11), 642.
- Cvjetanovic, Branko, “Health effects and impacts of water supply and sanitation,” 1986.
- Dai, Aiguo, “Drought under global warming: A review,” *Wiley Interdisciplinary Reviews: Climate Change*, 2011, 2 (1), 45–65.
- , “Increasing drought under global warming in observations and models,” *Nature Climate Change*, 2013, 3 (1), 52–58.
- Delprato, Marcos and Daniel Shephard, “Climate change and its impact on education completion rates across four sub-Saharan African countries: A non-parametric approach at the community level,” *International Journal of Educational Development*, 2024, 110, 103129.
- Esrey, Steve A, Richard G Feachem, and James M Hughes, “Interventions for the control of diarrhoeal diseases among young children: improving water supplies and excreta disposal facilities,” *Bulletin of the World Health organization*, 1985, 63 (4), 757.
- Ferreira, Francisco HG and Norbert Schady, “Aggregate economic shocks, child schooling, and child health,” *The World Bank Research Observer*, 2009, 24 (2), 147–181.
- Galiani, Sebastian, Paul Gertler, and Ernesto Schargrotsky, “Water for life: The impact of the privatization of water services on child mortality,” *Journal of Political Economy*, 2005, 113 (1), 83–120.
- Gust, Sarah, “(Not) going to school in times of climate change: Natural disasters and student achievement,” Technical Report, ifo Working Paper 2024.
- Hailu, Degol, Rafael Guerreiro Osorio, and Raquel Tsukada, “Privatization and renationalization: What went wrong in Bolivia’s water sector?,” *World Development*, 2012, 40 (12), 2564–2577.
- Hart, Oliver, Andrei Shleifer, and Robert W Vishny, “The proper scope of government: theory and an application to prisons,” *The Quarterly Journal of Economics*, 1997, 112 (4), 1127–1161.

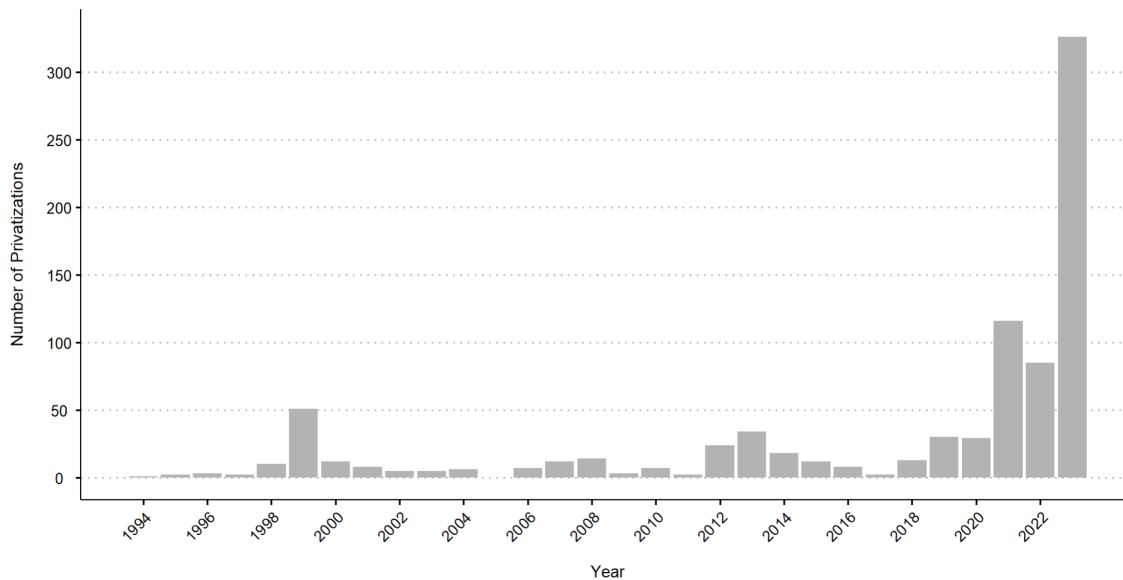
- Hutton, Guy, UE Rodriguez, Lucentezza Napitupulu, P Thang, and P Kov**, “Economic impacts of sanitation in southeast Asia: summary,” *World Bank Policy Research Working Paper*, 2007, (44121).
- IBGE**, “Brazilian Institute of Geography and Statistics: National Basic Sanitation Survey,” 2017. Accessed: January 29, 2025.
- Inoue, Carlos**, “Election cycles and organizations: How politics shapes the performance of state-owned enterprises over time,” *Administrative Science Quarterly*, 2020, 65 (3), 677–709.
- Jalan, Jyotsna and Martin Ravallion**, “Does piped water reduce diarrhea for children in rural India?,” *Journal of econometrics*, 2003, 112 (1), 153–173.
- Joshi, Kuhu**, “The impact of drought on human capital in rural India,” *Environment and Development Economics*, 2019, 24 (4), 413–436.
- Kearney, Christopher A, Kinsey Ellis, and V Jefferson Arcaina**, “Climate change injustice and school attendance and absenteeism: Proximal and distal ecological links,” in “Frontiers in Education,” Vol. 9 Frontiers Media SA 2024, p. 1455430.
- Lichand, Guilherme and Anandi Mani**, “Cognitive droughts,” *University of Zurich, Department of Economics, Working Paper*, 2020, (341).
- Lohmann, Steffen and Tobias Lechtenfeld**, “The effect of drought on health outcomes and health expenditures in rural Vietnam,” *World development*, 2015, 72, 432–448.
- Luo, Jiao and Aseem Kaul**, “Private action in public interest: The comparative governance of social issues,” *Strategic Management Journal*, 2019, 40 (4), 476–502.
- Mahoney, Joseph T, Anita M McGahan, and Christos N Pitelis**, “Perspective—The interdependence of private and public interests,” *Organization science*, 2009, 20 (6), 1034–1052.
- Marin, Sergio Venegas, Lara Schwarz, and Shwetlena Sabarwal**, “Impacts of extreme weather events on education outcomes: a review of evidence,” *The World Bank Research Observer*, 2024, p. lkae001.
- Moreira, Juliana Souza Scriptore, Carlos Roberto Azzoni, and Naercio Menezes-Filho**, “Sanitation conditions and education outcomes in Brazilian municipalities,” *Sustainable Development*, 2024, 32 (3), 1987–2000.

- Nordstrom, Ardyn and Christopher Cotton**, “Impact of a severe drought on education: More schooling but less learning,” *Available at SSRN 3601834*, 2020.
- Nübler, Laura, Karen Austrian, John A Maluccio, and Jessie Pinchoff**, “Rainfall shocks, cognitive development and educational attainment among adolescents in a drought-prone region in Kenya,” *Environment and Development Economics*, 2021, *26* (5-6), 466–487.
- Palacios, Paola and Libardo Rojas-Velásquez**, “Impact of weather shocks on educational outcomes in the municipalities of Colombia,” *International Journal of Educational Development*, 2023, *101*, 102816.
- Prüss-Ustün, Annette, Jennyfer Wolf, Jamie Bartram, Thomas Clasen, Oliver Cumming, Matthew C Freeman, Bruce Gordon, Paul R Hunter, Kate Medlicott, and Richard Johnston**, “Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: an updated analysis with a focus on low- and middle-income countries,” *International journal of hygiene and environmental health*, 2019, *222* (5), 765–777.
- Saiani, Carlos and Paulo Furquim Azevedo**, “Privatization as a Political Strategy: Evidence from Brazilian Basic Sanitation,” 2014.
- **and Paulo Furquim de Azevedo**, “Is privatization of sanitation services good for health?,” *Utilities Policy*, 2018, *52*, 27–36.
- Salvador, Coral, Raquel Nieto, Sergio M Vicente-Serrano, Ricardo García-Herrera, Luis Gimeno, and Ana M Vicedo-Cabrera**, “Public health implications of drought in a climate change context: a critical review,” *Annual review of public health*, 2023, *44* (1), 213–232.
- Shah, Manisha and Bryce Millett Steinberg**, “Drought of opportunities: Contemporaneous and long-term impacts of rainfall shocks on human capital,” *Journal of Political Economy*, 2017, *125* (2), 527–561.
- Shleifer, Andrei**, “State versus private ownership,” *Journal of economic perspectives*, 1998, *12* (4), 133–150.
- Sorenson, Susan B, Christiaan Morssink, and Paola Abril Campos**, “Safe access to safe water in low income countries: water fetching in current times,” *Social science & medicine*, 2011, *72* (9), 1522–1526.

- Thamtanajit, Kawin**, “The impacts of natural disaster on student achievement: Evidence from severe floods in Thailand,” *The Journal of Developing Areas*, 2020, 54 (4).
- Trenberth, Kevin E., Aiguo Dai, Gerard van der Schrier, Philip D. Jones, Jonathan Barichivich, Keith R. Briffa, and Justin Sheffield**, “Global warming and changes in drought,” *Nature Climate Change*, 2014, 4 (1), 17–22.
- Vicente-Serrano, Sergio M., Santiago Beguería, and Juan I. López-Moreno**, “A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index,” *Journal of Climate*, 2010, 23 (7), 1696–1718.
- Victora, Cesar G, Linda Adair, Caroline Fall, Pedro C Hallal, Reynaldo Martorell, Linda Richter, and Harshpal Singh Sachdev**, “Maternal and child undernutrition: consequences for adult health and human capital,” *The lancet*, 2008, 371 (9609), 340–357.
- Vins, Holly, Jesse Bell, Shubhayu Saha, and Jeremy J Hess**, “The mental health outcomes of drought: a systematic review and causal process diagram,” *International journal of environmental research and public health*, 2015, 12 (10), 13251–13275.
- WHO, World Health Organization and United Nations Children’s Fund UNCF**, *Progress on household drinking water, sanitation and hygiene 2000-2020: five years into the SDGs*, World Health Organization, 2021.
- **et al.**, *Poverty and health*, World Health Organization, 2003.
- **and** —, *Progress on household drinking water, sanitation and hygiene 2000-2017: special focus on inequalities*, World Health Organization, 2019.
- Williamson, Oliver E**, “Transaction cost economics: how it works; where it is headed,” *De Economist*, 1998, 146 (1), 23–58.
- , “Public and private bureaucracies: a transaction cost economics perspectives,” *Journal of Law, Economics, and Organization*, 1999, 15 (1), 306–342.
- Zamand, Mina and Asma Hyder**, “Impact of climatic shocks on child human capital: evidence from young lives data,” *Environmental hazards*, 2016, 15 (3), 246–268.
- Zimmermann, Laura**, “Remember when it rained—Schooling responses to shocks in India,” *World Development*, 2020, 126, 104705.

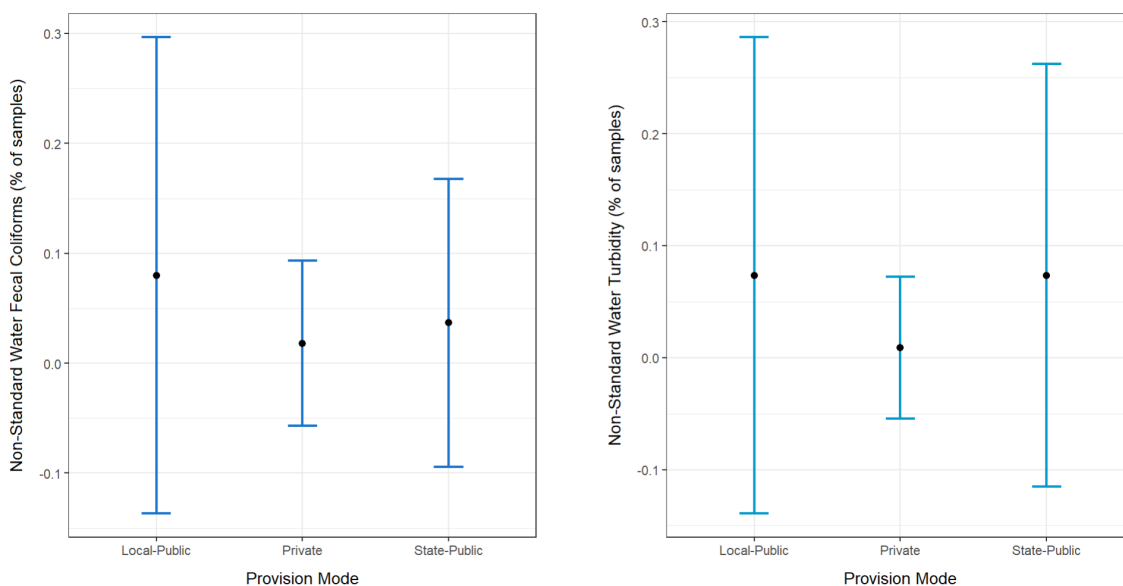
Tables and Figures

Figure 1: Evolution of Private Sanitation Services Provision in Brazil



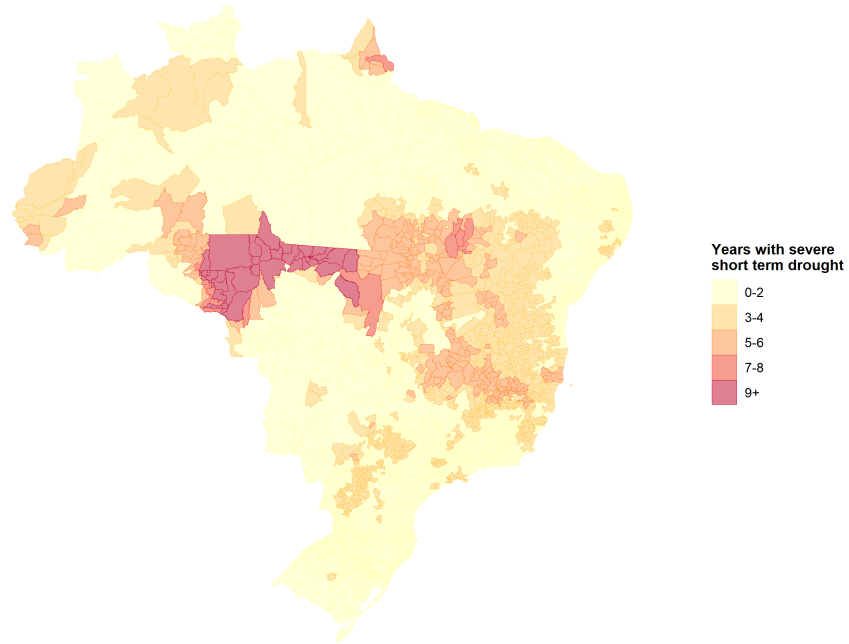
Note: This figure depicts the progression of private provision of sanitation services over the years. The information is sourced from the Brazilian Association of Private Companies of Water and Sewage Services (ABCON), highlighting the increasing role of private entities in the sanitation sector over time. [Back to text](#)

Figure 2: Water Quality Indicators by Type of Service Provider

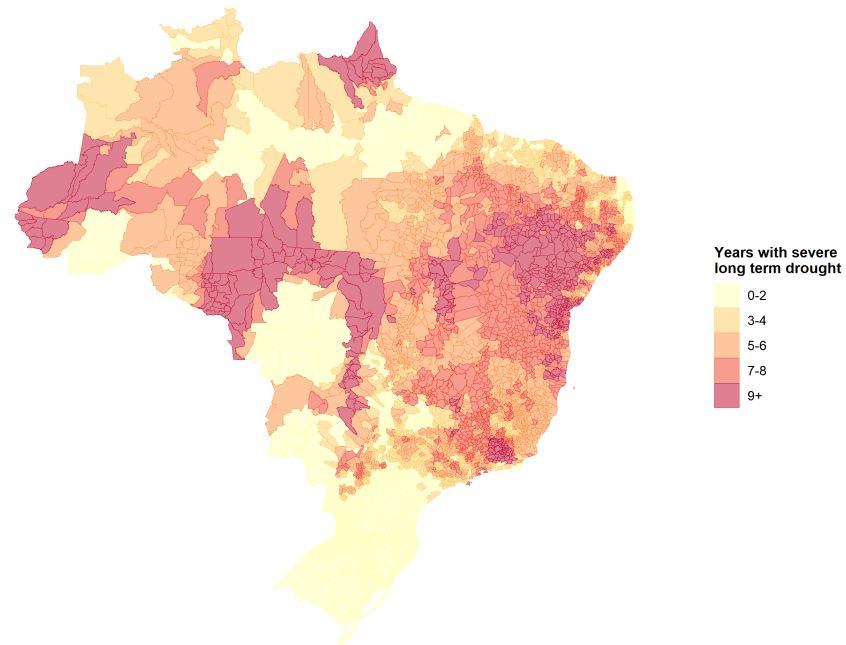


Note: This figure illustrates the percentage of water samples exceeding standard levels of fecal coliforms and turbidity. It distinguishes between the three types of water service providers: private provision, representing municipalities where private companies manage water services; local-public provision, encompassing municipalities served by municipal water companies; and state-public provision, referring to municipalities where state-run companies supply water services. The data is sourced from the 2020 National Information System on Sanitation (SNIS). [Back to text](#)

Figure 3: The Distribution of Long- and Short-Term Severe Droughts Across Space



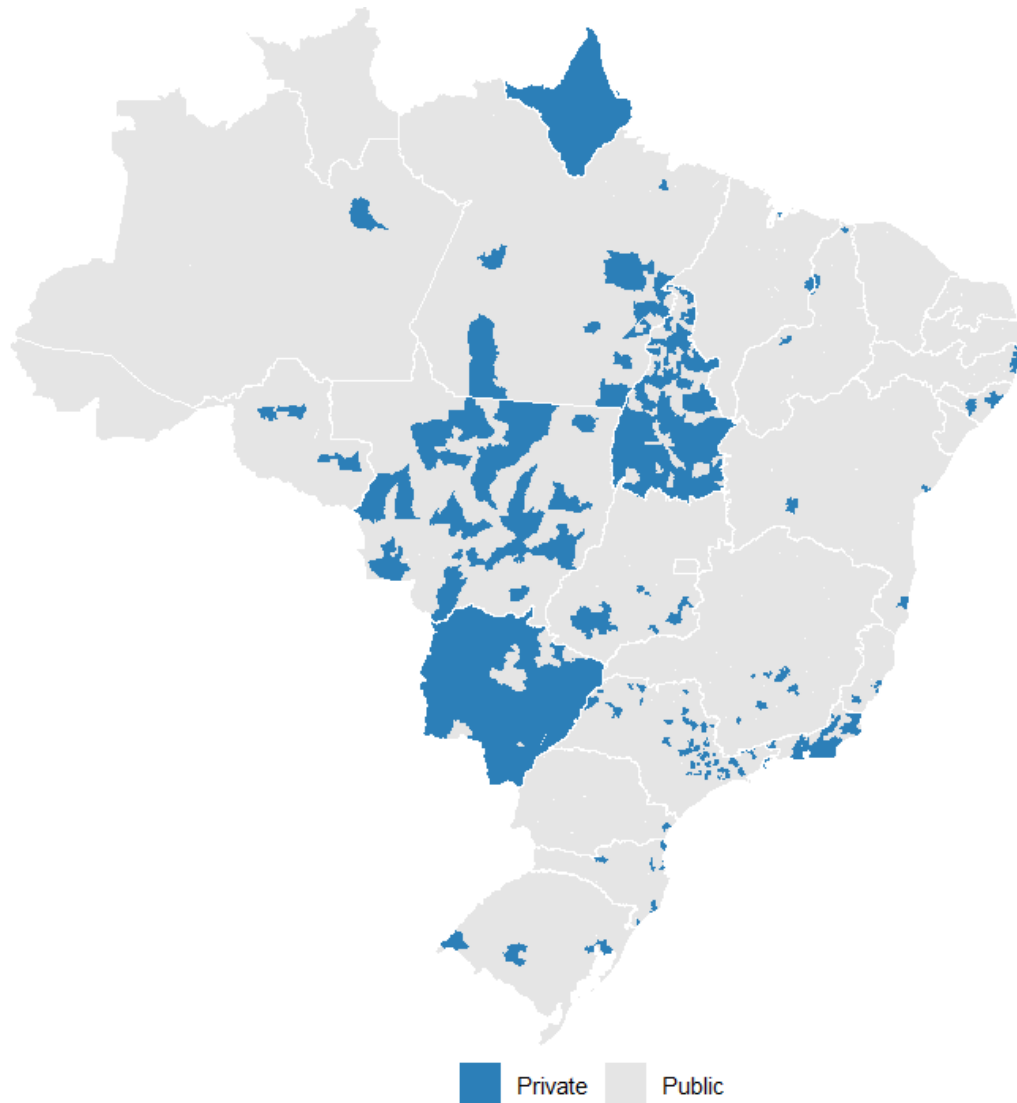
(a) Short-term severe drought



(b) Long-term severe drought

Note: Figure 3a presents the spatial distribution of severe short-term drought events in our data, and Figure 3b shows the same for severe long-term drought.

Figure 4: Private Provision of Water Services in Brazil



Note: This figure shows the Brazilian municipalities with privatized sanitation services by 2023. The information is sourced from the Brazilian Association of Private Companies of Water and Sewage Services (ABCON). [Back to text](#)

Table 1: Summary of Variables

Variable	Description	Purpose	Source
IDEB	Municipal average of IDEB scores	Dependent variable	Ministry of Education
SAEB	Municipal average of SAEB scores normalized to values between 0 and 10	Dependent variable	Ministry of Education
Approval Rate	Municipal average of the percentage of students who advance to the next grade level at the end of the academic year	Dependent variable	Ministry of Education
Dropout Rate	Municipal average of the percentage of students who leave school before completing the academic year	Dependent variable	Ministry of Education
Short-term severe drought	Dummy variable indicating whether the SPEI12 value is below -2	Explanatory variable	CRU TS
Severe Drought	Dummy variable indicating whether the absolute value of the SPEI12 integral is in the fourth quartile of the distribution	Explanatory variable	CRU TS
Private Provision	Dummy variable indicating whether the municipality has privatized the water service provision	Explanatory variable	ABCON, SNIS
Water Above Median	Dummy variable indicating whether the municipal coverage of water services is higher than the national median	Explanatory variable	SNIS
Population	Total municipal population (number of inhabitants)	Control variable	IBGE
Demographic Density	Ratio of total population to the municipal area	Control variable	IBGE
Sewage Collection	Percentage of the municipal population with access to sewage collection services	Control variable	SNIS
Schooling	Ratio of employees with at least secondary education to total formal employees	Control variable	Ministry of Labor
Low Income	Ratio of employees with incomes below two minimum wages to total formal employees	Control variable	Ministry of Labor
Degree of Dependency	Ratio of transfer revenue to budget revenue	Control variable	Ministry of Economy
Expenditure on Education	Ratio of expenditure on education to municipal budget revenue	Control variable	Ministry of Economy
Expenditure on Health	Ratio of expenditure on health to municipal budget revenue	Control variable	Ministry of Economy
Expenditure on Sanitation	Ratio of expenditure on sanitation to municipal budget revenue	Control variable	Ministry of Economy

Notes: This table provides the description of the variables employed in the econometric estimations. The data sources include the Climate Research Unit Time Series (CRU TS), the Brazilian Association of Private Companies of Water and Sewage Services (ABCON), the National Information System on Sanitation (SNIS), and the Brazilian Institute of Geography and Statistics (IBGE).

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Table 2: Descriptive Statistics

	Minimum	First Quartile	Median	Mean	Third Quartile	Maximum	Standard Deviation
IDEB - E1	0.9	4	5	4.92	5.8	9.5	1.19
IDEB - E2	0.3	3.4	4.1	4.07	4.7	8.1	0.87
SAEB - E1	2.65	4.65	5.35	5.38	6.09	9.51	0.95
SAEB - E2	2.42	4.32	4.78	4.78	5.23	8.09	0.64
Approval Rate - E1	0.25	0.86	0.93	0.91	0.98	1	0.09
Approval Rate - E2	0	0.78	0.86	0.84	0.93	1	0.11
Dropout Rate - E1	0	0	0.4	1.35	1.77	47.4	2.26
Dropout Rate - E2	0	1.07	2.97	4.32	6.2	100	4.52
SPEI12	-11.06	-1.17	-0.22	-0.22	0.69	4.95	1.42
Long-Term Severe Drought	0	3.44	7.91	14	16.34	432.37	22.47
Water Service Coverage	0	0.5	0.71	0.68	0.89	1	0.25

Notes: This table presents descriptive statistics for the dependent and main explanatory variables utilized in the analysis. The statistics are computed for the entire sample of Brazilian municipalities spanning the study period from 2004 to 2021. Data sources include the Ministry of Education, the Climate Research Unit Time Series (CRU TS), the Brazilian Association of Private Companies of Water and Sewage Services (ABCON), and the National Information System on Sanitation (SNIS). These statistics provide an overview of the distributions and are instrumental in understanding the characteristics of the dataset and the context of the analysis.

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Table 3: The Effect of Short-term Droughts and Coverage of Water Services on IDEB

	Basic Education Development Index - Elementary 1 and Elementary 2											
	IDEB-E1 (1)	IDEB-E2 (2)	IDEB-E1 (3)	IDEB-E2 (4)	IDEB-E1 (5)	IDEB-E2 (6)	IDEB-E1 (7)	IDEB-E2 (8)	IDEB-E1 (9)	IDEB-E2 (10)	IDEB-E1 (11)	IDEB-E2 (12)
Short-term severe drought	0.466*** (0.025)	0.225*** (0.019)	0.457*** (0.024)	0.224*** (0.018)	0.406*** (0.023)	0.189*** (0.018)	0.055*** (0.020)	-0.009 (0.016)	0.075*** (0.015)	-0.046*** (0.012)	-0.058*** (0.011)	-0.102*** (0.010)
Water Above Median	0.503*** (0.012)	0.294*** (0.009)	0.362*** (0.012)	0.188*** (0.009)	0.282*** (0.012)	0.135*** (0.009)	0.289*** (0.009)	0.144*** (0.007)	0.040*** (0.012)	0.020** (0.010)	0.047*** (0.009)	0.036*** (0.008)
Short-term severe drought × Water Above Median	-0.104*** (0.036)	0.103*** (0.027)	-0.121*** (0.034)	0.086*** (0.025)	-0.104*** (0.033)	0.098*** (0.025)	-0.038 (0.027)	0.026 (0.022)	-0.142*** (0.020)	0.087*** (0.017)	-0.070*** (0.015)	0.003 (0.014)
Population			-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000*** (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Demographic Density			-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.00005*** (0.00001)	-0.0001*** (0.00001)	0.001*** (0.0001)	0.001*** (0.0001)	-0.0002** (0.0001)	0.0001* (0.0001)
Schooling			0.975*** (0.033)	0.716*** (0.033)	0.969*** (0.033)	0.709*** (0.033)	-1.586*** (0.032)	-1.022*** (0.029)	3.706*** (0.026)	2.612*** (0.024)	-0.096*** (0.032)	-0.056* (0.029)
Low Income			-2.634*** (0.041)	-1.993*** (0.031)	-1.593*** (0.049)	-1.316*** (0.037)	-1.323*** (0.040)	-1.113*** (0.031)	-0.853*** (0.053)	-0.641*** (0.044)	-0.057 (0.040)	-0.074** (0.037)
Degree of Dependence					-1.726*** (0.045)	-1.140*** (0.034)	-1.016*** (0.037)	-0.720*** (0.029)	-2.958*** (0.060)	-1.681*** (0.049)	-0.092* (0.049)	-0.206*** (0.046)
Expenditure on Education					-0.057*** (0.005)	-0.037*** (0.004)	-0.047*** (0.004)	-0.029*** (0.003)	-0.001 (0.003)	-0.006** (0.003)	-0.004* (0.002)	-0.005** (0.002)
Expenditure on Health					0.118*** (0.011)	0.081*** (0.008)	0.086*** (0.009)	0.058*** (0.007)	0.003 (0.007)	0.014*** (0.005)	0.009* (0.005)	0.012*** (0.005)
Expenditure on Sanitation					-0.0002 (0.028)	-0.021 (0.021)	0.055** (0.023)	0.014 (0.018)	-0.020 (0.018)	-0.025* (0.015)	0.009 (0.013)	-0.009 (0.012)
Constant	4.727*** (0.008)	3.944*** (0.006)	6.085*** (0.038)	4.985*** (0.029)	6.249*** (0.038)	5.104*** (0.029)						
Observations	41,337	41,119	41,321	41,102	40,897	40,682	40,897	40,682	40,897	40,682	40,897	40,682
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes
Municipality FE	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R ²	0.057	0.041	0.162	0.150	0.193	0.175	0.201	0.163	0.493	0.402	0.007	0.007
Adjusted R ²	0.057	0.041	0.162	0.150	0.193	0.175	0.201	0.163	0.415	0.309	-0.147	-0.147
F Statistic	835.054*** (df = 3; 41333)	593.259*** (df = 3; 41115)	1,140.909*** (df = 7; 41313)	1,034.565*** (df = 7; 41094)	889.176*** (df = 11; 40885)	783.489*** (df = 11; 40670)	936.326*** (df = 11; 40877)	720.827*** (df = 11; 40662)	3,134.996*** (df = 11; 35433)	2,154.253*** (df = 11; 35215)	21.088*** (df = 11; 35425)	23.457*** (df = 11; 35207)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table illustrates the results of panel data linear regressions estimating the effect on IDEB scores for elementary 1 (E1) and elementary 2 (E2) students. The primary explanatory variables are short-term severe drought, represented as an indicator variable based on the short-term drought measure, and Water Above Median, a dummy variable for municipalities with water service coverage exceeding the national median. The models progressively incorporate control variables and fixed effects for both year and municipality to identify the optimal specification. Columns 1 and 2 report estimations based solely on the main explanatory variables and their interaction. Columns 3 and 4 introduce demographic and socioeconomic controls, while columns 5 and 6 add fiscal variables. Columns 7 and 8 account for all controls along with year fixed effects, and columns 9 and 10 extend the analysis to include municipality fixed effects. The preferred specification, detailed in columns 11 and 12, incorporates the full set of controls alongside both year and municipality fixed effects. The primary estimations, visualized in Figure 7, are derived from the specifications in columns 11 and 12.

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Table 4: The Effect of Long-term Droughts and Coverage of Water Services on IDEB

<i>Basic Education Development Index - Elementary 1 and Elementary 2</i>												
	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Long-term severe drought	0.569*** (0.017)	0.343*** (0.013)	0.503*** (0.017)	0.295*** (0.012)	0.468*** (0.016)	0.271*** (0.012)	-0.185*** (0.015)	-0.149*** (0.012)	0.318*** (0.011)	0.200*** (0.009)	-0.004 (0.009)	-0.010 (0.008)
Water Above Median	0.567*** (0.013)	0.324*** (0.010)	0.394*** (0.013)	0.195*** (0.010)	0.312*** (0.013)	0.141*** (0.010)	0.307*** (0.010)	0.146*** (0.008)	0.087*** (0.012)	0.044*** (0.010)	0.063*** (0.009)	0.044*** (0.009)
Long-term severe drought × Water Above Median	-0.213*** (0.024)	-0.032* (0.018)	-0.152*** (0.023)	0.011 (0.017)	-0.137*** (0.023)	0.022 (0.017)	-0.073*** (0.019)	0.004 (0.015)	-0.165*** (0.014)	-0.009 (0.012)	-0.084*** (0.011)	-0.024** (0.010)
Population			-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000*** (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Demographic Density			-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.00005*** (0.00001)	-0.0001*** (0.00001)	0.001*** (0.0001)	0.001*** (0.0001)	-0.0001** (0.0001)	0.0001* (0.0001)
Schooling			0.666*** (0.035)	0.502*** (0.026)	0.675*** (0.034)	0.505*** (0.026)	-1.565*** (0.032)	-1.007*** (0.026)	3.422*** (0.030)	2.377*** (0.025)	-0.089*** (0.032)	-0.057* (0.030)
Low Income			-2.691*** (0.041)	-2.039*** (0.031)	-1.656*** (0.049)	-1.368*** (0.036)	-1.229*** (0.040)	-1.058*** (0.031)	-0.742*** (0.052)	-0.568*** (0.043)	-0.063 (0.040)	-0.093** (0.037)
Degree of Dependence					-1.714*** (0.044)	-1.128*** (0.033)	-0.983*** (0.037)	-0.698*** (0.029)	-2.567*** (0.060)	-1.372*** (0.050)	-0.072 (0.049)	-0.190*** (0.046)
Expenditure on Education					-0.056*** (0.005)	-0.037*** (0.004)	-0.048*** (0.004)	-0.029*** (0.003)	-0.001 (0.003)	-0.006** (0.002)	-0.004* (0.002)	-0.005** (0.002)
Expenditure on Health					0.113*** (0.011)	0.079*** (0.008)	0.087*** (0.009)	0.058*** (0.007)	0.002 (0.007)	0.014** (0.005)	0.009* (0.005)	0.013*** (0.005)
Expenditure on Sanitation					0.008 (0.028)	-0.016 (0.021)	0.059** (0.023)	0.015 (0.018)	-0.015 (0.018)	-0.021 (0.014)	0.009 (0.013)	-0.009 (0.012)
Constant	4.608*** (0.009)	3.868*** (0.007)	6.216*** (0.039)	5.088*** (0.029)	6.373*** (0.038)	5.201*** (0.029)						
Observations	41,337	41,119	41,321	41,102	40,897	40,682	40,897	40,682	40,897	40,682	40,897	40,682
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes
Municipality FE	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R ²	0.079	0.060	0.176	0.162	0.206	0.187	0.209	0.169	0.506	0.416	0.005	0.002
Adjusted R ²	0.079	0.060	0.176	0.162	0.206	0.186	0.208	0.168	0.430	0.325	-0.149	-0.153
F Statistic	1,175.792*** (df = 3; 41333)	877.546*** (df = 3; 41115)	1,262.024*** (df = 7; 41313)	1,137.733*** (df = 7; 41094)	966.944*** (df = 11; 40885)	848.235*** (df = 11; 40670)	980.427*** (df = 11; 40877)	749.599*** (df = 11; 40662)	3,303.023*** (df = 11; 35433)	2,279.939*** (df = 11; 35215)	15.729*** (df = 11; 35425)	7.920*** (df = 11; 35207)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table depicts the results of panel data linear regressions estimating the effect on IDEB scores for elementary 1 (E1) and elementary 2 (E2) students. The key explanatory variables are long-term severe drought, represented as an indicator variable based on the long-term drought measure, and Water Above Median, a dummy variable identifying municipalities with water service coverage above the national median. Control variables and fixed effects for both year and municipality are gradually added across the models to determine the most appropriate specification. Columns 1 and 2 display the estimations based solely on the primary explanatory variables and their interaction. Columns 3 and 4 introduce demographic and socioeconomic controls, while columns 5 and 6 include fiscal variables. Columns 7 and 8 incorporate all controls along with year fixed effects, and columns 9 and 10 extend the analysis by including municipality fixed effects. The preferred specification, outlined in columns 11 and 12, integrates the complete set of controls as well as both year and municipality fixed effects. The primary estimations, visualized in Figure 9, are based on the specifications detailed in columns 11 and 12.

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Table 5: The Effect of Short-term Droughts and Private Provision of Water Services on IDEB

	Basic Education Development Index - Elementary 1 and Elementary 2											
	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Short-term severe drought	0.482*** (0.019)	0.307*** (0.014)	0.458*** (0.017)	0.295*** (0.013)	0.407*** (0.017)	0.261*** (0.013)	0.037*** (0.014)	0.001 (0.011)	0.033*** (0.011)	0.025*** (0.009)	-0.097*** (0.008)	-0.094*** (0.007)
Private Provision	-0.057* (0.030)	0.049** (0.022)	-0.141*** (0.028)	-0.007 (0.021)	-0.195*** (0.028)	-0.045** (0.021)	-0.203*** (0.022)	-0.073*** (0.018)	0.157*** (0.030)	0.157*** (0.025)	0.122*** (0.022)	0.054*** (0.020)
Short-term severe drought × Private Provision	-0.268*** (0.068)	-0.160*** (0.050)	-0.213*** (0.064)	-0.121*** (0.047)	-0.207*** (0.062)	-0.115** (0.046)	0.034 (0.051)	0.068* (0.040)	-0.050 (0.039)	-0.070** (0.032)	0.045 (0.028)	0.026 (0.026)
Population			-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	0.00000*** (0.00000)	0.00000*** (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Demographic Density			-0.00004*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.00002*** (0.00001)	-0.00004*** (0.00001)	0.001*** (0.0001)	0.001*** (0.0001)	-0.0002*** (0.0001)	0.0001 (0.0001)
Schooling			1.015*** (0.031)	0.706*** (0.023)	1.001*** (0.030)	0.693*** (0.022)	-1.602*** (0.030)	-1.016*** (0.023)	3.795*** (0.027)	2.559*** (0.022)	-0.102*** (0.028)	-0.080*** (0.026)
Low Income			-2.990*** (0.037)	-2.176*** (0.027)	-1.779*** (0.045)	-1.430*** (0.032)	-1.559*** (0.036)	-1.280*** (0.028)	-0.758*** (0.047)	-0.541*** (0.038)	-0.048 (0.034)	-0.052* (0.032)
Degree of Dependence					-1.970*** (0.042)	-1.242*** (0.030)	-1.147*** (0.034)	-0.743*** (0.026)	-3.116*** (0.056)	-1.773*** (0.046)	-0.122*** (0.045)	-0.203*** (0.042)
Expenditure on Education					-0.072*** (0.005)	-0.046*** (0.004)	-0.059*** (0.004)	-0.035*** (0.003)	-0.002 (0.003)	-0.007*** (0.003)	-0.004* (0.002)	-0.005** (0.002)
Expenditure on Health					0.147*** (0.011)	0.098*** (0.008)	0.105*** (0.009)	0.067*** (0.007)	0.007 (0.007)	0.019*** (0.006)	0.008* (0.005)	0.013*** (0.005)
Expenditure on Sanitation					-0.004 (0.029)	-0.021 (0.021)	0.077*** (0.024)	0.030 (0.018)	-0.031* (0.019)	-0.035** (0.015)	0.010 (0.013)	-0.013 (0.012)
Constant	4.877*** (0.006)	4.033*** (0.004)	6.403*** (0.033)	5.165*** (0.024)	6.546*** (0.032)	5.272*** (0.024)						
Observations	47,688	47,685	47,661	47,657	47,129	47,136	47,129	47,136	47,129	47,136	47,129	47,136
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes
Municipality FE	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R ²	0.014	0.011	0.150	0.145	0.192	0.177	0.185	0.159	0.503	0.405	0.006	0.006
Adjusted R ²	0.014	0.011	0.150	0.144	0.192	0.176	0.184	0.158	0.437	0.325	-0.127	-0.128
F Statistic	231.409*** (df = 3; 47684)	174.627*** (df = 3; 47681)	1,203.154*** (df = 7; 47653)	1,150.580*** (df = 7; 47649)	1,017.160*** (df = 11; 47117)	918.346*** (df = 11; 47124)	970.081*** (df = 11; 47109)	807.018*** (df = 11; 47116)	3,829.304*** (df = 11; 41567)	2,568.152*** (df = 11; 41564)	22.772*** (df = 11; 41559)	21.515*** (df = 11; 41556)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions estimating the effect on IDEB scores for elementary 1 (E1) and elementary 2 (E2) students. The primary explanatory variables are short-term severe drought, defined as a dummy variable derived from the short-term drought measure, and Private Provision, which indicates water services supplied by private companies. The models progressively incorporate control variables and fixed effects for both year and municipality to identify the most suitable specification for addressing the empirical question. Columns 1 and 2 include only the main explanatory variables and their interaction. Columns 3 and 4 add demographic and socioeconomic controls, while columns 5 and 6 introduce fiscal variables. Columns 7 and 8 include all controls alongside year fixed effects, and columns 9 and 10 extend the analysis by adding municipality fixed effects. The preferred specification, shown in columns 11 and 12, includes the full set of controls and both year and municipality fixed effects. The main estimations, depicted in Figure 11, are based on the specifications outlined in columns 11 and 12.

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Table 6: The Effect of Long-term Droughts and Private Provision of Water Services on IDEB

	<i>Basic Education Development Index - Elementary 1 and Elementary 2</i>											
	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2	IDEB-E1	IDEB-E2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Long-term severe drought	0.516*** (0.012)	0.347*** (0.009)	0.479*** (0.012)	0.322*** (0.009)	0.448*** (0.012)	0.301*** (0.009)	-0.201*** (0.011)	-0.136*** (0.009)	0.285*** (0.008)	0.226*** (0.007)	-0.027*** (0.007)	-0.007 (0.006)
Private Provision	-0.113*** (0.033)	-0.007 (0.024)	-0.166*** (0.031)	-0.042* (0.023)	-0.208*** (0.030)	-0.073*** (0.023)	-0.199*** (0.025)	-0.079*** (0.019)	0.239*** (0.032)	0.178*** (0.026)	0.195*** (0.023)	0.085*** (0.022)
Long-term severe drought × Private Provision	0.016 (0.056)	0.070* (0.042)	-0.026 (0.052)	0.041 (0.039)	-0.064 (0.051)	0.022 (0.038)	0.069 (0.042)	0.090*** (0.033)	-0.224*** (0.033)	-0.071*** (0.027)	-0.157*** (0.024)	-0.048** (0.023)
Population			-0.0000*** (0.00000)	-0.0000*** (0.00000)	-0.0000*** (0.00000)	-0.0000*** (0.00000)	-0.0000*** (0.00000)	-0.0000*** (0.00000)	0.0000*** (0.00000)	0.0000*** (0.00000)	-0.00000 (0.00000)	0.00000 (0.00000)
Demographic Density			-0.00003*** (0.00001)	-0.00005*** (0.00001)	-0.0001*** (0.00001)	-0.0001*** (0.00001)	-0.00003*** (0.00001)	-0.00004*** (0.00001)	0.001*** (0.0001)	0.001*** (0.0001)	-0.0002*** (0.0001)	0.0001 (0.0001)
Schooling			0.698*** (0.032)	0.490*** (0.023)	0.701*** (0.031)	0.488*** (0.023)	-1.592*** (0.030)	-1.007*** (0.023)	3.489*** (0.028)	2.314*** (0.022)	-0.105*** (0.028)	-0.084*** (0.026)
Low Income			-3.043*** (0.037)	-2.210*** (0.027)	-1.840*** (0.044)	-1.475*** (0.032)	-1.492*** (0.036)	-1.239*** (0.028)	-0.662*** (0.046)	-0.460*** (0.037)	-0.070** (0.034)	-0.071** (0.032)
Degree of Dependence					-1.955*** (0.041)	-1.225*** (0.030)	-1.116*** (0.034)	-0.722*** (0.026)	-2.707*** (0.057)	-1.445*** (0.046)	-0.118*** (0.045)	-0.194*** (0.042)
Expenditure on Education					-0.071*** (0.005)	-0.045*** (0.004)	-0.059*** (0.004)	-0.035*** (0.003)	-0.002 (0.003)	-0.007*** (0.003)	-0.004* (0.002)	-0.005** (0.002)
Expenditure on Health					0.142*** (0.011)	0.094*** (0.008)	0.106*** (0.009)	0.067*** (0.007)	0.006 (0.007)	0.018*** (0.005)	0.009* (0.005)	0.014*** (0.005)
Expenditure on Sanitation					0.006 (0.029)	-0.014 (0.021)	0.080*** (0.024)	0.031* (0.018)	-0.025 (0.018)	-0.031** (0.015)	0.010 (0.013)	-0.013 (0.012)
Constant	4.791*** (0.006)	3.975*** (0.005)	6.547*** (0.033)	5.262*** (0.024)	6.682*** (0.032)	5.363*** (0.024)						
Observations	47,688	47,685	47,661	47,657	47,129	47,136	47,129	47,136	47,129	47,136	47,129	47,136
Controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	No	No	No	Yes	Yes	No	No	Yes	Yes
Municipality FE	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R ²	0.037	0.031	0.166	0.159	0.206	0.190	0.190	0.163	0.518	0.421	0.004	0.002
Adjusted R ²	0.037	0.031	0.165	0.159	0.206	0.190	0.190	0.162	0.453	0.344	-0.130	-0.132
F Statistic	603.980*** (df = 3; 47684)	514.359*** (df = 3; 47681)	1,350.554*** (df = 7; 47653)	1,286.397*** (df = 7; 47649)	1,112.919*** (df = 11; 47117)	1,003.166*** (df = 11; 47124)	1,004.597*** (df = 11; 47109)	832.131*** (df = 11; 47116)	4,055.849*** (df = 11; 41567)	2,752.345*** (df = 11; 41564)	14.914*** (df = 11; 41559)	6.429*** (df = 11; 41556)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table displays the results of panel data linear regressions estimating the effect on IDEB scores for elementary 1 (E1) and elementary 2 (E2) students. The primary explanatory variables are long-term severe drought, defined as an indicator variable derived from the long-term drought measure, and Private Provision, representing water services provided by private companies. The models progressively incorporate control variables and fixed effects for both year and municipality to identify the most adequate specification. Columns 1 and 2 present estimates based solely on the main explanatory variables and their interaction. Columns 3 and 4 include demographic and socioeconomic controls, while columns 5 and 6 add fiscal variables. Columns 7 and 8 account for all controls alongside year fixed effects, and columns 9 and 10 extend the analysis by incorporating municipality fixed effects. The preferred specification, shown in columns 11 and 12, includes the full set of controls and both year and municipality fixed effects. The main estimations, depicted in Figure 13, are based on the specifications outlined in columns 11 and 12.

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Table 7: The Effect of Short-term Droughts and Coverage of Water Services on Educational Indicators

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	-0.058*** (0.011)	-0.102*** (0.010)	-0.059*** (0.010)	-0.066*** (0.008)	-0.0001 (0.001)	-0.009*** (0.001)	-0.056** (0.024)	-0.007 (0.047)
Water Above Median	0.047*** (0.009)	0.036*** (0.008)	0.040*** (0.008)	0.043*** (0.006)	0.004*** (0.001)	0.002 (0.001)	-0.162*** (0.022)	-0.140*** (0.043)
Short-term severe drought × Water Above Median	-0.070*** (0.015)	0.003 (0.014)	-0.027** (0.014)	0.044*** (0.011)	-0.011*** (0.001)	-0.011*** (0.002)	0.218*** (0.032)	0.261*** (0.064)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000* (0.00000)	-0.00000 (0.00000)
Demographic Density	-0.0002** (0.0001)	0.0001* (0.0001)	0.00002 (0.0001)	0.0001** (0.0001)	-0.00004*** (0.00001)	0.00000 (0.00001)	0.001*** (0.0002)	0.001*** (0.0004)
Schooling	-0.096*** (0.032)	-0.056* (0.029)	-0.053* (0.029)	-0.034 (0.023)	-0.017*** (0.003)	-0.011** (0.004)	0.432*** (0.076)	-0.042 (0.151)
Low Income	-0.057 (0.040)	-0.074** (0.037)	0.221*** (0.037)	-0.066** (0.029)	-0.100*** (0.004)	-0.037*** (0.005)	2.680*** (0.099)	3.372*** (0.196)
Degree of Dependence	-0.092* (0.049)	-0.206*** (0.046)	-0.047 (0.045)	-0.093** (0.036)	-0.019*** (0.005)	-0.028*** (0.006)	0.873*** (0.122)	2.288*** (0.243)
Expenditure on Education	-0.004* (0.002)	-0.005** (0.002)	-0.004** (0.002)	-0.002 (0.002)	0.0001 (0.0002)	-0.001** (0.0003)	-0.020*** (0.005)	0.005 (0.010)
Expenditure on Health	0.009* (0.005)	0.012*** (0.005)	0.007 (0.004)	0.006 (0.004)	-0.00001 (0.0005)	0.001** (0.001)	0.038*** (0.012)	-0.009 (0.023)
Expenditure on Sanitation	0.009 (0.013)	-0.009 (0.012)	0.012 (0.012)	-0.008 (0.009)	-0.0003 (0.001)	-0.0003 (0.002)	-0.009 (0.030)	-0.009 (0.060)
Observations	40,897	40,682	40,897	40,682	41,885	42,025	69,282	69,282
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.007	0.007	0.005	0.004	0.028	0.010	0.016	0.008
Adjusted R ²	-0.147	-0.147	-0.149	-0.150	-0.119	-0.139	-0.069	-0.078
F Statistic	21.088*** (df = 11; 35425)	23.457*** (df = 11; 35207)	15.739*** (df = 11; 35425)	14.163*** (df = 11; 35207)	95.156*** (df = 11; 36399)	31.993*** (df = 11; 36532)	96.744*** (df = 11; 63762)	46.098*** (df = 11; 63762)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The primary explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Water Above Median, a dummy variable denoting municipalities with water service coverage above the national median. The estimations include the full set of control variables and account for both year and municipality fixed effects, offering a comprehensive analysis of how water coverage and drought conditions influence educational outcomes.

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Table 8: Short-term Droughts and Coverage of Water Services

	Coefficient Estimate	95% Confidence Interval
IDEB-E1		
Short-term severe drought $\times$ Water Above Median	-0.070***	[-0.0986; -0.0403]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	-0.127***	[-0.1480; -0.1071]
IDEB-E2		
Short-term severe drought $\times$ Water Above Median	0.003	[-0.02428; 0.0299]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	-0.099***	[-0.1179; -0.0797]
SAEB-E1		
Short-term severe drought $\times$ Water Above Median	-0.027**	[-0.0540; -0.0006]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	-0.086***	[-0.1053; -0.0677]
SAEB-E2		
Short-term severe drought $\times$ Water Above Median	0.044***	[0.0230; 0.0657]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	-0.021***	[-0.0361; -0.0061]
Approval Rate-E1		
Short-term severe drought $\times$ Water Above Median	-0.011***	[-0.0141; -0.0084]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	-0.011***	[-0.0134; -0.0094]
Approval Rate-E2		
Short-term severe drought $\times$ Water Above Median	-0.011***	[-0.0148; -0.0072]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	-0.020***	[-0.0225; -0.0172]
Dropout Rate-E1		
Short-term severe drought $\times$ Water Above Median	0.218***	[0.1542; 0.2813]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	0.161***	[0.1156; 0.2075]
Dropout Rate-E2		
Short-term severe drought $\times$ Water Above Median	0.261***	[0.1348; 0.3874]
Short-term severe drought + Short-term severe drought $\times$ Water Above Median	0.254***	[0.1623; 0.3451]

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the estimations for the interaction between short-term severe drought (the indicator variable capturing long-term drought conditions) and Water Above Median (the dummy variable identifying municipalities with water service coverage above the national median), alongside the linear combination of short-term severe drought and the interaction term. The dependent variables consist of four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). The analysis compares the effects of droughts in municipalities with above-median water coverage to the total effect of droughts in these locations. This approach provides a deeper understanding of whether higher water coverage buffers the adverse impacts of water scarcity on educational performance and school attendance. The coefficients are estimated using the full set of control variables and both year and municipality fixed effects.

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Table 9: The Effect of Long-term Droughts and Coverage of Water Services on Educational Indicators

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1	IDEB-E2	SAEB-E1	SAEB-E2	AR-E1	AR-E2	DR-E1	DR-E2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Long-term severe drought	-0.004 (0.009)	-0.010 (0.008)	-0.061*** (0.008)	-0.004 (0.006)	0.015*** (0.001)	0.003*** (0.001)	-0.563*** (0.020)	-0.806*** (0.039)
Water Above Median	0.063*** (0.009)	0.044*** (0.009)	0.044*** (0.009)	0.054*** (0.007)	0.007*** (0.001)	0.003** (0.001)	-0.260*** (0.022)	-0.276*** (0.045)
Long-term severe drought × Water Above Median	-0.084*** (0.011)	-0.024** (0.010)	-0.035*** (0.010)	-0.021*** (0.008)	-0.015*** (0.001)	-0.006*** (0.001)	0.342*** (0.025)	0.453*** (0.049)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000** (0.00000)	-0.00000* (0.00000)
Demographic Density	-0.0001** (0.0001)	0.0001* (0.0001)	0.00003 (0.0001)	0.0001** (0.0001)	-0.00004*** (0.00001)	-0.00000 (0.00001)	0.001*** (0.0002)	0.001*** (0.0004)
Schooling	-0.089*** (0.032)	-0.057* (0.030)	-0.047 (0.029)	-0.032 (0.023)	-0.017*** (0.003)	-0.011*** (0.004)	0.431*** (0.076)	-0.037 (0.151)
Low Income	-0.063 (0.040)	-0.093** (0.037)	0.208*** (0.037)	-0.070** (0.029)	-0.097*** (0.004)	-0.040*** (0.005)	2.634*** (0.098)	3.317*** (0.196)
Degree of Dependence	-0.072 (0.049)	-0.190*** (0.046)	-0.044 (0.045)	-0.082** (0.036)	-0.014*** (0.005)	-0.025*** (0.006)	0.753*** (0.121)	2.117*** (0.242)
Expenditure on Education	-0.004* (0.002)	-0.005** (0.002)	-0.004** (0.002)	-0.002 (0.002)	0.0001 (0.0002)	-0.001** (0.0003)	-0.021*** (0.005)	0.004 (0.010)
Expenditure on Health	0.009* (0.005)	0.013*** (0.005)	0.008* (0.004)	0.006* (0.004)	-0.0001 (0.0005)	0.001** (0.001)	0.041*** (0.012)	-0.006 (0.023)
Expenditure on Sanitation	0.009 (0.013)	-0.009 (0.012)	0.012 (0.012)	-0.008 (0.009)	-0.0002 (0.001)	-0.0004 (0.002)	-0.005 (0.030)	-0.003 (0.060)
Observations	40,897	40,682	40,897	40,682	41,885	42,025	69,282	69,282
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.005	0.002	0.007	0.003	0.033	0.004	0.028	0.014
Adjusted R ²	-0.149	-0.153	-0.147	-0.152	-0.112	-0.146	-0.056	-0.071
F Statistic	15.729*** (df = 11; 35425)	7.920*** (df = 11; 35207)	21.975*** (df = 11; 35425)	9.221*** (df = 11; 35207)	114.538*** (df = 11; 36399)	11.861*** (df = 11; 36532)	169.520*** (df = 11; 63762)	83.927*** (df = 11; 63762)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The main explanatory variables are long-term severe drought, an indicator variable capturing long-term drought conditions, and Water Above Median, a dummy variable indicating municipalities with water service coverage above the national median. The regressions include the full set of control variables and account for both year and municipality fixed effects, offering a detailed examination of the interplay between long-term severe drought, water service coverage, and educational outcomes.

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Table 10: Long-term Droughts and Coverage of Water Services

	Coefficient Estimate	95% Confidence Interval
IDEB-E1		
Long-term severe drought $\times$ Water Above Median	-0.084***	[-0.1051; -0.0633]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.088***	[-0.1052; -0.0719]
IDEB-E2		
Long-term severe drought $\times$ Water Above Median	-0.024**	[-0.0437; -0.0047]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.034***	[-0.0496; -0.0187]
SAEB-E1		
Long-term severe drought $\times$ Water Above Median	-0.035***	[-0.0542; -0.0158]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.096***	[-0.1115; -0.0809]
SAEB-E2		
Long-term severe drought $\times$ Water Above Median	-0.021***	[-0.0359; -0.0052]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.025***	[-0.0368; -0.0125]
Approval Rate-E1		
Long-term severe drought $\times$ Water Above Median	-0.015***	[-0.0167; -0.0126]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	0.0004	[-0.0012; 0.0020]
Approval Rate-E2		
Long-term severe drought $\times$ Water Above Median	-0.006***	[-0.0091; -0.0036]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.003***	[-0.0055; -0.0012]
Dropout Rate-E1		
Long-term severe drought $\times$ Water Above Median	0.342***	[0.2933; 0.3904]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.221***	[-0.2603; -0.1828]
Dropout Rate-E2		
Long-term severe drought $\times$ Water Above Median	0.453***	[0.3557; 0.5493]
Long-term severe drought + Long-term severe drought $\times$ Water Above Median	-0.354***	[-0.4312; -0.2768]

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table depicts the estimations for the interaction between long-term severe drought (the indicator variable based on the long-term drought measure) and Water Above Median (the dummy variable representing municipalities with water service coverage above the national median), alongside the linear combination of long-term severe drought and the interaction term. The dependent variables consist of four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). The analysis examines the effect of droughts in municipalities with above-median water coverage and compares it to the total effect of droughts in these areas. This approach provides a more nuanced understanding of whether higher water coverage mitigates the adverse effects of long-term water scarcity on educational performance and school attendance. The estimations encompass the complete set of control variables and include both year and municipality fixed effects.

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Table 11: The Effect of Short-term Droughts and Private Provision of Water Services on Educational Indicators

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	-0.097*** (0.008)	-0.094*** (0.007)	-0.077*** (0.007)	-0.043*** (0.006)	-0.006*** (0.001)	-0.013*** (0.001)	0.063*** (0.018)	0.122*** (0.035)
Private Provision	0.122*** (0.022)	0.054*** (0.020)	0.052*** (0.020)	-0.024 (0.016)	0.011*** (0.002)	0.016*** (0.003)	0.022 (0.056)	-0.471*** (0.110)
Short-term severe drought × Private Provision	0.045 (0.028)	0.026 (0.026)	0.029 (0.026)	0.003 (0.020)	0.004 (0.003)	0.004 (0.004)	0.018 (0.068)	0.059 (0.133)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00000* (0.00000)
Demographic Density	-0.0002*** (0.0001)	0.0001 (0.0001)	0.00000 (0.0001)	0.0001*** (0.0001)	-0.0001*** (0.00001)	-0.00001 (0.00001)	0.001*** (0.0002)	0.002*** (0.0004)
Schooling	-0.102*** (0.028)	-0.080*** (0.026)	-0.069*** (0.026)	-0.061*** (0.020)	-0.015*** (0.003)	-0.010*** (0.004)	0.365*** (0.073)	0.042 (0.142)
Low Income	-0.048 (0.034)	-0.052* (0.032)	0.253*** (0.032)	-0.039 (0.025)	-0.110*** (0.004)	-0.038*** (0.004)	2.692*** (0.093)	3.433*** (0.181)
Degree of Dependence	-0.122*** (0.045)	-0.203*** (0.042)	-0.045 (0.042)	-0.115*** (0.033)	-0.027*** (0.005)	-0.023*** (0.006)	1.157*** (0.120)	2.528*** (0.234)
Expenditure on Education	-0.004* (0.002)	-0.005** (0.002)	-0.004** (0.002)	-0.002 (0.002)	0.0002 (0.0002)	-0.001** (0.0003)	-0.023*** (0.005)	0.004 (0.011)
Expenditure on Health	0.008* (0.005)	0.013*** (0.005)	0.008* (0.005)	0.007* (0.004)	-0.0003 (0.001)	0.001** (0.001)	0.045*** (0.012)	-0.008 (0.024)
Expenditure on Sanitation	0.010 (0.013)	-0.013 (0.012)	0.016 (0.012)	-0.011 (0.010)	-0.001 (0.001)	-0.001 (0.002)	-0.007 (0.032)	-0.0004 (0.062)
Observations	47,129	47,136	47,129	47,136	48,296	48,650	77,175	77,174
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.006	0.006	0.005	0.002	0.030	0.008	0.016	0.008
Adjusted R ²	-0.127	-0.128	-0.129	-0.132	-0.096	-0.121	-0.061	-0.069
F Statistic	22.772*** (df = 11; 41559)	21.515*** (df = 11; 41556)	18.148*** (df = 11; 41559)	8.944*** (df = 11; 41556)	121.036*** (df = 11; 42717)	30.306*** (df = 11; 43069)	103.413*** (df = 11; 71586)	54.170*** (df = 11; 71585)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators measure performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, examined separately. The main explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Private Provision, which identifies municipalities where water services are managed by private companies. The estimations incorporate the full set of control variables and include both year and municipality fixed effects, ensuring a comprehensive analysis of how drought conditions and governance structures influence educational outcomes.

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Table 12: The Short-term Droughts and Private Provision of Water Services

	Coefficient Estimate	95% Confidence Interval
IDEB-E1		
Short-term severe drought $\times$ Private Provision	0.045	[−0.0092; 0.0991]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	−0.052	[−0.1046; 0.0002]
IDEB-E2		
Short-term severe drought $\times$ Private Provision	0.026	[−0.0243; 0.0770]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	−0.068***	[−0.1166; −0.0186]
SAEB-E1		
Short-term severe drought $\times$ Private Provision	0.029	[−0.0216; 0.0789]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	−0.048	[−0.0969; 0.0004]
SAEB-E2		
Short-term severe drought $\times$ Private Provision	0.003	[−0.0365; 0.0435]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	−0.039**	[−0.0778; −0.0003]
Approval Rate-E1		
Short-term severe drought $\times$ Private Provision	0.004	[−0.0019; 0.0096]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	−0.002	[−0.0080; 0.0031]
Approval Rate-E2		
Short-term severe drought $\times$ Private Provision	0.004	[−0.0027; 0.0116]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	−0.009**	[−0.0157; −0.0018]
Dropout Rate-E1		
Short-term severe drought $\times$ Private Provision	0.018	[−0.1158; 0.1510]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	0.081	[−0.0487; 0.2103]
Dropout Rate-E2		
Short-term severe drought $\times$ Private Provision	0.059	[−0.2004; 0.3193]
Short-term severe drought + Short-term severe drought $\times$ Private Provision	0.182	[−0.0704; 0.4341]

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table displays the regression estimations for the interaction between short-term severe drought (the indicator variable capturing short-term drought conditions) and Private Provision (the dummy variable for municipalities with privately managed water services), alongside the linear combination of short-term severe drought and the interaction term. The dependent variables include four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). By contrasting the effects of droughts in municipalities with private provision against the total effect of droughts in these municipalities, the results provide insight into whether private provision mitigates the negative impacts of water scarcity on educational outcomes and school attendance. The coefficients are derived using the complete set of control variables, along with year and municipality fixed effects.

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Table 13: The Effect of Long-term Droughts and Private Provision of Water Services on Educational Indicators

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Long-term severe drought	-0.027*** (0.007)	-0.007 (0.006)	-0.068*** (0.006)	-0.008* (0.005)	0.010*** (0.001)	0.002*** (0.001)	-0.392*** (0.016)	-0.655*** (0.031)
Private Provision	0.195*** (0.023)	0.085*** (0.022)	0.097*** (0.021)	-0.019 (0.017)	0.018*** (0.002)	0.023*** (0.003)	-0.017 (0.059)	-0.795*** (0.114)
Long-term severe drought × Private Provision	-0.157*** (0.024)	-0.048** (0.023)	-0.096*** (0.022)	-0.002 (0.018)	-0.015*** (0.003)	-0.012*** (0.003)	0.086 (0.060)	0.895*** (0.117)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00000* (0.00000)
Demographic Density	-0.0002*** (0.0001)	0.0001 (0.0001)	0.00001 (0.0001)	0.0001** (0.0001)	-0.0001*** (0.00001)	-0.00001 (0.00001)	0.001*** (0.0002)	0.002*** (0.0004)
Schooling	-0.105*** (0.028)	-0.084*** (0.026)	-0.068*** (0.026)	-0.062*** (0.020)	-0.016*** (0.003)	-0.011*** (0.004)	0.392*** (0.072)	0.084 (0.141)
Low Income	-0.070** (0.034)	-0.071** (0.032)	0.233*** (0.032)	-0.048* (0.025)	-0.110*** (0.004)	-0.040*** (0.004)	2.708*** (0.092)	3.465*** (0.180)
Degree of Dependence	-0.118*** (0.045)	-0.194*** (0.042)	-0.051 (0.042)	-0.112*** (0.033)	-0.025*** (0.005)	-0.022*** (0.006)	1.116*** (0.120)	2.471*** (0.234)
Expenditure on Education	-0.004* (0.002)	-0.005** (0.002)	-0.005** (0.002)	-0.002 (0.002)	0.0003 (0.0002)	-0.001** (0.0003)	-0.024*** (0.005)	0.003 (0.011)
Expenditure on Health	0.009* (0.005)	0.014*** (0.005)	0.008* (0.005)	0.007* (0.004)	-0.0003 (0.001)	0.001** (0.001)	0.046*** (0.012)	-0.006 (0.024)
Expenditure on Sanitation	0.010 (0.013)	-0.013 (0.012)	0.015 (0.012)	-0.011 (0.010)	-0.001 (0.001)	-0.001 (0.002)	-0.003 (0.032)	0.006 (0.062)
Observations	47,129	47,136	47,129	47,136	48,296	48,650	77,175	77,174
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.004	0.002	0.006	0.001	0.034	0.004	0.024	0.015
Adjusted R ²	-0.130	-0.132	-0.127	-0.133	-0.092	-0.125	-0.052	-0.062
F Statistic	14.914*** (df = 11; 41559)	6.429*** (df = 11; 41556)	23.113*** (df = 11; 41559)	3.954*** (df = 11; 41556)	136.490*** (df = 11; 42717)	16.697*** (df = 11; 43069)	160.393*** (df = 11; 71586)	96.041*** (df = 11; 71585)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This figure presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators reflect the performance and attendance of elementary 1 (E1) and elementary 2 (E2) students analyzed separately. The primary explanatory variables are long-term severe drought, an indicator variable representing long-term drought conditions, and Private Provision, an indicator variable identifying municipalities where water services are managed by private companies. The estimations incorporate the full set of control variables, as well as year and municipality fixed effects, to provide a robust evaluation of the relationship between drought conditions, governance structures, and educational outcomes.

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Table 14: Long-term Droughts and Private Provision of Water Services

	Coefficient Estimate	95% Confidence Interval
IDEB-E1		
Long-term severe drought $\times$ Private Provision	-0.157***	[-0.2037; -0.1094]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.183***	[-0.2297; -0.1367]
IDEB-E2		
Long-term severe drought $\times$ Private Provision	-0.048**	[-0.0922; -0.0038]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.055**	[-0.0985; -0.0112]
SAEB-E1		
Long-term severe drought $\times$ Private Provision	-0.096***	[-0.1398; -0.0525]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.164***	[-0.2077; -0.1214]
SAEB-E2		
Long-term severe drought $\times$ Private Provision	-0.002	[-0.0371; 0.0326]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.011	[-0.0450; 0.0238]
Approval Rate-E1		
Long-term severe drought $\times$ Private Provision	-0.015***	[-0.0196; -0.0096]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.004	[-0.0095; 0.0003]
Approval Rate-E2		
Long-term severe drought $\times$ Private Provision	-0.012***	[-0.0187; -0.0062]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.010***	[-0.0161; -0.0039]
Dropout Rate-E1		
Long-term severe drought $\times$ Private Provision	0.086	[-0.0312; 0.2039]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	-0.306***	[-0.4221; -0.1900]
Dropout Rate-E2		
Long-term severe drought $\times$ Private Provision	0.895***	[0.6655; 1.1240]
Long-term severe drought + Long-term severe drought $\times$ Private Provision	0.239**	[0.0129; 0.4656]

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table shows the regression estimations for the interaction between long-term severe drought (the indicator variable capturing long-term drought conditions) and Private Provision (the dummy variable for municipalities with privately managed water services), alongside the linear combination of long-term severe drought and the interaction term. The dependent variables comprise four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). This analysis compares the effect of droughts in municipalities with private provision to the total effect of droughts in these locations, providing insight into whether private provision mitigates the negative impacts of prolonged water scarcity on educational outcomes and school attendance. The estimations incorporate the complete set of control variables and include both year and municipality fixed effects.

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Appendix

The appendix presents a series of supplementary econometric exercises and robustness checks designed to validate and extend the main regression results discussed in the core analysis. By conducting additional empirical specifications and sensitivity tests, this section aims to assess the consistency and reliability of the findings under alternative assumptions and subsamples. These exercises provide a deeper understanding of the robustness of the estimated effects, ensuring that the primary conclusions remain stable when confronted with variations in sample composition and potential sources of endogeneity or bias.

Long-term Drought Effects on Urban Municipalities

This section investigates whether the effect of long-term droughts, represented by the long-term severe drought variable, is more pronounced in urban municipalities. The underlying hypothesis is that long-term droughts exert a stronger hydrological impact in urban areas by reducing reservoir levels, which, in turn, disrupts water supply to urban populations where dependency on centralized water infrastructure is higher. In this sense, urban municipalities should be more affected by long-term droughts than by short-term ones, as the centralized infrastructure guarantees water access during short drought periods.

To test this potential effect, we restrict the sample to municipalities classified as urban according to IBGE criteria. We then re-estimate the econometric models employed in the main analysis, maintaining the same set of dependent variables and covariates. Specifically, we assess the impact of short-term and long-term droughts, water service coverage, and the mode of water provision (private or public), as well as interactions between drought measures and institutional arrangements.

Our findings indicate that when focusing on water service coverage (Tables 15 and 16), there is no evidence that long-term droughts yield a stronger negative effect on educational outcomes in urban settings. The coefficients for the interaction between long-term severe drought and water coverage above the median are not systematically negative or significant across the educational indicators.

However, results differ when considering the role of private sector participation in water provision. As shown in Tables 17 and 18, the interaction between long-term droughts and private provision reveals a more persistent negative impact on educational performance, particularly for IDEB and SAEB scores. The coefficients for these interactions are negative and statistically significant, indicating that, within urban municipalities, the adverse effects of extended water scarcity are exacerbated when water services are managed by private operators. This pattern is notably more robust for long-term droughts than for short-term

ones, pointing to a structural vulnerability in private urban water provision under chronic hydrological stress.

In summary, while the hypothesis that long-term drought effects are stronger in urban municipalities is not globally supported when considering water service coverage, partial evidence emerges when examining the interaction with private provision models. The negative impact observed in educational outcomes underscores the importance of governance and institutional arrangements in shaping the educational consequences of persistent hydrological scarcity in urban areas.

Heterogeneous Effects of Droughts in Municipalities with High versus Low Agricultural GDP

This section explores whether the effect of short-term droughts on educational outcomes is stronger in municipalities that are more dependent on agricultural activities. The underlying hypothesis is that, if short-term droughts significantly affect agricultural income, municipalities with higher reliance on agriculture – as measured by agricultural GDP – will experience more pronounced adverse effects during drought periods. In contrast, it is expected that long periods of water scarcity affect the opportunity cost of children’s time ([Zimmermann, 2020](#)), leading families to keep them in school so they can engage in activities that are not dependent on hydrological conditions.

To investigate this hypothesis, municipalities were grouped according to whether their agricultural GDP in 2004 (the first year of the panel data), as calculated by the IBGE, was above or below the national median. Separate regression analyses were performed for both groups, following the same models as in the main text. The aim is to compare the impacts of drought-related variables on educational indicators across municipalities with greater versus lesser dependence on agricultural income.

Comparing Tables 19 and 20, the results indicate that the short-term severe drought variable has a significant negative effect on the Dropout Rate for early (DR-E1) and later (DR-E2) years of basic education in municipalities with agricultural GDP above the median. This finding suggests that short-term droughts, by negatively impacting agricultural income, lead to higher dropout rates. In other words, students in these agriculturally dependent areas are more likely to abandon their studies when droughts reduce household resources and increase vulnerability.

Furthermore, the interaction between short-term severe drought and Water Above Median reveals a mitigating effect on most educational indicators (except for Approval Rate) in municipalities with agricultural GDP above the median. This suggests that higher wa-

ter coverage can buffer the negative educational impacts of short-term drought in rural, agriculture-dependent locations. In contrast, such an attenuating effect is not consistently found among municipalities with agricultural GDP below the median, reinforcing that water infrastructure serves as a critical line of defense where agricultural risk is high.

Turning to Tables 21 and 22, results show that long-term severe drought is associated with a larger negative effect on DR-E1 and DR-E2 among municipalities with agricultural GDP above the median. This indicates that long-term droughts exacerbate dropout rates over time in locations with high agricultural dependence, likely due to persistent reductions in household income and greater pressure on students to assist with household labor. Contradicting the evidence documented by the literature, long periods of water scarcity intensify the school dropout.

Moreover, when long-term severe drought is interacted with Water Above Median, the results show an attenuating effect on DR-E1 and DR-E2, meaning that higher water coverage dampens the negative impact of long-term droughts on dropout rates.

In addition, such effects are more pronounced on rural areas, as municipalities with agricultural GDP below the median present coefficients with reduced magnitude.

In summary, these findings provide evidence that (i) both short- and long-term droughts have more pronounced negative effects on dropout rates in municipalities with greater agricultural dependence, and (ii) water service coverage can partially mitigate these adverse effects. This pattern highlights the role of water infrastructure in building resilience against the most severe educational consequences of droughts in areas reliant on agriculture.

Robustness Check: Excluding Municipalities that Privatized Water Services During Drought Periods

The effectiveness of privatization in water services may not manifest immediately after the transfer of management, especially if private providers assume control during periods of acute water scarcity. Providers newly engaged amid drought are unlikely to have had the opportunity to implement structural or operational interventions to mitigate the adverse effects of droughts. Thus, the presence of municipalities that privatized services during drought could potentially bias the estimation of private provision effects.

To address this concern, a robustness check was performed by excluding municipalities that privatized their water utilities during periods of drought from the analysis. In 2021, there were 317 municipalities with privatized water services. By removing those municipalities that underwent privatization during short-term drought episodes (as identified by the short-term severe drought variable), the number of privatized municipalities in 2021 falls to 290.

Conducting the same exclusion using long-term droughts (identified by the long-term severe drought variable) reduces the number further to 256 privatized municipalities in 2021.

Comparative analysis of Tables 11 and 23 indicates that the estimated coefficients for short-term droughts remain mostly unchanged after the exclusion of municipalities privatized during short-term severe drought events. A similar pattern is observed for long-term droughts when comparing the corresponding results (Tables 13 and 24): the coefficients are stable and robust with respect to the exclusion of municipalities that privatized under high long-term severe drought.

These findings confirm that the main regression results are not driven by the potentially confounding effect of privatization during drought. Given the small number of municipalities affected by this exclusion, the integrity and external validity of the primary analysis remain uncompromised. Thus, the main conclusions regarding the effect of private water provision and drought on educational outcomes are robust to the timing of privatization events relative to drought periods.

Table 15: The Effect of Short-term Droughts and Coverage of Water Services on Educational Indicators - Urban Municipalities

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	-0.059*** (0.014)	-0.138*** (0.013)	-0.065*** (0.013)	-0.097*** (0.010)	0.001 (0.001)	-0.010*** (0.002)	-0.069** (0.031)	-0.008 (0.063)
Water Above Median	0.047*** (0.009)	0.029*** (0.009)	0.045*** (0.009)	0.038*** (0.007)	0.003*** (0.001)	0.002 (0.001)	-0.138*** (0.023)	-0.062 (0.047)
Short-term severe drought × Water Above Median	-0.057*** (0.017)	0.046*** (0.016)	-0.013 (0.016)	0.082*** (0.013)	-0.011*** (0.002)	-0.009*** (0.002)	0.200*** (0.038)	0.230*** (0.077)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000* (0.00000)	-0.00000 (0.00000)
Demographic Density	-0.0001 (0.0001)	0.0002** (0.0001)	0.00004 (0.0001)	0.0001*** (0.00005)	-0.00003*** (0.00001)	0.00000 (0.00001)	0.001*** (0.0002)	0.001*** (0.0004)
Schooling	-0.130*** (0.039)	-0.075** (0.037)	-0.083** (0.036)	-0.018 (0.029)	-0.017*** (0.004)	-0.015*** (0.005)	0.401*** (0.096)	-0.387** (0.195)
Low Income	-0.147*** (0.049)	-0.188*** (0.047)	0.147*** (0.045)	-0.082** (0.036)	-0.099*** (0.005)	-0.058*** (0.006)	2.584*** (0.125)	3.673*** (0.253)
Degree of Dependence	-0.165*** (0.056)	-0.207*** (0.053)	-0.085* (0.051)	-0.079* (0.041)	-0.027*** (0.006)	-0.032*** (0.007)	0.950*** (0.143)	2.537*** (0.289)
Expenditure on Education	-0.022 (0.022)	-0.043** (0.021)	-0.044** (0.020)	0.003 (0.017)	0.011*** (0.002)	-0.005 (0.003)	-0.438*** (0.053)	-0.262** (0.106)
Expenditure on Health	0.005 (0.032)	0.054* (0.030)	0.026 (0.029)	-0.007 (0.024)	-0.014*** (0.003)	0.006 (0.004)	0.628*** (0.075)	0.370** (0.152)
Expenditure on Sanitation	0.040 (0.056)	0.055 (0.053)	0.082 (0.051)	0.061 (0.041)	-0.009 (0.006)	-0.004 (0.007)	0.125 (0.142)	0.270 (0.288)
Observations	29,519	29,270	29,519	29,270	29,922	29,925	48,799	48,798
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.008	0.010	0.006	0.006	0.029	0.013	0.016	0.009
Adjusted R ²	-0.138	-0.137	-0.140	-0.141	-0.112	-0.129	-0.067	-0.075
F Statistic	18.844*** (df = 11; 25740)	23.365*** (df = 11; 25492)	13.876*** (df = 11; 25740)	14.742*** (df = 11; 25492)	70.565*** (df = 11; 26141)	32.375*** (df = 11; 26145)	66.342*** (df = 11; 45005)	36.041*** (df = 11; 45004)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The primary explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Water Above Median, a dummy variable denoting municipalities with water service coverage above the national median. This set of results considers only urban municipalities, based on IBGE classification. Similarly to the regressions presented in the main text, the estimations include the full set of control variables and account for both year and municipality fixed effects, offering a comprehensive analysis of how water coverage and drought conditions influence educational outcomes.

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Table 16: The Effect of Long-term Droughts and Coverage of Water Services on Educational Indicators - Urban Municipalities

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Long-term severe drought	-0.016 (0.011)	-0.035*** (0.010)	-0.069*** (0.010)	-0.027*** (0.008)	0.014*** (0.001)	0.002 (0.001)	-0.523*** (0.025)	-0.810*** (0.051)
Water Above Median	0.056*** (0.010)	0.032*** (0.009)	0.045*** (0.009)	0.043*** (0.007)	0.006*** (0.001)	0.002* (0.001)	-0.222*** (0.024)	-0.211*** (0.049)
Long-term severe drought × Water Above Median	-0.057*** (0.012)	0.007 (0.012)	-0.016 (0.011)	0.013 (0.009)	-0.012*** (0.001)	-0.006*** (0.002)	0.279*** (0.029)	0.466*** (0.059)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000** (0.00000)	-0.00000 (0.00000)
Demographic Density	-0.0001 (0.0001)	0.0001** (0.0001)	0.00004 (0.0001)	0.0001*** (0.00005)	-0.00003*** (0.00001)	0.00000 (0.00001)	0.0005** (0.0002)	0.001** (0.0004)
Schooling	-0.124*** (0.039)	-0.078** (0.037)	-0.077** (0.036)	-0.020 (0.029)	-0.018*** (0.004)	-0.016*** (0.005)	0.407*** (0.096)	-0.382** (0.195)
Low Income	-0.162*** (0.049)	-0.219*** (0.047)	0.134*** (0.045)	-0.094*** (0.036)	-0.099*** (0.005)	-0.062*** (0.007)	2.622*** (0.125)	3.725*** (0.253)
Degree of Dependence	-0.154*** (0.056)	-0.198*** (0.053)	-0.085* (0.051)	-0.075* (0.042)	-0.024*** (0.006)	-0.030*** (0.007)	0.879*** (0.142)	2.411*** (0.288)
Expenditure on Education	-0.018 (0.022)	-0.039* (0.021)	-0.037* (0.020)	0.006 (0.017)	0.010*** (0.002)	-0.005 (0.003)	-0.395*** (0.052)	-0.197* (0.106)
Expenditure on Health	0.0001 (0.032)	0.049 (0.030)	0.017 (0.029)	-0.010 (0.024)	-0.013*** (0.003)	0.006 (0.004)	0.573*** (0.075)	0.287* (0.152)
Expenditure on Sanitation	0.037 (0.056)	0.048 (0.053)	0.080 (0.051)	0.059 (0.041)	-0.009* (0.006)	-0.005 (0.007)	0.128 (0.142)	0.276 (0.287)
Observations	29,519	29,270	29,519	29,270	29,922	29,925	48,799	48,798
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.005	0.004	0.008	0.003	0.031	0.006	0.026	0.014
Adjusted R ²	-0.141	-0.144	-0.138	-0.144	-0.109	-0.138	-0.056	-0.069
F Statistic	12.851*** (df = 11; 25740)	8.372*** (df = 11; 25492)	18.257*** (df = 11; 25740)	8.003*** (df = 11; 25492)	76.759*** (df = 11; 26141)	14.368*** (df = 11; 26145)	108.119*** (df = 11; 45005)	59.367*** (df = 11; 45004)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The main explanatory variables are long-term severe drought, an indicator variable capturing long-term drought conditions, and Water Above Median, a dummy variable indicating municipalities with water service coverage above the national median. This set of results considers only urban municipalities, based on IBGE classification. Similarly to the regressions presented in the main text, the regressions include the full set of control variables and account for both year and municipality fixed effects, offering a detailed examination of the interplay between long-term severe drought, water service coverage, and educational outcomes.

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Table 17: The Effect of Short-term Droughts and Private Provision of Water Services on Educational Indicators - Urban Municipalities

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	-0.101*** (0.009)	-0.106*** (0.008)	-0.079*** (0.008)	-0.046*** (0.006)	-0.007*** (0.001)	-0.015*** (0.001)	0.075*** (0.020)	0.148*** (0.040)
Private Provision	0.103*** (0.023)	0.043** (0.022)	0.046** (0.021)	-0.026 (0.017)	0.007*** (0.002)	0.013*** (0.003)	0.172*** (0.060)	-0.269** (0.120)
Short-term severe drought × Private Provision	0.067** (0.028)	0.029 (0.027)	0.053** (0.026)	0.002 (0.021)	0.004 (0.003)	0.006 (0.004)	-0.022 (0.069)	0.066 (0.139)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000** (0.00000)	-0.00000 (0.00000)
Demographic Density	-0.0002** (0.0001)	0.0001* (0.0001)	0.00003 (0.0001)	0.0002*** (0.00005)	-0.00004*** (0.00001)	-0.00001 (0.00001)	0.001*** (0.0002)	0.001*** (0.0004)
Schooling	-0.147*** (0.036)	-0.106*** (0.034)	-0.093*** (0.033)	-0.036 (0.026)	-0.019*** (0.004)	-0.019*** (0.005)	0.381*** (0.093)	-0.260 (0.187)
Low Income	-0.183*** (0.044)	-0.158*** (0.042)	0.123*** (0.040)	-0.054* (0.032)	-0.108*** (0.005)	-0.055*** (0.006)	2.549*** (0.121)	3.665*** (0.243)
Degree of Dependence	-0.187*** (0.053)	-0.156*** (0.049)	-0.085* (0.048)	-0.071* (0.039)	-0.032*** (0.005)	-0.021*** (0.007)	1.142*** (0.141)	2.573*** (0.283)
Expenditure on Education	-0.020 (0.018)	-0.037** (0.016)	-0.043*** (0.016)	-0.004 (0.013)	0.010*** (0.002)	-0.004 (0.002)	-0.365*** (0.044)	-0.201** (0.089)
Expenditure on Health	0.008 (0.024)	0.042* (0.022)	0.030 (0.022)	0.004 (0.017)	-0.011*** (0.002)	0.004 (0.003)	0.496*** (0.061)	0.252** (0.123)
Expenditure on Sanitation	0.050 (0.054)	0.043 (0.051)	0.109** (0.049)	0.043 (0.040)	-0.015*** (0.006)	-0.003 (0.007)	0.141 (0.143)	0.300 (0.288)
Observations	33,040	32,792	33,040	32,792	33,493	33,504	52,715	52,714
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.008	0.008	0.005	0.003	0.030	0.011	0.015	0.008
Adjusted R ²	-0.122	-0.123	-0.125	-0.129	-0.095	-0.116	-0.062	-0.069
F Statistic	21.130*** (df = 11; 29227)	21.166*** (df = 11; 28978)	12.825*** (df = 11; 29227)	6.871*** (df = 11; 28978)	83.278*** (df = 11; 29679)	31.133*** (df = 11; 29690)	67.559*** (df = 11; 48896)	37.659*** (df = 11; 48895)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators measure performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, examined separately. The main explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Private Provision, which identifies municipalities where water services are managed by private companies. This set of results considers only urban municipalities, based on IBGE classification. Similarly to the regressions presented in the main text, the estimations incorporate the full set of control variables and include both year and municipality fixed effects, ensuring a comprehensive analysis of how drought conditions and governance structures influence educational outcomes.

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Table 18: The Effect of Long-term Droughts and Private Provision of Water Services on Educational Indicators - Urban Municipalities

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Long-term severe drought	−0.037*** (0.007)	−0.022*** (0.007)	−0.074*** (0.007)	−0.018*** (0.005)	0.008*** (0.001)	0.00000 (0.001)	−0.348*** (0.018)	−0.567*** (0.036)
Private Provision	0.173*** (0.024)	0.071*** (0.023)	0.091*** (0.022)	−0.025 (0.018)	0.013*** (0.003)	0.020*** (0.003)	0.110* (0.062)	−0.621*** (0.125)
Long-term severe drought × Private Provision	−0.135*** (0.025)	−0.037 (0.023)	−0.083*** (0.023)	0.008 (0.018)	−0.013*** (0.003)	−0.012*** (0.003)	0.114* (0.061)	0.929*** (0.123)
Population	−0.00000 (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)	−0.00000 (0.00000)	−0.00000 (0.00000)	0.00000** (0.00000)	−0.00000** (0.00000)	−0.00000 (0.00000)
Demographic Density	−0.0001** (0.0001)	0.0001* (0.0001)	0.00003 (0.0001)	0.0002*** (0.00005)	−0.00004*** (0.00001)	−0.00001 (0.00001)	0.001*** (0.0002)	0.001*** (0.0004)
Schooling	−0.148*** (0.036)	−0.109*** (0.034)	−0.089*** (0.033)	−0.037 (0.026)	−0.020*** (0.004)	−0.019*** (0.005)	0.419*** (0.093)	−0.194 (0.187)
Low Income	−0.208*** (0.044)	−0.183*** (0.042)	0.105*** (0.040)	−0.065** (0.032)	−0.110*** (0.005)	−0.059*** (0.006)	2.638*** (0.120)	3.823*** (0.242)
Degree of Dependence	−0.189*** (0.053)	−0.150*** (0.050)	−0.091* (0.048)	−0.069* (0.039)	−0.031*** (0.005)	−0.021*** (0.007)	1.148*** (0.140)	2.610*** (0.283)
Expenditure on Education	−0.016 (0.018)	−0.035** (0.016)	−0.038** (0.016)	−0.003 (0.013)	0.009*** (0.002)	−0.004 (0.002)	−0.340*** (0.044)	−0.170* (0.089)
Expenditure on Health	0.003 (0.024)	0.041* (0.022)	0.024 (0.022)	0.003 (0.017)	−0.011*** (0.002)	0.004 (0.003)	0.465*** (0.061)	0.209* (0.123)
Expenditure on Sanitation	0.040 (0.054)	0.036 (0.051)	0.104** (0.049)	0.041 (0.040)	−0.016*** (0.006)	−0.004 (0.007)	0.152 (0.142)	0.348 (0.287)
Observations	33,040	32,792	33,040	32,792	33,493	33,504	52,715	52,714
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.006	0.003	0.007	0.001	0.032	0.006	0.022	0.014
Adjusted R ²	−0.124	−0.129	−0.123	−0.130	−0.092	−0.122	−0.054	−0.063
F Statistic	15.096*** (df = 11; 29227)	6.723*** (df = 11; 28978)	17.768*** (df = 11; 29227)	2.882*** (df = 11; 28978)	89.947*** (df = 11; 29679)	16.394*** (df = 11; 29690)	101.996*** (df = 11; 48896)	61.070*** (df = 11; 48895)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This figure presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators reflect the performance and attendance of elementary 1 (E1) and elementary 2 (E2) students analyzed separately. The primary explanatory variables are long-term severe drought, an indicator variable representing long-term drought conditions, and Private Provision, an indicator variable identifying municipalities where water services are managed by private companies. This set of results considers only urban municipalities, based on IBGE classification. Similarly to the regressions presented in the main text, the estimations incorporate the full set of control variables, as well as year and municipality fixed effects, to provide a robust evaluation of the relationship between drought conditions, governance structures, and educational outcomes.

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Table 19: The Effect of Short-term Droughts and Coverage of Water Services on Educational Indicators - Agricultural GDP above the National Median

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	-0.061*** (0.016)	-0.052*** (0.015)	-0.064*** (0.015)	-0.020* (0.012)	0.002 (0.002)	-0.006*** (0.002)	-0.173*** (0.035)	-0.247*** (0.069)
Water Above Median	0.050*** (0.012)	0.024** (0.011)	0.048*** (0.011)	0.037*** (0.009)	0.002 (0.001)	-0.002 (0.002)	-0.090*** (0.028)	-0.051 (0.055)
Short-term severe drought × Water Above Median	-0.048** (0.020)	0.0003 (0.019)	-0.012 (0.018)	0.027* (0.015)	-0.011*** (0.002)	-0.009*** (0.003)	0.247*** (0.044)	0.294*** (0.086)
Population	0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000* (0.00000)	0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00001*** (0.00000)
Demographic Density	0.0001 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)	0.0004** (0.0002)	-0.00004** (0.00002)	0.00000 (0.00003)	0.001 (0.001)	0.001 (0.001)
Schooling	-0.107** (0.053)	0.134*** (0.051)	-0.062 (0.049)	0.046 (0.040)	-0.017*** (0.005)	0.012* (0.007)	0.132 (0.127)	-0.981*** (0.248)
Low Income	-0.201*** (0.060)	-0.173*** (0.056)	0.117** (0.055)	-0.065 (0.045)	-0.104*** (0.006)	-0.054*** (0.008)	2.657*** (0.145)	3.577*** (0.283)
Degree of Dependence	-0.197*** (0.070)	-0.209*** (0.066)	-0.301*** (0.065)	-0.145*** (0.052)	0.014* (0.007)	-0.010 (0.009)	-0.418** (0.172)	-0.002 (0.335)
Expenditure on Education	0.015* (0.008)	0.013 (0.008)	0.005 (0.008)	0.012* (0.006)	0.003*** (0.001)	0.002 (0.001)	-0.111*** (0.019)	-0.048 (0.036)
Expenditure on Health	-0.071** (0.035)	-0.064* (0.033)	-0.031 (0.032)	-0.051* (0.026)	-0.011*** (0.003)	-0.008* (0.004)	0.431*** (0.078)	0.217 (0.151)
Expenditure on Sanitation	0.140 (0.089)	0.220*** (0.085)	0.058 (0.083)	0.182*** (0.068)	0.023*** (0.009)	0.021* (0.011)	-0.937*** (0.206)	-0.640 (0.402)
Observations	20,957	20,871	20,957	20,871	21,354	21,444	35,194	35,194
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.008	0.005	0.006	0.003	0.022	0.009	0.013	0.006
Adjusted R ²	-0.143	-0.148	-0.145	-0.149	-0.123	-0.138	-0.072	-0.079
F Statistic	13.021*** (df = 11; 18196)	7.444*** (df = 11; 18104)	10.276*** (df = 11; 18196)	4.949*** (df = 11; 18104)	38.467*** (df = 11; 18586)	15.615*** (df = 11; 18669)	39.194*** (df = 11; 32408)	19.087*** (df = 11; 32408)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The primary explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Water Above Median, a dummy variable denoting municipalities with water service coverage above the national median. This set of results considers only municipalities with the agricultural GDP above the national median, based on the IBGE classification for 2004 (the first year of the panel data). Similarly to the regressions presented in the main text, the estimations include the full set of control variables and account for both year and municipality fixed effects, offering a comprehensive analysis of how water coverage and drought conditions influence educational outcomes.

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Table 20: The Effect of Short-term Droughts and Coverage of Water Services on Educational Indicators - Agricultural GDP below the National Median

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	−0.050*** (0.016)	−0.128*** (0.014)	−0.054*** (0.014)	−0.098*** (0.011)	−0.001 (0.002)	−0.009*** (0.002)	0.020 (0.033)	0.121* (0.066)
Water Above Median	0.046*** (0.013)	0.049*** (0.012)	0.032*** (0.012)	0.050*** (0.009)	0.006*** (0.001)	0.005*** (0.002)	−0.255*** (0.032)	−0.278*** (0.064)
Short-term severe drought × Water Above Median	−0.059** (0.023)	0.0001 (0.021)	−0.037* (0.021)	0.046*** (0.016)	−0.005** (0.002)	−0.009*** (0.003)	0.157*** (0.048)	0.170* (0.097)
Population	−0.00000*** (0.00000)	−0.00000 (0.00000)	−0.00000** (0.00000)	−0.00000*** (0.00000)	−0.00000*** (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)	0.00001 (0.00000)
Demographic Density	−0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001** (0.0001)	−0.0001*** (0.00001)	−0.00002* (0.00001)	0.002*** (0.0003)	0.002*** (0.001)
Schooling	−0.076* (0.041)	−0.126*** (0.037)	−0.039 (0.037)	−0.066** (0.029)	−0.015*** (0.004)	−0.017*** (0.005)	0.477*** (0.098)	0.122 (0.198)
Low Income	0.091* (0.055)	0.051 (0.051)	0.262*** (0.050)	−0.022 (0.040)	−0.074*** (0.005)	−0.016** (0.007)	2.302*** (0.136)	2.641*** (0.274)
Degree of Dependence	0.043 (0.070)	−0.152** (0.065)	0.124* (0.064)	−0.007 (0.051)	−0.022*** (0.007)	−0.033*** (0.009)	1.009*** (0.174)	2.679*** (0.350)
Expenditure on Education	−0.010 (0.009)	0.0002 (0.008)	−0.006 (0.008)	0.007 (0.006)	0.0001 (0.001)	−0.0003 (0.001)	−0.025 (0.020)	0.031 (0.041)
Expenditure on Health	0.018 (0.015)	0.005 (0.013)	0.012 (0.013)	−0.007 (0.010)	0.00002 (0.001)	0.001 (0.002)	0.048 (0.033)	−0.044 (0.066)
Expenditure on Sanitation	0.020 (0.022)	−0.023 (0.020)	0.017 (0.020)	−0.028* (0.016)	−0.0002 (0.002)	−0.001 (0.003)	0.006 (0.050)	−0.063 (0.100)
Observations	19,901	19,778	19,901	19,778	20,490	20,545	34,011	34,011
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.006	0.010	0.005	0.009	0.027	0.007	0.018	0.009
Adjusted R ²	−0.152	−0.148	−0.153	−0.150	−0.122	−0.145	−0.069	−0.078
F Statistic	9.018*** (df = 11; 17178)	15.883*** (df = 11; 17057)	7.852*** (df = 11; 17178)	13.366*** (df = 11; 17057)	45.395*** (df = 11; 17760)	11.393*** (df = 11; 17815)	51.589*** (df = 11; 31261)	24.963*** (df = 11; 31261)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The primary explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Water Above Median, a dummy variable denoting municipalities with water service coverage above the national median. This set of results considers only municipalities with the agricultural GDP below the national median, based on the IBGE classification for 2004 (the first year of the panel data). Similarly to the regressions presented in the main text, the estimations include the full set of control variables and account for both year and municipality fixed effects, offering a comprehensive analysis of how water coverage and drought conditions influence educational outcomes.

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Table 21: The Effect of Long-term Droughts and Coverage of Water Services on Educational Indicators - Agricultural GDP above the National Median

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Long-term severe drought	-0.022* (0.013)	0.011 (0.012)	-0.099*** (0.012)	0.004 (0.010)	0.021*** (0.001)	0.007*** (0.002)	-0.759*** (0.029)	-1.130*** (0.057)
Water Above Median	0.054*** (0.012)	0.025** (0.012)	0.040*** (0.011)	0.039*** (0.009)	0.005*** (0.001)	-0.001 (0.002)	-0.194*** (0.029)	-0.189*** (0.057)
Long-term severe drought × Water Above Median	-0.042*** (0.015)	-0.004 (0.014)	0.018 (0.014)	0.003 (0.011)	-0.018*** (0.001)	-0.007*** (0.002)	0.440*** (0.034)	0.548*** (0.067)
Population	0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000* (0.00000)	0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00001*** (0.00000)
Demographic Density	0.0001 (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)	0.0004** (0.0002)	-0.00004* (0.00002)	0.00000 (0.00003)	0.001 (0.001)	0.001 (0.001)
Schooling	-0.105** (0.053)	0.123** (0.051)	-0.050 (0.049)	0.043 (0.040)	-0.019*** (0.005)	0.010 (0.007)	0.238* (0.126)	-0.799*** (0.247)
Low Income	-0.217*** (0.060)	-0.186*** (0.057)	0.093* (0.055)	-0.065 (0.045)	-0.101*** (0.006)	-0.056*** (0.008)	2.648*** (0.144)	3.591*** (0.282)
Degree of Dependence	-0.158** (0.070)	-0.198*** (0.066)	-0.270*** (0.064)	-0.145*** (0.052)	0.016** (0.007)	-0.006 (0.009)	-0.291* (0.170)	0.254 (0.333)
Expenditure on Education	0.013 (0.008)	0.013 (0.008)	0.003 (0.008)	0.012* (0.006)	0.003*** (0.001)	0.002 (0.001)	-0.120*** (0.018)	-0.063* (0.036)
Expenditure on Health	-0.066* (0.035)	-0.064* (0.033)	-0.023 (0.032)	-0.051* (0.026)	-0.012*** (0.003)	-0.008* (0.004)	0.468*** (0.077)	0.277* (0.150)
Expenditure on Sanitation	0.128 (0.090)	0.216** (0.085)	0.040 (0.083)	0.182*** (0.068)	0.024*** (0.009)	0.020* (0.011)	-1.002*** (0.204)	-0.741* (0.399)
Observations	20,957	20,871	20,957	20,871	21,354	21,444	35,194	35,194
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.005	0.003	0.009	0.003	0.033	0.006	0.035	0.021
Adjusted R ²	-0.146	-0.149	-0.141	-0.149	-0.111	-0.142	-0.048	-0.064
F Statistic	8.506*** (df = 11; 18196)	4.928*** (df = 11; 18104)	15.688*** (df = 11; 18196)	4.712*** (df = 11; 18104)	58.302*** (df = 11; 18586)	9.437*** (df = 11; 18669)	106.711*** (df = 11; 32408)	61.893*** (df = 11; 32408)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The main explanatory variables are long-term severe drought, an indicator variable capturing long-term drought conditions, and Water Above Median, a dummy variable indicating municipalities with water service coverage above the national median. This set of results considers only municipalities with the agricultural GDP above the national median, based on the IBGE classification for 2004 (the first year of the panel data). Similarly to the regressions presented in the main text, the regressions include the full set of control variables and account for both year and municipality fixed effects, offering a detailed examination of the interplay between long-term severe drought, water service coverage, and educational outcomes.

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Table 22: The Effect of Long-term Droughts and Coverage of Water Services on Educational Indicators - Agricultural GDP below the National Median

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Long-term severe drought	-0.012 (0.013)	-0.029** (0.012)	-0.043*** (0.012)	-0.021** (0.009)	0.007*** (0.001)	-0.0005 (0.002)	-0.284*** (0.029)	-0.313*** (0.059)
Water Above Median	0.069*** (0.014)	0.063*** (0.013)	0.046*** (0.013)	0.071*** (0.010)	0.009*** (0.001)	0.005*** (0.002)	-0.332*** (0.033)	-0.382*** (0.068)
Long-term severe drought × Water Above Median	-0.091*** (0.016)	-0.039*** (0.015)	-0.061*** (0.014)	-0.044*** (0.011)	-0.009*** (0.002)	-0.004* (0.002)	0.263*** (0.037)	0.346*** (0.074)
Population	-0.00000*** (0.00000)	-0.00000 (0.00000)	-0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00000*** (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)	0.00000 (0.00000)
Demographic Density	-0.0001 (0.0001)	0.0001 (0.0001)	0.0001 (0.0001)	0.0001** (0.0001)	-0.0001*** (0.00001)	-0.00002* (0.00001)	0.001*** (0.0003)	0.002*** (0.001)
Schooling	-0.067 (0.041)	-0.121*** (0.038)	-0.032 (0.037)	-0.060** (0.029)	-0.015*** (0.004)	-0.017*** (0.005)	0.460*** (0.098)	0.099 (0.199)
Low Income	0.094* (0.055)	0.036 (0.051)	0.260*** (0.050)	-0.029 (0.040)	-0.072*** (0.005)	-0.017** (0.007)	2.256*** (0.136)	2.583*** (0.274)
Degree of Dependence	0.039 (0.070)	-0.157** (0.065)	0.115* (0.064)	-0.006 (0.051)	-0.020*** (0.007)	-0.034*** (0.009)	0.951*** (0.173)	2.608*** (0.350)
Expenditure on Education	-0.010 (0.009)	0.001 (0.008)	-0.006 (0.008)	0.008 (0.006)	-0.00001 (0.001)	-0.0003 (0.001)	-0.024 (0.020)	0.032 (0.041)
Expenditure on Health	0.018 (0.015)	0.004 (0.013)	0.010 (0.013)	-0.008 (0.010)	0.0001 (0.001)	0.001 (0.002)	0.045 (0.033)	-0.046 (0.066)
Expenditure on Sanitation	0.020 (0.022)	-0.025 (0.020)	0.016 (0.020)	-0.029* (0.016)	-0.00000 (0.002)	-0.001 (0.003)	0.005 (0.050)	-0.064 (0.100)
Observations	19,901	19,778	19,901	19,778	20,490	20,545	34,011	34,011
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.006	0.004	0.006	0.006	0.029	0.003	0.020	0.009
Adjusted R ²	-0.151	-0.154	-0.151	-0.153	-0.120	-0.150	-0.066	-0.078
F Statistic	9.926*** (df = 11; 17178)	6.671*** (df = 11; 17057)	9.979*** (df = 11; 17178)	9.156*** (df = 11; 17057)	48.734*** (df = 11; 17760)	4.956*** (df = 11; 17815)	59.033*** (df = 11; 31261)	26.523*** (df = 11; 31261)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators represent measures of performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, analyzed separately. The main explanatory variables are long-term severe drought, an indicator variable capturing long-term drought conditions, and Water Above Median, a dummy variable indicating municipalities with water service coverage above the national median. This set of results considers only municipalities with the agricultural GDP below the national median, based on the IBGE classification for 2004 (the first year of the panel data). Similarly to the regressions presented in the main text, the regressions include the full set of control variables and account for both year and municipality fixed effects, offering a detailed examination of the interplay between long-term severe drought, water service coverage, and educational outcomes.

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Table 23: The Effect of Short-term Droughts and Private Provision of Water Services on Educational Indicators - Excluding Privatizations during Droughts

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Short-term severe drought	-0.097*** (0.008)	-0.094*** (0.007)	-0.077*** (0.007)	-0.043*** (0.006)	-0.006*** (0.001)	-0.013*** (0.001)	0.066*** (0.018)	0.124*** (0.035)
Private Provision	0.117*** (0.023)	0.042* (0.022)	0.054** (0.021)	-0.038** (0.017)	0.008*** (0.002)	0.015*** (0.003)	0.165*** (0.059)	-0.373*** (0.116)
Short-term severe drought × Private Provision	0.062** (0.029)	0.027 (0.027)	0.034 (0.027)	-0.002 (0.021)	0.007** (0.003)	0.006 (0.004)	0.042 (0.072)	0.090 (0.141)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00000* (0.00000)
Demographic Density	-0.0002*** (0.0001)	0.0001* (0.0001)	-0.00001 (0.0001)	0.0001*** (0.0001)	-0.0001*** (0.00001)	-0.00000 (0.00001)	0.001*** (0.0002)	0.001*** (0.0005)
Schooling	-0.100*** (0.028)	-0.077*** (0.026)	-0.068*** (0.026)	-0.059*** (0.021)	-0.015*** (0.003)	-0.010*** (0.004)	0.368*** (0.073)	0.020 (0.142)
Low Income	-0.048 (0.034)	-0.051 (0.032)	0.250*** (0.032)	-0.038 (0.025)	-0.109*** (0.004)	-0.038*** (0.004)	2.674*** (0.093)	3.411*** (0.181)
Degree of Dependence	-0.117*** (0.045)	-0.199*** (0.042)	-0.044 (0.042)	-0.113*** (0.033)	-0.026*** (0.005)	-0.022*** (0.006)	1.119*** (0.120)	2.453*** (0.235)
Expenditure on Education	-0.004* (0.002)	-0.005** (0.002)	-0.004** (0.002)	-0.002 (0.002)	0.0002 (0.0002)	-0.001** (0.0003)	-0.023*** (0.005)	0.005 (0.011)
Expenditure on Health	0.009* (0.005)	0.014*** (0.005)	0.008* (0.005)	0.007* (0.004)	-0.0002 (0.001)	0.001** (0.001)	0.044*** (0.012)	-0.009 (0.024)
Expenditure on Sanitation	0.010 (0.013)	-0.013 (0.012)	0.016 (0.012)	-0.011 (0.010)	-0.001 (0.001)	-0.001 (0.002)	-0.006 (0.032)	-0.0001 (0.062)
Observations	46,891	46,903	46,891	46,903	48,057	48,413	76,803	76,802
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.006	0.006	0.005	0.002	0.029	0.007	0.015	0.008
Adjusted R ²	-0.128	-0.128	-0.129	-0.132	-0.098	-0.121	-0.061	-0.070
F Statistic	21.637*** (df = 11; 41348)	20.945*** (df = 11; 41350)	17.749*** (df = 11; 41348)	9.131*** (df = 11; 41350)	114.585*** (df = 11; 42505)	28.959*** (df = 11; 42859)	101.264*** (df = 11; 71241)	51.411*** (df = 11; 71240)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This table presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators measure performance and attendance for elementary 1 (E1) and elementary 2 (E2) students, examined separately. The main explanatory variables are short-term severe drought, an indicator variable reflecting short-term drought conditions, and Private Provision, which identifies municipalities where water services are managed by private companies. This set of results excludes municipalities that privatized water services during drought periods, based on the short-term severe drought variable. Similarly to the regressions presented in the main text, the estimations incorporate the full set of control variables and include both year and municipality fixed effects, ensuring a comprehensive analysis of how drought conditions and governance structures influence educational outcomes.

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Table 24: The Effect of Long-term Droughts and Private Provision of Water Services on Educational Indicators - Excluding Privatizations during Droughts

	<i>Educational Indicators - Elementary 1 and Elementary 2</i>							
	IDEB-E1 (1)	IDEB-E2 (2)	SAEB-E1 (3)	SAEB-E2 (4)	AR-E1 (5)	AR-E2 (6)	DR-E1 (7)	DR-E2 (8)
Long-term severe drought	-0.029*** (0.007)	-0.010 (0.006)	-0.071*** (0.006)	-0.011** (0.005)	0.010*** (0.001)	0.002** (0.001)	-0.396*** (0.016)	-0.656*** (0.031)
Private Provision	0.186*** (0.024)	0.069*** (0.023)	0.095*** (0.022)	-0.019 (0.018)	0.017*** (0.003)	0.018*** (0.003)	0.031 (0.061)	-0.621*** (0.118)
Long-term severe drought × Private Provision	-0.168*** (0.026)	-0.057** (0.024)	-0.097*** (0.024)	-0.006 (0.019)	-0.016*** (0.003)	-0.015*** (0.003)	0.090 (0.064)	1.001*** (0.124)
Population	-0.00000 (0.00000)	0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	-0.00000 (0.00000)	0.00000** (0.00000)	-0.00000*** (0.00000)	-0.00000* (0.00000)
Demographic Density	-0.0002*** (0.0001)	0.0001 (0.0001)	0.00001 (0.0001)	0.0001** (0.0001)	-0.0001*** (0.00001)	-0.00001 (0.00001)	0.001*** (0.0002)	0.002*** (0.0004)
Schooling	-0.105*** (0.028)	-0.082*** (0.026)	-0.068*** (0.026)	-0.060*** (0.021)	-0.016*** (0.003)	-0.011*** (0.004)	0.422*** (0.073)	0.133 (0.141)
Low Income	-0.066* (0.034)	-0.067** (0.032)	0.238*** (0.032)	-0.046* (0.025)	-0.110*** (0.004)	-0.040*** (0.004)	2.705*** (0.093)	3.448*** (0.181)
Degree of Dependence	-0.113** (0.045)	-0.196*** (0.042)	-0.048 (0.042)	-0.112*** (0.033)	-0.025*** (0.005)	-0.023*** (0.006)	1.116*** (0.120)	2.480*** (0.234)
Expenditure on Education	-0.004* (0.002)	-0.005** (0.002)	-0.005** (0.002)	-0.002 (0.002)	0.0003 (0.0002)	-0.001** (0.0003)	-0.024*** (0.005)	0.003 (0.011)
Expenditure on Health	0.009* (0.005)	0.014*** (0.005)	0.008* (0.005)	0.007* (0.004)	-0.0003 (0.001)	0.001** (0.001)	0.046*** (0.012)	-0.007 (0.024)
Expenditure on Sanitation	0.009 (0.013)	-0.015 (0.012)	0.015 (0.012)	-0.012 (0.010)	-0.001 (0.001)	-0.001 (0.002)	-0.004 (0.032)	0.013 (0.062)
Observations	46,605	46,607	46,605	46,607	47,763	48,109	76,328	76,327
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.004	0.002	0.006	0.001	0.034	0.004	0.024	0.015
Adjusted R ²	-0.130	-0.132	-0.127	-0.133	-0.092	-0.125	-0.052	-0.062
F Statistic	14.617*** (df = 11; 41096)	6.097*** (df = 11; 41088)	23.772*** (df = 11; 41096)	3.937*** (df = 11; 41088)	134.953*** (df = 11; 42245)	14.993*** (df = 11; 42589)	160.926*** (df = 11; 70800)	95.097*** (df = 11; 70799)

Signif. codes: *p<0.1; **p<0.05; ***p<0.01.

Notes: This figure presents the results of panel data linear regressions for four educational indicators: IDEB score, SAEB score, Approval Rate (AR), and Dropout Rate (DR). These indicators reflect the performance and attendance of elementary 1 (E1) and elementary 2 (E2) students analyzed separately. The primary explanatory variables are long-term severe drought, an indicator variable representing long-term drought conditions, and Private Provision, an indicator variable identifying municipalities where water services are managed by private companies. This set of results excludes municipalities that privatized water services during drought periods, based on the long-term severe drought variable. Similarly to the regressions presented in the main text, the estimations incorporate the full set of control variables, as well as year and municipality fixed effects, to provide a robust evaluation of the relationship between drought conditions, governance structures, and educational outcomes.

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