Área 3 – Economia do Trabalho, Economia Social e Demografia.

Raindrops for education: Drought Shocks and School Performance in Brazilian Rural Schools[1]

Danyelle Branco

Doutora em Economia Aplicada pela Universidade Federal de Viçosa
Pós-doutoranda em Economia Aplicada pela Universidade Federal de Viçosa, com artigos apresentados em congressos nacionais e internacionais (ANPEC Nacional e Regional, International Conference of Agricultural Economists (ICAE) e World Congress of Environmental and Resource Economists. Com artigos publicados nos periódicos Economic Development and Cultural Change, Pesquisa e Planejamento Econômico e Revista Econômica do Nordeste.
Endereço: Rua Nasser Simão Muanis, n.157. Viçosa-MG. CEP: 36576-026
E-mail: danyellebranco@gmail.com
Fone: (31) 9 8670-6541

José Gustavo Féres

Doutor em Economia pela Université de Toulousse I.
Técnico de planejamento e pesquisa no Instituto de Pesquisa Econômica Aplicada (IPEA), com artigos publicados em periódicos como Economic Policy, Environment and Development Economics, Ecological Economics e Applied Economics.

[1] The authors would like to acknowledge the financial support provided by the Latin American and Caribbean Environmental Economics Program (LACEEP Senior Grant). The authors would also like to thank Bladimir Carillo, Claudio Araujo and Miguel Foguel for the helpful suggestions.

Área 3 – Economia do Trabalho, Economia Social e Demografia.

Raindrops for education: Drought Shocks and School Performance in Brazilian Rural Schools

Abstract

This paper examines the effects of drought shocks on student achievement. Using data on test scores and schooling from rural area of Northeastern Brazil, we show that negative rainfall shocks are associated to lower student's scores on both math and language exams. Infant health and school supply are important mechanisms. Exposure to drought shocks are associated with higher hospitalization rate among children. In addition to that, the shocks are also correlated with temporary school closings. Finally, our results provide suggestive evidence that drought tends to be more harmful to children that study in schools with no cistern or other water storage devices. Therefore, investing in basic infrastructure like cisterns is a low-cost policy strategy that may offset the negative effects of droughts and improve school performance in Brazilian rural areas.

Keywords: drought shocks; student achievement; school supply.

Resumo

Este artigo examina os efeitos dos choques de seca sobre o desempenho escolar dos alunos. Usando dados sobre notas e escolaridade da área rural do Nordeste do Brasil, mostramos que os choques negativos de chuva estão associados a menores pontuações dos alunos em ambos os exames de matemática e português. A saúde infantil e a oferta escolar são mecanismos importantes. A exposição aos choques causados pela seca está associada à maior taxa de hospitalização entre crianças. Além disso, os choques também estão correlacionados com o fechamento temporário de escolas. Finalmente, nossos resultados fornecem evidências sugestivas de que a seca tende a ser mais prejudicial para crianças que estudam em escolas sem cisternas ou outros dispositivos de armazenamento de água. Portanto, investir em infraestrutura básica como cisternas é uma estratégia política de baixo custo que pode compensar os efeitos negativos das secas e melhorar o desempenho escolar nas áreas rurais brasileiras.

Palavras-chave: choques de seca; desempenho do estudante; oferta escolar.

JEL codes: I2; Q54.

1 Introduction

A consolidated body of research suggests that the risk of extreme events will rise with the increasing global average temperature (COATES et al., 2014; IPCC, 2013; KREFT et al., 2014; MARENGO, 2009). Further, higher temperature variability could amplify the magnitude of climate shocks. Changes in the frequency and level of these events may cause severe damages in regions that are vulnerable to harsh climate scenarios (HALLEGATTE; HOURCADE; DUMAS, 2007). In particular, weather shocks can have serious welfare consequences in both the short and the long runs if it affects education production, children's schooling, and accumulation of human capital.

This study examines how weather shocks, more specifically drought shocks, affect educational outcomes of children attending schools in rural Northeastern Brazil. In particular, we assess how droughts may affect students achievement measured by Prova Brasil scores in math and language, a national standardized exam. We believe that focus on Northeastern Brazil provides a compelling setting to investigate the potential impacts of weather events. This is the driest Brazilian region and it has long been subject to harsh climatic conditions, with recurrent events of drought and rising temperatures (AB'SÁBER, 1999; MARENGO, 2009). Brazilian Northeast is one of the most populated semi-arid area of the world, where more than 23.5 million inhabitants (12% of the Brazilian population) are living (AB'SÁBER, 1999; CORREIA et al., 2011; INSA/MCTI, 2014). Moreover, there is plenty of anecdotal evidence showing that schools in rural semiarid areas are forced to temporally cease activities due to lack of water storage infrastructure. Such disruptions may hamper school attendance and therefore contribute to poor students achievement. Furthermore, this region has limited social safety nets, consequently households face credit constraints and they do not have access to the portfolio of adaptation strategies available in more developed regions.

We hypothesize that drought shocks have negative impact on students achievement. There are different mechanisms through which weather shock may affect child schooling. One can have a direct effect, known as "thermal stress", which can cause cognitive impairment, discomfort and fatigue (ZIVIN; HSIANG; NEIDELL, 2018; ZIVIN; SHRADER, 2016). Another potential mechanism is school supply. Drought shocks may lead schools to close or cease activities due to lack of water for consumption and hygiene, decreasing the educational provision and making impossible for the children attend school. As an attempt to prevent this, the governors should investing in basic infrastructure like cisterns. Such improvement could maintain schools open, enriches learning and nurturing the environment of disadvantaged children.

We also assess whether negative rainfall shocks could drive children to become sick. Previous studies have documented the relationship between weather shocks and health outcomes. Heat waves and cold waves, for instance, could directly affect cardiovascular stress, respiratory diseases, and cerebrovascular diseases (DESCHÊNES; MORETTI, 2009). Also, indirect impacts could be associated to scarcity and lack of adequate water supply, leading to disruption on agricultural production, reducing food availability and increasing malnutrition (ROCHA; SOARES, 2015). The lack of drinkable water increases the risk of infectious diseases, such as diarrheal diseases. One estimated 94% of the diarrheal disease burden in developing countries are associated with risk factors such as unsafe drinking water, lack of sanitation and poor hygiene (WHO, 2008). Furthermore, extreme events could contribute to the persistence of infectious endemic diseases, such as dengue and leptospirosis, enhancing the region's vulnerability (SOUZA et al., 2013). If drought shocks lead to higher incidence of particular diseases, this could reduce school attendance, hindering students learning and delaying their progress in school.

As the last mechanism, we investigate whether the drought shocks are associated with increased child labor. According to the luxury axiom (BASU; VAN, 1999), the reduction in the household income should increase child labor. A negative rainfall shock could affect agricultural production leading to a drop in family income. As a consequence, the poorest agricultural families tend to increase the supply of child labor in order to substitute adult labor or improve family wealth (BAR; BASU, 2009; BEEGLE; DEHEJIA; GATTI, 2006; BHALOTRA; HEADY, 2003; BOUTIN, 2014; HYDER; BEHRMAN; KOHLER, 2015). On the other hand, the drought shock could reduce the opportunity cost of studying. In this case, parents may reallocate the child's time endowment to human capital accumulation rather than to labor market activities (Shah and Steinberg, 2017; Kruger et al., 2012). Whether the income or substitution effect prevails is an empirical question.

Identification requires that drought shocks, conditional on municipality and year fixed-effects, are not correlated with other latent determinants of students achievement. We argue that this is plausible insofar as parents are unlikely to anticipate precisely a rainfall shock at a given moment in time and place. One potentially important concern is that if for some reason the drought shocks lead only the low-performing students to take the exam, the estimated effect of drought on achievement at the end of the year may not capture the causal impact of negative shocks on learning. We address this issue and there is very little evidence that this is the case. We make use of high frequency gridded information on precipitation and temperature to construct a municipality-by-year weather dataset which then is combined with Prova Brasil microdata and Educational Census by using place and exam month.

We focus our analysis on young students (fifth and ninth graders) from schools located in rural areas. We provide evidence for both grades that students from schools that are exposed to drought shocks perform worse on standardized math and language exams. A one standard deviation increases in the number of drought months per academic year leads to a reduction of 0.39 and 0.27 percentage points in math and language scores, respectively, for fifth graders. For the ninth grade students, the effect of drought on math and language achievement are -0.29 and -0.24 percentage points, respectively. Our results also suggest that the shock effect seem to be more detrimental for girls and those students with lower educated mothers. We also find suggestive evidence that drought tends to be more harmful to children that study in schools with no cistern or other water storage device. Therefore, investing in basic infrastructure is a low-cost policy strategy in rural areas that may considerably improve school performance. The results do not seem to be driven by student selection and are robust to placebo tests. In particular, we find no association between drought that occurs after the exam and performance at the exam.

By investigating the potential transmission mechanisms linking weather shocks to school performance, we find that the impact of drought shocks negatively affects school supply by increasing temporary school closing. Infant health also plays a major role in explaining student achievements. Exposure to a drought shock increase the hospitalization rate among children. The estimate suggests that a negative shock increases by 2,6 percent the hospitalization rate by infectious and parasitic diseases per 1,000 inhabitants, relative to a mean of 0.46. Finally, we find no statistically significant effect of negative rainfall shocks in child labor, thus it is unlikely this channel is driving the test score results in our sample.

Recent papers have addressed the relationship between general shocks, such as income shocks, macroeconomic crises, and children's schooling (ATKIN, 2016; BEEGLE; DEHEJIA; GATTI, 2006, 2009; FERREIRA; SCHADY, 2004; SHAH; STEINBERG, 2017). Kruger et al., (2012) find that exogenous shocks to local economic activity are associated with increased child labor and reduced schooling, in Brazil. They also stress out that these shocks have even more strength in children living in rural areas. Duryea et al., (2007) also analyze the impact of household economic shocks on schooling and employment transitions of young people living in Brazilian metropolitan areas. They show that an unemployment shock significantly increases the probability that a child enters the labor force, drops out of school, and fails to advance in school. Guarcello et al., (2003) observe a similar response for households in Guatemala, and also point out that child labor has a high degree of persistence because children who are sent to work are subsequently less likely to return to school. de Janvry et al. (2006) show that economic shocks have large effects in taking children out of school and induce they to increase their work participation in Mexico. They also find that the conditional transfers help protect enrollment, but do not refrain parents from increasing child work in response to shocks.

Our results contribute to an emerging literature that documents the relationship between specific weather-related events and educational outcomes. Boutin, (2014) finds no relationship between climate change and school attendance in Malawi. However, she observe that climate vulnerability negatively affects child labor incidence and intensity, while has no significant impact on household chores. Shah and Steinberg, (2017) investigate positive rainfall shocks in India and show that going from regular rainfall to a positive rainfall shock increases wages by 2%, decreases school attendance by 2 percentage points, and decrease the probability that a child is enrolled in school by 1 percentage point. These papers focus on weather shocks as quasi-random shocks to wages. However, it is important to notice that while heavy rainfall and droughts can influence agricultural income, they can also affect the supply of education, the environmental sanitary conditions and the proliferation of mosquito vectors that transmit a number of diseases. We contribute to the literature by exploring these other factors that could be important mechanisms through which rainfall shocks affect human capital formation.

The rest of the study is organized as follows. The next Section presents the conceptual issues. Section 3 describes database construction. The econometric specification is presented in Section 4. Section 5 presents the results on the relationship between droughts and school performance, the robustness checks, as well as the discussion on the potential transmission mechanism underlying this relationship. Finally, Section 6 summarizes the main conclusions and presents some policy recommendations.

2 Conceptual issues

The modeling of the cognitive achievement production function is often based on the idea that knowledge acquisition is a cumulative process by which current and past family and school inputs are combined with child's innate characteristics to produce a cognitive outcome (TODD; WOLPIN, 2003, 2007). Cognitive achievement production functions typically consider achievement for child i residing in household j at age a, S_{ija}, to be a function of an initial child's endowed mental capacity μ_{ij0}, as well as the history of family and school inputs, respectively, $F_1, ..., F_a, T_1, ..., T_a$, and exogenous environmental factors Z. Other cognitive achievement determinant of importance includes student health H. Following Todd and Wolpin (2007, 2003) a model of education production function can be expressed as:

$$S_{ija} = s(\mu_{ij0}, F_1, \ldots, F_a, T_1, \ldots, T_a, Z, H) \quad (1)$$

Drought shocks may have direct effects on learning through heat stress that may affects physiology in ways that can be detrimental to cognitive performance or reduced expected productivity (PARK, 2018; WARGOCKI; WYON, 2007; ZIVIN; HSIANG; NEIDELL, 2018; ZIVIN; SHRADER, 2016). We also hypothesize that the shocks may have disruptive effects on school routine. As supported by several reports in the media, extreme weather events can affect the school routine by causing temporary school closings and interruption of classes, due to lack of water for consumption and hygiene. As a result, student achievement could suffer as classes are discontinued (GROGGER, 1997).

Poor health in childhood may also be an important mechanism through which drought shock affects education; thus, *"if poor health among school aged children has an effect on the acquisition of skills, it is more likely to come through impairing children's ability to learn while they are in school"* (CURRIE, 2009). The literature suggests that in developing countries children who are in poor health tend to have lower educational attainments (BLEAKLEY, 2007; MIGUEL; KREMER, 2004). Bleakley (2007) provides evidence that the eradication of hookworm in the American South had a significant effect on school enrollment, school attendance, and that in addition, literacy increased markedly.

In this paper, we do not attempt to estimate tightly the education production function specified in (1) once that initial endowments are not observed and we also do not observe past family and school inputs and test scores. Instead, to arrive at an empirically implementable specification, we propose a reduced-form strategy that relies on the evidence that variation in rainfall levels within municipalities over time is orthogonal to any other past and contemporaneous latent determinants of learning. Our empirical strategy is detailed in section 4.

3 Data

3.1 Educational data

To assess the impact of drought shocks on student achievement, this paper uses two different databases, Prova Brasil microdata and Educational Census, both developed and coordinated by Instituto Anísio Teixeira (Inep). These datasets provide information at the level of the school, the teacher, and the student. The Prova Brasil is a national standardized exam applied each two years to all fifth and ninth graders students. The student scores on exam are our main outcome variables. All students from public schools with at least twenty students enrolled in each grade are required to take this test. The Prova Brasil exam is applied at the same day in all schools in November, and it is composed of two parts, language (Portuguese) and math. The fifth grade students have to answer twenty-two questions, while the ninth grade ones need to answer twenty-six questions. The score is calculated separated for language and math, and only for those students who answered more than 3 questions in each portion. In addition, students also respond to a socioeconomic survey that contains information such as whether they have a job, also if they help with domestic activities, mother's education level etc, and teachers and principals provide information on their experience and school routine. The exam has been applied since 1995, but it was only in 2007 that rural schools were included.

Before 2010, elementary School in Brazil had two possible systems, but after this year, all Brazilian schools have implemented the Law nº 11,274/2006. This law institutes the nine years primary School, with the compulsory inclusion of six-year-old instead of seven-year-old children, and it also reorganized school curriculum.[2] We restrict our analysis to the period between 2011 and 2015, when it is possible to compare the scores, and to schools situated in rural areas, because rural population is more likely to suffer insults due to drought shocks than urban ones. In panel A of table 1, we report summary statistics for fifth graders who take the Prova Brasil exam, while panel B provides statistics for ninth grade students. For fifth grade, our analysis sample consists of 350,838 students from 6,098 elementary schools. The numbers for ninth grade are slightly smaller, comprising 253,946 students from 3,977 primary schools.

Although Prova Brasil database provides some information at school level, it does not contain details on schools or teachers. We thus use the Educational Census to complete the information about school infrastructure and teachers' characteristics. The dataset is annual and every school receives an unique identification code. Since 2009, this number has been the same to identify the school on both Educational Census and Prova Brasil, which allows us to merge them and to link teachers to schools that took the exam over time. Panel C of table 1 reports the summary statistics for the teachers in our sample, most are women and have bachelor degree. Finally, Panel D of Table 1 reports information on school functioning. This Panel presents all schools from Educational Census. We use information on school functioning from all schools (not only the ones who participate in Prova Brasil) to explore the school supply mechanism.

3.2 Weather data

We use the latest global atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF), the ERA-Interim data, to build a series for temperature and precipitation. ERA-Interim provides worldwide estimates for weather conditions at the 0.1 × 0.1 degree latitude/longitude grid and covers the period from 1 January 1979 onwards. To construct a municipality-by-month of weather panel we use a geo-spatial software to aggregate the data to the municipality level and calculate an average of the points located inside the municipality limits. Considering the small grid of the dataset, almost all municipalities (1,485 of an total of 1,794) have had points inside their limits. For those that have had not, we employ the same approach as (ROCHA; SOARES, 2015). We compute the centroid for each of the 309 remaining municipalities and then locate the four closest nodes to build a monthly series as the weighted average of estimates related to these four nodes. We use the inverse of the distance to each node as weight. We make use of this data to construct our measure of drought shock.

An episode of drought is defined when the following condition holds

$$r_{jm} < \left(\overline{r_j} - r_j^{SD}\right) \tag{2}$$

where r_{jm} indicates the monthly rainfall in municipality j and calendar month m. $\overline{r_j}$ is the average historical monthly rainfall in municipality j, and r_j^{SD} is the historical

[2] We also thought to estimate separately for the period 2007-2009, but it is not possible considering that the number of rural schools that took the exam in 2007 was too low.

monthly standard deviation of rainfall for municipality *j*, both calculated over the 1979-2016 period. Thus, an episode of drought occurs always that rainfall in a given month was more than one standard deviation below the historical average for municipality *j*. Then our measure of drought shock is computed as the fraction of drought months occurring in the current year up to the month when Prova Brasil exam takes place. For example, if the exam was made in November 2005, then the drought shock is computed as the sum of drought months between January and November 2005.

3.3 Other data

To explore a potential mechanism, we construct a dataset on infant health by using microdata from the Brazilian National System of Hospital Information (Datasus/SIH). The database records every hospitalization by hospital units participating in the Brazilian Health Unique System (SUS)[3] and provides information on, among other things, the municipality of residence, years of age and sex. Thus, we are able to build a municipality-by-month on hospitalization panel over the 2008-2016 period. The region of interest is Northeastern Brazil and we restrict our sample to children aged 9 to 15, because our main sample on educational data. The municipality of reference in the panel is the municipality where the child lives, so that we are able to capture the shock that she was subject to.

3.4 Variation in drought shocks and outcomes

Because the statistical approach of this study relies on within-municipality variation, we confirm that there is in fact substantial within-municipality variability in the data for identification. To evaluate the within-municipality variability in the data more formally, we regress drought measure on a full set of municipality and year fixed effects. The residual variation in this regression is a direct measure of within-municipality variability. Thus, the further R-squared is from 1 the greater is the within-municipality variation. We find that about 77 percent of the total variation in our drought shock exposure cannot be explained by this set of fixed effects, a substantial within-municipality variation.

We also evaluate the within-municipality variability in the main outcomes of interest, language and math scores for fifth and ninth grade students. For fifth graders, we find that a substantial portion of the total variation in math and language scores is due to within-municipality differences, about 87 and 88 percent, respectively. For ninth grade students, municipality and year fixed effects cannot explain 93 percent of the variation in math score, and the value does not change when we look to language score variation. In summary, this analysis shows that there is meaningful variation in the data for identification.

4 Empirical Strategy

In order to identify the impacts of drought shocks on student achievement, we estimate the following regression

$$S_{ihmt} = \propto + \beta_1 D_{mt} + \beta_2 X_i + \beta_3 Y_h + \omega T_{mt} + \theta_m + \varphi_t + \varepsilon_{ihmt} \quad (3)$$

---

[3] This involves all public hospitals and some private hospitals which are associated to SUS.

where S_{ihmt} is the learning outcome of student *i*, enrolled at school h in municipality m and surveyed in year *t*. Learning is measured by Prova Brasil scores in math and language. The variable of interest is D_{mt}, that is the number of drought months in *m* from January to November (the month in which the exam is taken) of the current year, *t*. The β_1 is the key parameter of interest, it captures the effect of current-year droughts on math and language test scores. We also control for child socioeconomic characteristics, by including X_i, just as students' gender, age fixed effects, mother's education, race, a dummy for whether the student has ever dropped out in previous years and a dummy for whether the student has ever repeated a grade. School's characteristics are also accounted by including the vector Y_h (whether the school has water storage facilities, computer lab and offers free transport for students). These controls were add in order to absorb confounding effects driven by within-school heterogeneity. The term T_{mt} is the average temperature in the municipality *m*, on year of survey *t*. It allows us controlling for other climatic variations possibly correlated with droughts also occurring at the municipality level.

The term θ_m is a vector of municipality fixed effects, which absorb any unobservable time invariant factors at the municipality level, including initial conditions and persistent municipality characteristics such as geography. The model also includes year of survey fixed effects (φ_t), that capture aggregate shocks impacting all Northeast region, including demand shocks, labor market conditions, educational policies and programs. This specification allows us to compare children from the same municipality who take the Prova Brasil exam in different years. Standard errors are clustered at the municipality level to account for serial correlation.

The identifying assumption underlying this statistical approach is that, conditional on municipality and year fixed effects, there are not omitted determinants of children's education correlated with the incidence of weather shocks. This seems plausible, given that the occurrence of extreme weather event at a given moment in time and place is unpredictable. Thus, our approach exploits arguably random fluctuations in rainfall from municipality-specific deviations in long-term rainfall after controlling for all seasonal factors and common shocks to all municipalities. If this assumption holds, we are able to identify the causal impact of drought shocks on student achievement.

Although much of the variation in rainfall shocks over time within municipalities appears to be idiosyncratic, an identification issue could arise when following this specification. A potential problem in our analysis concerns student selection at the Prova Brasil exam. For instance, if for some reason the drought shocks lead only the low-performing students to take the exam, the estimated effect of drought on achievement at the end of the year may capture the worsening of the pool of students rather than the causal impact of shocks on learning. We address this issue in section 5.4 and there is very little evidence that this is the case.

5 Results

5.1 Impact on student achievement

In table 2 we report the results from equation (3) estimating the impact of contemporaneous drought shocks on students achievement. Panel A displays the results for fifth graders. In columns 1 and 3 we estimate our simplest specification, which include only year and municipality fixed effects. Columns 2 and 4 present our full specification, which we add controls for student and school characteristics in order to absorb confounding effects driven by observed heterogeneity in students' background and school infrastructure.

In panel A of table 2, column 1 reports a significant negative relationship between drought and math achievement. The coefficient rises slightly as we move from column 1 to 2. It appears that the heterogeneity in students and school characteristics plays a restricted role in generating the noticed correlation between drought shocks and math scores. In columns 3 and 4 we estimate the impact of drought shocks on fifth graders Portuguese score. We also find a significant negative correlation between drought and language achievement. Besides, when we control for observed students and school characteristics the coefficient is pretty much the same (column 4).

Panel B of table 2 repeats the same sequence of specifications for ninth grade students. When we move from column 1 to column 2, there is no striking differences between the coefficients, and it remains negative and statistically significant at the 5% level. This result indicates that the effect of negative rainfall shock on math achievement is important for the older children as well. For language scores, the point estimates basically does not change, as we move from columns 3 to 4, remaining negative and statistically significant.

Column 2 and column 4 of table 2 are our preferred specifications, and are the ones we use in the remainder of the paper, for both fifth and ninth grade students. The magnitudes are similar in size. A one standard deviation increases in the number of drought months per academic year leads to a reduction of 0.39 and 0.27 percentage points in math and language scores, respectively, for fifth graders. For the ninth grade students, the effect of drought on math and language achievement are -0.29 and -0.24 percentage points, respectively. Overall, we find a negative and statistically significant impact of drought shocks on both math and language achievement.

5.2 Heterogeneities

In appendix table A1, we look at the heterogeneity of drought impact by students' socioeconomic characteristics. In each column we regress students achievements on the drought shock, as well as its interaction with different student characteristics. Panel A shows the results for fifth grader students, while panel B presents the coefficients for ninth graders. Columns 1 and 5 replicates our benchmark specification, respectively, for math and language, without interaction terms. In the rest of the columns, we add interaction terms between the drought indicator and a dummy for white, for boys and low-educated mother (student's mother is illiterate or has not completed elementary school), respectively.

Panel A of table A1 provides evidence for fifth graders. Overall, we find that differential effects are in general statistically significant, for both math and language test scores, with exception of race. The results show that the effects of negative rainfall shock on school achievement seem to be larger for girls. Furthermore, the shocks tend to be more detrimental to those students with lower educated mothers. In this period children may benefit from instruction at home. Moreover, better educated parents may react differently to the drought shock than less educated ones. The observed concentration of damage among children with lower educated mother is consistent with a larger compensatory response by high-education parents compared to low-education parents. In other words, higher educated mothers might know better ways to mitigate the effects of the shock. Panel B documents there is little evidence for a differential response to drought shock according to students' socioeconomic characteristics for ninth graders, with the only exception being gender.

Table A2 of the appendix examines heterogeneity in the effect of drought shocks by school's infrastructure. Each column presents the result from our main specification, added by an interaction term between the drought indicator and a different school characteristic. Panel A shows the results for fifth graders, while panel B repeats the exercise for ninth grade students. Columns 1 and 4 show the results for our preferred specifications, without interaction terms. In columns 2 and 5, we add an interaction term between the shock and a dummy for schools with cistern. Column 3 and column 6 add an interaction term for a variable that indicates if the school provides transportation for children to attend the classes. The results provide suggestive evidence that drought tends to be more harmful to children that study in schools with no cistern. In years of negative rainfall shocks, rural schools may cease activities due to lack of adequate water for consumption and hygiene, decreasing the educational provision and making more difficult for the children attend to school. As an attempt to prevent this, cisterns should be installed to store water. Such improvement could helps on the functioning, enriches learning and nurturing environments of disadvantaged children.

5.3 Effects of shocks before and after the Prova Brasil year

In appendix table A3, columns 1 and 4 replicates our benchmark specification, respectively, for math and language performance. In column 2 and 5 we assess the extent to which droughts have either persistent or transitory effects on learning, by exploring the relationship between math and language achievement and our benchmark indicator of drought shock for the previous two school years. In the remainder columns we provide a natural placebo test. We regress students performance in math and language on our drought measure computed in the following academic year. As before, panel A shows the results for fifth graders and panel B for ninth grade students.

According to the results of table A3, there is no evidence of a significant association between math and language test scores and past drought shocks. Other studies in the literature have found that intervention programs, violence and temperature effects on test scores "fade out" over time, especially in earlier grades (ANDRABI et al., 2011; CASCIO; STAIGER, 2012; DEMING, 2009; MONTEIRO; ROCHA, 2017; SHAH; STEINBERG, 2017). The interpretation that the effect of drought shocks on learning is only transitory should be taken with attention. Although test score impacts often fade over time, their effects on knowledge is more persistent (CASCIO; STAIGER, 2012). Furthermore, drought may affect student attainment through its effects on learning, which may affect completed years of schooling in the long run. Also, as expected, the placebo test shows that there is no relationship between drought shocks during the following year and test scores in the current year.

5.4 Student selection

The primary concern for our main results in table 2 is self-selection of students at the Prova Brasil exam. If Prova Brasil data is sampling a different set of children in schools when experiencing droughts relative to a set when the shock does not occur, this may bias our estimates. Specifically, if higher-ability children are less likely to take the exam when rainfall is low, the estimated effect of droughts on students achievement may capture the worsening of the pool of students rather than the causal impact of weather shock on learning.

In order to address this issue, table 3 examines for student selection at the Prova Brasil exam. Panel A shows the results for fifth graders, while panel B provides evidence for ninth grade students. First, we regress some socioeconomic characteristics of the students who take the exam on the drought shock during the school year. In the first column we regress on drought a dummy variable indicating gender equal to male. The results show that a shock during the school year is not significantly associated with a higher probability of observing a male in the sample of students taking the exam, for both fifth and ninth grade. In the columns 2 to 4, we repeat the same specification for race (white), mother's education (student's mother is illiterate or has not completed elementary school) and student age, respectively. The coefficients on below are typically small and statistically insignificant, with the only statistically significant coefficient plausibly arising due to sampling error. The remaining column examines the relationship between drought shocks and participation rate of students who take the exam. The point estimate for the fifth graders is negative but statistically insignificant, and for ninth grade students is positive but insignificant either. Thus, we observe no significant association between negative rainfall shock and the number of students taking the Prova Brasil exam.

5.5 Mechanisms

In this section, we try to uncover the specific mechanisms linking negative rainfall shocks to students achievement. This relationship can be driven by a variety of channels. In the context of Northeast Brazilian, we may think in three main potential channels acting in our setting. First potential connection is through school supply. Negative rainfall shocks may lead schools to close or cease activities due to lack of water. Second, we assess whether the scarcity of water could cause children to become sick and attend school less. Finally, we examine whether, due to a drop in family income, the drought shocks are associated with increased child labor and reduced school attendance.

5.5.1 School supply

We analyze if drought shocks may lead to disruption of regular classroom routines and procedures due to lack of water for consumption and hygiene, decreasing educational provision and affecting children learning. As a result, student achievement may suffer as classes are discontinued.

To investigate the effects of the drought shocks on the school supply, we use nine years (2008-2016) of microdata from the Educational Census. Table 4 presents the results from estimating drought events for school routine. For column 1, we evaluate the effect of an additional drought shock during school year on interruption of classes. One drought shock during the current academic year is associated with an increase of 3 percent in the likelihood of temporary school closings, relative to mean of 0.24. Column 2 reports the regression of temporary closings on the drought shock computed in previous school years. $Drought_{-1}$ captures the negative rainfall shock at year $y - 1$ and $Drought_{-2}$ at year $y - 2$. We observe a statistically significant association between drought shock during the previous school year.

5.5.2 Infant health

If drought shocks lead to higher incidence of particular diseases, this could cause children to attend school less during drought years, and thus doing worse on Prova Brasil exam. A series of studies have documented the relationship between weather shocks and health outcomes. Precipitation is crucial for agricultural productivity, thus water scarcity may be associated with lower agricultural production, higher food prices and, therefore, lower nutrient intake, which could rise de incidence of nutritional diseases. Also, it may be related with lack of adequate drinkable water, which increases the risk of infectious diseases (Bandyopadhyay et al., 2012; Burgess and Deschenes, 2011; Carlton et al., 2013; Carrillo, forthcomign; Rocha and Soares, 2015; WHO, 2016, 2008).

To investigate the effects of drought shocks on infant morbidity, we use a municipality-by-month on hospitalization panel from January 2008 to October 2016, with children between 9 and 15 years old. We estimate the following equation:

$$H_{jmt} = \propto + \beta_1 R_{jmt} + \omega T_{jmt} + \theta_j + \varphi_t + \mu_m + \delta_{mt} + \varepsilon_{jmt} \quad (4)$$

where H_{jmt} is the infant hospitalization rate per 1,000 inhabitants in municipality j, on month *m* and year *t*. R_{jmt} is our drought indicator, a dummy equal one if rainfall over month *m* in year *t* was more than one standard deviation below the historical average for municipality j. T_{jmt} is the average temperature in the municipality in the same month. We also control for municipality (θ_j), year (φ_t), month (μ_m) and month-by-year (δ_{mt}) fixed effects. Standard errors are clustered at the municipality level.

The results are reported in table 5. Column 1 estimates the impact of drought shock on children aged 9 to 15. We find that exposure to negative rainfall shock increase the hospitalization rate among children in 0.83 percent. In columns 2 and 3, we report these coefficients separately estimated for children aged 9–11 and aged 12–15 in order to observe if the effect is concentrated in an specific group. As in the first column, the results are positive and statistically significant, but the effect appears to be slightly larger for the younger children (1 percent) than to older ones (0.72 percent). This result supports the view that infant health in the Northeast region are affected by rainfall fluctuations.

In order to examine a little deeper on the impact of drought shocks on infant health, we look at causes of hospitalization. We group our sample into four categories: infectious and parasitic diseases, malnutrition, respiratory infections, and all other diagnoses. In contexts of water scarcity, these are consider the main drivers of infant morbidity and mortality. Diarrhea is caused mainly by pathogens that are ingested from contaminated water (for consumption and hygiene) and food. Through reduced capacity to absorb nutrients, diarrhea can also lead to increased malnutrition. Rainfall scarcity also facilitates the irritation of the airways. A drier environment leaves children more susceptible to nasal bleeding and coughing due to the concentration of dust in the air. For those who already suffer from respiratory diseases, drought shocks increase the risk of having a crises (FEWTRELL et al., 2007; ROCHA; SOARES, 2015; WHO, 2008, 2016).

In panel A of table 6 we report the results from equation (4) estimating the impact of negative rainfall shocks on hospitalization by cause of children aged 9–11. The first column presents the effect on hospitalization rate by infectious and parasitic diseases. The point estimate of the coefficient of interest is 0.0116, which is statistically different from zero at the 5 percent level of significance. This estimate suggests that one drought shock increases by 2,6 per cent the hospitalization rate by infectious and parasitic diseases per 1,000 inhabitants, relative to mean of 0.46. The coefficient for malnutrition (column 2) is also statistically significant. A negative rainfall shock is associated with an increase of 5 per cent in hospitalization by malnutrition for children aged 9-11. Column 3 shows that respiratory diseases are positively related with drought shock, increasing by 3.23 per cent during drought months, relative to mean of 0.61. In Panel B, we present these coefficients estimated for children aged 12-15. Most of the magnitudes are similar in size, although the effect of rainfall negative shocks on malnutrition is not statistically different from zero for the older children. Overall, the results show that health may be one of the mechanisms through which drought shocks affect students achievements.

5.5.3 Child labor

The impact of drought shocks on agricultural production is straightforward. Almost all of the total area sown in Northeastern Brazil is rainfed. Only 2 percent of net area is irrigated. Therefore, we would expect rainfall to be an important driver of agricultural productivity and household income. According to the literature, family wealth is associated with child labor, as poorest the family as higher the chance of a child works (BALAND; ROBINSON, 2000; BASU; VAN, 1999; KRUGER; SOARES; BERTHELON, 2012). For example, facing a negative rainfall shock could lead parents increase their use of child labor, typically by having children substitute adult labor in household activities or farm work, preventing children to attending classes or diminishing time devoted to school activities (BAR; BASU, 2009; BEEGLE; DEHEJIA; GATTI, 2006); or yet, children could work at the parents establishments to improve family income. This would reduce school attendance and consequently contribute to poor students achievement. On the other hand, higher wages are associated with lower schooling rates (Rosenzweig and Evenson, 1977; Shah and Steinberg, 2017), thus decreasing agricultural revenues may diminish the opportunity cost of school attendance. In this sense, negative shocks could be associated to school performance improvements. The answer to the question whether the effects of weather shocks are positive or negative to school achievement is a priori ambiguous.

To analyze the effects of drought shocks on the likelihood of a child being or not employed, we specify the following regression equation:

$$W_{imt} = \propto + \beta_1 D_{mt} + \beta_2 X_i + \omega T_{mt} + \varphi_t + \theta_m + \varepsilon_{ihmt} \quad (5)$$

where W_{ihmt} is equal to one if child *i* works and zero otherwise, in municipality *m* and surveyed in year *t*. The variable of interest is D_{mt}, that is the number of drought months in *m* from January to November of the current year, *t*. The β_1 is the key parameter of interest, it captures the effect of current-year droughts on child labor. We also control for child socioeconomic characteristics, by including X_i, just as students' gender, age fixed effects, race, mother's education, and dummies indicating if students have a car or a housekeeper. The term T_{mt} is the average temperature in the municipality *m*, on year of survey *t*. It allows us controlling for other climatic variations possibly correlated with droughts also occurring at the municipality level. The model also includes year of survey fixed effects (φ_t) and municipality fixed effects, θ_m. Standard errors are clustered at the municipality level to account for serial correlation.

The coefficient from table 7 refers to the effect of the drought shocks on the likelihood of child working. Column 1 estimates the impact of drought shock on children aged 8 to 19. In columns 2 and 3, we report these coefficients separately estimated for children aged 8–13 and aged 14–19. We seek to understand whether there are differential effects by age. If increased wages increase the benefit to working for older children, then the substitution effect would be relatively more important for them (SHAH; STEINBERG, 2017). The results in table 7 indicate that there is no statistically significant effect of negative rainfall shocks in child labor, and thus it is unlikely this channel is driving the test score results in our sample.

6 Concluding Remarks

In this paper, we tried to shadow some light on rural school issues. The Brazilian public debate is dominated by urban-related educational themes, mainly focused on enhancing teaching quality. Little attention is devoted to rural schools, which suffer from basic infrastructure problems, high dropout rates and poor student achievement.

This study provides evidence that drought shocks have negative impact on the performance of students from rural schools located in the Northeastern Brazil. We assessed how droughts may affect student achievement as measured by Prova Brasil scores, a national standardized exam. Our results show that drought shocks are associated to lower scores on both mathematics and language exams, for fifth and ninth graders.

We are able to provide evidence for two mechanisms through which adverse rainfall shocks affect students achievement. Drought shock increases the hospitalization rate among children, specially by specific causes as malnutrition, respiratory diseases, infectious and parasitic diseases. In addition to that, droughts are also associated to temporarily school closings. Both health and school supply related effects may be associated to lower school attendance and therefore contribute to poor student achievement.

However, schools equipped with cisterns seem to be able to mitigate the negative effects of droughts. Cisterns may prevent water scarcity problems that could eventually force schools to temporarily cease their activities. Therefore, investments in this low-cost water storage device may bring considerable benefits to rural children, improving school attendance and education supply. In order to intervening on the health-related transmission mechanism, governmental policy could focus on improving water and sanitation infrastructure. Many rural areas lack access to safe drinking water especially during drought years. Improving access to safe drinking water may reduce waterborne diseases like diarrhea and improve school attendance.

We also find that the effect of drought is transitory, although this result should be taken with caution. Though test score impacts often fade over time, their effects on knowledge is more persistent. Furthermore, drought may affect student attainment through its effects on learning, which may affect completed years of schooling in the long run.

References

AB’SÁBER, A. N. Sertões e sertanejos: uma geografia humana sofrida. **Estudos Avançados**, v. 13, n. 36, p. 5–59, 1999.

ANDRABI, T. et al. Do Value-Added Estimates Add Value? Accounting for Learning Dynamics. **American Economic Journal: Applied Economics**, v. 3, n. 3, p. 29–54, jul. 2011.

ATKIN, D. Endogenous Skill Acquisition and Export Manufacturing in Mexico. **American Economic Review**, v. 106, n. 8, p. 2046–2085, 2016.

BALAND, J.-M.; ROBINSON, J. A. Is Child Labor Inefficient ? **Journal of Political Economy**, v. 108, n. 4, p. 663–679, 2000.

BANDYOPADHYAY, S.; KANJI, S.; WANG, L. The Impact of Rainfall and Temperature Variation on Diarrheal Prevalence in Sub-Saharan Africa. **Applied Geography**, v. 33, p. 63–72, 2012.

BAR, T.; BASU, K. Land : in the Long Run and Short Run. **Journal of the European Economic Association**, v. 7, n. May, p. 487–497, 2009.

BASU, K.; VAN, P. H. The Economics of Child Labor: Reply. **American Economic Review**, v. 89, n. 5, p. 1386–1388, 1999.

BEEGLE, K.; DEHEJIA, R. H.; GATTI, R. Child labor and agricultural shocks. **Journal of Development Economics**, v. 81, n. 1, p. 80–96, 2006.

BEEGLE, K.; DEHEJIA, R. H.; GATTI, R. Why should we care about child labor? The education, labor market, and health consequences of child labor. **Journal of Human Resources**, v. 44, n. 4, p. 871–889, 2009.

BHALOTRA, S.; HEADY, C. Child Farm Labor: The Wealth Paradox. **The World Bank Economic Review**, v. 17, n. 2, p. 197–227, 2003.

BLEAKLEY, H. Disease and Development: Evidence from Hookworm Eradication in the American South. **The Quarterly Journal of Economics**, v. 122, n. 1, p. 73–117, 2007.

BOUTIN, D. Climate vulnerability, communities' resilience and child labour. **Revue d'économie politique**, v. 124, n. 4, p. 625, 2014.

BURGESS, R.; DESCHENES, O. Weather and death in India. **Cambridge, United …**, n. April, 2011.

CARLTON, E. J. et al. Heavy Rainfall Events and Diarrhea Incidence: The Role of Social and Environmental Factors. **American Journal of Epidemiology**, v. 179, n. 3, p. 344–352, 2013.

CARRILLO, B. Early Rainfall Shocks and Later-Life Outcomes: Evidence from Colombia. **The World Bank Economic Review**, [s.d.].

CASCIO, E. U.; STAIGER, D. O. Knowledge, Tests, and Fadeout in Educational Interventions. NBER Working Paper No. 18038. p. 0, 2012.

COATES, L. et al. Exploring 167 years of vulnerability: An examination of extreme heat events in Australia 1844-2010. **Environmental Science and Policy**, v. 42, p. 33–44, 2014.

CURRIE, J. Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development. **Journal of Economic Literature**, v. 47, n. 1, p. 87–122, 2009.

DE JANVRY, A. et al. Can conditional cash transfer programs serve as safety nets in keeping children at school and from working when exposed to shocks? **Journal of**

Development Economics, v. 79, n. 2, p. 349–373, 2006.

DEMING, D. Early Childhood Intervention and Life-Cycle Skill Development: Evidence from Head Start. **American Economic Journal: Applied Economics**, v. 1, n. 3, p. 111–134, jun. 2009.

DESCHÊNES, O.; MORETTI, E. Extreme Weather Events, Mortality, and Migration. **The Review of Economics and Statistics**, v. 91, n. 4, p. 693–713, 2009.

DURYEA, S.; LAM, D.; LEVISON, D. Effects of economic shocks on children's employment and schooling in Brazil. **Journal of Development Economics**, v. 84, n. 1, p. 188–214, 2007.

FERREIRA, F.; SCHADY, N. Do Macroeconomic Crises Always Slow Human Capital Accumulation? **The World Bank Economic Review**, v. 18, n. 2, p. 131–154, 2004.

FEWTRELL, L. et al. Water, Sanitation and Hygiene: quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage. **WHO Environmental Burden of Disease Series no 15**, n. 15, 2007.

GROGGER, J. Local Violence and Educational Attainment. **The Journal of Human Resources**, v. 32, n. 4, p. 659–682, 1997.

GUARCELLO, L.; MEALLI, F.; ROSATI, F. **Household vulnerability and child labor: the effects of shocks, credit rationing, and insurance. Understanding Children's Work, An Inter-Agency Research Cooperation Project**. [s.l: s.n.].

HALLEGATTE, S.; HOURCADE, J. C.; DUMAS, P. Why economic dynamics matter in assessing climate change damages: Illustration on extreme events. **Ecological Economics**, v. 62, n. 2, p. 330–340, 2007.

HYDER, A.; BEHRMAN, J. R.; KOHLER, H.-P. Negative Economic Shocks and Child Schooling: Evidence from Rural Malawi. **Development Southern Africa**, v. 32, n. 4, p. 458–479, 2015.

INSA/MCTI. **População do Semiárido brasileiro ultrapassa 23,5 milhões de habitantes**, 2014. Disponível em: <http://www.insa.gov.br/noticias/populacao-do-semiarido-brasileiro-ultrapassa-235-milhoes-de-habitantes-2/#.VpbM7hUrLIU>

IPCC. **Climate Change 2014: Impacts, Adaptation, and Vulnerability**. New York: [s.n.].

KREFT, S. et al. **Global Climate Risk Index 2015: Who Suffers Most From Extreme Weather Events?** Berlim: [s.n.].

KRUGER, D.; SOARES, R. R.; BERTHELON, M. Household Choices of Child Labor and Schooling: A Simple Model with Application to Brazil. **Journal of Human Resources**, v. 47, n. 1, p. 1–31, 2012.

MARENGO, J. **Mudanças climáticas e eventos extremos no Brasil**. [s.l: s.n.].

MIGUEL, E.; KREMER, M. Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities. **Econometrica**, v. 72, n. 1, p. 159–217, 2004.

MONTEIRO, J.; ROCHA, R. Drug Battles and School Achievement: Evidence from Rio de Janeiro's Favelas. **The Review of Economics and Statistics**, v. 99, n. 2, p. 213–228, maio 2017.

PARK, J. **Hot Temperature, High Stakes Exams, and Avoidance Behavior: Evidence from New York City Public SchoolsUnpublished Manuscript, Harvard University Economics Department, Submitted.** [s.l: s.n.].

ROCHA, R.; SOARES, R. R. Water scarcity and birth outcomes in the Brazilian semiarid ☆. **Journal of Development Economics**, v. 112, p. 72–91, 2015.

ROSENZWEIG, M.; EVENSON, R. Fertility, Schooling, and the Economic Contribution of Children in Rural India: An Econometric Analysis. **Econometrica**, v. 45, n. 5, p. 1065–1079, 1977.

SHAH, M.; STEINBERG, B. M. Drought of Opportunities: Contemporaneous and Long-Term Impacts of Rainfall Shocks on Human Capital. **Journal of Political Economy**, v. 125, n. 2, p. 527–561, 2017.

SOUZA, E. C. DE et al. Impactos das mudanças climáticas sobre o bem-estar relacionado à saúde no Brasil. **Pesq e Planej Econ.**, v. 43, n. 1, p. 49–8, 2013.

TODD, P. E.; WOLPIN, K. I. On the specification and estimation of the production function for cognitive achievement. **Economic Journal**, v. 113, n. 485, p. 3–33, 2003.

TODD, P. E.; WOLPIN, K. I. The Production of Cognitive Achievement in Children: Home, School, and Racial Test Score Gaps. **Journal of Human Capital**, v. 1, n. 1, p. 91–136, 2007.

WARGOCKI, P.; WYON, D. P. The Effects of Moderately Raised Classroom Temperatures and Classroom Ventilation Rate on the Performance of Schoolwork by Children (RP-1257). **HVAC&R Research**, v. 13, n. 2, p. 193–220, 2007.

WHO. **Water Quality Interventions to Prevent Diarrhoea: Cost and Cost-Effectiveness**. Geneva: [s.n.].

WHO. **Natural Disaster Profiles**. Geneva: [s.n.]. Disponível em: <http://www.who.int/hac/techguidance/ems/natprofiles/en/index.html>.

ZIVIN, J. G.; HSIANG, S. M.; NEIDELL, M. Temperature and Human Capital in the Short and Long Run. **Journal of the Association of Environmental and Resource Economists**, v. 5, n. 1, p. 77–105, 2018.

ZIVIN, J. G.; SHRADER, J. Temperature Extremes, Health, and Human Capital. **The Future of Children**, v. 26, n. 1, p. 31–50, 2016.

Table 1. Summary Statistics

	Rural Schools			
	Mean	SD	N	Year
Panel A - Prova Brasil takers - 5th graders				
	167.56	42.05	326433	11, 13, 15
Math score	181.98	42.95	326433	11, 13, 15
Age	11.27	1.39	326433	11, 13, 15
% white	0.23	0.42	278508	11, 13, 15
% boys	0.52	0.5	326433	11, 13, 15
% low educated mother	0.64	0.48	210799	11, 13, 15
% low educated father	0.65	0.48	178181	11, 13, 15
% have repeated a grade	0.45	0.5	318991	11, 13, 15
% have dropped out	0.16	0.36	319933	11, 13, 15
Panel B - Prova Brasil takers - 9th graders				
Portuguese score	228.52	43.43	162828	11, 13, 15
Math score	233.11	42.99	162828	11, 13, 15
Age	14.36	0.66	162828	11, 13, 15
% white	0.2	0.4	144723	11, 13, 15
% boys	0.41	0.49	162828	11, 13, 15
% low educated mother	0.64	0.48	131364	11, 13, 15
% low educated father	0.73	0.44	108588	11, 13, 15
% have repeated a grade	0.27	0.45	162037	11, 13, 15
% have dropped out	0.05	0.21	162240	11, 13, 15
Panel C - Teacher-level variables				
Age	36.50528	8.803206	251906	11, 13, 15
% Male	0.329967	0.470202	251906	11, 13, 15
% White	0.253986	0.435291	251906	11, 13, 15
% BA diploma	0.621282	0.485069	251906	11, 13, 15
% Pos diploma	0.002777	0.052624	251906	11, 13, 15
Panel D - School-level variables				
% Schools in activity	0.6367	0.4809	591233	08 to 16
% Temporarily closed schools	0.2421	0.4283	591233	08 to 16
% Closed schools	0.0223	0.1478	591233	08 to 16

Notes: This table provides summary statistics based on Prova Brasil and Educational Census datasets.

Table 2. Drought shocks effects on student achievement

	1 Math score	2 Math score	3 Language Score	4 Language Score
	Panel A - Prova Brasil takers - 5th graders			
Drought shock	-0.61	-0.65	-0.51	-0.53
	[0.3371]*	[0.3248]**	[0.3088]*	[0.2974]*
N	326433	326433	326429	326429
R-sq	0.192	0.238	0.169	0.248
	Panel B - Prova Brasil takers - 9th graders			
Drought shock	-0.72	-0.81	-0.67	-0.67
	[0.3352]**	[0.3512]**	[0.3971]*	[0.4029]*
N	162828	162828	162838	162838
R-sq	0.133	0.167	0.122	0.17
Basic controls	No	Yes	No	Yes
Temperature control	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes

Note: Basic controls include students' sex, race, age fixed effects, dummy for level of mother’s education, also some school characteristics as dummies indicating whether there is a computer lab, science lab, cistern and free transportation for students. Temperature control includes the average temperature at municipality level. We report robust standard errors clustered at the municipality level (in brackets). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 3. Student selection

	1 Male	2 White	3 Low educated mother	4 Age	5 Rate of participation in Prova Brasil exam
	Panel A - Prova Brasil (5th grade)				
Drought shock	-0.0004	-0.0013	0.0013	-0.0014	-0.0322
	[0.0019]	[0.0017]	[0.0018]	[0.0082]	[0.2664]
N	327824	327824	327824	327824	27080
R-sq	0.031	0.023	0.178	0.106	0.97
	Panel B - Prova Brasil (9th grade)				
Drought shock	0.003	-0.0035	-0.0018	-0.0107	0.0784
	[0.0025]	[0.0019]*	[0.0023]	[0.0068]	[0.3473]
N	163243	163243	163243	163243	20552
R-sq	0.027	0.037	0.177	0.071	0.959
Basic controls	Yes	Yes	Yes	Yes	Yes
Temperature control	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes

Note: Basic controls include students' sex, race, age fixed effects, dummy for level of mother’s education, also some school characteristics as dummies indicating whether there is a computer lab, science lab, cistern and free transportation for students. Temperature control includes the average temperature at municipality level. We report robust standard errors clustered at the municipality level (in brackets). Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1.

Table 4. School routine

	1 Temporary school closing	2 Temporary school closing
Drought shock	0.0076 [0.0019]***	0.0077 [0.0019]***
$Drought_{-1}$		0.0070 [0.0016]***
$Drought_{-2}$		0.0017 [0.0015]
Basic controls	Yes	Yes
Temperature control	Yes	Yes
Year FE	Yes	Yes
Municipality FE	Yes	Yes
N	591233	591233
R-sq	0.1534	0.1536

Note: Basic controls include some school characteristics as dummies indicating whether there is a computer lab, science lab, cistern and free transportation for students. Temperature control includes the average temperature at municipality level. We report robust standard errors clustered at the municipality level (in brackets). Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1.

Table 5. Drought effect on infant hospitalization rate

	Dependent variable: hospitalization rate		
	1 Ages 9-15	2 Ages 9-11	3 Ages 12-15
Drought shock	0.032 [0.0129]**	0.019 [0.0088]**	0.013 [0.0076]*
Temperature control	Yes	Yes	Yes
Month FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
N	450394	450394	450394
R-sq	0.48	0.424	0.365

Note: The dependent variable is infant hospitalization rate per 1,000 inhabitants. We report robust standard errors clustered at the municipality level (in brackets). Temperature control includes the average temperature at municipality level. Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1.

Table 6. Drought effect on infant hospitalization rate by cause

	1 Infectious and parasitic diseases	2 Malnutrition	3 Respiratory diseases	4 Other causes
Children aged 9-11				
Drought shock	0.0116	0.0033	0.0197	-0.0125
	[0.0050]**	[0.0013]**	[0.0059]***	[0.0048]***
N	450394	450394	450394	450394
R-sq	0.389	0.135	0.347	0.144
Children aged 12-15				
Drought shock	0.0097	0.0011	0.0079	-0.0052
	[0.0031]***	[0.0007]	[0.0023]***	[0.0041]
N	450394	450394	450394	450394
R-sq	0.352	0.097	0.283	0.115
Temperature control	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Month-by-year FE	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes

Note: The dependent variable is infant hospitalization rate per 1,000 inhabitants. We report robust standard errors clustered at the municipality level (in brackets). Temperature control includes the average temperature at municipality level. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 7. Drought shocks and child labor

	Dependent variable: child labor		
	1 Ages 8 - 19	2 Ages 8 - 13	3 Ages 14 - 19
Drought shock	-0.0003	-0.0024	0.0018
	[0.0013]	[0.0019]	[0.0016]
Basic controls	Yes	Yes	Yes
Temperature control	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
N	331812	158577	173235
R-sq	0.039	0.03	0.063

Note: Basic controls include students' sex, race, age fixed effects, dummy for level of mother's education. Temperature control includes the average temperature at municipality level. We report robust standard errors clustered at the municipality level (in brackets). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

APPENDIX

Table A1. Heterogeneity in the drought shocks effect by students' socioeconomic characteristics

	1	2	3	4	5	6	7	8
	Math score	Math score	Math score	Math score	Language score	Language score	Language score	Language score
Panel A - Prova Brasil takers - 5th graders								
Drought shock	-0.61	-0.6287	-0.9072	-0.477	-0.5319	-0.4899	-0.813	-0.3124
	[0.3371]*	[0.3243]*	[0.3320]***	[0.3293]	[0.2974]*	[0.2963]*	[0.3224]**	[0.3136]
Drought shock x white		-0.0909				-0.2265		
		[0.1889]				[0.2405]		
Drought shock x boy			0.5306				0.5699	
			[0.1709]***				[0.1904]***	
Drought shock x low educated mother				-0.4435				-0.5778
				[0.1766]**				[0.2213]***
N	326433	326433	326433	326433	326429	326429	326429	326429
R-sq	0.238	0.238	0.238	0.238	0.248	0.248	0.248	0.248
Panel B - Prova Brasil takers - 9th graders								
Drought shock	-0.8114	-0.8417	-1.127	-0.7617	-0.6747	-0.7285	-0.9582	-0.4865
	[0.3512]**	[0.3440]**	[0.3554]***	[0.3658]**	[0.4029]*	[0.3929]*	[0.4092]**	[0.4223]
Drought shock x white		0.2008				0.3566		
		[0.3926]				[0.4124]		
Drought shock x boy			0.784				0.7043	
			[0.2681]***				[0.2695]***	
Drought shock x low educated mother				-0.1088				-0.4126
				[0.2439]				[0.2699]
N	162828	162828	162828	162828	162838	162838	162838	162838
R-sq	0.167	0.167	0.167	0.167	0.17	0.17	0.17	0.17
Basic controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Temperature control	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

Table A2. Heterogeneity in the drought shocks effect by school characteristics

	1	2	3	4	5	6
	Math score	Math score	Math score	Language score	Language score	Language score
Panel A - Prova Brasil takers - 5th graders						
Drought shock	-0.6455	-0.8177	-0.574	-0.5319	-0.6994	-0.4953
	[0.3248]**	[0.3249]**	[0.3388]*	[0.2974]*	[0.2978]**	[0.2923]*
Drought shock x cistern		0.9926			0.9655	
		[0.4526]**			[0.4516]**	
Drought shock x school bus			-0.1924			-0.0984
			[0.3728]			[0.3577]
N	326433	326433	326433	326429	326429	326429
R-sq	0.192	0.238	0.238	0.172	0.248	0.248
Panel B - Prova Brasil takers - 9th graders						
Drought shock	-0.8114	-0.9692	-0.686	-0.6747	-0.8393	-0.6339
	[0.3512]**	[0.3685]***	[0.4152]*	[0.4029]*	[0.4282]*	[0.5108]
Drought shock x cistern		0.955			0.9963	
		[0.5663]*			[0.5899]*	
Drought shock x school bus			-0.2674			-0.087
			[0.4434]			[0.5227]
N	162828	162828	162828	162838	162838	162838
R-sq	0.167	0.167	0.167	0.17	0.17	0.17
Basic controls	Yes	Yes	Yes	Yes	Yes	Yes
Temperature control	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Basic controls include students' sex, race, age fixed effects, dummy for level of mother's education, also some school characteristics as dummies indicating whether there is a computer lab, science lab, cistern and free transportation for students. Temperature control includes the average temperature at municipality level. We report robust standard errors clustered at the municipality level (in brackets). Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table A3. Drought effect on student achievement in different timing

	1	2	3	4	5	6
	Math score	Math score	Math score	Language score	Language score	Language score
Panel A - Prova Brasil takers - 5th graders						
Drought shock (current year)	-0.65	-0.43	-0.61	-0.53	-0.48	-0.51
	[0.3248]**	[0.3590]	[0.3220]*	[0.2974]*	[0.3377]	[0.2999]*
Drought shock (Lag, Year -1)		-0.01			-0.13	
		[0.2867]			[0.2402]	
Drought shock (Lag, Year -2)		0.92			0.51	
		[0.4655]**			[0.3983]	
Drought shock (Lead, Year +1)			-0.34			-0.28
			[0.2747]			[0.2360]
N	326433	326433	326433	326429	326429	326429
R-sq	0.238	0.238	0.238	0.248	0.248	0.248
Panel B - Prova Brasil takers - 9th graders						
Drought shock (current year)	-0.81	-0.80	-0.81	-0.67	-0.60	-0.68
	[0.3512]**	[0.4022]**	[0.3396]**	[0.4029]*	[0.4634]	[0.3889]*
Drought shock (Lag, Year -1)		0.13			-0.12	
		[0.3512]			[0.3429]	
Drought shock (Lag, Year -2)		-0.28			-0.13	
		[0.5027]			[0.5444]	
Drought shock (Lead, Year +1)			-0.05			0.07
			[0.3215]			[0.3209]
N	162828	162828	162828	162838	162838	162838
R-sq	0.167	0.168	0.168	0.17	0.17	0.17
Basic controls	Yes	Yes	Yes	Yes	Yes	Yes
Temperature control	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Basic controls include students' sex, race, age fixed effects, dummy for level of mother's education, also some school characteristics as dummies indicating whether there is a computer lab, science lab, cistern and free transportation for students. Temperature control includes the average temperature at municipality level. We report robust standard errors clustered at the municipality level (in brackets). Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1.