Malaria and Primary education in Mali: a longitudinal study in the village of Donéguébougou.

J. THUILLIEZ[1*], M.S. SISSOKO[2], O.B TOURE[2], P. KAMATE[2], M.B. NIAMBELE[2], B. KAMATE[2], O. GUINDO[2], A. BALAM[2], J.C BERTHELEMY[1] and O.K DOUMBO[2]

Very preliminary and incomplete. Do not cite or circulate. Comments welcomed.

Abstract:
This article assesses the role of malaria and some social determinants on primary education and especially on school achievements in Donéguébougou, a small village located in a malaria-endemic area near Bamako, Mali. Field data were colleted by the authors between November 2007 and June 2008 on 227 schoolchildren living in Donéguébougou. Various malaria indicators and different econometric models were used to explain the variation in cognitive abilities, teachers' evaluation scores, school progression and absenteeism. Malaria is the first cause of school absenteeism. Malaria is also the most costly disease among other health expenses despite the fact that mean cost per consultation for malaria is lower than average cost per consultation. Fixed effects estimates clearly demonstrate that clinical malaria, repeated malaria infections, asymptomatic malaria, and malarial anaemia have a direct impact on cognitive performances in Donéguébougou. The impact on teachers' evaluation scores is not identified but results suggest that the use of bed nets tends to improve school progression and cognitive performances. We conclude that it is time to consider malaria as one of the most common chronic mental health problems among school children in tropical and subtropical areas.

1. INTRODUCTION

In Mali, malaria is endemic among more than 90% of the total population. According to the 2005 statistical yearbook, children under 5 represent 34.9 % of all consultations for malaria. At the Gabriel Touré paediatric Hospital in Bamako, malaria ranks high among causes of childhood mortality, is the first cause of paediatric consultations with approximately 40% of total consultations (Keita et al., 2004), and is the most common cause of febrile convulsions in children between the ages of 16 months and 10 years (Sagara et al., 2002, quoting Diawara F.M, personal communication). In addition, children who survive to school age continue to be vulnerable to malaria (Kazadi et al., 2004; Clarke et al., 2004).
Five reasons motivate the study of the quality of education and associated factors:

(i) Macroeconomic assessments of the effects of malaria on long-turn incomes quantified the impact of malaria on growth (Sachs and Gallup, 2001) but failed to identify transmission channels. Higher levels of education quality increase growth

[1] CES-TEAM-CNRS, Département d'Economie du Développement, Université Paris1 PANTHEON-SORBONNE, PARIS, FRANCE.
[*] Corresponding author. E-mail address: Josselin.Thuilliez@malix.univ-paris1.fr
[2] MRTC (Malaria Research and Training Center), DEAP (Département d'Epidémiologie et des Affections parasitaires), Faculté de Médecine, de Pharmacie et d'Odonto-Stomatologie, BAMAKO, MALI.

rates of national income (Jamison et al., 2007) and theoretically allow countries to get out "poverty trap" (Berthélémy, 2006). Therefore, the issue of education is very important for understanding the development and growth of affected countries.

(ii) Macroeconomic studies found that malaria could have a significant macroeconomic impact on human capital accumulation (Bleakley, 2007; Thuilliez, 2007). Consequently, research on this relation needs more microeconomic foundations.

(iii) Human capital economic theory states that bad health conditions have negative effects on capacity and productivity of the population. Malaria could have these effects. If the direct impact of malaria on efficiency and productivity has already been explored (Audibert et al., 1999, 2003a, 2003b), indirect and long-term impact on human capital quality through education is less known.

(iv) Accumulated evidence finds that early test scores are correlated with education, earnings and future labour participation (Leibowitz 1974; Robertson and Symons 1990; Cameron and Heckman 1998; Currie and Duncan 1999).

(v) Despite the significant impact of malaria on school-age children, there is a lack of evidences in social sciences and medical literature about the link between malaria and school achievements. Confirmatory studies are needed.

2. BACKGROUND AND PREVIOUS LITERATURE

(a) Production of educational achievement in Children

Economists have conceptualized learning as a production process (Ben-Porath, 1967). Recently, Petra and Wolpin (2007) have surveyed different models used in the literature to estimate production functions for cognitive achievement. They assume that "knowledge acquisition is a cumulative process by which current and past inputs are combined with a child's genetic endowment of mental capacity (determined at conception) to produce a cognitive outcome":

$$E_{ija} = E_a(Z_{ij}(a),\mu_{ij0}) \qquad (1)$$

Where E_{ija} is the educational achievement for child *i* residing in household *j* at age *a*, $Z_{ij}(a)$ is the vector of all inputs applied at any time up until age *a*, and μ_{ij0} denotes the child endowed mental capacity.

Challenges to arrive at an empirical specification of (1) that takes into account data limitations (particularly missing data on inputs) are numerous and require restrictions on the original empirical linear structure. Currie and Stabile (2006) and Fletcher and Wolfe (2008) use cohort data sets and fixed effects models to understand the influence of Attention Deficit Hyperactivity Disorder in education, grade repetition and tests scores in two developed countries (United States and Canada). Our modelling approach is built on these works in the particular context of a developing country.

A considerable literature has been devoted to the estimation of the correlation between child health and child schooling achievement in developing countries since the early 1980's. Early childhood stunting, child malnutrition, iron deficiency anemia, iodine deficiency, visual acuity have been generally associated with poorer cognition and school achievement in later childhood and, as a result, reduced adult economic productivity. Reviews of the educational consequences of nutritional and health status can be found in Leslie and Jamison (1990) or more recently in Dumont (2000). However, results and conclusions remain ambiguous and differ according to the school achievement indicators, health measures and the methodology used. Moreover, studies based on field data are very scarce.

(b) Malaria and Cognitive achievement at the individual level

The question of the link between Malaria, school achievements and cognitive abilities is not a new one. One of the first studies about the impact of malaria on mental development has been made in Texas by Kelley (1917). Table 1 gives a synthesis of methods, outputs and results of recent studies in this field of research. This literature review has been made using Pubmed search engine of relevant published literature from 2003 to 2008. We excluded studies about the cognitive impairments after cerebral malaria that are not directly linked with our analysis and that have already been the subject of numerous literature reviews. A former literature review (from 1960 to 2002) can be found in Mung'Ala-Odera el al. (2004) for cerebral malaria and in Holding and Snow (2001) or Kihara et al. (2006) for the probable pathways of cognitive impairment post *P. falciparum* malaria. Mung'Ala-Odera et al. (2004) estimate that at least 1,300 to 7,800 children will have neurologic sequelaes following cerebral malaria in stable endemic areas per year. Deficits in attention, memory, visuo-spatial skills, language and executive functions may occur after malaria infection. These deficits are not only caused by cerebral *falciparum* malaria, but also appear to occur in less severe infections. Malaria can affect children's schooling attainment through several channels summarized in Figure 1.

FIGURE 1: Direct Impacts of *falciparum* Malaria on School Performance *(Source: Author).*

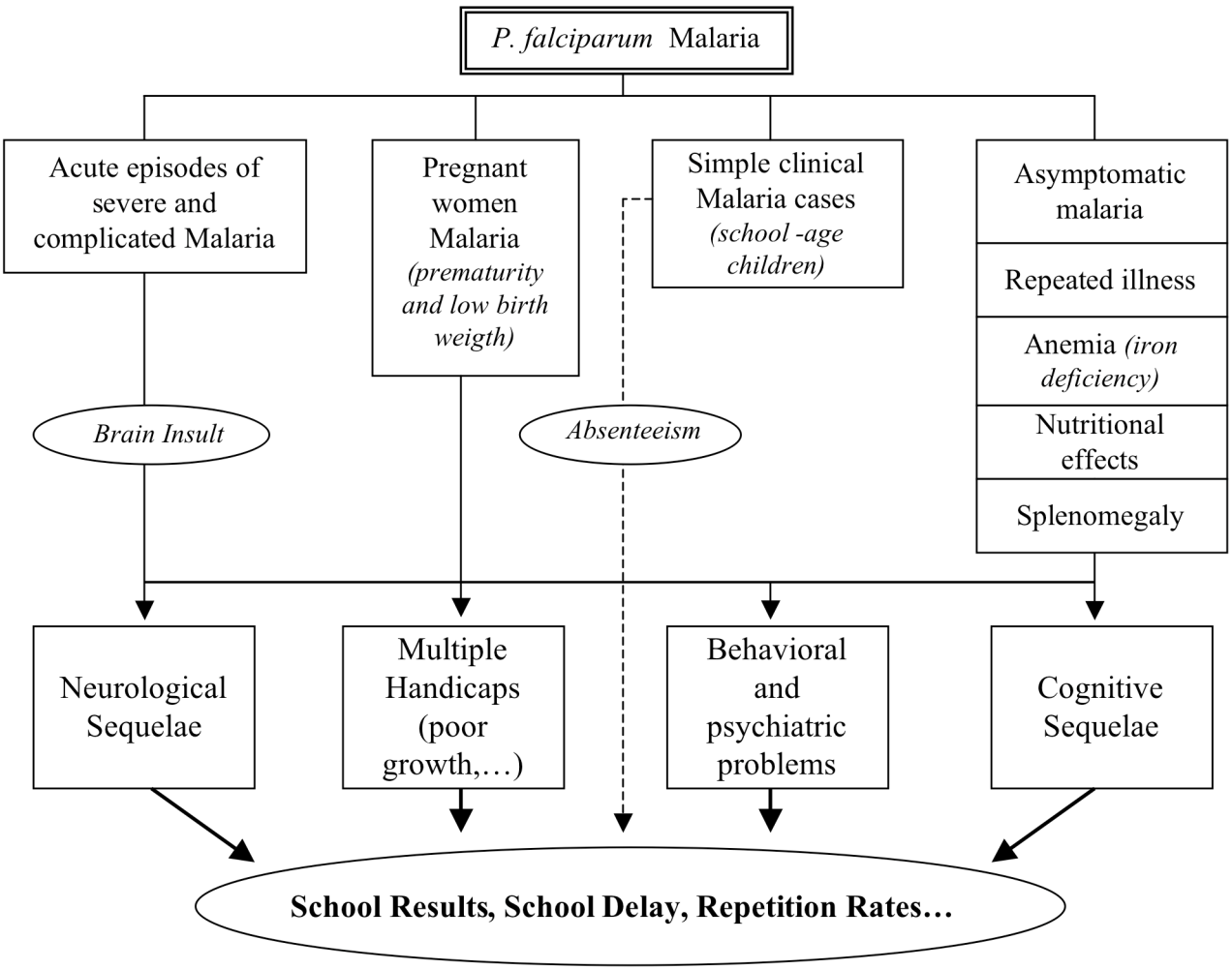

TABLE 1: Studies examining cognitive function following *falciparum* and *vivax* malaria or evaluating the effect of malaria prevention on school outputs since 2003.

	Study	Objectives	Study Design	Study Place	Duration	Population and Sample Size	School Outputs	Main Results
1	Fernando et al. (2003a)	To assess the short term impact of an acute attack of malaria on cognitive performance of schoolchildren.	Matched Case / Control study. Passive case detection using microscopy.	Sri Lanka (Moneragala)	Prospective study from January 1998 to November 1999 and 14 days follow-up in November 1999.	Age: 6-11 years (Grade 1 to 5) 648 schoolchildren: 199 children with malaria (MC), 144 children with non-malarial fever (NMFC), 305 healthy children (HC).	Grade specific examination papers (mathematics and language), absenteism.	At the time of presentation and 2 weeks later, children diagnosed with malaria had significantly lower scores in mathematics and language ($P<0.001$) than NMFC and HC. The impairment seems to be cumulative with repeated attacks. A child having an acute attack of uncomplicated malaria was absent from school 5.4 days in average against 3.4 days for a child with non-malarial fever. Children absent for long duration due to a malaria episode have significantly lower scores.
2	Fernando et al. (2003b)	To measure the impact of repeated attacks of malaria infection on the cognitive performances of children at school entry.	Cross sectional Study. Past history of malarial attacks were collected from the parent or legal guardian by interview.	Sri Lanka (Moneragala and Anuradhapura)	January 1997 / 1 month (school entry).	Age: 5-6 years (Grade 1) / 325 schoolchildren	Cognitive performance (writting skill, reading skill, ability to count, ability to identify numbers,...)	All indices of cognitive performance were poorer in children who had experienced more than 5 attacks of malaria during their lifetime compared to children who had had less than 4 attacks.
3	Fernando et al. (2003c)	To measure the impact of repeated attacks of malaria infection on the school performances of schoolchildren.	Case / Control study. Passive case detection using microscopy.	Sri Lanka (Kataragama)	Prospective study from January 1992 to November 1997. Examination in November 1997.	Age: 6-14 years (Grade 1 to 7) / 571 schoolchildren	Grade specific special examination designed for the study (25 questions, mathematics and language), 3 routine end of shool examinations for 1997.	Significant negative correlation between the total number of malarial attacks experienced by the child during the six years follow-up and tests and school scores. Experiencing more than six malarial infections decreased language and mathematic scores by 15% relative to those who had experienced fewer than 3 malarial infections.There is no significant association between anthropometric indices and school performances.
4	Fernando et al. (2006)	To investigate the impact of malaria and its prevention on educational attainment.	Randomized, double-blind, Placebo / Control, Clinical Trial.	Sri Lanka (Kataragama)	March to November 1999.	Age: 6-11 years (Grade 1 to 5) / 647 schoolchildren	End-of-term examinations (mathemathics and language), Absenteism.	School absenteism due to malaria was reduced by 62.5%. Post-intervention, children who received chloroquine scored 26% higher in language and mathematics than children who received placebo. Educational attainment was significantly associated with taking chloroquine prophylaxis and absenteeism due to malaria.
5	Jukes et al. (2006)	To assess long-term impact of early childhood malaria prophylaxis on educational outcomes.	Follow-up of a Controlled trial.	Gambia (Farafenni)	April 1984 to March 1988 for intervention follow-up. May to November 2001 for data collection and cognitive assessment.	Age: 3-59 months at the beginning of the survey / 1190 children	Cognitive tests (visual, Raven's matrices, Digit span, Fluency, Proverbs, Vocabulary) Years at school, School enrolment.	Results are suggestive of a long-term effect of Malaria prophylaxis on cognitive function and educational attainment but confirmatory studies are needed.
6	Clarke et al. (2008)	To assess the effect of Intermittent preventive treatment (IPT) of malaria on health and education in schoolchildren.	Cluster-randomised, double-blind, placebo-controlled trial.	Bondo District (Western Kenya)	March 2005 to March 2006.	Age: 11-16 years (Grade 5 to 6) / 818 schoolchildren included in the analysis of education outcomes (intention to treat population).	Tests of everyday attention for children (TEA-Ch), behaviour in class (teacher ratings of innatentive and hyperactive-impulsive behaviours), educational attainments (end of school term exam).	Significant improvements in TEA-Ch (counting sounds and code transmission) were seen in the IPT group compared with control group. No effect was shown for educationnal achievement and inattentive behaviour.

Our study is different from previous studies in a number of ways. First we used a different study design (cohort data set) and specific panel data econometric models to assess the education production function and compare the incidence of malaria with other factors. We address the possibility of omitted variables bias by estimating within-child fixed effects models. Second, we used several measures of malaria incidence in child to take into account different patterns. Third, we used better assessments of socio-economic variables and a range of school outputs. Fourth, the time period under study is one full school year.

3. DATA AND METHODS

(a) Study site

The village of Donéguébougou is a setting of high seasonal (from June to November) malaria transmission intensity (annual Entomologic Inoculation Rate > 100 infective bites per person). According to Kamaté (2002), transmission is assured principally by *An.gambiae s.l* (91.6% in 2000 against 8.4% by *An. funestus*). It was found that incidence rates (number of malaria episodes/person/time) decreased significantly with increasing age during two transmission seasons (1999 and 2000) but remained stable between years (Dicko et al., 2007). Donéguébougou is a village of approximately 1390 people (a full census of the residents has been undertaken before the study in 2007 by the MRTC/DEAP). The village has a primary school since 1994. First, from 1994 to 1997, the school has been managed by the community. Next it became a Malian public school in 1998. Data on school characteristics by grade are given in Table A1. As the teacher in Grade 6 (who is also the school director) has not change since 1998, Grade 6 results are a reliable indicator to compare school performances since 1998 (Table 5). With regards to facilities available in the school, all students were exposed to a similar environment. Quality of teaching can be controlled with specific estimation techniques or by introducing grade dummies. None of the children had attended pre-schools or nursery previously. In this study, we only focus on the *P. falciparum* malaria, which is far more severe than the other types of malaria. *P. ovale* and *P. malariae* malaria cases were insignificant in comparison with *P. falciparum* malaria cases.

(b) Ethical Clearance

The study protocol was reviewed and approved by the Ethics Committee of the National School of Medicine and Pharmacy of Mali. Treatment of malaria and other illnesses detected during the course of the study was provided to the study population at no cost to participants. Pupils not participating in the study were also treated free of charge. Community informed consent was obtained before the beginning of the study. A meeting was made in the village with traditional leaders and village head to explain the objective and method of the study. School written informed consent was also obtained from the school director and the school parents' association. Last, after a meeting made in the school to explain the objective and method of the study, individual written informed consent was obtained for every pupil from parents or the legal guardians. 227 students (81 girls and 146 boys) among the 229 schoolchildren were included in the study. One legal guardian refused to take the responsibility of the consent for one child (Grade 5) because the parents were living outside the village. One child (Grade 1) arrived after the beginning of the study.

(c) Survey Methods

The data were collected during the all school year from November 2007 to June 2008. Once informed consents were obtained, all enrolled students received monthly clinical and laboratory exams (active monthly follow-up). Time period between two active monthly follow-ups was approximately constant. Cognitive tests were administered the same day directly in the school. All students presenting with clinical symptoms or physical exam findings were treated according to the national standard of care. Those presenting with clinical signs of uncomplicated malaria had their thick and thin smears read immediately to ensure timely diagnosis and treatment.

The active surveillance was supplemented by continuous passive case surveillance. Students were passively followed by the village health centre in collaboration with the school teachers and the school director. Everyday, class teachers identified and recorded the names of any children who were ill or absent to maximise case detection. Any child falling sick during school days, weekends or holidays was immediately referred to the village health centre where he received a complete clinical exam. Again, all students presenting with clinical symptoms or physical exam findings were treated according to the national standard of care and those presenting with clinical signs of uncomplicated malaria had their thick and thin smears read immediately to ensure timely diagnosis and treatment.

To assess home inputs and other socio-economic household characteristics, a questionnaire was designed and interviews were made with the head of each student household.

Data of active monthly follow-up and cognitive tests were checked for internal validity at the end of each cross-sectional survey by one investigator and corrected on-site, if necessary. Socio-economic questionnaires followed the same procedure during the survey. Data were entered by double keyboarding and validated using Microsoft Access© (Microsoft Corporation, Redmond, Washington DC, USA) and Epi Info© (Center for Disease Control and Prevention, Atlanta, GA, USA). All the data were analysed using Stata© statistical software (Stata Corporation, Austin, TX, USA).

(d) Health Status

The health status element we are specifically interested in is *P. falciparum* malaria. Nevertheless, different sets of data were collected in the field respect to health by the medical team under the supervision of three doctors.

Anthropometric indices and hemoglobin level. The weight of each child was measured using an electronic balance and height was measured using a stadiometer. Blood was obtained by finger-prick under aseptic conditions and the hemoglobin level was determined by hemoglobin analyzer in the field (Hemacue©, Labnet International, Buckley WA). Anaemia was defined as an ordinal variable to dissociate:

$$\begin{cases} 0 = \text{No anaemia. Children with Hb} \geq 11.0 \text{ g/dL.} \\ 1 = \text{Mild anaemia - Children with Hb between 8.0 and 10.9 g/dL.} \\ 2 = \text{Moderate anaemia - Children with Hb between 6.1 and 7.9 g/dL.} \\ 3 = \text{Severe anaemia - Children Hb} \leq 6.0 \text{ g/dL.} \end{cases}$$

The age of each child was calculated in years and months on the basis of the date of birth given on their birth certificate maintained by school and confirmed, if necessary, by the village census. The weight and height of the children and Hemoglobin level were measured monthly during the cross-sectional survey. The evaluation of growth attainment requires the use of a reference population that allows for standardized variation at any age as recommended by the World Health Organization. In order to compare children of different ages by sex, the anthropometric measurements of this study were converted into two indexes:

height-for-age, and weight-for-age using the 2000 CDC (Centre for Disease Control and prevention) Growth Charts. These curves are interpreted as indicative of chronic, total, and acute malnutrition. The growth attainment of each child was then expressed as z-scores. The z-score measures the degree to which a child's measurements deviate from those expected based on a reference population. As there was no significant variation between mean z-score from one month to another and from the first and last month, annual mean height-for-age and mean weight-for-age z-scores were used in the analysis. Indeed the changes in z-scores over time for the same child are likely to reflect some measurement error, rather than through changes in nutritional status.

Malaria indices. The measurement of malaria is key for our analysis. As mentioned before, each participant underwent a full monthly clinical examination, during which axillary temperature was measured using an electronic thermometer. Malaria finger prick were performed monthly in all participants and every time symptoms or signs of malaria were present during the study. Parasitaemia (parasites / µL) was determined on a Giemsa-stained thick blood film (asexual forms of each *plasmodium* sp were counted on 300 leukocytes, assuming an average leukocyte count of 7500/µL of blood). Quality control through double reading was also conducted on randomly selected 10% of the slides by one physician. During the study, clinical Malaria was diagnosed if a child had at least one clinical symptom compatible with malaria (elevated body temperature (> 37.5), cephalgia, vomiting, stomachache, diarrhea) together with a malaria-positive smear for *P. falciparum* parasitaemia. From these parasitological and clinical examinations, different indices of malaria were used in this study:

- The absolute number of new clinical malaria episodes per student per month and year were used as some measures of malaria incidence. A minimum period of seven days between two consecutive positive malaria smears for the same species of parasite was required to count the second positive smear as a new symptomatic episode.
- Three Malaria Risk Indices were computed to avoid some measurement bias in the health status. The use of a "pyrogenic threshold" has been proposed as the best definition of malaria in endemic areas (Trape et al., 1985). In our study it was considered that subjects, feverish or not feverish, with a level of parasitaemia over than 500 *P. falciparum* trophozoites/µL (Clarke et al., 2004) might be suspected either of having a malaria attack, or having had one recently. This variable is a dummy equal to one if the child has a parasitaemia > 500 *P. falciparum* trophozoites/µL and zero otherwise. As Audibert et al. (1999), we also considered other thresholds (1000 and 1200) in order to test the sensitivity of the results.
- Annual and monthly geometric means *P. falciparum* parasitaemia were used in some regressions in order to assess the impact of parasitaemia on school outputs.
- Asymptomatic malaria was defined as a malaria-positive smear for *P. falciparum* parasitaemia associated with no clinical symptom.
- Malarial anaemia was defined as an ordinal variable to dissociate:
  - 0 = No malarial anaemia. Children with a malaria-positive smear for *P. falciparum* parasitaemia and absence of anaemia (i.e., Hb > 11.0 g/dL)
  - 1 = Mild malarial anaemia - Children with a malaria-positive smear for *P. falciparum* parasitaemia and Hb between 8.0 and 10.9 g/dL.
  - 2 = Moderate malarial anaemia - Children with a malaria-positive smear for *P. falciparum* parasitaemia and Hb of 6.1–7.9 g/dL.
  - 3 = Severe malarial anaemia - Children with a malaria-positive smear for asexual *P. falciparum* parasitaemia and Hb ≤ 6.0 g/dL.

- Splenomegaly was assessed by spleen measurement using Hackett classification (1944). The maximum value taken by the splenic index in this study is 1.
- Past Convulsions were used as a last indicator to take into account the severe malaria history of the child. This variable was defined on the basis of a questionnaire administered to the head of household and questions asked to the child mother.

(e) Socio-economic data about households

Socio-economic data were collected in December 2007, using a questionnaire administered by researchers to the head of household in every pupil family. Another questionnaire was administered quarterly in December 2007, March 2008 and July 2008 in order to account for seasonal variations.

Home input measures. It is very difficult to estimate incomes and economic levels in rural areas. We chose several types of resources to estimate income level and socio-economic status. We distinguish four types of socio-economic indices (Audibert et al., 2003b):

- "Convenience Property": a relative index of household socio-economic status (SES) was derived based on dichotomous variables (durable goods such as TV set, radio set, motorcycle, housing infrastructure…) using principal components analysis (PCA). Long run wealth is supposed to explain the maximum variance and covariance in the asset variables (Filmer and Pritchett, 2001).
- "Store-of-value property": through an indicator of livestock possession.
- "Productive capital": through an indicator of agricultural equipment or land area pertaining to the household.
- "Monetary Income": to evaluate monetary income from agricultural or non-agricultural activities, we tried to estimate average amount received per month and the source of income using quarterly interviews. Proceeding this way is very archaic but it was not possible to use a more demanding procedure.

The borrowing constraint hypothesis states that credit access could play a role in the children's human capital investments (Jacoby and Skoufias, 1997). Therefore, we solicited information about formal or informal access to credit in the interviews. Household socioeconomic characteristics are given in Table2. Quintiles were defined on the basis of the convenience property PCA score. Nobody had access to formal credit in our sample.

Human Capital factors. Age, literacy and education of the head of household and mother and father of the child were used as measured human capital factors. Questions about child labour were also included in the interviews. The mean age of the head of household[2] is 44.67 (standard deviation = 12.46). Only 5.13% of them can read or write. 86.34% of the 227 children worked the week before the interview and 40.91% of them worked more than one hour. These household or productive tasks were never paid. 20.80% of the schoolchildren had school homework to do the week before the interview. Among them, 33.33% dedicated more than one hour per week to do schoolwork at home. Only 12.77% of schoolchildren have somebody (generally one sister or brother) who can help them to do their homework.

[2] The head of household is not necessarily the father or mother of the children in Donéguébougou.

TABLE 2: Household socio-economic characteristics.

	All Households				Means	
	Scoring Factor	*Means*	*SD*	*Impact on PCA score*	*Poorest Quintile*	*Richest Quintile*
Variables used for Convenience Property Index:						
House characteristics:						
Floor is made of finish surface	0.267	0.230	0.423	0.631	0.043	0.583
Roof material is corrugated iron	0.282	0.863	0.345	0.817	0.478	1.000
Number of buildings	0.156	2.564	1.385	0.112	2.347	3.208
Number of rooms	0.232	4.358	2.328	0.099	3.565	5.833
Other place of residence	0.124	0.051	0.221	0.561	0.000	0.083
Household has Pit Toilet	0.111	0.452	0.499	0.222	0.260	0.541
Household owns at least one:						
Radio	0.272	0.641	0.481	0.565	0.217	0.875
Watch	0.261	0.512	0.501	0.520	0.130	0.750
Television	0.157	0.170	0.378	0.415	0.043	0.291
Bicycle	0.219	0.658	0.476	0.460	0.260	0.875
Motorcycle	0.379	0.555	0.499	0.759	0.086	0.916
Car	0.163	0.008	0.092	1.771	0.000	0.041
Mobile Phone	0.244	0.111	0.315	0.774	0.000	0.333
Cart	0.324	0.376	0.486	0.666	0.043	0.791
Plough	0.266	0.128	0.335	0.794	0.000	0.458
Donkey	0.345	0.230	0.423	0.815	0.000	0.666
Socio-economic Indices:						
Convenience Property	.	0.000	1.698	.	-2.253	2.399
Store-of-value Property (CFA Francs)	.	34891.74	64391.96	.	15211.35	61717.01
Productive Capital Property						
Land Area property dedicated to agriculture (Hectares)		2.243	2.546		1.833	2.368
Electric Pump to irrigate		0.487	0.500		0 .289	0.652
Monetary Income (CFA Francs)	.	49966.52	78002.22	.	11224.64	82791.67
Savings (dummy variable)	.	0.165	0.275	.	0.086	0.208
Access to Informal credit (dummy variable)	.	0.854	0.271	.	0.898	0.833

Notes:

1. Except for the number of buildings and the number of rooms, each variable takes the value 1 if true, 0 otherwise.
2. Scoring factor is the "weigth" assigned to each variable (normalized by its mean and standard deviation) in the linear combination of the variables that constitute the first principal component. Impact on PCA score is the impact of a change of an increase one unit for each variable (= Scoring factor / SD).
3. The percentage of the covariance explained by the first principal component is 16%. The first eigenvalue is 2.89; the second eigenvalue is 2.30.
4. Quintiles were defined on the basis of the Convenience Property PCA score.
5. There was no formal access to credit.

Ethnicity and Religion. Among the 117 families participating in the study, the Bambara ethnic group makes up 94.02% of the population. A minority is Peulh (5.98%). The population has an important proportion of Muslims (59.83%) and Christians (37.61%). Some of the families (2.56%) defined themselves as atheist. There is an average of 7.11 persons per household (standard deviation = 3.76). The mean size of the families does not depend on religion (student's *t*-test non-significant) but depends on ethnic group (student's *t*-test $P = 0.030$) and is lower among the Peulh group (4.47 persons per household). Population behaves as a traditional patrilinear society. Only 3% of households have a woman as the head of the family. Summary statistics about socio-economic variables under study are given in Table A2.

(f) School achievements

Assessments. We focus on a set of outcomes that are intended to capture the child's human capital accumulation. These include cognitive function (specific tests), educational attainments (routine school notes), school delay and absenteeism. A battery of cognitive tests was administered monthly to participants the day of the medical active monthly follow-up. Tests were grade specific but not time-specific for two main reasons: children get used faster to the procedure and it is possible to account for learning progression. Specific cognitive tests

were developed with the team of Donéguébougou teachers. They were derived from validated instruments already used in other studies (Jukes et al., 2006). It was a multi-step process: first, new questions or statements were developed based on the format of the original test questions. Next the content of the assessment was modified but the basic format remained the same. The teachers assessed the suitability of the content to the age and level programs and defined four categories: knowledge and comprehension (crystallised intelligence), writing, visual memory, inductive reasoning (fluid intelligence). A Malian adaptation of the Mill Hill vocabulary test was the measure of knowledge and comprehension. Writing abilities were tested by asking to the students to reproduce some words or paragraphs. Visual memory was tested with a visual search test, assessing short-term memory for target pictures from amongst distracters. Inductive reasoning was tested with mathematics exercises where children had to find different combinations of numbers. All tests were administered by the teachers in one session lasting around 45 minutes in the school. A little game was made at the end of the session to test inattentive behaviours. Tests of academic performance can be assessed using school progress reports and the teacher's judgement (Nokes et al., 1991). Routines evaluations were given by teachers, according to the national education program (first grade children have no evaluation). Absences and causes of absenteeism were also routinely registered each morning and afternoon by the teachers. Teachers gave the causes of absenteeism according to their own knowledge of the child and village events. If the cause reported was illness, it was confirmed by analyzing the health centre registry and then attributed to a specific disease.

Output Variables. First, all cognitive variables were standardised by class but not by cross-sectional follow-up to take into account scores evolution in time (Figure A1). A principal component analysis was then performed on the four cognitive function variables to compute a cognitive function score (Bartlett 1937; Jukes et al., 2006). Internal reliability was high (cronbach $\alpha > 0.7$). Second, routine school notes and final year exams were also standardized in order to compare all the children and annual mean standardized notes were used. As Figure A2 shows, annual average standardized academic school notes are highly correlated with the annual cognitive mean function score ($r = 0.81$). Therefore, the cognitive function score seems to be a good measure of educational achievement. Summary statistics are provided in Table A2. Third, a school delay variable was constructed following the Moock and Leslie (1986) procedure. We first run an OLS regression of the school grade on age in a log-log equation:

$$logG_i = \alpha + \beta log(a_i) + \varepsilon_i \qquad (2)$$

Where G_i is the observed primary education grade level and a_i is the age of child i.
Then we subtract the predicted values of the logarithm of G_i, from the child's observed grade level. This provides the dependant variable GA_i, primary education grade level given age.

$$GA_i = E_i - e^{est(logGi)} \qquad (3)$$

GA_i is positive (negative) if the child is ahead (behind) in school relative to other children of the same age.

4. EMPIRICAL SPECIFICATION

Before running estimates of education quality functions designed to assess the marginal impact of health status on school achievement of children, a preliminary step is required. It

deals with the conditions to be met for a pooling of time-series and cross-section data. Our data is a single cohort of children but we have different time dimensions in our educational outputs (panel dimension for cognitive assessments and cross-sectional dimension for academic measures and school delay). The impact of health on learning and achievement was addressed using the different multiple regression techniques presented in Todd and Wolpin (2007), Currie and Stabile (2006) and Fletcher and Wolfe (2008). For the needs of our study, we define the general linear model as:

$$E_{i,t} = \alpha_1 X_{i,t} + \alpha_2 X_{i,t-1} + \ldots + \alpha_t X_{i,1} + \beta_t \mu_{i,0} + \nu_{i,t} \rho_1 + \nu_{i,t-1} \rho_2 + \ldots + \nu_{i,1} \rho_t + \varepsilon_{i,t} \quad (4)$$

where $E_{i,t}$ is the education output for child i at time t, $X_{i,t}$ represent observed inputs and $v_{i,t}$ unobserved inputs at time t, $\mu_{i,0}$ denotes the child endowed mental capacity and $\varepsilon_{i,t}$ is a measurement error. We use different estimation techniques to estimate the education production function.

First, we use the contemporaneous cumulative specification with orthogonal endowments and omitted inputs:

$$E_{i,t} = \alpha_1 X_{i,t} + \alpha_2 X_{i,t-1} + \ldots + \alpha_t X_{i,1} + e_{i,t} \quad (5)$$

Where $e_{i,t}$ is a residual term that includes the effect of any omitted inputs, endowments, and measurement error. Observable lagged inputs are included but omitted factors are supposed to be orthogonal to the included input measures. This model was estimated using OLS regressions techniques.

Second, the fixed-effect specification (within child) was preferred to the random-effect model on the basis of the Hausman specification test:

$$E_{i,t} = \alpha_1 X_{i,t} + \alpha_2 X_{i,t-1} + \ldots + \alpha_t X_{i,1} + b_i + e_{i,t} \quad (6)$$

Where b_i are individual fixed effects.

A comparison of (5) and (6) indicates whether the OLS estimates are driven by omitted variables at the child level. We did not estimate family fixed effects models because main family-level factors are supposed to be captured by children fixed effects. Measurement error of the health variables is a potentially important problem. However the research protocol already described and the use of well measured malaria indicators lower the risk of measurement errors.

5. RESULTS AND IMPLICATION

(a) Factors associated with cognitive performances: panel analysis.

Table 3a shows comparisons in the cognitive function mean score between different sub-samples. Mean cognitive scores of children with clinical malaria (active and passive follow-up) and asymptomatic malaria (active follow-up) are significantly lower than mean cognitive score of children without clinical malaria or without asymptomatic malaria. Moreover, there seems to be a negative relationship between *P. falciparum* parasitaemia and the cognitive function mean score and between level of malarial anaemia and the cognitive function mean score: differences between mean cognitive scores are highly significant in both cases. The results are also suggestive of a cumulative effect of repeated simple malaria cases. In average, children who experienced two malaria infections between two active follow-ups had lower scores relative to children who experienced one or no malaria infection. For the splenic index

and past convulsion history of the child, the effect seems to play in the same direction but the difference is not significant. One explanation of this result could be that splenomegaly is not only caused by malaria but is multifactor and that the convulsion history of the child is based on a question asked to the mother and not on reliable observations. Other studies have already proven the long-term effects of cerebral malaria on cognitive achievement (Chandy et al., 2008). We also find no significant impact of any malarial indices on inattentive behaviours scores. For other infections (non malarial anaemia, helminth infections and respiratory infections), there were no significant differences between mean cognitive function scores. Nevertheless, these results do not account for several confounding factors: individual specific effects, age, grade, socioeconomic status, lagged realisation of the variables… The econometric models already described are useful to control for these factors.

TABLE 3a: Cognitive performances of study children in relation to health status.

		Obs (%)	Cognitive Function Mean Score	SD	Student's *t*-test and Anova *F*-test *P value*
Active Follow-up					
Clinical Malaria	No	1766 (98.43)	0.008	1.417	0.033**
	Yes	28 (1.56)	-0.562	0.942	
P. falciparum Parasitemia	<500	1491 (83.11)	0.072	1.394	
	500-1000	108 (6.02)	-0.035	1.426	<0.001***
	1000-1200	19 (1.05)	-0.080	1.475	
	>1200	176 (9.81)	-0.588	1.428	
Asymptomatic Malaria	No	1037 (57.80)	0.064	1.356	0.023**
	Yes	757 (42.19)	-0.088	1.484	
Splenomegaly	No	1702 (94.87)	0.006	1.418	0.428
	Yes	92 (5.12)	-0.113	1.316	
Anemia					
Non malarial Anaemia	No	828 (46.15)	0.099	1.320	
	Mild	177 (9.86)	0.016	1.547	0.503
	Moderate	4 (0.22)	-0.541	1.159	
	Severe	*no obs*	*no obs*	*no obs*	
Malarial Anaemia	No	587 (32.72)	0.010	1.497	
	Mild	191 (10.64)	-0.439	1.339	<0.001***
	Moderate	7 (0.39)	-0.749	1.171	
	Severe	*no obs*	*no obs*	*no obs*	
Respiratory infections	No	1773 (98.82)	0.001	1.415	0.665
	Yes	21 (1.17)	-0.132	1.189	
Helminth Infections	No	1788 (99.66)	-0.002	1.412	0.146
	Yes	6 (0.33)	0.836	1.545	
Passive Follow-up					
Clinical Malaria between two active follow-up	No	1666 (92.86)	0.027	1.424	0.003***
	Yes	128 (7.13)	-0.355	1.200	
Respiratory infections between two active follow-up	No	1759 (98.04)	-0.004	1.419	0.356
	Yes	35 (1.95)	0.174	1.033	
Helminth Infections between two active follow-up	No	1785 (99.49)	-0.003	1.413	0.192
	Yes	9 (0.50)	0.612	1.292	
Active and Passive follow-up					
Repeated Malaria between two active follow-up	0	1666 (92.86)	0.027	1.424	
	1	123 (6.85)	-0.348	1.222	0.012**
	2	5 (0.27)	-0.534	0.399	
Interviews					
Childhood Past Convulsion	No	23 (10.13)	0.011	1.044	0.347
	Yes	204 (89.86)	-0.205	1.046	
Childhood Hospitalization	No	14 (6.16)	-0.016	1.069	0.836
	Yes	211 (92.95)	0.043	0.681	
Childhood Malnutrition	No	10 (4.40)	-0.030	1.045	0.636
	Yes	212 (93.39)	0.129	1.006	

Notes:
*** denotes statistical significance at the 1% level, ** at the 5% level, * at the 10% level.

Table 3b presents our baseline OLS estimates of the effect of malaria on child outcomes. Other control variables included in the model but not presented here are dummies for mother alive, father alive, age7 to age17, grade, sex, religion, ethnicity, savings, informal access to credit, convenience property score, store-of-value property, capital property, monetary income, age of the head of household, literacy of the head of household, child work hours, child spent time in homework, whether or not the child has somebody who helps him for homework. Table 3b indicates that children with higher malaria indices have worse cognitive function scores. For instance, regression (2) indicates that children with clinical malaria the day of the active follow-up score 0.342 less than children without malaria. This impact is only for the direct effect of an attack of malaria the day of the active follow-up. We can also look at the impact of a malaria attack between two active follow-ups: children who had experienced a clinical attack of malaria between two active follow-ups score 0.414 less compared to children who had had no attack. These effects seem to last as some coefficients of the lagged malaria variables are significantly different from zero and negative. Once again, except for the splenic index, all indices of malaria have a significant negative impact on cognitive function scores. The effect is also large relative to the effect of other variables. One way to think about the size of these effects is to compare them with the effect of the weight for age z-score which has consistently significant effects. For example, a one-point increase in the weight for age z-score is associated to a 0.14 increase in the cognitive function score. As we said the weight for age z-score does not change significantly for the same child during one year and a one point increase (or decrease) in z-score is a rather rare event, particularly for children aged between 7 and 17, whereas malaria is a common illness in this area. We can interpret this coefficient as the long-term effect of childhood nutritional status. Another interesting result is that the higher is parasitaemia, the lower is the cognitive score as regressions (1), (3), (4) and (5) tend to highlight. For instance, children with a *P. falciparum* malaria parasitaemia ≥1200 parasites / μL (with or without clinical symptoms) have an average cognitive score 0.261 less compare to children with a *P. falciparum* malaria parasitaemia <1200 parasites / μL. We also confirm a former result found in the literature about the impact of asymptomatic malaria on cognitive results (Clarke el al., 2008). Our results show that asymptomatic infection affects significantly (at the 10% level) the cognitive performance of the child but this impact (-0.128) seems to be less than the effect of clinical malaria. Children with mild moderate malarial anaemia (defined before) have lower scores than children with no malarial anaemia, controlling for the haemoglobin level. It is possible that the coefficient of moderate malarial anaemia is not significant (however negative) because of a very few number of moderate malarial anaemia cases (see Table 3a). The effects of splenomegaly and past convulsion on cognitive function are not significant.

Other variables of interest that had significant positive effects on outcomes were head of household literacy, age dummies (reference category was age equal to six years), hours spent in household tasks, time spent in doing homework, Muslim dummy, male dummy, informal access to credit, and monetary income (though very low). Variables that had a significant negative effect on outcomes were grade dummies (reference category was first grade), and productive capital variables.

Last, results suggest that effective malaria interventions could also be a valuable addition to school health programs as the number of children sleeping under bed nets the night before the interview is significantly (at the 1% level) and positively associated with cognitive performances in all regressions.

TABLE 3b: The contemporaneous cumulative specification with orthogonal endowments and omitted inputs.

	Dependant variable is Cognitive function PCA score							
	Contemporaneous Cumulative Model - OLS estimations							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Malaria Index								
Monthly Geom Mean *P. falciparum* Parasitaemia	-0.000***							
	(0.000)							
Lagged Monthly Geom Mean P. falciparum Parasitaemia	-0.000							
	(0.000)							
Clinical Malaria	.	-0.342**						
		(0.162)						
Lagged Clinical Malaria	.	-0.424***						
		(0.141)						
P. falciparum Parasitaemia tresholds								
500	.	.	-0.210**					
			(0.087)					
Lagged 500	.	.	-0.105					
			(0.078)					
1000	.	.	.	-0.269**				
				(0.109)				
Lagged 1000	.	.	.	-0.181**				
				(0.088)				
1200	.	.	.	.	-0.261**			
					(0.111)			
Lagged 1200	.	.	.	.	-0.177*			
					(0.092)			
Asymptomatic Malaria	.	.	.	.	.	-0.128*		
						(0.067)		
Lagged Asymptomatic Malaria	.	.	.	.	.	-0.117*		
						(0.068)		
Splenomegaly	.	.	.	.	.	.	-0.096	
							(0.142)	
Lagged Splenomegaly	.	.	.	.	.	.	0.088	
							(0.132)	
Malarial Anaemia								
Mild	.	.	.	.	.	.	.	-0.232*
								(0.120)
Moderate	.	.	.	.	.	.	.	-0.270
								(0.282)
Lagged Malarial Anaemia								
Mild	.	.	.	.	.	.	.	-0.087
								(0.092)
Moderate	.	.	.	.	.	.	.	-0.775***
								(0.216)
Clinical Malaria between two active follow-up	-0.400***	-0.414***	-0.400***	-0.378***	-0.379***	-0.390***	-0.416***	-0.417***
	(0.104)	(0.102)	(0.104)	(0.104)	(0.105)	(0.103)	(0.102)	(0.103)
Lagged Clinical Malaria between two active follow-up	-0.140	-0.147	-0.160	-0.141	-0.144	-0.169*	-0.167*	-0.154
	(0.100)	(0.100)	(0.099)	(0.099)	(0.099)	(0.098)	(0.099)	(0.099)
Past Convulsion	-0.055	-0.047	-0.054	-0.054	-0.053	-0.055	-0.048	-0.034
	(0.102)	(0.102)	(0.102)	(0.102)	(0.102)	(0.102)	(0.103)	(0.103)
Number of children who slept under bednets the night before the interview	0.086***	0.082***	0.085***	0.082***	0.084***	0.090***	0.085***	0.084***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Health control								
Haemoglobin concentration	-0.033	-0.034	-0.037	-0.037	-0.036	-0.040*	-0.031	-0.067**
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.028)
Weight for age z-score	0.145***	0.144***	0.137***	0.137***	0.139***	0.140***	0.148***	0.148***
	(0.039)	(0.039)	(0.040)	(0.040)	(0.040)	(0.040)	(0.039)	(0.039)
Intercept	-0.708	-0.631	-0.736	-0.671	-0.680	-0.750	-0.778	-0.411
	(0.483)	(0.485)	(0.482)	(0.485)	(0.484)	(0.476)	(0.480)	(0.497)
Number of observations	1567	1567	1567	1567	1567	1567	1567	1567
R squared	0.209	0.210	0.212	0.213	0.212	0.212	0.207	0.211

Notes:

1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical significance at the 1% level, ** at the 5% level, * at the 10% level.

2. Reference category for Malarial Anaemia is no malarial anaemia.

3. Other control variables are: mother alive, father alive, age7-age17, grade, sex, religion, ethnicity, convenience property, store-of-value property, capital property, monetary income, savings, informal acces to credit, age of the head of houshold, literacy of the head of household, child work hours, child spent time in homework, child has somebody who helps him for homework.

The robustness of these effects is investigated in Table 3c, which presents fixed effects estimates. Except for regression (2) and (7), the results are very similar to those of Table3b, indicating that the OLS results are not driven by unobserved heterogeneity between children. We also gain statistical significance in almost all regressions. Regression (7) and (1) are modified slightly compared to the OLS results. The effect of clinical malaria the day of active follow-up is now insignificant and positive but the lagged value of this variable and the effect of clinical malaria between two active follow-ups keep the same value and remain statistically significant. The low number of clinical malaria cases during active follow-up can be one explanation. The effect of the splenic index on cognitive score now appears to be statistically significant and negative. This can be due to the fact that the fixed effects model manages to capture other invariant confounding factors determining splenomegaly. We take all the results presented in Table 3b and 3c as evidences that children with clinical malaria, asymptomatic malaria, chronic parasitaemia, malaria anaemia may suffer economic consequences of diminished human capital accumulation. The role of splenomegaly in depressing the cognitive performance of the child needs confirmatory studies.

It is useful to think about the estimation biases that the effects of malaria treatment might create. Recall that all the children have received early treatment at no cost. First, it is possible that the absolute value of the effect of malaria is underestimated as the treatment is supposed to be effective and to improve education achievement (Clarke et al., 2008). Second this could generate socioeconomic differences or inequalities in educational outcomes, with high-income children more likely to be treated and more likely to perform better than low-income children. This issue has not been examined carefully in this paper because the study was not designed to answer to this particular question. However, we estimate models that include interaction terms between malaria indices and the convenience property score to investigate whether higher long-term incomes tend to mitigate the effect of malaria. The same height specifications of the fixed effects models, adding the interaction term, are presented in Table A3. Only few of them are statistically significant. Other results are globally unchanged. As we are using permanent family socio-economic indices, the interaction terms are identified by the fact that malaria indices vary within child. Being in a higher income family offers little protection against the negative effects of malaria on tests scores.

We have also estimated models excluding children who were declared by their parents to have a known disease or had a physical handicap at the beginning of the study (sickle-cell anaemia, asthma, rheumatism, one child was one-eyed…) The fixed effects estimates presented in Table A4 are globally unchanged.

We next focused on the question of the influence of other infections detected during active or passive follow-ups (mainly helminth infections and respiratory infections) on cognitive achievement to think about the magnitude of these effects compared to the effect of malaria. We address this question by adding other health controls variables for these infections. Using interacted variables of clinical malaria with other infections would not have been very useful in this analysis as the number of comorbidity cases was very low. Table A5 shows that, in fixed effects models, having been diagnosed with other health problems is not predictive of poorer outcomes and does not change the effect and significance of malaria variables. These results suggest that on average malaria has a greater impact on cognitive function than other health problems.

Last, Table A6 asks whether the impact differ for boys and girls by adding interaction variables of male dummy and malaria indices. It appears that girls suffer much than boys from the effects of malaria.

Table 3c: Fixed-effect (within child) estimations of the Cognitive PCA Score.

	Dependant variable is Cognitive function PCA score Fixed effects models (within child)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Malaria Index								
Monthly Geom Mean *P. falciparum* Parasitaemia	-0.000*** (0.000)							
Lagged Monthly Geom Mean P. falciparum Parasitaemia	-0.000 (0.000)							
Clinical Malaria	.	0.050 (0.131)						
Lagged Clinical Malaria	.	-0.254*** (0.078)						
P. falciparum Parasitaemia tresholds								
500	.	.	-0.211*** (0.052)					
Lagged 500	.	.	-0.091** (0.045)					
1000	.	.	.	-0.237*** (0.065)				
Lagged 1000	.	.	.	-0.125** (0.051)				
1200	.	.	.	.	-0.240*** (0.066)			
Lagged 1200	.	.	.	.	-0.133** (0.053)			
Asymptomatic Malaria	.	.	.	.	.	-0.107** (0.046)		
Lagged Asymptomatic Malaria	.	.	.	.	.	-0.104** (0.041)		
Splenomegaly	.	.	.	.	.	.	-0.276*** (0.096)	
Lagged Splenomegaly	.	.	.	.	.	.	-0.213*** (0.080)	
Malarial Anaemia								
Mild	.	.	.	.	.	.	.	-0.203** (0.085)
Moderate	.	.	.	.	.	.	.	0.166 (0.222)
Lagged Malarial Anaemia								
Mild	.	.	.	.	.	.	.	-0.041 (0.060)
Moderate	.	.	.	.	.	.	.	-0.312 (0.242)
Clinical Malaria between two active follow-up	-0.429*** (0.067)	-0.439*** (0.068)	-0.425*** (0.068)	-0.419*** (0.068)	-0.420*** (0.068)	-0.397*** (0.070)	-0.413*** (0.068)	-0.436*** (0.068)
Lagged Clinical Malaria between two active follow-up	-0.308*** (0.061)	-0.319*** (0.062)	-0.318*** (0.060)	-0.311*** (0.060)	-0.313*** (0.060)	-0.311*** (0.061)	-0.303*** (0.060)	-0.321*** (0.061)
Health control								
Haemoglobin concentration	-0.011 (0.019)	-0.006 (0.019)	-0.014 (0.019)	-0.013 (0.019)	-0.014 (0.019)	-0.012 (0.019)	-0.011 (0.019)	-0.028 (0.020)
Intercept	-3.136*** (0.329)	-3.310*** (0.327)	-3.011*** (0.330)	-2.993*** (0.335)	-2.967*** (0.335)	-3.085*** (0.328)	-3.203*** (0.324)	-2.942*** (0.358)
Number of observations	1567	1567	1567	1567	1567	1567	1567	1567
Number of Children	227	227	227	227	227	227	227	227
R squared	0.322	0.319	0.327	0.327	0.327	0.323	0.324	0.322
Breush Pagan *F*-test	18.56***	18.42***	18.66***	18.61***	18.58***	18.47***	18.71***	18.45***
Hausman specification test	89.18***	126.91***	215.67***	854.55***	238.95***	103.83***	126.51***	262.49***

Notes:

1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical significance at the 1% level, ** at the 5% level, * at the 10% level.

2. Breush Pagan Lagrangian multiplier test for the presence of individual specific effects.The Hausman specification test compares the fixed versus random effects under the null hypothesis that the individual effects are uncorrelated with the other regressors in the model (Hausman, 1978). If correlated (H0 is rejected), a random effect model produces biased estimators, violating one of the Gauss-Markov assumptions; so a fixed effect model is preferred.

3. Reference category for Malarial Anaemia is no malarial anaemia ie either no anaemia at all or non malarial anaemia.

4. Models also include dummies for age7-age17.

(b) Factors associated with academic performance and school delay: cross-section analysis.

All the results for educational achievement are given in Table 4. By contrast with the Sry Lankan studies (Table 1) and with our panel estimations, we do not find an impact of malaria on the so-called academic school notes. In regressions (1) and (3) of Table 4, annual geometric mean parasitaemia has a negative but insignificant impact on academic notes and school delay variables. Regression (2) and (4) also suggest that repeated attacks of malaria have a negative impact on outcomes but this impact is also insignificant so that it is impossible to conclude that malaria, as measured in our study, has an impact on structural educational outcomes. Other variable that have an impact on school delay is the head of household literacy. Family incomes do not seem to play any role in the educational achievement of the child, as none of the socioeconomic indices coefficients are significantly different from zero.

Main reasons could be: the short duration of the study, the lack of reliable malaria history of schoolchildren for at least the past 5 years or early childhood, the reduced number of observations for cross-sectional regressions in comparison with previous panel regressions. Indeed, the time period under study here seems to be insufficient to clearly determine the long-term effects of malaria on school delay and national exams results (only sixth grade children pass national entry grade 7 examinations). Fernando et al. (2003c) followed some children during a larger time period (from 1992 to 1997). They found that malaria infections were a major predictor of children's performance in language and mathematics school examinations. Nevertheless their educational outcomes are not panel data because children were assessed at the end of the follow-up. Moreover they do not use other educational outcomes that reflect long-term education quality such as school delay, school dropout or repetition rates. We suggest that future investigations should try to use regional or national longitudinal surveys (Curry and Stabile, 2006) or to follow children during a larger time period to investigate this issue.

Uncontrolled events in the assessment of the children are suggestive of a bad quality of Malian education in rural area and may also explain these results. First, we did not use repetition rates in our analysis because children in grade 1 or 3 cannot repeat. We suppose that this is a kind of incentive to keep them at school. Second, all children are not assessed regularly: first grade children have no examination, third grade children were only assessed one time in April 2008 whereas fifth grade children were assessed two times in April and June 2008 and sixth grade children received five examinations. These non-standardized methods can bias our estimates of the impact of malaria on academic performances, as the standardized annual average note under study here does not take into account assessment numbers and examination date. Other events such as strikes or teachers' trainings disturbed children education. School entry date (initially planned at the beginning of October) was postpone to the beginning of November. Teacher absenteeism (Table A1) is higher than student absenteeism (Table 6). Even if these events are captured by grade fixed effects, they can strongly affect school outcomes measurement. In this study in general, and more specifically for these particular outcomes, we try to minimize the influence of the intervention on the normal course of the school. The teachers' assessment methods were let as they were in previous years for ethical reasons and because teachers are the last guarantors of education quality in rural areas.

TABLE 4: Educational achievement of study children in relation to malaria indices (OLS regressions).

	Dependant variable is Standardized Academic School notes (mean)		Dependant variable is School Delay	
	(1)	(2)	(3)	(4)
Malaria Index				
Annual Geom Mean *P. falciparum* Parasitemia	-0.000	.	-0.000	.
	(0.000)		(0.000)	
Repeated Malaria				
0	.	0.207	.	-0.082
		(0.200)		(0.169)
1	.	0.017	.	-0.073
		(0.234)		(0.183)
>2	.	-0.368	.	-0.201
		(0.392)		(0.192)
Past Convulsions	-0.089	-0.086	0.245	0.258
	(0.247)	(0.233)	(0.161)	(0.166)
Number of children who slept under bednets the night before the interview	0.054	0.052	0.124**	0.122**
	(0.066)	(0.067)	(0.059)	(0.059)
Health control				
Mean Haemoglobin concentration	-0.048	-0.032	0.112	0.115
	(0.064)	(0.065)	(0.073)	(0.076)
Weight for Age z-score	0.0725	0.073	0.211**	0.210**
	(0.108)	(0.104)	(0.092)	(0.093)
Other Controls				
Male	-0.162	-0.187	0.243	0.236
	(0.162)	(0.163)	(0.162)	(0.164)
Muslim	0.303*	0.264*	0.099	0.109
	(0.157)	(0.157)	(0.146)	(0.149)
Bambara	-0.234	-0.187	0.081	0.087
	(0.383)	(0.379)	(0.336)	(0.346)
Age (years)	0.263***	0.268***	-0.119***	-0.127***
	(0.067)	(0.068)	(0.035)	(0.038)
Age of the Head of Household	0.003	0.003	-0.008	-0.008
	(0.008)	(0.008)	(0.006)	(0.006)
Head of Household literate (can read or write)	0.351	0.357	0.497*	0.491*
	(0.351)	(0.346)	(0.290)	(0.292)
Convenience Property	-0.051	-0.051	0.013	0.011
	(0.048)	(0.048)	(0.043)	(0.043)
Store-of-value Property	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Monetary Income	-0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Productive Capital (land area)	-0.009	-0.010	0.003	0.002
	(0.015)	(0.017)	(0.017)	(0.017)
Intercept	-2.625**	-2.862**	0.512	0.569
	(1.123)	(1.168)	(0.966)	(0.979)
Observations	167	167	227	227
R-squared	0.214	0.226	0.279	0.281

Notes:

1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical
2. Reference category for repeated malaria attacks is no attack of malaria.
3. Other control variables are: mother alive, father alive, grade dummies.

Another possible explanation could be that our malaria indicators only capture short-term or means-term effects but failed to capture the long-term effect of malaria on education. This hypothesis is strengthened by the significant positive effect of the weight for age z-score in regressions (3) and (4). As discussed above, the weight for age z-score is supposed to reflect the acquired nutritional status of the child. We also find a positive and significant impact of the use of bed nets on school delay, which indicates that child protection against malaria matters. As we said, it is also possible that we cannot capture the effect of malaria on these particular outcomes because we don't have reliable indicators of the malaria history of each child or simply because malaria has no long-term effect on these school outcomes.

Nevertheless, other results seem to indicate that malaria prevention has a positive effect for Donéguébougou schoolchildren. Table 5 gives the percent of successful candidate at national entry grade 7 examinations since 1998. Before 2007-2008, the school had never reached a 100% of successful candidates and there was no trend indicating that such a result should be expected in 2007-2008. We take this result as a testimony that improved health surveillance system, especially giving more attention to malaria, allows improving school performances of the child. Next sub-sections provide other evidences of the impact of malaria on education through absenteeism or health expenses.

Table 5: Grade 6 school exam performance since 1998

School Year	Annual Mean Results	% of successful candidate at national entry Grade 7 examination
1998-1999	5.484	70.59
	(1.008)	(0.462)
1999-2000	5.931	39.28
	(1.113)	(0.497)
2000-2001	6.585	71.11
	(1.109)	(0.458)
2001-2002	6.785	70.37
	(0.970)	(0.465)
2002-2003	5.737	88.88
	(0.792)	(0.323)
2003-2004	6.208	95.65
	(0.807)	(0.208)
2004-2005	5.763	97.05
	(1.335)	(0.171)
2005-2006	5.962	91.66
	(0.823)	(0.288)
2006-2007	5.935	73.68
	(1.842)	(0.452)
2007-2008	6.213	100
	(1.401)	(0.000)

Notes:

1. Standard deviation in parenthesis.
2. Annual Mean results for 1998-2008 is 6.060 and mean standard deviation for 1998-2008 is 1.120.

(c) School absenteeism

Results for absenteeism are given in Table 6. Teacher absenteeism is given in Table A1. Malaria is the first cause of absenteeism (28.57% of total absenteeism and 38.23% of school absenteeism for medical reason). These figures are in accordance with results found in Dakar, Senegal (Trape et al., 1993). On average, a child having an acute attack of uncomplicated malaria was absent from school for 0.58 days. This figure is lower than other results found in the literature (Fernando et al., 2003) Nevertheless, in our study, schoolchildren have received specific attention and early treatment. Therefore, it is possible that absenteeism due to malaria has been significantly reduced in comparison with other situations.

TABLE 6: Absenteeism by causes

Cause of absenteeism	Number of lost days
Health	34 (74.72)
Confirmed Malaria Cases	13 (28.57)
Malaria Coinfections	2 (4.39)
Pregnancy	9 (19.78)
Respiratory Infections	2.5 (5.49)
Headache	1.5 (3.29)
Wounds/Burn/Whitlow	1 (2.19)
Helminth Infections	0.5 (1.09)
Dysentery/Food Poisoning	1 (2.19)
Sent to the health center by the teacher but not ill	2 (4.39)
Sent to the health center by the teacher but did not come	1.5 (3.29)
Exclusion for economic reason (subscription fees not payed)	3 (6.59)
Unknown	8 (17.58)
Total	45.5 (100)

Notes:
1. Percent of total lost days in parenthesis.

2. Some children had malaria coinfections. Two children had Malaria and Respiratory Infection (1 day lost) and one child had Malaria and Wound (1 day lost).

(d) Health Expenses

Although all treatments were provided at no cost for all schoolchildren, estimates of Health costs for primary school children are given in Table 7. The cost estimates are based on prices provided by the pharmacy of the national hospital (Hôpital du Point G, Bamako, August 2008) and national tariffs for Artemisinin-based combination therapies (ACT). As the health centre is inside the village, there were no travelling costs for the families. All malaria cases were uncomplicated malaria cases. These figures complete the economic assessment of the impact of malaria on primary education in Donéguébougou. Despite the fact that average cost per consultation for malaria is lower than average expenses per consultation, malaria is the most costly disease representing 44.05% of total health expenses. In addition to the compulsory scholar material (ruler, pen, slate, notebook which amount from 500 to 800 CFA Francs per children per year), subscription fees are 2500 CFA Francs per schoolchildren per year. Books and other learning supports are provided by the public school at no cost for the students. Hence, malaria ranks high among the school budget items for children families. Health and especially malaria can be perceived as a major financial risk in the children's human capital investment decisions.

TABLE 7: Health costs estimates by illnesses (CFA Francs) during the whole school year

Most frequent Infections/Illnesses	Obs	Mean Cost per Consultation	Total cost
Confirmed Malaria Cases	122 (44.36)	1199.631 [1161.601-1237.661]	146355 (44.05)
Respiratory Infections	28 (10.18)	1352.089 [1215-1489.178]	37858.5 (11.37)
Wounds/Burn/Whitlow	26 (9.45)	1518.481 [1372.287-1664.674]	39480.5 (11.86)
Headache	13 (4.72)	622 [622-622]	8086 (2.42)
Helminth Infections	8 (2.90)	952.375 [665.923-1238.826]	7619 (2.28)
Dysentery/Food Poisoning	7 (2.54)	916.142 [825.751-1006.534]	6413 (1.92)
Decayed tooth	5 (1.81)	897.1 [596.232-1197.967]	4485.5 (1.34)
Other (Pyodermite,…)	40 (14.54)	1300.175 [545.446-2054.903]	52007 (15.62)
Malaria Coinfections:			
Malaria + Respiratory Infection	6 (2.18)	1733.167 [1507.863-1958.47]	10399 (3.12)
Malaria + Helminth Infection	1 (0.36)	1168.5	1168.5 (0.35)
Total (CFA Francs)	275 (100)	1210.271 [1097.411-1323.131]	332824.5 (100)
Total (Euros)	275 (100)	1.845 [1.672-2.017]	507.385 (100)
Total (Dollars)	275 (100)	2,727 [2.473-2.982]	750.162 (100)

Notes:

1. 95% confidence intervals into brackets and total percentages in parenthesis.
2. Figures given here do not account for coinfections to avoid estimation biases (except for Malaria coinfections).
3. Exchange rate (15/08/08): 1 euro = 655.96 CFA Francs, $1 = 443.67 CFA Francs.
4. As the active monthly follow-up is an extraordinary cost, only passive follow-up costs were taken into account to assess health expenses.
5. There were no travelling costs as the health center is just near the school.

6. CONCLUSION AND DISCUSSION

Macroeconomic and microeconomic studies are very complementary in the study of the economic burden of malaria. This paper concentrates on the microeconomic level and focuses on a neglected threat: the impact of malaria on basic education and cognitive development of schoolchildren. These results validate macroeconomic investigation on the causal effects of malaria on educational achievement.

We find that children with clinical malaria, repeated malaria infections, asymptomatic malaria and malarial anaemia suffer large negative consequences in terms of achievement tests scores. Short-term impact of malaria seems to be a more important determinant of reduced human capital accumulation than other health determinants and the results also provide evidences of a lasting effect of malaria in time. The role of splenomegaly in depressing the cognitive performance of the child needs confirmatory studies. Clinical malaria is also the first cause of school absenteeism. Even if the cross-sectional results failed to clearly identify the effects of repeated malaria attacks and geometric mean parasitaemia on academic performance and school delay, we find evidence that the use of bed nets can improve schooling attainment. Cross-sectional and Panel results are suggestive of a high, significant and positive effect of the use of bed nets on educational achievement. Fighting malaria could have large payoff in terms of improving the academic outcomes of many children in developing countries. The estimated cost for the school of Donéguébougou during one school year has been estimated to approximately 3.30 US dollars per children per year, taking into account that all infrastructures were available on site before the beginning of the study.

In this article we tackled the problem of malaria measurement, adequate econometric models and study design to correctly assess the link between malaria and education. Nevertheless, the

time period under study here was not sufficient to clearly determine the long-term effects of malaria on school repetition rates, school delay and academic notes. Even if our results are suggestive of an impact of malaria and malaria prevention on the long-term educational attainment of the child (section 5b), future investigations should try to go further and to follow children during a larger time period at a larger scale (including several villages for instance). We insist on the need to have good panel data to investigate this issue. This requests a very demanding procedure but would improve our knowledge about the effects of malaria on education. Nowadays, we believe that malaria has to be considered as one of the most common chronic mental health problems among school children in tropical and subtropical areas. This unrecognized and underestimated disorder has to be taken into account more seriously by policy makers in national education programs and school health interventions.

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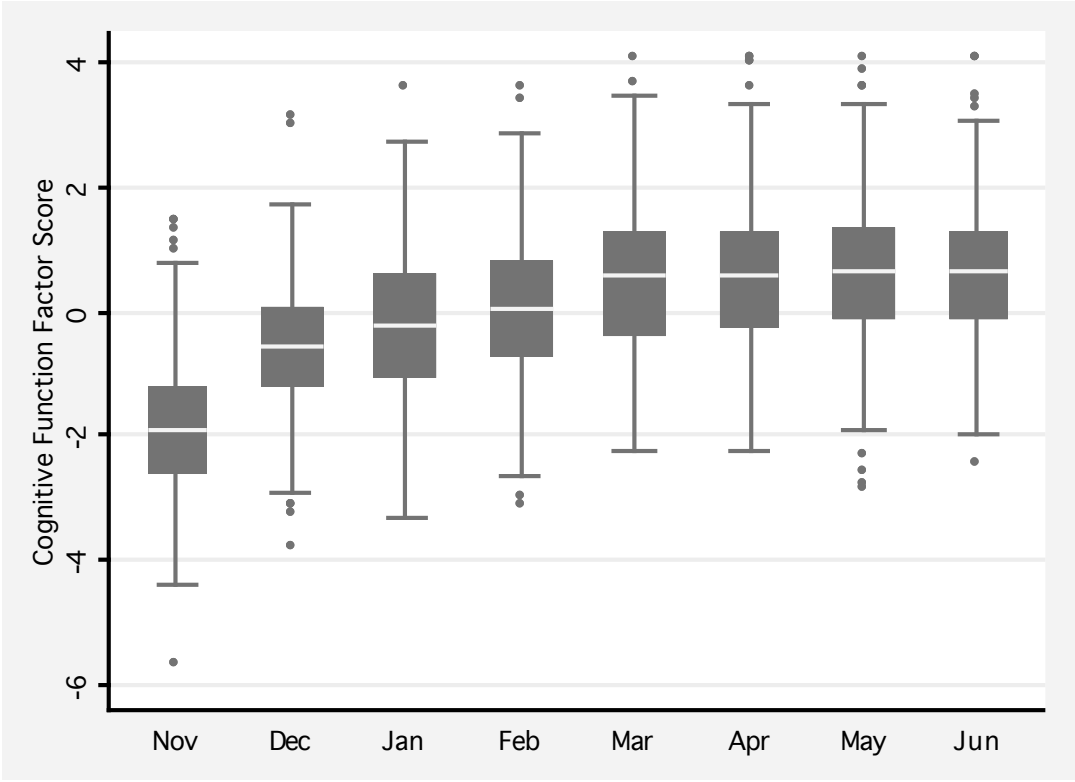
APPENDIX

Table A1: Data on School Characteristics

Grade	Number of Children Per classroom % of total)	Children mean age	Cause of Absenteism	Teacher Absenteeism in days (% of total)
Grade 1	60 (25.99)	7.716 [7.631-7.800]		20 (27.77)
			Strike	18 (25.00)
			Disease	1 (1.38)
			Other (familly, personnal)	1 (1.38)
Grade 3	65 (28.63)	9.905 [9.790-10.020]		43 (59.72)
			Strike	18 (25.00)
			Disease	24 (33.33)
			Other (familly, personnal)	1 (1.38)
Grade 4 and 5	76 (37.89)	12.649 [12.519-12.778]		6 (8.33)
			Strike	3 (4.16)
			Disease	2 (2.77)
			Other (familly, personnal)	1 (1.38)
Grade 6	17 (7.49)	13.808 [13.453-14.164]		3 (4.16)
			Strike	3 (4.16)
Total	227 (100)	10.667 [10.547-10.788]		72 (100)
			Strike	42 (58.33)
			Disease	27 (37.50)
			Other (familly, personnal)	3 (4.16)

Notes:
1. Number of children in Grade 4 is 16 (7.05) and in Grade 5 is 70 (30.84).
2. Because of insufficient teachers, Grade 4 and 5 have been grouped in one classroom.
3. 95% confidence intervals into brackets and percentages in parenthesis.

FIGURE A1: Cognitive Function Factor Score evolution in time and distribution.



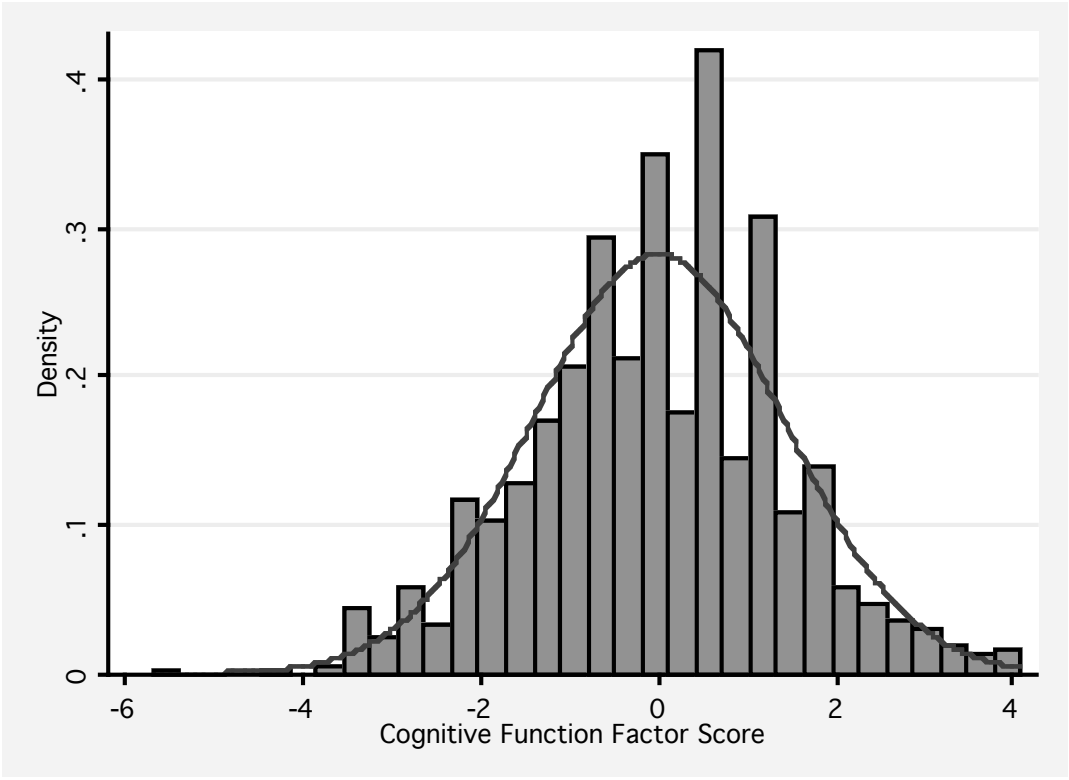


FIGURE A2: Cognitive Function Factor Score and Annual Average Standardized Academic School notes.

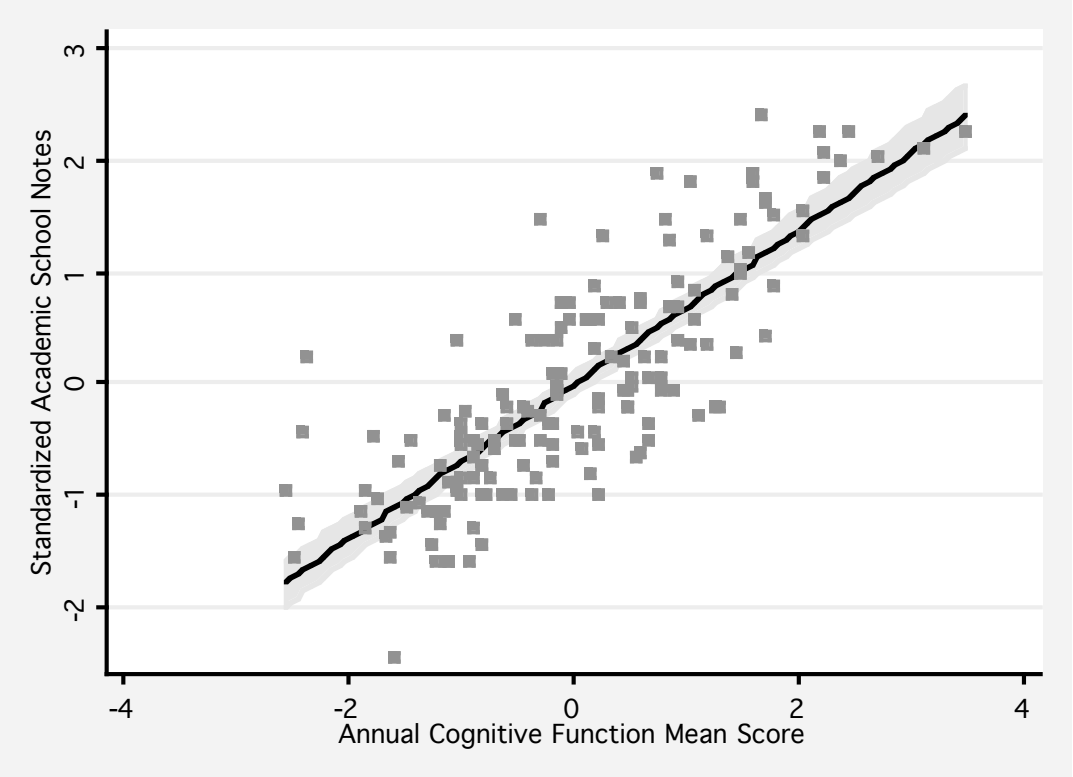


Table A2: Descriptive Statistics

Variable	Obs	Mean	SD	Min	Max
Active Follow-up variables					
Cognitive function factor score	1794	0.000	1.413	-5.696	4.097
Temperature	1802	36.511	0.436	34	39.9
Positive Blood smear	1802	0.437	0.496	0	1
Weight	1802	28.61795	7.941081	13.9	56.6
Height	1802	132.135	12.6093	105	166
Weight for age z-score	1802	-1.424	0.988	-5.167	1.845
Height for age z-score	1802	3.999	0.345	2.834	5.270
Haemoglobin concentration	1802	12.045	1.391	6.6	16.4
P falciparum parasitaemia (parasites / μL)	1802	920.482	6427.123	0	183275
P malariae parasitaemia (parasites / μL)	1802	4.355	83.081	0	2050
P ovale parasitaemia (parasites / μL)	1802	0.509	15.358	0	475
Clinical Malaria cases Prevalence	1802	0.016	0.127	0	1
Asymptomatic Malaria Prevalence	1802	0.421	0.493	0	1
Splenomegaly Prevalence	1802	0.051	0.220	0	1
Anaemia	1802	0.218	0.429	0	2
Helminth InfectionsPrevalence	1802	0.003	0.057	0	1
Respiratory infectionsPrevalence	1802	0.011	0.107	0	1
Passive Follow-up variables					
Clinical Malaria Prevalence	275	0.487	0.500	0	1
Tenperature	266	37.534	0.974	36	40.4
Helminth Infections Prevalence	275	0.032	0.178	0	1
Respiratory infections Prevalence	275	0.127	0.333	0	1
Active and Passive Follow-up variables					
Repeated Malaria per children Attacks during school year	227	0.722	0.891	0	4
Cross-sectional School Outcomes					
School Delay	227	0.087	1.120	-3.630	4.079
Standardized Academic school Notes	167	0.000	0.993	-2.418	2.400
Interview variables (117 households, 227 children)					
Muslim	227	0.581	0.494	0	1
Bambara ethnic group	227	0.947	0.224	0	1
Childhood Past Convulsion	227	0.101	0.302	0	1
Childhood Past Hospitalization	225	0.062	0.242	0	1
Childhood Past Malnutrition	222	0.045	0.207	0	1
Mother alive	227	0.995	0.066	0	1
Father alive	227	0.885	0.319	0	1
Head of Household literate (can read or write)	117	0.051	0.221	0	1
Number of wife of the Head of Household	117	1.384	0.505	1	3
Number of Children in the Household	117	5.880	2.871	0	16
Number of persons who slept in the household the night before the interview	116	7.112	3.764	1	22
Number of children who slept in the household the night before the interview	117	4.119	2.930	0	19
Bednet in the household	117	0.512	0.501	0	1
Insecticide treated bednet in the household	117	0.444	0.499	0	1
Number of children who slept under net the day before the interview	117	0.461	1.038	0	5
Use of Insecticides	117	0.786	0.411	0	1

Table A3: Effects of interactive terms of malaria and socio-economic indices on cognitive score.

	Dependant variable is Cognitive function PCA score							
	Fixed effects models (within child)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Monthly Geom Mean *P. falciparum* Parasitaemia X convenience property index	-0.000							
	(0.000)							
Clinical Malaria X convenience property index	.	-0.049						
		(0.063)						
P. falciparum Parasitaemia tresholds								
500 X convenience property index	.	.	-0.047*					
			(0.028)					
1000 X convenience property index	.	.	.	-0.054*				
				(0.033)				
1200 X convenience property index	.	.	.	.	-0.075**			
					(0.033)			
Asymptomatic Malaria X convenience property index	.	.	.	.	.	0.026		
						(0.026)		
Splenomegaly	.	.	.	.	.	.	-0.048	
							(0.059)	
Malarial Anaemia								-0.042
Mild X convenience property index	.	.	.	.	.	.	.	(0.043)
Moderate X convenience property index	.	.	.	.	.	.	.	-0.090 (0.110)
Clinical Malaria between two active follow-up X convenience property index	-0.011	-0.009	-0.010	-0.005	-0.003	-0.019	-0.011	-0.014
	(0.036)	(0.036)	(0.035)	(0.035)	(0.035)	(0.034)	(0.036)	(0.035)
Number of observations	1567	1567	1567	1567	1567	1567	1567	1567
R squared	0.323	0.319	0.329	0.328	0.329	0.323	0.325	0.322

Notes:

1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical significance at the 1% level, ** at the 5% level, * at the 10% level.
2. Reference category for Malarial Anaemia is no malarial anaemia ie either no anaemia at all or non malarial anaemia.
3. Models also include dummies for age7-age17.

Table A4: Fixed-effect (within child) estimations of the Cognitive PCA Score, excluding children with a known handicap or disease at the beginning of the study.

	Dependant variable is Cognitive function PCA score Fixed effects models (within child)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Malaria Index	-0.000***							
Monthly Geom Mean *P. falciparum* Parasitaemia	(0.000)							
	-0.000							
Lagged Monthly Geom Mean P. falciparum Parasitaemia	(0.000)							
Clinical Malaria		0.047						
		(0.131)						
Lagged Clinical Malaria		-0.252***						
		(0.078)						
P. falciparum Parasitaemia tresholds								
500			-0.203***					
			(0.052)					
Lagged 500			-0.095**					
			(0.046)					
1000				-0.239***				
				(0.064)				
Lagged 1000				-0.127**				
				(0.051)				
1200					-0.241***			
					(0.066)			
Lagged 1200					-0.136**			
					(0.053)			
Asymptomatic Malaria						-0.120***		
						(0.046)		
Lagged Asymptomatic Malaria						-0.105**		
						(0.041)		
Splenomegaly							-0.244**	
							(0.097)	
Lagged Splenomegaly							-0.212**	
							(0.082)	
Malarial Anaemia								
Mild								-0.242***
								(0.086)
Moderate								0.149
								(0.221)
Lagged Malarial Anaemia								
Mild								-0.028
								(0.060)
Moderate								-0.292
								(0.240)
Clinical Malaria between two active follow-up	-0.409***	-0.419***	-0.405***	-0.399***	-0.400***	-0.376***	-0.397***	-0.421***
	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)	(0.071)	(0.069)	(0.070)
Lagged Clinical Malaria between two active follow-up	-0.331***	-0.343***	-0.342***	-0.335***	-0.336***	-0.335***	-0.327***	-0.345***
	(0.061)	(0.062)	(0.060)	(0.060)	(0.060)	(0.061)	(0.060)	(0.061)
Health control								
Haemoglobin concentration	-0.011	-0.006	-0.014	-0.013	-0.014	-0.012	-0.011	-0.033
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)
Intercept	-3.076***	-3.255***	-2.954***	-2.928***	-2.903***	-3.009***	-3.154***	-2.823***
	(0.333)	(0.330)	(0.334)	(0.339)	(0.338)	(0.332)	(0.327)	(0.364)
Number of observations	1518	1518	1518	1518	1518	1518	1518	1518
Number of Children	220	220	220	220	220	220	220	220
R squared	0.324	0.321	0.329	0.329	0.329	0.325	0.325	0.325

Notes:
1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical significance at the 1% level, ** at the 5% level, * at the
2. Reference category for Malarial Anaemia is no malarial anaemia ie either no anaemia at all or non malarial anaemia.
3. Models also include dummies for age7-age17.

Table A5: Comparing the effect of malaria with other infections.

	Dependant variable is Cognitive function PCA score Fixed effect model (within child)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Malaria Index								
Monthly Geom Mean *P. falciparum* Parasitaemia	-0.000***							
	(0.000)							
Lagged Monthly Geom Mean P. falciparum Parasitaemia	-0.000							
	(0.000)							
Clinical Malaria		0.058						
		(0.132)						
Lagged Clinical Malaria		-0.256***						
		(0.078)						
P. falciparum Parasitaemia tresholds								
500			-0.207***					
			(0.052)					
Lagged 500			-0.091**					
			(0.045)					
1000				-0.233***				
				(0.065)				
Lagged 1000				-0.129**				
				(0.051)				
1200					-0.235***			
					(0.066)			
Lagged 1200					-0.138***			
					(0.053)			
Asymptomatic Malaria						-0.102**		
						(0.046)		
Lagged Asymptomatic Malaria						-0.106**		
						(0.041)		
Splenomegaly							-0.267***	
							(0.096)	
Lagged Splenomegaly							-0.213***	
							(0.080)	
Malarial Anaemia								
Mild								-0.195**
								(0.086)
Moderate								0.177
								(0.227)
Lagged Malarial Anaemia								
Mild								-0.040
								(0.060)
Moderate								-0.313
								(0.245)
Clinical Malaria between two active follow-up	-0.432***	-0.444***	-0.429***	-0.423***	-0.424***	-0.402***	-0.418***	-0.441***
	(0.067)	(0.068)	(0.068)	(0.067)	(0.067)	(0.070)	(0.068)	(0.068)
Lagged Clinical Malaria between two active follow-up	-0.303***	-0.314***	-0.313***	-0.305***	-0.307***	-0.307***	-0.299***	-0.317***
	(0.061)	(0.062)	(0.060)	(0.060)	(0.060)	(0.061)	(0.060)	(0.061)
Health control								
Haemoglobin concentration	-0.011	-0.006	-0.015	-0.013	-0.014	-0.012	-0.011	-0.027
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)	(0.020)
Respiratory infections (at active follow-up)	-0.153	-0.166	-0.138	-0.158	-0.153	-0.131	-0.137	-0.137
	(0.130)	(0.132)	(0.131)	(0.131)	(0.131)	(0.130)	(0.132)	(0.129)
Helminth Infections (at active follow-up))	0.194	0.197	0.196	0.186	0.186	0.182	0.203	0.156
	(0.246)	(0.247)	(0.247)	(0.246)	(0.246)	(0.243)	(0.247)	(0.244)
Respiratory infections between two active follow-up	0.160	0.162	0.158	0.169	0.172	0.163	0.153	0.152
	(0.108)	(0.110)	(0.108)	(0.107)	(0.108)	(0.111)	(0.108)	(0.109)
Helminth Infections between two active follow-up	0.133	0.164	0.0949	0.0908	0.102	0.161	0.138	0.185
	(0.142)	(0.142)	(0.141)	(0.140)	(0.142)	(0.145)	(0.142)	(0.148)
Intercept	-3.147***	-3.333***	-3.024***	-3.002***	-2.977***	-3.105***	-3.220***	-2.975***
	(0.329)	(0.326)	(0.330)	(0.335)	(0.334)	(0.327)	(0.324)	(0.357)
Number of observations	1567	1567	1567	1567	1567	1567	1567	1567
Number of Children	227	227	227	227	227	227	227	227
R squared	0.324	0.321	0.329	0.329	0.329	0.325	0.326	0.323

Notes:
1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical significance at the 1% level, ** at the 5% level, *
2. Reference category for Malarial Anaemia is no malarial anaemia ie either no anaemia at all or non malarial anaemia.
3. Models also include dummies for age7-age17.

Table A6: Comparing the effect of malaria for boys and girls.

	Dependant variable is Cognitive function PCA score							
	Fixed effects models (within child)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Monthly Geom Mean P. falciparum Parasitaemia X Male	0.000**							
	(0.000)							
Clinical Malaria X Male	.	0.091						
		(0.246)						
P. falciparum Parasitaemia tresholds								
500 X Male	.	.	0.196*					
			(0.112)					
1000 X Male	.	.	.	0.233*				
				(0.139)				
1200 X Male	.	.	.	.	0.238*			
					(0.142)			
Asymptomatic Malaria X Male	.	.	.	.	.	0.064		
						(0.097)		
Splenomegaly	.	.	.	.	.	.	0.427**	
							(0.216)	
Malarial Anaemia								
Mild X Male	.	.	.	.	.	.	.	0.055
								(0.190)
Moderate X Male	.	.	.	.	.	.	.	-0.065
								(0.107)
Clinical Malaria between two active follow-up X Male	0.253*	0.260*	0.225	0.222	0.234	0.256*	0.274*	0.280*
	(0.144)	(0.145)	(0.142)	(0.142)	(0.142)	(0.143)	(0.144)	(0.144)
Number of observations	1567	1567	1567	1567	1567	1567	1567	1567
R squared	0.325	0.321	0.330	0.330	0.330	0.325	0.329	0.324

Notes:
1. Robust standard errors in parenthesis. Standard errors clustered at the household level. *** denotes statistical significance at the 1% level, ** at the 5% level, * at
2. Reference category for Malarial Anaemia is no malarial anaemia ie either no anaemia at all or non malarial anaemia.
3. Models also include dummies for age7-age17.