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The impact of a malaria elimination initiative on school outcomes: Evidence from Southern Mozambique

Laia Cirera [a], Judit Vall Castelló [b,c], Joe Brew [a,d], Francisco Saúte [e], Elisa Sicuri [a,f,*]

[a] ISGlobal, Hospital Clínic - Universitat de Barcelona, Barcelona, Spain
[b] Department of Economics & Institut D'economia De Barcelona (IEB), Universitat de Barcelona, Spain
[c] Centre for Research in Health and Economics (CRES), Universitat Pompeu Fabra, Barcelona, Spain
[d] Vrije Universiteit, Amsterdam, The Netherlands
[e] Centro de Investigação em Saúde de Manhiça (CISM), Manhiça, Mozambique
[f] LSE Health, Department of Health Policy, London School of Economics and Political Science, London, UK

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A B S T R A C T

Despite the significant improvements achieved over the last ten years, primary education attainment in Mozambique is still low. Potential reasons acting from the demand perspective include ill health, among other factors. In Mozambique, ill health is still largely linked to malaria, which is a leading cause of outpatient contacts, hospital admissions and death, particularly among under-five and school-aged children. Despite this, in Mozambique and more generally, in malaria endemic countries, the identification and measurement of how improved malaria indicators may contribute to better school outcomes remains largely unknown. In particular, there is a low understanding of the extent to which better health translates immediately into school indicators, such as absenteeism and grades. In this study, we exploit the first year of a malaria elimination initiative implemented in Magude district (Southern Mozambique) that started in 2015, as a quasi-experiment to estimate the impact of malaria on selected primary school outcomes. While malaria was not eliminated, its incidence drastically dropped. We use as control a neighbouring district (Manhiça) with similar socio-economic and epidemiological characteristics. By employing a difference-in-differences (DiD) approach, we examine whether the positive health shock translated into improved school outcomes. Using information from school registers, we generated a dataset on school attendance and grades for 9,848 primary-school students from 9 schools (4 in the treated district and 5 in the control district). In our main specification, a repeated cross-section analysis, we find that the elimination initiative led to a 28% decrease in school absenteeism and a 2% increase in students' grades. Our results are robust across different specifications, including a panel DiD individual fixed effects estimate on a sub-sample of students. These findings provide evidence on the negative impact of malaria on primary education attainment and suggest remarkable economic benefits consequent to its elimination.

1. Introduction

Despite the substantial improvements achieved over the past decade, malaria remains one of the leading causes of mortality and morbidity in the World Health Organization (WHO) African Region, accounting for 94% of global malaria cases (World Health Organization, 2020). Children are at highest risk of contracting the infection and carry most of the disease burden. If not promptly diagnosed and treated, the infection can turn into severe or cerebral malaria leading to long-term disability or death (Carneiro et al., 2010; World Health Organization, 2020). The malaria toll goes far beyond its impact on health. At the aggregate level, an influential work provided early evidence on the contribution of malaria to reduced economic growth in endemic countries (Gallup and Sachs, 2001). More recently, the impact of malaria has been identified and measured on other development indicators such as fertility, acting through child mortality (McCord et al., 2017).

At the individual level, there are several channels through which malaria affects economic growth and development, one of the most important being the constraint it imposes to skills acquisition throughout life due to reduction in cognitive ability and school attainment (Cutler et al., 2010; Sachs and Malaney, 2002). In economics, the identification of such channels has been boosted by an extensive

* Correspondence to: ISGlobal, Hospital Clínic - Universitat de Barcelona, Rosselló 132, Barcelona 08036, Spain.
E-mail address: elisa.sicuri@isglobal.org (E. Sicuri).

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biomedical and epidemiological literature pointing to childhood malaria as a significant contributor to long-term low cognitive performance (Holding and Snow, 2001; Kihara et al., 2006). More precisely, the contribution of malaria to children's poor cognitive outcomes starts before birth, during mothers' pregnancy, when malaria worsens maternal anaemia, impeding in utero nutrition and limiting the new-born's cognitive development later in life (Lozoff and Georgieff, 2006). Cerebral malaria in early childhood has also been seen associated with increased cognitive impairments lasting up to nine years after disease onset (Boivin et al., 2007; Carter et al., 2005; Idro et al., 2010; John et al., 2008). Even in the absence of a severe manifestation of the infection, prolonged and repeated malaria attacks can deteriorate children's cognitive performance in the short term and up to 6 years follow-up (Fernando, et al., 2003a, 2003b, 2003c). While most studies are observational, a few randomized controlled trials (RCTs) provided evidence on the causal impact of childhood malaria preventive interventions on educational and cognitive outcomes, both in the short-term (Clarke et al., 2008, 2017; Fernando et al., 2006) and at 15 years intervention follow-up (Jukes et al., 2006).[1]

The abundant bio-medical evidence has motivated several economic studies which have assessed long-term impacts of childhood exposure to malaria on economic outcomes through retrospective (historical) studies applied to secondary data and by using health shocks, mainly eradication campaigns from the Global Malaria Eradication Programmes (1955–1969), as exogenous sources of variation in exposure. Specifically, this literature exploited malaria intensity variation across country regions prior to the start of the campaigns as well as variation in exposure of cohorts born before and after the malaria eradication programs took place. By employing such a strategy, Lucas (2010) found that in Paraguay and Sri Lanka, malaria eradication campaigns significantly improved educational attainment; Shih and Lin (2018) also found a sharp increase in education attainment for men and married women as a result of the Taiwan's eradication campaign; and in south-western Uganda, Barofsky et al. (2015) found a positive impact of the campaign on primary school completion.

Contrarily, other similar studies found less clear evidence on educational outcomes. This is the case of Cutler et al. (2010) and of Venkataramani (2012), both finding a suggestive, but not determinant impact of the eradication campaigns on education attainment in India and Mexico, respectively. By using a different identification strategy, namely variation in temperature as an instrument for malaria exposure in the United States, Barreca (2010) assessed that in utero exposure to malaria leads to low education attainment and decreased income levels in adulthood.

The impact on educational attainment remains, therefore, puzzling. As it was hypothesised by Bleakley (2010), substantial drops in malaria transmission or even the elimination of malaria, while preserving children's cognitive ability, may not always lead to school attainment improvements. In areas with high poverty levels and a high prevalence of low-skilled jobs, the effect of improved childhood health may favour the decision to work rather than to study. In such contexts, and if labour is regulated and fairly paid, disease elimination could boost long-term income and wealth even without improving schooling attainment.

In order to reply to this doubt, it is key to understand whether health improvements due to a substantial decrease in malaria translate into immediate improved school indicators. The above-mentioned economic studies were unable to look at short-term schooling indicators given their historical perspective.

The present study aims to investigate the contribution of malaria reduction to immediate education attainment, namely school attendance and grades, by using the first-year of a malaria elimination initiative in Southern Mozambique, the *Magude Project* (Aide et al., 2019), as a natural experiment. Given that the initiative only took place in the Magude district, we exploit variation in selected outcomes across time between this district and a neighbouring district not subject to the intervention (Manhiça district) to estimate the causal effects of the initiative on school outcomes.

In Mozambique, despite the remarkable improvements in enrolment rates over the last 20 years, primary educational attainment is still poor, with retention and completion rates as low as 20% (Fox et al., 2012). Such low performance is the result of supply side inefficiencies, including lack of qualified teachers and basic infrastructure. Factors acting from the demand side also play a considerable role, including families' lack of liquidity to pay for school supplies and the lack of expected benefits from a labour market still dominated by low skill jobs, particularly in rural areas (Sparreboom and Staneva, 2015). Ill health is a further and largely unexplored cause of low school attendance in the context of Mozambique. Importantly, Mozambique, one of the poorest countries in the world, is characterised by the presence of child labour (Salvucci et al., 2019). In addition to working outside the house, either routinely or sporadically, children, particularly girls, are a fundamental support at home for housekeeping tasks and for looking after their younger siblings.

With the available data, we are unable to assess the contribution of the initiative on choice between work inside and outside the family, and school (and on children time use in general). However, this study focuses on the impact on one element of that choice only, that is on school presence and grades, and may provide key evidence for a better understanding of the effect of improved childhood health on household's preferences and choices.

In addition, this study may provide key evidence on the short-term mechanisms through which malaria impacts economic outcomes in the long term.

Our manuscript differs from the previous economic studies for the ensuing reasons. To estimate the impact of the *Magude Project*, we gathered unexplored data from schools' registers, which we were able to verify and digitalise on site. While our main identification is cross-sectional —due to the highly unbalanced structure of our panel—, we also estimated panel difference-in-difference regressions on sub-samples of children and controlled for key time invariant non-observed characteristics (i.e. individual fixed effects) such as students' ability and motivation, which are substantial determinants of school outcomes (Boissiere, 2004). In contrast to the eradication campaigns of the '60s, in which only interventions targeting communities as a whole were employed (e.g., indoor residual spraying), the *Magude Project* also included a pharmacological preventive intervention administered to each eligible individual in the treated district (i.e. the mass drug administration — MDA). While we do not know MDA specific uptake among school children, an overall MDA adherence rate of 83% (Galatas et al., 2020b) suggests that our results reflect a "treatment on the treated" rather than an "intention to treat" estimation approach. Finally, we employed a sample of more than 9,800 primary-school students, making our estimates generalisable to other community-wide efforts towards malaria elimination implemented in similar contexts.

In addition, we analysed the contribution of school attendance (as an intermediate outcome) to school grades (as a final outcome). In particular, we were able to disentangle, at least in a subgroup of diligent students, the short-term mechanisms that are likely to affect grades. Specifically, a reduction in malaria incidence could affect students' performance in the short term through two main channels: 1) by increasing the quantity of time spent at school, which, mechanically,

[1] There are other recent papers assessing the impact of other types of policy interventions, such as conditional cash transfers, on educational outcomes in South African setting (see, for example, (Mostert and Vall Castello, 2020).

increases the amount of knowledge received[2]; 2) by improving the health status of students and their capacity to better assimilate and store knowledge, therefore, the quality of time spent at school is enhanced. The latter point represents the fact that with good or improved health, students' capacity to learn, should also improve and work at its full, which would result in better school performance, irrespective of a reduction in absenteeism (i.e., a child at school with no fever can learn more than a child at school with fever, irrespectively of the baseline cognitive abilities). While we consider cognitive ability as time-invariant in the short-term, the capacity to assimilate and store knowledge is time-variant, can be observed in the short-term and depends on children's current health status.

Our results show that, consequent to the elimination initiative, which significantly reduced malaria incidence in the treated district (Galatas et al., 2020b), school absenteeism decreased by 28%. We also find a significant positive impact on school performance, both when using grades as a continuous variable (mean grade) and as a discrete variable (probability of passing the exams). While the malaria elimination initiative has an independent and significant impact on both students' attendance and performance, we demonstrate the contribution of the former on the latter. Our findings remain unaltered to a series of robustness checks that account for potential selection and confounding effects.

2. Material and methods

2.1. Malaria elimination in Mozambique

Mozambique ranks fourth in the world in terms of number of malaria cases, after Nigeria, Democratic Republic of Congo and Uganda (World Health Organization, 2020). In the 1960s, malaria control efforts were intensified in the south of the country, and although significant reductions of malaria prevalence were achieved, elimination was not achieved (Aide et al., 2019). Within the context of a renewed attention towards malaria elimination in the Southern Africa region (Maharaj et al., 2016), in 2014 a new initiative was funded to design and implement a program to support the National Malaria Control Program to accelerate towards malaria elimination in southern Mozambique.

The program started by generating evidence through a pilot project in the district of Magude, Maputo province (Fig. A1). The implementation package in phase I consisted in strengthening the malaria surveillance system, maximizing bed net ownership, and deploying a universal indoor residual spraying (IRS) round before the rainy season (August 2015), followed by two monthly MDA rounds. MDA constituted the novel intervention, as it employed an antimalarial drug not used in the country prior to the initiative and it targeted the whole population, with door-to-door distribution (see Galatas et al. (2020b)) for a full description of the initiative). A similar package of interventions was implemented one year later (phase II).

The effectiveness of the initiative was evaluated by employing an interrupted time series model (Galatas et al., 2020b). Results showed that the *Magude Project* led to a significant reduction in prevalence and incidence in phase I and gains were sustained over phase II (reduction in malaria infection prevalence and case incidence over phase I and II by 84.7% and 65.6%, respectively). Findings from phase I evaluation (a 71.3% reduction in malaria prevalence) have been confirmed, even if to a lower extent, by another study which has applied the synthetic control method on data from 17 neighbouring districts (Thomas et al., 2021).

2.2. Data

In order to identify the effects of the initiative on school outcomes, we created a novel dataset containing individual level data from primary school children, aged between 6 and 12 years. By using information provided by the Ministry of Education (Table 1), we randomly selected 5 public schools from Magude and 4 from Manhiça, based on the probability proportional to size sampling approach, according to which higher probability of selection is assigned to higher size clusters, larger schools in our case (see Fig. 1). Due to resource constraints we could not afford including a higher number of schools. Within each school, all children enrolled during the academic years 2015 and 2016 were included in the database. The socioeconomic characteristics of all primary school age children in the treated and control districts, not only those included in our database, are similar (Table 2). Socio-demographic data were gathered from the Demographic Surveillance Systems of Manhiça (Sacoor et al., 2013) and Magude (Galatas et al., 2020a).

Information on school outcomes was gathered from school attendance register books and consisted of students' daily absenteeism as well as routine end of term examinations.[3] Information was digitilised through pictures taken page by page from the paper registries and then entered in a central database.[4] Examples of original data taken from schools' registers are presented in Fig. A2 and A3.

The delivery of phase I interventions, including one round of IRS (August 2015) followed by two rounds of MDA, concluded early February 2016; accordingly, school data covers the period from one academic year prior to the MDA implementation inception (February to October 2015) to the whole academic year after (February to October 2016). There is no data for November, December and January, as those are holiday months (see Fig. A4).

Our final sample included information on school outcomes for 2,761 students in the treatment area and 7,087 students in the control area. The uneven number of students between treatment and control areas reflects the larger population of the latter in comparison to the former. In both areas, the number of students included in the study corresponds to about 20% of total children aged 6–12 years censed (see Table 2). For each student, the daily absenteeism is a binary variable, for the eligible schooldays (excluding weekends and public holidays), that takes the value 0 –if the student is present– or 1 –if the student is absent. Grades are measured each trimester, on a scale from 0 to 20, for each of the following subjects: natural sciences, social sciences, maths, music, physical education, Portuguese (language) and visual education. Teachers are responsible for grading each student based on individual tests, which are uniform across all schools in the country. Table 3 shows the means of the outcome variables of interest: absenteeism (Panel A)

Table 1
Public Primary schools and enrolled students in control and treatment districts, 2015.

Variables	Manhiça (control)	Magude (treatment)
Number of primary schools	96	63
Number of enrolled students	36,753	10,865
% female students	49%	48%
Average number of students per school	383	172

[2] Knowledge is understood as the acquisition of basic concepts learnt at primary-school level and reflected in the end of term grades (short-term). In this context, we believe that increasing the time spent at school, makes a difference and translates, on average, into increased knowledge.

[3] This information is part of the routine indicators that schools need to report to the District Government on a regular basis. As such, the District Government agents perform regular visits to the schools to undertake data quality checks and provide support with the register books.

[4] We used a team of 10 data entry clerks and the Open Clinica open source software for the digitalisation process. Double manual entry was performed, which is still considered as the gold standard of good clinical practice for data from collected paper forms.

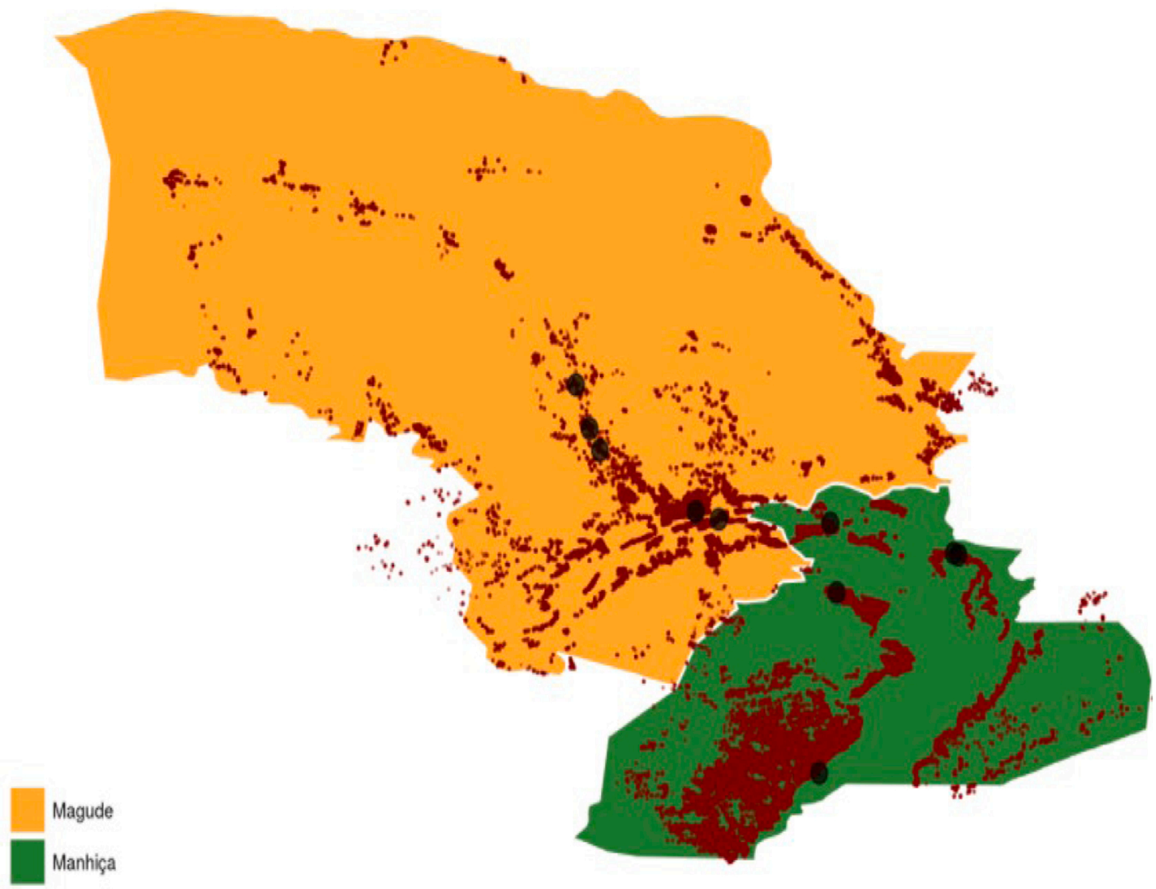

Fig. 1. Schools' location in the districts of Magude (intervention) and Manhiça (control), Notes: Map of selected schools from Magude (in orange) and Manhiça (in green) districts. The black dots represent the schools' locations within each district. The red dots are the households' geolocation identified in the 2015 demographic census.

and grades for all subjects (in Panel B) for the treatment and control areas, before and after the intervention. Absenteeism was higher in the treatment area before the intervention and this gap disappeared once the intervention took place. Similarly, average grades were lower in the treatment area before the intervention but overpass those in the control area after the intervention.[5]

Attrition in our database was consequent to: 1) students' mismatching over time (the match was based on students' names and surnames as recorded in the attendance books); 2) to students' dropout rates or 3) to inaccuracies in the management of the registries. Therefore, our panel is unbalanced, and we treat data as repeated cross-sections in our main analysis. In the annex (Table A1) we provide further details regarding the sample's structure and design and in the robustness checks section we further explore issues related to potential sample selection.

Table 2
Summary statistics on socioeconomic characteristics of all primary school-age children in treated and control districts in 2015 (pre-intervention period).

Variables	Manhiça (control)		Magude (treatment)	
	mean	SD	mean	SD
Socioeconomic characteristics				
age	9.9	2	9.7	2
number siblings / household	4.3	2.3	4.8	2.8
average household size	6.4	3	7.9	4.4
sex (% females)	50%		50%	
head of the household with primary school studies finished(%)	19%		10%	
has electricity (%)	47%		31%	
has bike (%)	23%		30%	
Number of observations (children 6–12)	37,974		11,122	

Notes: Socioeconomic data refers to all children between 6 and 12 years old from the latest demographic census from 2015, in Manhiça (control) and Magude (treatment) districts.

2.3. Empirical models

The impact of the interventions on school performance (grades) is assessed by estimating the following model:

$$P_{ijt} = \alpha + \beta_1 Treatment_j + \beta_2 After_t + \beta_3 (Treatment_j * After_t) + \delta_s + \Omega_p + \mu_t + \varepsilon_{ijt} \quad (1)$$

where P_{ijt} is either a continuous test score measure or a binary variable indicating whether the student i has passed the course, in district j, and trimester t. *Treatment* indicates whether the student belongs to the

[5] The higher absenteeism level in the pre-intervention period in the treated area might be partially driven by the fact that Magude is a larger and less populated district, with longer distances from students' households to school on average, and poorer roads and infrastructure. Although sharing important characteristics from any rural district in Southern Mozambique, Magude district shows lower socioeconomic levels as reflected by key indicators such as lower access to electricity, lower parents' educational level or bigger average household size. However, these characteristics of the district remain constant in our two-year sample period and are captured in our econometric specification by the treatment dummy variable.

Table 3
Sample design and difference in predictor means.

	2015 (pre-intervention)			2016 (post-intervention)		
	Treat (i)	Control (ii)	Diff.	Treat (iv)	Control (v)	Diff.
Panel A. Absenteeism						
Mean absenteeism	7.60%	6.50%	**1.10%**	6.20%	6.30%	**−0.10%**
	(2.65)	(2.45)		(2.41)	(2.43)	
Number of students	1,252	3,532		1,602	2,904	
Number of observations	143,506	361,920		196,652	294,333	
Panel B. Performance						
Mean grade (all subjects)	12.13	12.28	**−0.2**	12.52	12.43	**0.1**
	(2.76)	(2.77)		(2.75)	(2.78)	
Number of students	1,428	3,965		1,730	4,197	
Number of observations	28,518	79,971		34,853	86,240	

Notes: The pre-intervention period is the academic year 2015 (from February until October) and the post-intervention period is the academic year 2016 (from February until October). The sample consists of all students with available data on absenteeism and performance within the 9 randomly selected schools.

intervention district (Magude) and *After* refers to the period after the implementation of the MDA (academic year 2016). The estimated coefficient of the interaction term $(\widehat{\beta}_3)$ identifies the effects of the elimination initiative on students' performance. We include school (δ) and subject (Ω) fixed effects to control for school and subject specific time-invariant characteristics. More specifically, school fixed effects control for all time-invariant (observable and non-observable) school characteristics (i.e., overall quality of the teachers, school infrastructure and materials, etc.), and subject fixed effects for subject specific characteristics, such as differences in the level of difficulty across subjects. We also control for quarterly seasonality in school grades by including trimester (μ) fixed effects.

Analogously, to assess the impact of the initiative on students' absenteeism we estimate the following model:

$$A_{ijt} = \alpha + \beta_1 Treatment_j + \beta_2 After_t + \beta_3 (Treatment_j * After_t) + \delta_s + \mu_t + \lambda_m + \varepsilon_{ijt} \quad (2)$$

Where A_{ijt} is a binary variable indicating whether student i in district j was present (A=0) or absent (A=1) at school on day t, and the coefficient $\widehat{\beta}_3$ represents our treatment effect. δ denotes school fixed effects. Given the periodicity of students' absenteeism data, which is daily, we estimate regressions controlling for trimester (μ) but also for calendar-month (λ) fixed effects (10 months before and 10 months after the intervention).

We finally explore the two different potential channels that could have driven the observed improvement in students' performance, by estimating the following model:

$$P_{ijt} = \alpha + \beta_1 After_t + \beta_2 (Treatment_j * After_t) + \beta_3 Absenteeism_{ijt} + \beta_4 Att_{incrij} + \beta_5 (Att_{incrij} * Treatment_j * After_t) + \delta_s + \mu_t + \eta_i + \varepsilon_{ijt} \quad (3)$$

Where P_{ijt} is the end of term grade, for student i in district j at trimester t. *Absenteeism* reflects students' absence by trimester. Att_{incr} is a dummy variable indicating the students who increased overall attendance from one academic year to the other. The $\widehat{\beta}_5$ coefficient of the interaction term identifies the potential differential effects of the malaria initiative on performance for those students within Magude that increased attendance, and thus, reflects the effect of the intervention on performance due to the increased quantity of time spent at school. Once the "quantity effect" is controlled by interaction Att_{incrij}*-$Treatment_j$*$After_t$ and represented by $\widehat{\beta}_5$, the $\widehat{\beta}_2$ coefficient of the interaction $Treatment_j$*$After_t$ reflects the increased capacity to assimilate and store knowledge (increased quality of time spent at school), regardless of students' absenteeism levels. We also include school (δ), trimester (μ) and individual (ɱ) fixed effects. In this specification, the individual fixed effects capture the individual time-invariant unobservable, such as students' innate cognitive ability, or students' distance to school.[6] The variable $Treatment_j$ is not included in this specification, except as interaction, as it would be collinear to individual fixed effects.

While the intervention was delivered at the district level and schools represent a random subset within each arm (treatment vs control), there could still exist potential shocks at the school level (i.e., changes in teachers or directors that affect performance of one specific school, schools' materials, etc.) leading to unobserved correlation among individuals belonging to the same school. As such, in our regression specifications (1), (2) and (3), we clustered standard errors at the school level. As there are only nine schools, the common cluster-robust approach suggested by (Bertrand et al., 2004) could result in inappropriately small standard errors. Therefore, in addition to calculating these standard errors, we calculate and report the p-values associated with the wild cluster bootstrap-T method developed by Cameron et al. (2008).

3. Results

Figs. 2 and 3 plot the quarterly mean absenteeism and test scores (all subjects), respectively, for primary school students in treatment and control districts over academic years 2015 and 2016.[7] Prior to the interventions (academic year 2015), the control district showed better educational outcomes with lower levels of absenteeism and higher mean

[6] We assume students' distance from home to school as time-invariant, as it is unlikely that students have moved out to another house from one academic year to another.

[7] For each student, daily absenteeism is a binary variable, for each eligible school day, equal to 0 if the student is present and 1 if the student is absent. Grades are measured on a scale from 0 to 20. Although daily data is analysed, absenteeism data is aggregated by trimester for facilitating comparability with performance outcomes.

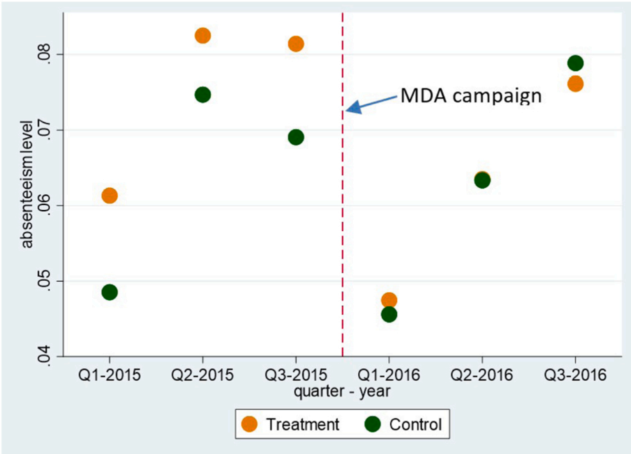

Fig. 2. School absenteeism in Magude (treatment) and Manhiça (control) districts, Notes: The vertical red dashed line shows the implementation of the MDA campaign. Treatment is defined as students attending schools located in the district where the malaria elimination initiative took place (Magude), and the pre-intervention period refers to the academic year 2015.

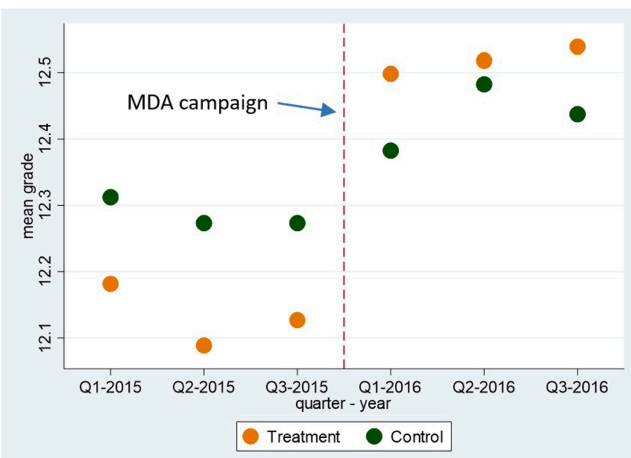

Fig. 3. School average grades in Magude (treatment) and Manhiça (control) districts, Notes: The vertical red dashed line shows the implementation of the MDA campaign. Treatment is defined as students attending schools located in the district where the malaria elimination initiative took place (Magude), and the pre-intervention period refers to the academic year 2015.

grades than the intervention district. However, trends in both absenteeism levels and mean grades were similar and parallel in the two districts. After the intervention was implemented (academic year 2016), there was a more pronounced drop in absenteeism as well as a more pronounced increase in mean grades in the treatment vis-a-vis the control group. Consequently, in 2016, Magude caught up with absenteeism levels in Manhiça and it even overtook the performance levels of the control group.

Table 4 reports the main results on test scores from the difference-in-difference model outlined in Eq. (1). We used two versions of the dependent variable: a continuous test score measure (Panel A) and a binary variable (Panel B), the latter indicating whether the student has passed the course (which occurs when grades are above 10). Column (1) shows results of the model with school fixed effects, column (2) shows results of the model with school and trimester fixed effects and column (3) shows the model with the additional inclusion of subject fixed effects. The difference-in-difference estimated coefficients are positive, significant (at 1% significance levels) and stable across specifications,

Table 4
Impact of the malaria elimination initiative on school performance, all subjects.

Dependent variable	All subjects		
	(1)	(2)	(3)
Panel A. Mean grade value			
Treatment	-0.470***	0.47***	-0.639***
	(0.0595)	(0.0595)	(0.060)
After	0.164***	0.170	0.176
	(0.0418)	(0.0825)	(0.0735)
Treatment*after	**0.241*****	**0.241*****	**0.240*****
	(0.0687)	(0.0687)	(0.0645)
	[0.005]	[0.005]	[0.005]
Constant	11.849***	11.877***	12.159***
	(0.0238)	(0.0662)	(0.507)
School FE	x	x	x
Trimester FE		x	x
Subject FE			x
Observations	229,427	229,427	229,427
R^2	0.015	0.015	0.047
Panel B. Pass value			
Treatment	-0.004	-0.004	-0.034**
	(0.009)	(0.009)	(0.009)
After	0.002	0.0016	0.003
	(0.005)	(0.006)	(0.005)
Treatment*after	**0.021***	**0.021***	**0.020**
	(0.010)	(0.010)	(0.010)
	[0.10]	[0.10]	[0.11]
Constant	0.866***	0.869***	0.778***
	(0.003)	(0.005)	(0.043)
School FE	x	x	x
Trimester FE		x	x
Subject FE			x
Observations	229,427	229,427	229,427
R^2	0.004	0.004	0.128

Notes: OLS coefficients, with standard errors clustered by school in parentheses. P-values of wild bootstrap clustering procedure presented in brackets for the interaction term (based on 400 repetitions). All models controlling for school FE. Model (2) also controlling for quarterly seasonality and model (3) controlling for subject and trimester FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

indicating that the interventions increased the overall grade by 0.24 percentage points. Given the pre-intervention mean grade of 12.13 in the intervention area, the policy increased average grades for treated students by 2%.[8] Analogously, the intervention increased the probability of passing exams by 2 percentage points, which corresponds to an average increase of 2.3% with respect to the pre-intervention mean.[9]

As there is consensus on the fact that some subjects better reflect children's cognitive performance than others, such as maths (Moeller et al., 2014), we also explored the impact of the intervention on maths grades only. The impact of the malaria elimination initiative on maths test scores is twice the impact on overall subjects mean grades (Table A2).[10]

Results on the effect of the initiative on school absenteeism (Eq. 2) are shown in Table 5, with all models controlling for school fixed effects, and columns (2) and (3) also controlling for month and trimester fixed effects, respectively. There is robust evidence of a reduction in school absenteeism as a result of the malaria elimination initiative across the different models. More specifically, the difference-in-difference estimate shows a reduction in absenteeism by 2 percentage points. Given that Magude's pre-intervention absenteeism level was 7.63%, the decrease due to the interventions amounts to 27.72% .[11]

[8] This is obtained as (0.24/12.13)*100.
[9] Given that the pre-intervention mean pass rate in the treatment group was 87.6%, the increase due to the intervention is: (0.02/0.876*100).
[10] When estimating the impact on all the subjects except maths, the coefficient of the interaction treatment*after is still significant but drops to 0.18, highlighting the importance of maths in driving the overall results on grades.
[11] Calculated as (0.021/0.0763)*100.

Table 5
Impact of the malaria elimination initiative on school absenteeism.

	(1)	(2)	(3)
Treatment	-0.0135***	-0.015***	-0.013**
	(0.0595)	(0.006)	(0.006)
After	0.0035	0.012	0.000
	(0.0042)	(0.015)	(0.005)
Treatment*after	**-0.024*** **	**-0.020** **	**-0.021** **
	(0.006)	(0.007)	(0.008)
	[0.005]	[0.035]	[0.035]
Constant	0.052***	0.041	0.039***
	(0.003)	(0.011)	(0.004)
School FE	x	X	x
Month FE		X	
Trimester FE			x
Observations	996,411	996,411	996,411
R^2	0.017	0.020	0.019

Notes: OLS coefficients, with standard errors clustered by school in parentheses. P-values of wild bootstrap clustering procedure presented in brackets for the interaction term (based on 400 repetitions). All models controlling for school FE. Model (2) also controlling for monthly seasonality and model (3) controlling for trimester FE. * p < 0.10, ** p < 0.05, *** p < 0.01.

Finally, we investigated the potential channels that might be driving the improvement in students' performance as a result of the initiative. Table A3 shows results for a sub-sample of students (N = 1607) that could be followed across the two academic years on both absenteeism and grades. Specifically, (col 1) shows the estimates of Eq. (1) on grades. When controlling for students' absenteeism (col 2) or individual students' fixed effects[12] (col 3), the impact of the initiative on performance decreases but the impact remains positive and significant. Finally, (col 4) presents the results of estimating Eq. (3). The coefficient $\widehat{\beta}_5$ is positive and significative, suggesting that those students in Magude who increased their attendance, also experienced a higher improvement in their performance, specifically by 0.275 percentage points, when compared to the remaining students. These findings indicate that part of the effect of the intervention on students' performance is likely to derive directly from increased attendance (increased "quantity" of time spent at school). $\widehat{\beta}_3$, should, therefore, represent the consequence of improved learning capacity due to better health, irrespective of increased attendance. This coefficient ($\widehat{\beta}_3$) shows that as a result of the initiative, the quality of the time spent at the school increased and translated into an improvement in grades by 0.427 percentage points, corresponding to an average increase of 3.5% with respect to the pre-intervention mean.[13]

3.1. Robustness checks

We test the parallel trends assumption by interacting the treatment variable with quarterly time dummies. Given that the interaction terms between pre-treatment time dummies and the treatment indicator are very close to zero (Fig. A6 and A7), we demonstrate that, although some interventions already took place in August 2015 (i.e. indoor residual spraying), pre-intervention outcome trends are not significantly different between treatment and control districts. These results hold for both absenteeism and performance outcomes, and only after the MDA administration (November 2015–January 2016) coefficients are significantly different from zero.

A further robustness check is relative to the patchy follow-up of students over time which makes our database unbalanced. To exclude any potential bias arising from attrition, the core analysis on school attendance (Eq. 2) has been repeated on three subsamples (Table A4): one including only those months with complete information (col 2); removing unrealistically long consecutive chains of presences [14] (col 3) and using a balanced database[15] (col 4).

In addition, while the identification strategy isolates the intervention effect from common trends and district time-invariant heterogeneity, it does not necessarily isolate it from heterogeneity across students. In consequence, in column (5) individual FE have been included to the balanced database. Regardless of the sub-sample or controls included, our main findings are maintained.

Finally, there exists evidence on the presence of positive externalities of health interventions targeting school-age students. Failing to account for them might result in underestimating the benefits of an intervention and, thus, drawing misleading conclusions (Miguel and Kremer, 2004). In the context of this study, there may be positive externalities acting from the intervention to the control area (reduced malaria transmission in areas close to the border can benefit the adjacent control area) and negative externalities from the control to the intervention area (the control area did not reinforce malaria management, limiting the effect of the malaria elimination initiative in the area of the intervention district adjacent to the control district). In absence of randomization of schools into treatment, we tested for the potential presence of externalities by calculating each schools' distance to the shared border between Magude and Manhiça districts (nearest point). We, then, generated an interaction term between distance to border and the period after the MDA distribution ($Distance_{border} * After$) and included such interaction in the basic Eq. (2).

As Table A4 (col 6) shows, we did not find any differential effect of the initiative by distance to the border (insignificant coefficient of the interaction term $Distance_{border} * After$). Nevertheless, the effect of the initiative remained constant and significant, pointing to either negligible externalities or to a compensation between positive and negative externalities.

4. Discussion

This study has explored the impact of a malaria elimination initiative in Southern Mozambique on educational outcomes of 9848 primary school children for the academic years 2015 (pre-intervention) and 2016 (post-intervention). One year after the kick-off of the initiative, results showed that the reduced malaria burden consequent to the elimination initiative in the treated district (Galatas et al., 2020b; Thomas et al., 2021) translated into improved primary school students' attendance and performance relative to the control district.

We converted our results to different metrics and did some simple linear projections in order to facilitate comparisons with short- and long-term similar studies. Our results showed that students' mean grades increased by 2%, and this impact was more than doubled on a subject requiring higher cognitive performance, such as maths. Equivalently, this represents an increase in students' score rates of 0.24 –all subjects— and 0.6 –only maths— out of a total of 20 marks, or an increase of 0.09 –all subjects— and 0.17 –only maths— standard deviations. These results align with existing findings on the short-term impact of malaria on performance among primary school students. Fernando et al. (2003a), (2003b) found that in Sri Lanka, a child with malaria at school, scores 0.6 (in maths) and 0.8 (in language) marks less out of 10 than a healthy child. In another study in Tanzania, a 10 percentage-point - decrease in malaria prevalence on the year of birth compared with baseline, was associated with a 0.06 standard deviation increase in English literacy achievement (Klejnstrup et al., 2018).

12 In order to control for individual unobservable factors both correlated with school attendance and performance, such as students' effort and motivation, which could potentially confound our estimates.

13 Given that the pre-intervention mean value in the treatment group was 12.08%, the increase due to the intervention is: (0.427/12.08 *100).

14 These are chains of 100 consecutive presences, which, given the observed baseline absenteeism levels, would occur with a probability below 0.00001.

15 We keep in our sample only students with complete information across academic months and years.

The magnitude of our results is also in the same range of other —non-malaria— education interventions aimed at improving students' learning in developing countries, such as teacher training, volunteer teachers or students and teachers performance incentives, with a mean effect size comprised between 0.09 and 0.12 standard deviations (McEwan, 2015).

While we provided evidence over a relative short time, our results may represent a starting point of the swelling mid- and long-term effects of malaria elimination on human capital accumulation. In order to be able to compare our estimates with existing findings on longer-term outcomes of malaria elimination and eradication programs, we translated our main treatment effects on school attendance and performance in terms of school days and grade levels gained and convert those into years of schooling, under the (strong) assumption that the gains are constant over time. Given a baseline absenteeism level of 7.6% and an average treatment effect of the policy in reducing absenteeism by 2.1 percentage points, we found that the intervention preserved, on average, 4 days per student per year, which in turn, translates into a gain of 0.022 years of schooling per student.

We estimated that the improvement in overall grades translated into an increase of passing exams -and consequently successfully passing from one academic year to another - by 2.3%. Knowing that the average primary school years completed in Mozambique is 3.5 years (United Nations Educational Scientific and Cultural Organization UNESCO, 2018) and assuming a constant dropout rate, the impact of the initiative on students' performance would imply an increase of 0.08 years of schooling.[16] Aggregating the impact of the initiative on both absenteeism and performance outcomes and assuming an independent effect of each component, this yields an increase of 0.11 years of schooling.[17]

In order to facilitate comparison with other economic studies based on historical data, we rescaled our regression coefficients in terms of malaria incidence change (71.3% malaria incidence reduction between August 2015-June 2017 according to Galatas et al., 2020b), which translates into an estimated increase of 0.015 years of schooling per a 10% reduction in malaria incidence. Compared to the educational effects found in the long-term literature, our estimates are lower. For example, in Sri Lanka and Paraguay, Lucas (2010) found a 10% decrease in malaria incidence to be associated with a 0.1 year increase in schooling, Barofsky et al. (2015) found very similar results in Uganda (an impact of 0.09 years of schooling), while in contrast, Cutler et al. (2010) found no impact on educational outcomes. However, considering the different timeframes covered in the analysis (1 year vs 15–20 years after the intervention), our estimates could potentially achieve a similar impact in the mid and long-term. While these across study comparisons should be taken with caution, they are key to understand the magnitude of the impact of the malaria elimination initiative assessed in this study in comparison with previous campaigns. Caution is necessary as we are referring to different countries, malaria control and elimination interventions and time periods. Importantly, the main parasite responsible for malaria in sub-Saharan Africa (*Plasmodium falciparum*) differs from Sri Lanka, Paraguay, or India (*Plasmodium Vivax*) and as a consequence, the whole malaria epidemiology, its clinical consequences and economic impacts are likely to be different.

In the context of our study, as a result of the initiative, school attendance increased by 28%. By focusing on a sub-sample of students that we were able to follow-up over the academic years, we showed that the increase in attendance partially explains variation in performance (the quantity effect, i.e. the increase in the amount of time spent at school), with a contribution of 39%[18] to the overall improvement in grades. We also found that regardless of students' increased attendance, the initiative had a significant impact in boosting students' performance, via a plausible improvement in the quality of time spent at school, consequent to the higher capacity to use cognitive ability at full. The contribution of the "quality effect" to the increase in grades was of 61%.[19] Importantly, we disentangled the effect of improved quantity and quality of time spent at school not on the whole sample but on a sub-sample of students for whom attrition was limited: these students (N = 1607) were identified for most of the study period in school registries and they represented a subsample of the most diligent students in both treatment and control areas, that is, of children with low absenteeism even before the intervention. Their mean rate of absenteeism was, in fact, 2 percentage points lower than the one of children excluded from this analysis. For this sub-sample, there should be no issues of endogeneity of absenteeism in the grades' equation: for these more diligent children, while variations in presence at school lead to variations in grades, variations in grades should not lead to remarkable variations in presence at school.

We did not identify presence of externalities across the two districts. Negligible externalities may be the consequence of infrequent movements of people and mosquitos between the districts. Although there is no reliable data, people are likely to move frequently between the two districts mainly for economic reasons (in each district there is a big sugar cane factory, and extended sugar cane fields, with a large number of temporary workers moving across districts) (Lazzarini, 2017). Therefore, we find the hypothesis pointing to the compensation between positive and negative externalities more likely.

Our analysis was affected by some limitations. The use of routine data from school records, may cast doubts on both the accuracy and the validity of our data sources. While there may exist some measurement errors inherent to the data, the routine data quality checks undertaken by the government and the digitalisation process may significantly reduce and prevent them. In addition, routine school grades have not only been used as proxies for student's cognitive achievement in the literature (Fernando et al., 2003c; Thuilliez et al., 2010), but they have also been shown to lead to results that are highly correlated with those obtained when using specific cognitive function score tests (Thuilliez et al., 2010). Therefore, the use of school registers' data is consistent with the literature and sound from a methodological perspective. Furthermore, the use of administrative data allowed us to rely on a wide sample size, which would be not feasible to achieve if primary data were collected.

Due to the unbalanced nature of our database, we could not identify any potential school composition effect of the intervention (Jones, 2016). However, we cannot exclude that the intervention may have allowed children who were very often or even totally absent due to sickness in the pre-intervention period (year 2015) to increase their presence in 2016. This may have lowered the impact of the intervention on performance.

Baseline school outcomes (attendance and performance) appear lower in the intervention district (Manhiça) than in Magude. This might be explained by factors related to poorer roads infrastructure, higher average distances to school or the slightly lower socioeconomic status levels in the district of Magude.

Schooling outcomes (in both intervention and control areas) are likely to have been affected also by national education policies, thanks to an increasing investment in education over the last years (UNICEF, 2019). This may explain the increasing trends in presence and grades in the control group (Figs. 2 and 3). All children in our sample, in both the

[16] If initiative increase passed grades (and consequently finished years) by 2.3%, and average years completed is 3,5, then the impact of initiative is 0.023*3.5 = 0.08.

[17] Obtained from a gain of 0.022 years in addition to 0.09 years.

[18] Obtained as the impact share of the coefficient $\widehat{\beta}_5$ (0.275,Table A3), to the overall improvement on grades (0.275 + 0.427).

[19] Obtained as the impact share of the coefficient $\widehat{\beta}_2$ (0.427,Table A3), to the overall improvement on grades (0.275 + 0.427).

intervention and control groups, were exposed to very similar school environment and quality of education over time, which is confirmed by the validation of the "parallel trends" assumption. Our DiD model was able to differentiate out the effect of national level education policies that impacted both the intervention and the control schools.

Other minor *caveats* are also worth mentioning.

Given the nature of our dataset, we could not control for specific time invariant school children characteristics potentially relevant to explain variation in school outcomes. Specifically, we could not control for gender or socio-economic status (the latter may be considered as time invariant over two years) due to an imperfect matching between school and demographic census data (i.e. only about 35% of children could be matched by name, surname and neighbourhood). However, while we could not investigate the specific contribution of such factors, the impact of the elimination initiative on school outcomes does not seem to be affected by time-invariant children characteristics as witnessed by the robustness of our results across our main specifications (Eqs. 1 and 2) and the individual fixed-effects specification (column 3 in Table A3 and column 5 in Table A4).

From a public health perspective, our findings provide key estimates of the beyond-health benefits associated with malaria elimination. Within the renewed efforts towards the elimination of the disease in Southern Africa, our estimated figures provide strong arguments for health policy makers and funders for advocating towards elimination in the region. The existence of such benefits may justify the initial large investments needed to eliminate the disease and may also help overcoming the free-riding issue intrinsic to disease elimination as a global public good (Barrett, 2013).

Our study also provides further evidence on the micro-foundations of the links between health, education, and economic growth. Results from this study shed light on the channels through which health can improve schooling outcomes in the short-term, which in turn, are essential proxies for countries' economic development (Bloom et al., 2003; Finlay, 2007). Notably, this is the first study exploring such links in Mozambique.

Lastly, this study provides a plausible reply to the initial question on whether improved health among children translates into enhanced school outcomes. The reply is affirmative in the context of this study, with a 28% reduced absenteeism and 2% improved grades. While malaria is not the cause of all school absences, we found a remarkable increase in presences due to the malaria elimination initiative. While we cannot deny that some healthier children may have engaged in extra scholar activities, including work, malaria drop caused a substantial improvement in school outcomes. In particular, we found that, at least among the most motivated students, irrespectively of the amount of time spent at school, the higher capacity of children to learn due to better health, is a key factor to increase performance.

Author contributions

Laia Cirera, Elisa Sicuri: Study Conceptualization. Laia Cirera, Joe Brew, Francisco Saute: Data Curation. Laia Cirera, Elisa Sicuri and Judit Vall: Formal analysis. Laia Cirera and Elisa Sicuri: Writing original draft. All authors: Reviewing and editing.

CRediT authorship contribution statement

Laia Cirera: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Judit Vall Castelló:** Formal analysis, Investigation, Methodology, Software, Validation, Visualization. **Joe Brew:** Data curation, Validationa. **Francisco Saúte:** Data curation, Funding acquisition, Resources, Validation. **Elisa Sicuri:** Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

All authors declare no competing interests.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ehb.2021.101100.

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