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The Effect of Transitory Health Shocks on Schooling Outcomes: The case of dengue fever in Brazil*

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Abstract

In this paper, we estimate the causal effect of transitory individual-level health shocks on schooling outcomes in Brazil. We focus on dengue fever, which, despite putting half of the world's population at risk, has received relatively little attention, possibly due to its low mortality. We link individual register data on dengue infections with detailed individual records from the Brazilian school census and use a fixed effects estimation strategy to estimate the effect of dengue infections on grade retention and dropout. We find that dengue infections during the school year have a substantial negative effect on measures of student success, with an increase in grade retention of 3.5 percent and an increase in dropout of 4.6 percent. Using information on monthly attendance from the monitoring system of conditionalities of the Brazilian cash transfer Bolsa Família, we provide evidence that infections reduce school attendance.

JEL Classification: I12, J13, K42, O12

Keywords: Health shocks, dengue, educational outcomes, drop-out

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1 Introduction

The recent COVID-19 pandemic has put a spotlight on the devastating effects infectious diseases can have on societies. While the direct health impact of COVID-19 was mostly felt by individuals with underlying risk factors, including chronic conditions and old age, the indirect impact of the lockdowns and school closures had a detrimental impact on the learning and educational outcomes of children around the world (Azevedo et al. (2021), Grewenig et al. (2021), Werner and Woessmann (2023)). In contrast to COVID-19, with the focus on school closures and the effect of home learning, infectious diseases may also affect the learning and human capital more directly when infected students suffer from the direct health consequences of an infection, for example, by directly impacting their learning or by missing school because of ill health. Estimating the causal effect of ill health on schooling outcomes is challenging because of the potential endogeneity of ill health or supply-side effects, as in the case of COVID-19. Dengue fever provides an interesting case to investigate the effect of transitory health shocks on student outcomes. Because dengue fever is a communicable disease, registration of cases provides an individual-level dataset not available for other infections, and because of the endemic nature, a sufficient number of infections are available to estimate precise effects. At the same time, in most cases, regular dengue has no long-term consequences, making it an ideal exemplar to study transitory health shocks, ruling out that the infection has a detrimental impact on the health and other outcomes through long-lasting symptoms.[1]

In this paper, we estimate the effect of dengue infections on the schooling outcomes of secondary school students in Brazil. Combining official records on dengue infections with individual-level records from the Brazilian school census, we investigate the effect of infections during the school year on regular grade promotion, grade retention and dropout, which are key measures of educational success. To address the underlying endogeneity problem, we estimate econometric specifications including school and neighborhood fixed effects, while controlling for a very rich set of individual and classroom level fixed effects, as well as for temperature. Conditional on those FEs, dengue infections will be as good as random, and the specific nature of the infection, without lasting health effects, allows us to better understand how relatively short, transitory shocks impact the human capital accumulation of students. Previous evidence on the effect of contemporaneous health shocks on educational outcomes is scarce. This is probably due to a mix of data limitations, as

[1] This is particularly true when investigating dengue infections of children because they are much less likely to have been infected with other strains of dengue previously, dramatically reducing the chance for developing severe dengue, a serious complication associated with re-infection with other dengue strains.

individual records on health shocks that can be linked to individual schooling records are limited, and problems with isolating the effect of the individual health shock from general equilibrium effects. For example, during the COVID-19 pandemic, with school closures and restrictions on social mixing, the direct effect of infections is difficult to isolate, leading to a lack of such research. A notable exception is Gensowski et al. (2019) who study the effect of Polio infections in early life on education attainment and labor market outcomes in Denmark. Exploiting quasi-random variation in paralysis incidence in this population, focusing on long-term disability rather than transitory health shocks, they find that paralysis increases educational attainment and increases the propensity to work in white-collar jobs. There is also a small literature on the effects of shocks to parental health on children's educational outcomes. Alam (2015) find for Tanzania that paternal health shocks reduce attendance at school, most likely through the effect on income, leading to detrimental long-term effects on educational attainment. In contrast, Aaskoven et al. (2022) find that severe parental health shock affects children's school achievements using a rich longitudinal dataset of Danish children through the non-pecuniary cost of the illness negatively affecting school grades and secondary school completion rates. This paper is also related and contributes to the literature on the cost of dengue. For example, Foureaux Koppensteiner and Menezes (2023) provide estimates on the effect of maternal dengue infections in-utero on health at birth and longer-term health, linking dengue records with birth and hospitalization records. Closer to our context, Barron et al. (2019) study the effect of a dengue outbreak in Colombia on educational outcomes. In contrast to the direct effect of dengue infections on educational outcomes in our paper, they focus on the behavioral response to the outbreak on those not directly affected by dengue. By studying these indirect effects, they find that an unexpected dengue outbreak leads to between 4 and 10 percent fewer students sitting their school-leaving examinations for every additional 10 cases of severe dengue per 10,000 municipality inhabitants.

In this paper, we provide the first causal evidence on the effects of dengue infections on schooling outcomes leveraging matched health and schooling records from Brazil. To address the potential endogeneity of dengue infections, we apply school and time fixed effects and control for a large set of individual and classroom time varying characteristics. We find that dengue infections during the school year have a substantial negative effect on educational outcomes in secondary school, increasing grade retention by at least 3.5 percent and dropout by 4.6 percent compared to the mean incidence of retention and dropout. The results are robust to a battery of alternative specifications, including two-way fixed effects specifications using school and neighborhood fixed effects, allowing for neighborhood specific trends, including classroom fixed effects, and including temperature controls. We find that the effects are driven by dengue infections during the concurrent school year, but we also find longer-term effects by documenting the lasting effect of dengue infections on retention and dropout in the subsequent year. We also provide suggestive evidence that the effect in part is due to the negative impact an infection has on attendance, using monthly attendance records from the monitoring system of conditionalities of the Brazilian cash transfer Bolsa Família. Our results document the relevance of transitory health shocks on measures of school success. The increase in retention and dropout in response to dengue infections is substantial and shows that health shocks, even when generally considered relatively mild and of transitory nature, can have drastic consequences for human capital accumulation. The results are important for optimal policy making, providing causal estimates of a previously unknown consequence of dengue fever on the human capital accumulation of adolescents in Brazil. These novel estimates are relevant, for example, to the optimal design of vector control programs, including the targeting of interventions around the residence and schools of students. The results will also provide important inputs for the decision on the adoption and targeting of newly available dengue vaccines. In October 2023, the Strategic Advisory Group of Experts on Immunization of the WHO recommended the adoption of the Qdenga vaccine to children aged 6-16 in dengue hotspots. Our results show that secondary school students, ranging in age from 15-18, are affected negatively by dengue infections and the protection through the vaccine should be extended to at least age 18 to protect students at school from the negative impact of dengue.

The remainder of the paper is structured as follows. In section 2 we provide details on the data used in the paper. Section 3 provides background information on dengue. In section 4 we discuss the identification problem and introduce the estimation strategy. Section 5 provides and discusses the results and section 6 concludes.

2 Background

Dengue fever is a viral infection transmitted by *Aedes* mosquitos and is endemic in as many as 100 countries in the tropics and subtropics, putting more than half of the world's population at risk of infection. With global warming, the dengue vector is now rapidly expanding its habitat, leading to infections in previously unaffected areas, including the south of the United States, France, Greece, Spain, Portugal and Croatia (Ebi and Nealon (2016). Symptoms of dengue infections vary widely, ranging from subclinical infections, where individuals have no symptoms and are unlikely aware of their infection, to severe infections with flu-like symptoms, including high fever, severe headache, muscle and joint pain, nausea, vomiting, and skin rash lasting 1-2 weeks. There are currently several serotypes of the virus (DENV-1, DENV-2, DENV-3, and DENV-4) causing dengue and circulating in the population. As infection with one strain is believed to lead to lifelong immunity to the same strain, but only temporal and partial immunity to other serotypes, the prevalence of the different serotypes varies with immunity levels in the population. Subsequent infection with a different dengue strain is associated with an increased risk of developing severe dengue complications (Murugesan and Manoharan (2020)), including *dengue hemorrhagic fever*, a rare but potentially life-threatening complication from dengue infections. Regular dengue has a relatively low mortality rate compared to other tropical infectious diseases such as malaria or yellow fever, contributing to dengue being considered a neglected tropical disease. Severe dengue carries a mortality risk of approximately 4% (Andrioli et al. (2020)). Because of lower exposure to previous strains, the incidence of severe dengue is much smaller for younger populations, but the lack of immunity also increases the chances of first-time infection. In our sample of secondary school students, only 0.3% of all dengue cases are severe dengue, compared to an estimated incidence of severe dengue of 5% of all cases in the general population (Centers for Disease Control and Prevention (2021)). After the re-occurrence of dengue fever in Brazil in the 1990s, dengue became a notifiable disease, where every known case is recorded by public health authorities. Since the re-occurrence, Brazil has developed one of the largest vector control programs in the world, which includes targeted information campaigns, the application of insecticides in household water tanks, fumigation of affected urban areas, and improvements of waste collections to remove breeding opportunities.

3 Data

Estimating the effect of individual health shocks on schooling outcomes requires data linking various measures of educational attainment with information on health shocks at the individual level. In this paper, we focus on health shocks from infections with dengue fever, requiring detailed information on dengue infections of young people linked with schooling records. We have access to such linked administrative records for the universe of secondary school students in state schools in Minas Gerais. We describe the individual datasets below.

3.1 Schooling outcomes

Schooling records come from the *Brazilian School Census* (Censo Escolar, in Portuguese). The Brazilian School Census is based on an annual collection of individual, classroom and school characteristics across all Brazilian schools. In this paper, we focus on students in state secondary schools in the state of Minas Gerais, providing us with a more homogeneous student body. The school census contains extremely detailed information on the physical infrastructure of schools and classrooms, such as quality of premises and equipment available. Individual student records provide basic information on the age, sex and race of students. Information on schools, classrooms, and individual students are identified by unique identifiers, allowing us to link students to classrooms and schools, enabling us to link students to information collected on subject teachers, such as age, sex, educational background, specializations and training of teachers. The school census collects a range of measures of school success in a second collection at the end of the school year. They include information on whether the student has dropped out during the school year, which we name *dropout*. The second collection also includes information on an important educational outcome, whether the student is retained in the same grade in the following year, which we denote *Retention*. This happens either because students fall below a minimum attendance requirement or at the discretion of the school with regards to the student missing learning targets for the grade. Panel B of Table 1 reports the fractions of students in secondary school who pass or are retained in the same the grade or drop out of school by grade. We drop from the sample the small number of students who during the year, migrated out of the state or moved to private schooling. Focusing on the sample without dengue infections reveals that 18%, 10% and 8% of students are retained in the first, second, and third year of primary school, respectively. Likewise, we find that 11%, 8% and 5% drop out of school.

3.2 Dengue data

Information on dengue infections is based on official notifications of dengue fever cases from the *Notifiable Diseases Information System* (Sistema de Informação de Agravos de Notificação (SINAN), in Portuguese). Dengue fever is a notifiable disease, and every known case must be recorded in SINAN. SINAN also collects information on the individual and the infection, including on the date of notification and on the diagnosis, i.e., information on whether the dengue infection was diagnosed by clinical assessment through common symptoms such as fever, headache, nausea, rash, and the Tourniquet-Test[2] or through serological/virological dengue tests. Over the 2011-2017 period, the monthly average dengue incidence rate in Minas Gerais was 97 cases per 100,000 population, among the highest dengue incidence in the world (Zeng et al. (2021)). The incidence of dengue among secondary school students can be inferred from Table 1. We find that just over 1% of students get infected with dengue every year, with roughly similar incidence by grade, with several thousand students suffering from dengue every year. We find that students with dengue are more likely to be non-white and more likely to be in receipt of *Bolsa Família*–the Brazilian conditional cash transfer.

3.3 Temperature data

We complement our data with high-frequency temperature measures to use as controls in our regressions. These data come from the ERA5 reanalysis released by the *European Centre for Medium-Range Weather Forecasts* (ECMWF) as part of the *Copernicus Climate Change Services.* ERA5 provides hourly information on temperatures at 2 m altitudes for a grid with resolution 0.25×0.25 degrees. We create municipality-level averages by using the inverse-distance weighted average of all weather grid points within a 50 km range of the municipality centroid. We create two different measures, daily average temperature and daily maximum temperature to explore in more detail the effect of average versus extreme temperature as control variables. For the controls in our regressions, we create a count of days in 5 °C bands of daily average temperature starting with a lower bound of 10 °C and ending at the upper bound of 45 °C over the duration of the school year.

3.4 Information from Bolsa Família program

We complement the main data with information from register data on *Bolsa Família* as a proxy for socio-economic status. We record a household to be in receipt of *Bolsa Família* if the household is ever receiving the cash transfer. Approximately one-third of students are in receipt of the cash transfer, indicating a high dependency on welfare transfers among the group of state school students. For students whose families are in receipt of Bolsa Família, we also have information from the *Sistema Presença*on monthly school attendance. School attendance of these students is recorded as one of the conditionalities for receiving the cash transfer. Families of students that fall below 85% attendance in a given month are at risk of having their welfare transfer suspended. We

[2]This is a clinical diagnostic test that determines capillary fragility and hence a patient's hemorrhagic tendency, a common symptom of dengue. It forms part of the WHO algorithm for the diagnosis of dengue fever.

link the monthly attendance records of those students to their official school record and generate average attendance, as well as dummies taking a value 1 for students with integral attendance, and zero otherwise, both at the monthly and annual aggregation.

4 Identification Strategy

When estimating the effect of health shocks on educational outcomes, a simple regression using cross-sectional data is unlikely to provide unbiased estimates. This is because the risk of contracting dengue may be related to the socio-economic conditions at the local level. If these conditions are unobservable, it could lead to omitted variable bias. For example, areas with worse public services may have less efficient vector control efforts in place, resulting in a higher incidence of dengue. At the same time, other public services may also be of lower quality, for example, the provision of public education leading to failed inference. To address the identification issue, we make use of the rich administrative data for a period of 11 years, including detailed information on the residence and the schools attended by the students. This allows us to include both school and location fixed effects making use of the time dimension of the data. We estimate the following equation for outcomes Y_{ist}, for student i studying at school s in year t.

$$Y_{ist} = \alpha + \beta_t + \delta_s + dengue_{ist}\gamma_1 + X_{ist}\theta + \epsilon_{ist} \tag{1}$$

where Y_{igst} denotes the outcome variables, which include an indicator variable taking the value of 1 if the students are approved and move to the next grade and 0 otherwise, and equivalent indicators for retention and dropout. X_{ist} is a vector of covariates that include race, sex, age of students and grade, as well as their classroom characteristics such as the share of girls, black students and share of students above the appropriate target age for the grade. We also include year fixed effects, β_t, to take account of any systematic differences in the outcomes across years. All estimates include school fixed effects δ_s as students attending the same school tend to come from households with similar socio-economic background. Our key parameter of interest is the indicator variable, d_{igst} that equals 1 if the student has contracted dengue during the school year t. The identification strategy assumes that conditional on school and time fixed effects, dengue infections are as good as random. To probe the estimations further, we additionally include neighborhood fixed effects, controlling for the fact that students attending the same school may live in different neighborhoods, with different infection risk and socio-economic characteristics. As is now standard in the literature, we also separately include neighborhood specific time trends. Lastly, we also estimate specification including classroom FE. Students in secondary schools which are in the same 'class' are together with the same peers, but have lessons with different teachers, for example for math, Portuguese, physics, etc. Classroom FE hence control for any classroom specific factors, for example teacher specific shocks, and hence also control for a potential dengue infection of teachers. In further specifications, we also include temperature controls. High temperatures have been linked to worse school outcomes in the literature (Park et al. (2020)). Because temperature may also affect the reproduction and survival of the dengue vector (Campbell et al. (2013)), temperature controls will allow us to test for the role of temperature in the relationship. For the weather controls, we include counts of the number of days over the school year with temperatures between 10-15, 15-20, 20-25, 25-30, 30-35, and higher than 35. Robust standard errors are clustered at the school level.

5 Results

5.1 Main estimates

We present the main results in Table 2. We start in column (1) with the estimates including just school and year fixed effects without controls or additional fixed effects. In columns (2) - (8) we probe the results by including additional individual, classroom, and weather controls and a number of additional fixed effects. We start in Panel A with the outcome of passing the grade, i.e. students successfully completing the grade and enrolling in the next grade. We find that a dengue infection during the school year decreases the propensity for a student to pass this grade by 0.0084 percentage points, significant at the 1 percent level of significance. Compared to the baseline mean incidence of 0.7879), dengue leads to a 1 percent decrease in passing students. When including student level controls in column (2), the coefficient strengthens to 0.0116 percentage points or 1.5 percent decrease in approved students. The inclusion of additional classroom controls (column (3)), the weather controls (number of days with average temperature in 5 °C temperature bins in column (4) and the number of days with maximum temperature in the 5 °C temperature bins in column (5)), neighborhood fixed effects (column (6) and neighborhood fixed effects and neighborhood specific time trends (column (7), and additional classroom FE in column (8) leaves the coefficient virtually unchanged lending additional credibility to the identification strategy. The negative effect of dengue infections on passing the grade can either be caused by an increase in students dropping out of school or by an increase in students being retained in the same grade. To understand what drives the reduction in passing the grade, we separately look at grade retention and dropout in Panels B and C, respectively.

In Panel B, we start by estimating the effect of dengue on retention. In column (1), where we only include school and year fixed effects, we document an increase of 0.0044 percentage points in response to a dengue infection, significant at the 1 percent level of significance. Compared to the baseline mean incidence of 0.1268, this equates to a 3.5 percent increase in retention. When including student level controls in column (2), the coefficient strengthens to 0.0071 percentage points, or 5.6 percent increase in retention. Once again, we test the sensitivity of the estimates by the inclusion of additional classroom controls (column (3)), weather controls (columns (4) and (5)), neighborhood fixed effects (column (6) and neighborhood fixed effects and neighborhood specific time trends in column (7). In column (8), we provide the estimates when including classroom fixed effects. We find again that the inclusion of these additional fixed effects and controls leads to very similar estimates when compared to the coefficient from our preferred specification in column (3). Besides the negative consequences on the individual student, for example, by harming their confidence and removing the student from their established peer group, the effect on retention is economically meaningful as every year repeated by students reduces their lifetime earnings by one year, delaying their entry into the labor market, and directly adding to the demand for public education by increasing the student body in public schools for the year repeated leading to additional cost to the public purse.

In Panel C, we present the results for dropout. We find that dengue infections increase dropout significantly. Starting with a specification including school and year fixed effects, we find that a dengue infection leads to an increase in dropout of 3.9 percentage points, a 4.6 percent increase compared to the mean dropout incidence. The inclusion of controls also strengthens the coefficient slightly, but less so than for retention. Across the different alternative specifications, coefficients are very stable and range between 0.0031 and 0.0043, or a 3.6 and 5.1 percent when compared to the mean. The estimated impact of dengue on dropout is substantial and shows that health shocks, even when generally considered relatively mild and of transitory nature, can have drastic consequences for human capital accumulation. Taken together, the effects on dropout and retention indicate that dengue fever contributes substantially to school failure with the considerable negative consequences for students. Although grade retention can provide incentives for students to work harder (Foureaux Koppensteiner (2014)), the literature on grade repetitionn documents the negative effects of grade repetition on school completion, and other educational outcomes (Jacob and Lefgren (2009), Manacorda (2012). Likewise, the negative consequences of dropout have been widely documented, including on educational attainment, criminal involvement and underage fertility (Chuang (1997), Marcotte (2013), Bjerk (2012)) pointing to the high social cost of transitory health shocks to date overlooked in the literature.

To probe the robustness of the estimates and understand the underlying channel further, we engage in two additional exercises. First, we estimate the effect of dengue infections with a sample of children that get infected during the school year and drop observations with infections during December and January, which are the months between the school years. This allows us to rule out that the effects are driven by selection of individuals getting infected before the return of school. We present the estimates from this exercise in Panel A of Table 3 following the specification of column (3) in Table 2 including school and year fixed effects and controlling for student and classroom covariates. The effects on retention are almost identical to the previous estimates, whereas the effects on dropout are slightly smaller, but indistinguishable from the coefficients of the other specifications in Table 2. As a further exercise, we also estimate the effect of infections in the previous school years, enabling us to investigate the longer-term effects across academic years. This reduces the number of observations, as we both limit the cohort by one and also lose observations from the effect of contemporaneous infections. We present the results in Panel B of the Table. Using infections in the previous academic year, we find – as expected – a smaller effect on retention and dropout. Still the effect sizes are sizeable and statistically significant, with dengue in the previous school year increasing retention in the subsequent academic grade by 3.3 percent and increasing dropout by 3.7 percent compared to the mean.

Another concern to the interpretation of the estimates is related to the severity of dengue infections. As we are interested in transitory health shocks, we exclude all cases of severe dengue, as severe dengue may indicate longer-term effects on health making it difficult to interpret the effects from what we assume are transitory health shocks. As outlined in the data section, severe dengue is incredibly rare among children and adolescents, most likely due to the infection being their first exposure to the virus, which limits reinfection with differing dengue strains. To check whether our results hold for regular dengue, we exclude all severe dengue cases from the sample and re-estimate the effects on the schooling outcomes. We report the effects in Table 4 and compare the coefficients directly for the full sample and the sample without severe cases for our preferred specification. We find, unsurprisingly, given the very small number of severe dengue cases in this age group of 143, we find that the coefficients are virtually identical, confirming that the effects are not driven by a small sample of severe dengue cases.

Lastly, as a final test of our identification strategy, we engage in a placebo exercise. In Table 5, we regress future dengue infections (happening in the subsequent years) on retention and dropout. We do this by creating the lead of the indicator of dengue infections. By definition, future infections cannot affect present outcomes, and any significant coefficient would indicate a problem with the identification problem. Indeed, we find that the effect of the lead variable of dengue infections had a small, positive and insignificant effect on both, retention and dropout, providing extra credibility to our identification strategy.

5.2 Heterogeneous effects

In this section, we investigate the heterogeneous effects of dengue infections by characteristics of students and by grade. Starting with student characteristics, we focus on three categories. First, we estimate the effect separately by gender; second, by race (white–non-white); and finally by whether a family is in receipt of the cash transfer Bolsa Família. We report the estimates in Table 6.

We start with the estimates by gender in Panel A. We find that dengue infections have a much more pronounced effect for girls both for retention (with a coefficient of 0.0097, a 10.4 percent increase) and dropout (with a coefficient of 0.007, a 10.3 percent increase), whereas the coefficients for boys are much smaller and not statistically significantly different from zero. A formal test shows that the coefficients by gender are significantly different from each other. These effects show that health shocks can have different effects by gender, with girls being much more affected than boys.

Next, we stratify the sample by race, where we group self-declared race into white versus non-white, where non-white includes mixed, black, Asian and indigenous backgrounds, splitting the groups into roughly equal sizes. For retention, we find stronger effects for girls, but the difference is not statistically significant. We find the opposite for dropout, with stronger effects for non-white, but again, the difference is not statistically significant. These opposing effects may at least partially be explained by the interdependence between retention and dropout. With a larger increase in dropout for non-white students, mechanically the effect on retention for the same group will be more limited.

Next, in this exercise, we investigate the heterogeneous effects by recipient status of Bolsa Família. We find that the effect is stronger for non-recipient, when looking at retention, but stronger for dropout for recipients. Because the incidence differs substantially between the groups, when comparing the effect sizes a comparison to the mean is important. For example, the effect on retention for non-recipients of the cash transfer is about 6.5 percent compared to the mean incidence. The percent effect for dropout is 4.1 percent for Bolsa Família recipients and 4.2 percent for non-recipient, so basically identical across the groups.

As a second heterogeneity exercise, we estimate the effect on our outcomes separately by grade level. Secondary school in Brazil lasts for three years after which students either enter the labor market or apply for a university place. To learn whether the effects of dengue infections vary by grade, we estimate the effect of dengue on our outcomes separately by grade. We present the results in Table 7. Starting with passing the grade in Panel A, we find a smaller effect for first grade compared to second and third grade (-0.0087, compared to -0.0122 and -0.0118 in second and third grade, respectively). Possibly this is because a smaller fraction of students are promoted to the second grade, when compared to the other transition and graduation.

Next, we look at the effects for retention by grade in Panel B. We find a much smaller positive, but insignificant effect on retention for year 1 in column (1), while the effects are more pronounced for second and third year. We find a coefficient of 0.0105 for being retained in the second year, a 10 percent increase compared to the mean. In third year, because of the smaller baseline level of retention, the coefficient of 0.0081, equates also to a 10 percent increase compared to the mean.

Lastly, we look at the effect on dropout by grade in Panel C. We find the strongest in year one of secondary school, with an increase in dropout of 0.5 percentage points, or a 4.8 percent increase when compared to the baseline of 11 percent. The coefficient for second year is smaller, positive but insignificant. For third year, the effect is sightly smaller when compared to first year, but given the smaller incidence of dropout in third year of 5.3, the effect equates to an increase of 6 percent, the strongest relative effect by grade.

5.3 Effects on attendance

To understand better how dengue infections affect schooling success, we use additional attendance records for students receiving Bolsa Família to learn about the effect infections have on attendance. There are three caveats to this exercise. First, because we have information only for students in families receiving Bolsa Família, this limits the sample to just over 200,000 observations. Second, because the effect of dengue infections is likely different by Bolsa Família recipient status, as revealed in the heterogeneity analysis, the results are not necessarily representative for the full sample. Third, because monthly attendance is top coded at 85% (full attendance), this limits the real variation in attendance. We engage in two exercises. In the first exercise, we aggregate monthly attendance records at the annual level to estimate the effect a dengue infection during the school year has on attendance in the same year. In a second exercise, we make use of the more high frequency nature of the data and estimate the effects using the monthly attendance records and monthly exposure while including individual fixed effects. In column (1) of Panel A in Table 8, we report the coefficient using annual attendance, where we created a dummy for full attendance. We find that a dengue infection reduces full attendance by 1.3 percentage points, or by 1.5% when compared to the baseline, but the coefficient is only marginally significant. When using average attendance, we find a negative coefficient of about 10% (compared to the baseline), but the coefficient is not statistically significant. We repeat the exercise using the monthly attendance records. We find again a negative, insignificant, coefficient for average attendance, and a negative and marginally significant effect for the dummy attendance outcome (column (4)).

In Panel B of the table, we include the lagged variable of dengue infections to investigate the effect of attendance in the following months. We do this because a dengue infection may occur later in the month impacting attendance in the subsequent month. Across specification and outcome measures, we find that the lagged values have a negative effect on attendance (either dummy or average attendance), but none of the coefficients are statistically significant.

Taken together, these exercises provide some suggestive evidence that the negative effect on schooling outcomes may in part be due to the effect an infection has on school attendance, pointing to a possible underlying mechanism, but unfortunately, given the sample restrictions attendance records, the exercise is under-powered.

6 Final Remarks

In this paper we provide the first causal evidence on the devastating effects of dengue fever on the schooling outcomes of secondary school students in state schools in Minas Gerais, Brazil. Leveraging matched administrative data linking official dengue records with information from official school census records, we find that dengue infections during the school year lead to a substantial increase in grade retention among students. An infection with dengue increases the propensity for grade retention on average by 5 percent. An increase in the number of students repeating a grade is not only costly to individual students by reducing lifetime earnings and possibly contributing to dropout from school but also to tax payers, adding students to the school system by prolonging the duration spent in secondary schooling (Eide and Showalter (2001)). We also find a substantial increase in dropout from secondary school, with an average increase of just over 4 percent. Dropout from school has severe long-term consequences on a range of important outcomes, including labor market outcomes, health and crime (Campolieti et al. (2010), Rouse (2005), Anderson (2014)). With tens of thousands of secondary school-age children being infected with dengue every year in the state of Minas Gerais alone, the cost in terms of lost learning and on the educational system from repetition are substantial. The economic and societal costs from the increase in dropout are difficult to estimate, because of the many intangible costs to consider, but they add to the direct and indirect costs of grade retention.

The results in this paper are important for a range of public policies on dengue, as they point to severe negative consequences of dengue infections on schooling outcomes of secondary school students, previously ignored in the literature. The results particularly inform any decisions regarding the adoption and the targeting of novel and effective dengue vaccines. Recently, WHO recommended the adoption of a new dengue vaccine for children aged 6-16 in regions with high prevalence of dengue. Given our results, documenting the detrimental effect of dengue infections on secondary school students from the ages of 15-18, the extension to this age group would benefit a vulnerable group with a high incidence and particularly negative effect of infections on their human capital accumulation. The vaccination of this age group would reduce the incidence of grade retention and dropout substantially. Future cohorts will benefit from the earlier vaccination, preventing the negative effect on education. Similarly, although the analysis in this paper focuses on secondary school students, primary school students likely also suffer the negative effects of dengue on their education.

The evidence in this paper also contributes to the targeting of vector control activities, for example, the fumigation around schools to avoid infection during school hours. The free distribution of insect repellent at schools during dengue outbreaks may also help to reduce local transmission and should be considered by school authorities. Lastly, information campaigns in schools during dengue outbreaks may help to inform students and their parents about the negative consequences of dengue infections on their learning and about how to avoid infections from Aedes mosquitoes.

The results in this paper are also crucial for a broader understanding of the potential negative consequences of transitory health shocks, for example, from other infectious diseases, including COVID-19 and seasonal flu, for which there is currently no evidence. Given the scale of school failure in Brazil–it is estimated that only 50 percent of students who start primary school will complete secondary education–the paper also sheds light on previously unknown contributors to school failure, transitory health shocks to students. Reducing the incidence of avoidable health shocks, as in this case dengue, provides one mechanism to also reduce school failure and the associated waste in education. According to some estimates, school failure causes costs of R$ 30 billion, roughly $ 6 billion annually, equivalent to 20% of public expenditure to education and understanding contributing factors may help to reduce school failure.

Table 1: Fraction of students who pass, are retained or drop-out by infection status

Panel A:

	With Dengue				Without Dengue			Total
	Pass Obs	*Retention*	*Dropout*	Total	*Pass* Obs	*Retention*	*Dropout*	
First Year	15,600	4,734	2,655	22,996	1,383,870	338,921	213,072	1,936,343
Second Year	14,402	2,301	1,446	18,152	1,202,205	148,021	115,289	1,465,824
Third Year	12,698	1,501	861	15,068	1,047,963	95,985	63,666	1,207,873
Total	42,700	8,536	4,962	56,216	3,634,038	582,927	392,027	4,666,256

Panel B:

	With Dengue				Without Dengue			
	Pass (%)	*Retention*	*Dropout*	Total	*Pass* (%)	*Retention*	*Dropout*	Total
First Year	67.84	20.59	11.55	1.17	71.47	17.50	11.00	98.83
Second Year	79.34	12.68	7.97	1.22	82.01	10.1	7.87	98.78
Third Year	84.27	9.96	5.71	1.23	86.77	7.95	5.27	98.77

Panel C:

	With Dengue				Without Dengue		
Bolsa Família	Obs	%	Total	Bolsa Família	Obs	%	Total
Yes	17,072	30.37	56,216	Yes	1,333,977	28.94	4,610,040
No	39,144	69.63	56,216	No	3,276,063	71.06	4,610,040

Panel D:

	With Dengue				Without Dengue		
Age Group	Obs	%	Total	Age Group	Obs	%	Total
<16	6,940	12.35	56,216	<16	646,205	14.02	4,610,040
16	14,995	26.67	56,216	16	1,257,642	27.28	4,610,040
17	18,388	32.71	56,216	17	1,420,272	30.81	4,610,040
18	11,088	19.72	56,216	18	847,556	18.39	4,610,040
>18	4,805	8.55	56,216	>18	438,365	9.51	4,610,040

Panel E:

	With Dengue				Without Dengue		
Race	Obs	%	Total	Race	Obs	%	Total
White	20,053	35.67	56,216	White	1,808,609	39.23	4,610,040
Non-White	36,163	64.33	56,216	Non-White	2,801,431	60.77	4,610,040

Panel F:

	With Dengue				Without Dengue		
Gender	Obs	%	Total	Gender	Obs	%	Total
Female	31,204	55.51	56,216	Female	2,470,237	53.58	4,610,040
Male	25,012	44.49	56,216	Male	2,139,803	46.42	4,610,040

Notes: The table includes the number of students who caught dengue during the academic year per grade and the proportion of students who caught dengue and is retained in the same grade or dropped out from school.

Table 2: Main results: Effect of contracting dengue on academic achievement

	Panel A: *Pass*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dengue	-0.0084***	-0.0116***	-0.0106***	-0.0109***	-0.0109***	-0.0095***	-0.0112***	-0.0108***
	(0.0019)	(0.0018)	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0017)	(0.0016)
Mean dep. var.	0.7879	0.7879	0.7879	0.7879	0.7879	0.7879	0.7879	0.7879
R-squared	0.0000	0.1413	0.1547	0.1548	0.1548	0.1508	0.1524	0.0789
	Panel B: *Retention*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dengue	0.0044***	0.0071***	0.0068***	0.0071***	0.0071***	0.0063***	0.0073***	0.0068***
	(0.0016)	(0.0016)	(0.0016)	(0.0016)	(0.0016)	(0.0015)	(0.0015)	(0.0015)
Mean dep. var.	0.1268	0.1268	0.1268	0.1268	0.1268	0.1268	0.1268	0.1268
R-squared	0.0000	0.0412	0.043	0.0431	0.0431	0.0413	0.0427	0.0219
	Panel C: *Dropout*							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dengue	0.0039***	0.0043***	0.0036***	0.0037***	0.0037***	0.0031***	0.0038***	0.0039***
	(0.0013)	(0.0012)	(0.0012)	(0.0012)	(0.0012)	(0.0011)	(0.0012)	(0.0011)
Mean dep. var.	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
R-squared	0	0.1093	0.1236	0.1236	0.1236	0.1213	0.1205	0.0609
Students controls	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Classroom controls	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Weather	No	No	No	No	Yes	No	No	No
Weather max	No	No	No	Yes	No	Yes	Yes	Yes
School/Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighbourhood FE	No	No	No	No	No	Yes	Yes	No
Neighbourhood X Year FE	No	No	No	No	No	No	Yes	No
Classroom FE	No	No	No	No	No	No	No	Yes
Obs	4,666,256	4,666,256	4,666,256	4,666,256	4,666,256	4,666,256	4,666,256	4,656,483

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. In parentheses, robust standard errors clustered at the school level (Columns 1 to 5) and at the neighborhood level (Columns 6 and 7). The analysis includes students in the 1^{st}, 2^{nd} and 3^{rd} years of secondary school, over the period of 2007 to 2017. Explanatory variable Dengue is a dummy that equals 1 if the student had dengue during the academic year and 0 otherwise. Dependent variables retention and Dropout are dummy variables that equal 1 if the student is retained in the grade or dropped out from school respectively. All regressions include time and school fixed effects. Equation 7 includes Neighborhood X Time fixed effects. Our preferred models are in Column 4. Controls include individual characteristics, and classroom composition. Individual controls are age, sex, race and grade. Classroom controls are share of black students, share of girls and share of students above the appropriate age. Temperature bins with count of days with max temp 10-15; 15-20; 20-25; 25-30;30-35;35-40;40-45.

Table 3: Robustness Checks

	Panel A: Academic months	
	retention	*Dropout*
Dengue	0.0072***	0.0035***
	(0.0015)	(0.0011)
Mean dep. var.	0.1268	0.085
Observations	4,666,256	4,666,256
Controls	Yes	Yes
School/Year	Yes	Yes
	Panel B: Previous year	
	Retention	*Dropout*
Dengue	0.0036**	0.0030**
	(0.0017)	(0.0015)
Mean dep. var.	0.109	0.082
Observations	2,395,779	2,395,779
Controls	Yes	Yes
School/Year	Yes	Yes

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. Controls, FE and cluster follow our preferred specification. In Panel A, Dengue is a variable that equals 1 if the student caught Dengue during the academic months, i.e., excluding December and January, and 0 otherwise. In Panel B, Dengue equals 1 if the student caught Dengue in the previous year.

Table 4: Robustness Checks: Results without Severe Dengue Cases

	(1)	(2)	(3)	(4)	(5)	(6)
	Pass		*Retention*		*Dropout*	
Dengue	-0.0109***	-0.0108***	0.0071***	0.0070***	0.0037***	0.0037***
	(0.0017)	(0.0017)	(0.0016)	(0.0016)	(0.0012)	(0.0012)
Mean dep. Var	0.7879	0.7879	0.1268	0.1268	0.085	0.085
Observations	4,666,256	4,666,113	4,666,256	4,666,113	4,666,256	4,666,113
Severe Cases Obs.	143	0	143	0	0	143
R-squared	0.1548	0.1548	0.0431	0.0431	0.1236	0.1236

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. Controls, FE and cluster follow our preferred specification. Columns 1, 3 and 5 are the baseline results for each of the three dependent variables. Columns 2, 4 and 6 refer to the estimations without severe dengue cases for each outcome.

Table 5: Placebo Test using Dengue Leads

	(1) *Retention*	(2) *Dropout*
Dengue	0.0023	0.0008
	(0.0018)	(0.0010)
Mean dep. var.	0.1268	0.085
Observations	2,395,782	2,395,782
Controls	Yes	Yes
School/Year	Yes	Yes

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. Controls, FE and cluster follow our preferred specification. Dengue is a variable that equals 1 if the student caught Dengue in the year after, i.e., the lead variable of dengue.

Table 6: Heterogeneity Analysis

	Panel A: By gender			
	Retention		*Dropout*	
	(1)	(2)	(3)	(4)
	Female	Male	Female	Male
Dengue	0.0097***	0.0039	0.007***	0.0002
	(0.0019)	(0.0025)	(0.0015)	(0.0018)
Mean dep. var.	0.093	0.1656	0.068	0.104
Female - Male	0.0058**		0.0068***	
Test [p-value]	[0.0510]		[0.0041]	
Obs	2,501,441	2,164,815	2,501,441	2,164,815
R-squared	0.0293	0.0344	0.1047	0.1349
	Panel B: By race			
	Retention		*Dropout*	
	(1)	(2)	(3)	(4)
	White	Non-white	White	Non-white
Dengue	0.0089***	0.0059***	0.0031*	0.0041***
	(0.0024)	(0.0019)	(0.0018)	(0.0015)
Mean dep. var.	0.1083	0.1386	0.073	0.093
White-Non-white	0.0033		-0.001	
Test [p-value]	[0.3287]		[0.6964]	
Obs	1,828,656	2,837,593	1,828,656	2,837,593
R-squared	0.0396	0.0435	0.1248	0.121
	Panel C: By Bolsa Família			
	Retention		*Dropout*	
	(1)	(2)	(3)	(4)
	Receive	Don't receive	Receive	Don't receive
Dengue	0.0003	0.0079***	0.0043**	0.0032**
	(0.0026)	(0.0016)	(0.0022)	(0.0013)
Mean dep. var.	0.1409	0.1209	0.1054	0.077
Obs	1,351,049	3,315,207	1,351,049	3,315,207
R-squared	0.0038	0.0025	0.1156	0.0695
Controls	Yes	Yes	Yes	Yes
School/Year FE	Yes	Yes	Yes	Yes

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. Controls, FE and cluster follow our preferred specification.

Table 7: Results by Grade

	Panel A: *Pass*		
	(1)	(2)	(3)
	First Year	*Second Year*	*Third Year*
Dengue	-0.0087***	-0.0122***	-0.0118***
	(0.0029)	(0.0030)	(0.0031)
Test (1)=(2) [pv]		[0.4126]	
Test (1)=(3) [pv]		[0.5117]	
Test (2)=(3) [pv]		[0.9392]	
Mean dep. var.	0.7143	0.8198	0.8673
Obs	1,959,339	1,483,975	1,222,937
R-squared	0.1679	0.1292	0.065
	Panel B: *Retention*		
	(1)	(2)	(3)
	First Year	*Second Year*	*Third Year*
Dengue	0.0034	0.0105***	0.0081***
	(0.0028)	(0.0027)	(0.0027)
Test (1)=(2) [pv]		[0.0738]*	
Test (1)=(3) [pv]		[0.2873]	
Test (2)=(3) [pv]		[0.5348]	
Mean dep. var.	0.1754	0.1013	0.0797
Obs	1,959,339	1,483,975	1,222,937
R-squared	0.0357	0.0275	0.0163
	Panel C: *Dropout*		
	(1)	(2)	(3)
	First Year	*Second Year*	*Third Year*
Dengue	0.0053***	0.0017	0.0034*
	(0.0019)	(0.0020)	(0.0019)
Test (1)=(2) [pv]		[0.2073]	
Test (1)=(3) [pv]		[0.4944]	
Test (2)=(3) [pv]		[0.5388]	
Mean dep. var.	0.1101	0.0787	0.0528
Obs	1,959,339	1,483,975	1,222,937
R-squared	0.1456	0.1139	0.0563
Controls	Yes	Yes	Yes
School/Year	Yes	Yes	Yes

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. Controls, FE and cluster follow our preferred specification. [Pv] corresponds to the p-value from the test between coefficients.

Table 8: Effects of Dengue on Attendance

Panel A: Effects of dengue on attendance

	(1)	(2)	(3)	(4)
	School FE		Students FE	
	Attendance	Average	Average	Attendance
Dengue	-0.0131*	-0.0934	-0.0171	-0.0091*
	(0.0082)	(0.2199)	(0.3567)	(0.0051)
Mean dep. Var	0.8881	96.56	96.56	0.9639
Observations	237,714	237,714	1,000,602	1,000,602
R-squared	0.0225	0.0339	0.0002	0.0002

Panel B: Effects of dengue one month prior on attendance

	(1)	(2)	(3)	(4)
	Students FE			
	Attendance	Attendance	Attendance	Attendance
Dengue Lagged	-0.1882	-0.1899	-0.0066	-0.0055
	(0.4074)	(0.3897)	(0.0055)	(0.0053)
Dengue	0.016		-0.01*	
	(0.4254)		(0.0062)	
Mean dep. Var	96.56	96.56	0.9639	0.9639
Observations	835,296	835,296	835,296	835,296
R-squared	0.0003	0.0003	0.0002	0.0002

Notes: $*p < 0.1, **p < 0.05, ***p < 0.01$. Controls, FE and cluster follow our preferred specification. Attendance is a dummy variable that equals 1 if the student had 100% attendance during the academic year and 0 otherwise. Panel A presents the effects of dengue on attendance. In Column 1, Attendance is a dummy variable and equals 1 if the student has full attendance in the academic year; in Column 2, Average attendance is the mean of the students' attendance during the academic year. In Column 3, we use attendance per month, and in Column 4, Attendance is a dummy that equals 1 if the student received full attendance in the month. In these latter two columns, we use students, month and year fixed effects. Panel B repeats Columns 3 and 4 from Panel A, but using attendance as a dummy taking 1 if full attendance in a given month and the student caught dengue one month prior. In Panel B, we use students, month and year fixed effects.

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