Child Health and Education:
The Primary School Deworming Project in Kenya

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Abstract

There are few convincing estimates of the impact of child health and nutritional gains on educational outcomes in poor countries. This study examines the effect of an inexpensive health intervention - a school-based deworming program - on a range of primary education outcomes in rural western Kenya. The intervention consists of medical treatment for hookworm, roundworm, whipworm, and schistosomiasis: these parasites infect over 92 percent of school-aged children in western Kenya. Among the 75 schools in the study, the selection of schools for assistance was randomized, providing plausible identification of treatment effects. The program is associated with significantly higher school participation in treatment schools (pupils are considered participants if present in school on the day of an unannounced attendance check), especially among girls and younger children. However, treatment is not significantly associated with academic test score performance or grade promotion rates after two years of medical treatment.

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1. Introduction

There is an active ongoing debate on the links between health and economic development. Robert Fogel's (1994) historical work on nutrition, and David Bloom and Jeffrey Sachs (1998) cross-country empirical suggest that poor health plays an important role in underdevelopment. Bloom and Sachs attribute most of Africa's poor economic performance to unfavorable health and demographic factors. However, other cross-country work has disputed whether this is a causal link (Pritchett and Summers 1996; Easterly 1999)[1], and the microeconomic empirical literature has typically not found significant effects of poor health on individual wages, conditional on education, across a variety of African and Asian settings (Mwabu 1991; Smith 1999; Strauss and Thomas 1998).

It remains possible that the positive cross-country correlation between health and income is caused by the negative impact of poor childhood health on educational attainment in less developed countries, which then translates into lower adult income. However, although poor health is often thought to be an important impediment to primary school participation and learning in less developed countries, there is little convincing research on the impact of health and nutritional gains on educational outcomes. The links between health and primary school participation in sub-Saharan Africa are especially poorly understood: cross-country research indicates that primary school enrolment in Africa is significantly lower than primary enrolment in other regions after controlling for national income, parental education, and urbanization, and that average primary school participation in Africa actually declined slightly between 1980 and 1990, a reversal of the rising trend of previous decades (Schultz 1999).

This study provides a unique opportunity to assess the impact of poor health on school participation and academic achievement. We examine the impact of an inexpensive health intervention - a school-based deworming program - on a range of primary education outcomes among 30,000

[1] Historical evidence has also demonstrated that higher incomes need not always lead to better health: Haines et al. (2000) document the dramatic decline in life expectancy and height among United States males during the 19th century – a period of rapid and increasing economic growth – due to increased urbanization and deteriorating diets.

schoolchildren in rural western Kenya. The health intervention consists of medical treatment for common intestinal helminths: hookworm, roundworm, whipworm, and schistosomiasis, parasites that infected 92 percent of schoolchildren at the start of the project. Among the seventy-five primary schools in the sample, the selection of schools for assistance through the program was randomized, providing plausible identification of the impact of health gains on education.

The main empirical result of the paper is that the health program is associated with significantly higher school participation after two years of medical treatment: average school non-participation fell by one-third among treated pupils. Treatment effects are especially large for girls and younger children. Pupils are considered school participants if they are present in school on the day of an unannounced attendance check. However, deworming is not associated with gains in either academic test score performance or promotion rates in the two years after treatment.

The rest of the paper is organized as follows: Section 2 reviews the existing literature on child health and education. Section 3 describes the ongoing non-governmental health project in rural Kenya, and presents the baseline educational and medical characteristics. Section 4 describes the estimation strategy, and Section 5 presents the empirical results. The final section summarizes the results, and discusses future extensions.

2. Intestinal Helminth (Worm) Infections and Child Health

Intestinal helminth (worm) infections – including hookworm (*Necator americanus, Ancylostoma duodenale*), roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichura*) and schistosomiasis – are among the most widespread diseases in less developed countries: recent studies estimate that 1.3 billion people worldwide are infected with roundworm, 1.3 billion with hookworm, 900 million with whipworm, and 200 million with schistosomiasis, and infection rates are particularly high in Sub-Saharan Africa (Bundy, et al. 1998; WHO 1993). The geohelminths - hookworm, roundworm, and whipworm - are transmitted through poor sanitation and hygiene, and schistosomiasis is acquired by bathing in

infected freshwater streams and lakes. School-aged children typically exhibit the greatest prevalence of infection and the highest infection intensity, as well as the highest disease burden (since morbidity is related to infection intensity), due to a combination of high exposure and immunological factors (Bundy 1988).

Although light helminthic infections are often asymptomatic, the adverse health and nutritional impacts of severe worm infections on children are well documented: helminthic infections often lead to iron deficiency anemia, protein energy malnutrition, stunting (a measure of chronic undernutrition), wasting (a measure of acute undernutrition), listlessness and abdominal pain.[2] If left untreated, the infections may also have more serious medical consequences in a minority of cases: roundworm infections sometimes lead to fatal intestinal obstruction, hookworm infection can cause severe anemia, whipworm is associated with chronic dysentery, and schistosomiasis is fatal in a small fraction of cases (Bundy 1994).

Although it has been hypothesized that children with intense infections may be less attentive in school and as a result show reduced educational achievement, existing research has not succeeded in estimating the impact of helminthic infections on educational outcomes. As discussed below, the few existing randomized studies that investigate the treatment effects of deworming focus principally on cognitive performance (such as tests of recall) rather than outcomes of more direct interest to economists and policymakers, including pupil attendance and enrollment in school, repetition rates, academic exam scores, and ultimately, labor market outcomes.

Intestinal helminths are treated using low-cost single-dose oral therapies appropriate for delivery at infrequent intervals of six months to a year (Bundy and Guyatt 1996). The broad-spectrum anthelmintic albendazole is used to treat the geohelminths, and praziquantel is used to treat schistosomiasis. These drugs have been endorsed by scientific committees of the World Health Organization and have virtually no side effects (WHO 1992). However, girls older than 12 years of age

[2] Refer to Adams et al. (1994), Corbett et al. (1992), Hotez and Pritchard (1995), and Pollitt (1990).

are typically excluded from mass deworming treatment projects – in which individualized pregnancy screening is not feasible – due to the potential embryotoxicity of the deworming drugs.

Medical treatment with albendazole and praziquantel is inexpensive: a single yearly treatment of albendazole costs less than 50 cents per person per year and praziquantel costs roughly one dollar for a primary school pupil of average weight. School-based deworming programs that use the existing school infrastructure to deliver anthelmintics and health education to a large number of children have been identified as an especially cost-effective public health intervention in high prevalence areas and have been endorsed by the World Bank and World Health Organization (Bundy et al. 1990; Warren et al 1993; World Bank 1993; World Health Organization 1987), as mass treatment eliminates the need for costly individual parasitological screening.

There is increasing interest in implementing school-based deworming projects in less developed countries, as evidenced by the recent FRESH – Focusing Resources on Effective School Health – initiative involving the World Bank, World Health Organization, UNESCO, and UNICEF, as well as ongoing World Bank school health projects in Uganda and India, Partnership for Child Development projects in Ghana, Tanzania, and Vietnam, and government programs in Egypt (PCD 1997). Wide adoption of school-based helminth control programs will likely require the active participation of education ministries in developing countries, and this may require evidence on the effect of deworming on educational outcomes. However, it remains unclear whether deworming leads to educational gains (Dickson et al. (2000)).

2.1. Evidence on Child Health and Education

Behrman (1996) concludes that there is little convincing evidence of a causal relationship between improved child health and primary education outcomes in poor countries. Although most cross-sectional studies find a positive association between health status and education, few address the unobserved individual characteristics and behavioral responses that may bias ordinary least squares

estimates, and the existing experimental evidence is limited and often inconclusive. One exception to this generalization is anemia: a growing number of prospective studies suggest that iron supplementation has a positive impact on the educational outcomes of anemic schoolchildren (Nokes et al. 1998).

The existing literature on the impact of helminthic infections is a case in point. William Watkins and Ernesto Pollitt (1997) comprehensively review the studies examining the impact of intestinal worms on mental performance. Although most cross-sectional studies associate worm infections with reduced mental performance and school achievement, their results are potentially flawed because it is difficult to identify and measure all personal characteristics that determine school performance. Omitting relevant explanatory variables may lead to spurious correlations if unmeasured characteristics that lead to better school performance are also associated with a lower risk of helminth infection. As discussed below, randomized selection into treatment and comparison groups in the proposed study will address some of the issues that make cross-sectional studies difficult to interpret since students in the treatment and comparison groups should be similar along both measured and unmeasured characteristics.

While at least five recent randomized studies have examined the impact of worm infections on cognitive performance among primary school children, the overall evidence on the impact of deworming on cognition is inconclusive (Dickson et al. 2000; Drake et al. 1999). In a review of these studies, Dickson et al. claim that "the evidence of benefit for mass [deworming] treatment of children related to positive effects on [physical] growth and cognitive performance is not convincing. In light of these data, we would be unwilling to recommend that countries or regions invest in programmes that routinely treat children with anhelmintic drugs." These existing studies have small sample sizes, limited outcome measures, and short time periods of study, shortcomings addressed in the current study and in future project research. Only two of the existing randomized studies examine deworming treatment effects on school attendance, and they reach different conclusions (Simeon, Grantham-McGregor, Callender and Wong 1995; Watkins et al. 1996a, 1996b). Of the five existing randomized studies, two find that deworming is associated with improved test performance among either heavily infected pupils or wasted

pupils (Nokes, et al. 1992; Simeon, Grantham-McGregor, Callender, and Wong 1995), two other studies find insignificant test score treatment effects (Simeon, Grantham-McGregor, and Wong 1995; Watkins et al. 1996a, 1996b), and one finds significantly negative deworming treatment effects (Pollitt, et al. 1991). Due to their limited durations – the longest existing randomized study tracks outcomes for less than one school year – none of these studies estimates deworming treatment effects on promotion rates.

3. The Primary School Deworming Project in Busia, Kenya

The Primary School Deworming Project (PSDP) offers a unique opportunity to evaluate the impact of a school-based helminth control program on primary education outcomes in Kenya within the context of a social experiment.[3] The non-governmental organization Internationaal Christelijk Steunfonds Africa (ICS) is carrying out the project in Kenya's Busia district, a poor and densely-settled farming region in western Kenya adjacent to Lake Victoria. The average daily wage for agricultural labor in Busia is 0.85 U.S. dollars, which is low by Kenyan standards (Gugerty [2000]).

The seventy-five schools participating in the program consist of all rural primary schools in Budalangi division and Funyula division in southern Busia district, and contain over 30,000 pupils between the ages of six and eighteen. Budalangi and Funyula divisions are in turn composed of eight administrative subunits called geographic zones. Figure 1 places Busia district in a map of Kenya, and Figure 2 locates the 75 sample schools within Budalangi and Funyula divisions. Parasitological surveys conducted by the Kenyan Ministry of Health and ICS indicate that these divisions have the highest helminth infection rates in Busia district.

[3] Helminthic infections have long been recognized as an important public health problem in Kenya. The British Colonial Government's *Kenya Native Affairs Department Annual Report 1927* writes that: "The most prevalent diseases in the Kavirondo districts [which include present-day Busia district] are respiratory complaints, worms, malaria, and ulcers." Regarding helminthic infections in central Kenya, the report writes that: "A very high rate of helminthic infection, estimated to be as high as 78 percent, exists among the natives, and a great deal of the idleness and lethargy of the [locals] may be attributable to this cause." (Colony and Protectorate of Kenya 1928).

In January 1998, the seventy-five PSDP schools were randomly divided into three groups of twenty-five schools – Group 1, Group 2, and Group 3, as follows: the schools were first stratified by geographic zone and by their involvement in other non-governmental assistance programs.[4] The schools were then listed alphabetically, and each third school was assigned to a given project group. The location of schools in each group is indicated in Figure 2. Due to the administrative constraints of ICS, the health intervention is being phased in to each group of schools over several years. The Group 1 schools received free deworming treatment in 1998, 1999, and 2000, the Group 2 schools in 1999 and 2000, and Group 3 will receive treatment in 2001. This implies that Group 1 schools were treatment schools in 1998, while Group 2 and Group 3 schools were the comparison schools; in 1999, Group 1 and Group 2 schools were the treatment schools and Group 3 schools served as comparison schools. This design will allow us to evaluate the impact of deworming over the course of three years in future research; this study presents the first two years of project results.

The randomization of treatment assignment allows differences in educational outcomes across treatment and comparison schools to be attributable to the health intervention. Medical treatment was not randomized among students within schools because ICS believed that this would meet resistance from parents. The program consists of deworming medical treatment with albendazole and praziquantel provided at six-month intervals. In addition to medical treatment, the project intervention in treatment schools consists of NGO public health lectures on worm prevention methods, and the provision of health education materials focusing on proper hygiene and sanitation.

3.1. Baseline Characteristics

The ICS field staff administered questionnaires in early 1998 to collect information on school and pupil characteristics, including household asset ownership and sanitation facilities at home, personal

[4] Twenty-seven of the seventy-five project schools were also involved in other projects, which consisted of financial assistance for textbook purchase, classroom construction, and teacher training.

hygiene, and certain health symptoms associated with worm infection, such as self-reported blood in stool, as well as school financial, demographic and academic characteristics. Similar pupil and school questionnaires were also administered in early 1999, before 1999 medical treatment.

Table 1 presents average baseline pupil and school characteristics, and indicates that the randomization succeeded in creating groups similar along a range of demographic, nutritional, and socioeconomic dimensions. There are no statistically significant differences across the Group 1, Group 2, and Group 3 schools in terms of total pupil population, distance to Lake Victoria, school sanitation facilities, pupil weight-for-age, self-reported health problems, pupil asset ownership, or school funding per pupil. In rural Kenya, local school funds are principally used to purchase textbooks, desks, chalk, and classroom construction. Rates of helminthic infections in the surrounding geographic zone are also nearly identical across the three groups. There are small but statistically significant differences in self-reported blood in stool and cleanliness (observed by NGO fieldworkers) across Group 1 and Group 3 schools.

However, despite randomized selection into treatment and comparison groups - which produces groups with similar characteristics in expectation – Group 1 schools had substantially lower average scores on 1996 Kenya government primary school academic examinations than both Group 2 and Group 3 schools – the difference between Group 1 and Group 2 schools is significantly different than zero at traditional confidence levels – suggesting that Group 1 schools were of lower academic quality on average.[5] These pre-treatment test scores are included as explanatory variables in the empirical section to control for pre-existing variation in school quality.

3.2. Medical Aspects

[5] 1996 test scores are only available averaged by grade, for each school. Scores were normalized to a *N(0,1)* for each grade. The test score magnitudes presented in Table 1 are thus not directly comparable to the 1998 test score results presented in Tables 10 and 11, which were normalized at the individual level.

In January and February 1998, a randomly chosen sample of ninety grade three to eight pupils in each of the 25 treatment (Group 1) schools participated in a parasitological survey conducted by the Kenya Ministry of Health, Division of Vector Borne Diseases. Each child was given a plastic container and asked to provide a fecal sample; samples were examined in duplicate within 24 hours using the Kato-Katz method. Table 2 presents the survey results, which indicate that nearly 92 percent of pupils had at least one helminthic infection and nearly 37 percent had at least one moderate to heavy helminthic infection using modified WHO infection intensity standards described in Brooker et al (2000b). Table 2 indicates that younger pupils and boys are somewhat more likely to have moderate to heavy helminthic infections. The prevalence of helminthic infections in western Kenya is high by international standards, although there are a number of African settings with similar infection profiles (Brooker et al 2000a).

Table 3 presents the pupil and school characteristics associated with moderate to heavy helminthic infections in early 1998 using probit estimation. The rate of moderate to heavy infections in the geographic zone and proximity to Lake Victoria are both strongly associated with infection status. A ten percent increase in the zonal prevalence of moderate to heavy infections is associated with an 8.1 percent higher individual likelihood of having such an infection. The average school score on 1996 government exams is negatively but insignificantly associated with infection prevalence conditional on other factors. Younger children, pupils with slow grade progression, those with poor nutritional status (as measured by weight-for-age), and pupils with few assets at home (especially latrines) are significantly more likely to have moderate to heavy infections. The importance of latrine ownership is consistent with the fact that intestinal helminths are transmitted through poor hygiene and sanitation; latrine and other asset ownership is also related to higher socioeconomic status, which appears to be negatively associated with infection. Poor nutritional status is often the result of helminthic infections, while the negative association between grade progression and infection could result from either a negative impact of worms on academic performance or omitted pupil characteristics.

The medical protocol was designed in collaboration with the Partnership for Child Development, and was approved by the Ethics Committee of the Kenya Ministry of Health, the Busia District Medical Officer of Health, and the Massachusetts Institute of Technology Committee on the Use of Humans as Experimental Subjects (COUHES). Following WHO and PCD recommendations (WHO [1992]), all schools with geohelminth (hookworm, roundworm, and whipworm) prevalence over 50 percent were mass treated with albendazole, while all schools with schistosomiasis prevalence over 30 percent were mass treated with praziquantel.[6] All treatment schools met the geohelminth cut-off in 1998 and 1999 and were mass treated with albendazole. Six schools met the schistosomiasis cut-off in 1998 and sixteen schools met the cut-off in 1999, and these schools received mass treatment with praziquantel. Infected pupils in schools that did not qualify for mass treatment were treated individually. The NGO obtained community consent in all treatment schools in 1998 – a series of community and parent meetings were held in treatment schools at which the project was described, and parents unwilling to have their child participate in the project were asked to inform the school headmaster. Under the recommendation of the Kenya Ministry of Health, individual parental consent was also required for all children receiving medical treatment beginning in January 1999; consent typically took the form of parents signing their name in a notebook kept at school by the headmaster.

Although the medical profession remains somewhat divided on the issue, current practice is to exclude all females of reproductive age during mass treatment with both albendazole and praziquantel because the drugs may be embryotoxic (WHO 1992), and pregnancy test reagent strips require trained staff to administer and are not practical during mass treatment (Bundy and Guyatt 1996). Under the medical protocol, girls thirteen years of age and older were not supposed to receive medical treatment. Personal interviews (i.e., asking girls when they had their most recent menstrual period) may not be effective in this setting because pregnant girls might conceal such information from the interviewer,

[6] In 1998, pupils received 600 mg albendazole doses during each round of treatment. In 1999 and 2000, pupils were treated with 400 mg albendazole (WHO [1992]). Praziquantel is provided at approximately 40mg/kg (WHO[1992]).

fearing that the information might not be held in confidence. Pregnant girls are often expelled from Kenyan primary schools.

Many pupils eligible for medical treatment in Group 1 schools did not receive medical treatment in 1998, and absence from school on the day of drug administration was the cause of non-compliance in nearly all recorded cases. Table 4 presents the medical treatment information collected by ICS field workers, and indicates that 77 percent of eligible pupils – all boys, and girls under thirteen years old – in treatment schools received at least some medical treatment through the program in 1998. Twenty-two percent of girls ineligible for medical treatment (girls aged 13 and older) also received medical treatment in 1998, due to confusion in the field about pupil age, and because several of the government public health nurses who administered the drugs believed that they were safe to administer to older girls and did so. Figure 3 presents the proportion of pupils in treatment (Group 1) schools receiving medical treatment in 1998 by pupil sex and year of birth. While the proportion of boys receiving medical treatment in 1998 is across all age cohorts, there is a sharp decline in treatment for girls older than the 1985 year of birth cohort (the eligibility cut-off).

Compliance rates for both eligible and ineligible pupils are considerably lower in 1999 than in 1998: approximately 57 percent of eligible pupils received medical treatment at some point in 1999, while only 7 percent of ineligible pupils received treatment. Rates of treatment among ineligible older girls fell substantially between 1998 and 1999, presumably because the eligibility rule was more strictly enforced. Figure 4 presents the proportion of pupils in Group 1 and 2 schools receiving medical treatment in 1999, and illustrates the sharp drop in treatment among ineligible older girls, as well as the substantial drop among older boys. The drop in compliance among eligible older pupils is due to two principal factors, according to field worker records on the causes of non-compliance. First, a substantial subset (up to twenty percent) of the initial sample had either graduated from school or dropped out by 1999. Second, the decision to obtain individual parental consent in 1999 – rather than only the community consent required in 1998 – also contributed to lower compliance rates, since it required all parents to come to

school to sign the consent book; the bottom row of Table 4 presents the relatively low rates of parental consent provided in Group 1 and Group 2 schools. The potential estimation biases resulting from non-compliance are discussed in section 4.

A different form of non-compliance with assigned treatment status could result from children in comparison schools obtaining deworming drugs from sources outside of the NGO deworming program, although there is evidence that this source was minor. The 1999 PSDP Pupil questionnaire indicates that less than five percent of comparison school pupils had ever received medical treatment for worms independently of the program; this suggests that even fewer pupils were benefiting from medical deworming treatment during the study period, since re-infection occur within months after treatment. An additional survey – conducted in Budalangi and Funyula divisions during May to July 1999 to assess the availability of deworming drugs in the area – yields similar conclusions. All hospitals, health clinics, dispensaries, and pharmacies, as well as many local shops (*dukas*) in all towns and markets in the area were surveyed, for a total of 89 health facilities and shops. None of the 64 local shops surveyed had the WHO-recommended broad-spectrum treatments for geohelminths (albendazole and mebendazole) or schistosomiasis (praziquantel) in stock on the day of the visit, though a minority of local shops carried cheaper but less effective anthelminthic medicines (levamisole hydrochloride and piperazine). The survey indicated that over eighty percent of clinics and pharmacies stocked albendazole; however, praziquantel is rarely found even in government clinics, and where it is stocked in clinics and pharmacies it is prohibitively expensive for most residents of the area, costing an average of nearly 900 Kenyan Shillings per dose (60 Kenyan Shillings equaled 1 USD in 1999), several weeks of average wages per dose. The results of both surveys confirm the impressions of the non-governmental organization fieldworkers that few children in Busia received medical treatment for helminthic infections outside of the ICS Primary School Deworming Project.

Pupils assigned to comparison schools could also transfer to treatment schools in order to receive deworming medical treatment through the program; Figure 2 illustrates the high density of primary

schools in this area, which facilitates pupil transfers across schools. However, there is no evidence of large net flows of transfer pupils into treatment schools in either 1998 or 1999. Table 5 indicates that the rate of transfers across schools was nearly symmetric across all three groups of schools in 1998 and 1999: among sample pupils, approximately two percent transferred into a different school in 1998, with nearly equal proportions transferring into Group 1, Group 2, and Group 3 schools. Approximately eight percent of pupils had transferred into a different school by the end of 1999, again with similar proportions transferring to all three groups, although a slightly larger proportion transferred into Group 2 schools (9.6 percent) than into either Group 1 (8.2 percent) or Group 3 (7.4 percent) schools.

Table 6 presents the prevalence of moderate to heavy helminthic infections among Group 1 and Group 2 schools in early 1999 – one year after the first round of medical treatment, and before the start of the second year of medical treatment – and indicates that the prevalence of hookworm, roundworm, and schistosomiasis were significantly lower in Group 1 (Treatment) schools. Overall, 27 percent of pupils in Group 1 schools had a moderate to heavy infection in early 1999 compared to 53 percent in Group 2 schools. The program was less effective against whipworm infections perhaps as a result of whipworm resistance to single dose albendazole treatments (Renganathan et al. [1994]). Widespread flooding in 1998 associated with the El Nino weather system may have contributed to the rise in schistosomiasis prevalence between 1998 and 1999; the schistosomiasis parasite is transmitted through contact with infected fresh water.

Table 6 also indicates that rates of moderate to heavy infections were substantially lower among eligible Group 1 pupils who did not receive medical treatment in 1998 (36 percent) than among eligible Group 2 pupils (52 percent). The untreated and treated eligible pupils in Group 1 schools had nearly identical rates of moderate to heavy infections before treatment in early 1998. The large difference across untreated eligible Group 1 pupils and eligible Group 2 pupils suggests that there may be substantial externality benefits for untreated pupils in treatment schools due to reduced environmental exposure to helminths, as local prevalence falls following mass treatment. Another possible cause of lower infection

rates among untreated pupils in Group 1 schools could be the impact of the project's worm prevention health education component, but Table 6 suggests that this is unlikely. Worm prevention education in 1998 emphasized the need to practice good hygiene, in order to avoid ingesting roundworm and whipworm larvae; wearing shoes in order to avoid hookworm infection; and not playing in infected fresh water to avoid schistosomiasis. However, the bottom three rows of Table 6 indicate that there are no significant differences across treatment and comparison school pupils in terms of observed pupil cleanliness, the proportion of pupils wearing shoes, or pupil exposure to fresh water in early 1999, suggesting that the health education activities did not lead to behavioral change in treatment schools.

Although many mechanisms have been proposed, anemia remains the most frequently hypothesized link between helminthic infections and cognition (Bundy 1994; Drake et al. 1999; Stoltzfus et al. 1997). Table 6 indicates that severe anemia is relatively rare in Busia: fewer then 4 percent of pupils in Group 2 schools (comparison schools in 1998) fell below the Kenya Ministry of Health anemia threshold of 100 g/L in early 1999 before receiving medical treatment. The rate using the WHO 120 g/L threshold is considerably higher, but remains relatively low by African standards: a recent survey of studies of anemia among school children in less developed countries indicates that there is considerably less anemia in Busia than in the six other sub-Saharan African settings examined in Hall et al (2000).

Group 1 pupils also showed gains on self-reported health outcomes after the first year of deworming treatment: five percent fewer Group 1 pupils reported having been sick in the past week, and three percent fewer pupils claimed to be sick often in early 1999. Both of these differences are significantly different than zero at 95 percent confidence.

4. Estimation Strategy

The most important feature of the identification strategy is the project's randomized design. Since treatment status was randomly assigned across schools, program participation is not correlated in expectation with either observed or unobserved individual characteristics or with infection status,

eliminating selection bias if the randomization is properly carried out. Recent research stresses the value of experimental methods in identifying treatment effects: Heckman et al. [1998] examine the biases associated with non-experimental estimation methods in the analysis of the U.S. Job Training Partnership Act, and conclude that their "analysis highlights the benefits of randomized trials. While the [selection] bias is reduced using nonexperimental methods ... it is not eliminated" (1077).[7] Estimators relying on the randomized design are described below.

4.1. Intention to Treat (ITT) Estimators

This estimator represents the average impact of assignment to medical treatment in the PSDP on educational outcomes. The linear equation in (1) illustrates the simplest estimation strategy. Y_i is the school average outcome, T_{1i} and T_{2i} are the treatment school indicators for the first year and second year of medical treatment, and u_i is the school random effect, where *i* refers to the school. Weighted least squares is used since the pupil population varies across schools. Randomized treatment assignment implies that the coefficient estimates β_1 and β_2 – the mean differences across treatment and comparison schools in the first and second years of medical treatment, respectively – are unbiased estimates of the reduced-form intention to treat (ITT) effect of deworming.

$$Y_i = a + \beta_1 \cdot T_{1i} + \beta_2 \cdot T_{2i} + u_i \qquad (1)$$

Equation 2 illustrates a second intention to treat (ITT) estimator, using individual level data. Linear regression is employed to estimate test score treatment effects, and both probit and linear probability models are used when a pupil participation observation is the dependent variable. School participation data was collected during up to five unannounced NGO visits per year, at which pupils present in school were considered participants, and pupils who were either absent or had dropped out were considered non-participants. Y_{ij} is the individual educational outcome measure, X_{ij} are school and

[7] Heckman and Smith [1995] discuss potential limitations of social experiments of the sort examined in this study.

pupil characteristics, T_{1i} and T_{2i} are assigned school treatment status, E_{ij} is an indicator variable for treatment eligibility (which equals one in both treatment and comparison schools for all boys, and for girls thirteen years of age and older), and e_{ij} is the individual disturbance term, where *i* refers to the school and *j* to the student. Disturbance terms are assumed to be independent across schools, but are allowed to covary freely across pupils within the same school; the school effect – which may reflect the impact of the school headmaster and a common learning environment – is captured in the u_i term. School and pupil characteristics control for pre-treatment differences across schools and increase the precision of the coefficient estimates. These controls include the average school result on the 1996 Kenya government District Mock exams for grades 5 to 8,[8] the prevalence of serious helminthic infections in the pupil's grade and geographic zone (the average prevalence for 1998 and 1999), indicators for school involvement in other ongoing non-governmental organization assistance projects,[9] and grade cohort indicator variables.

$$Y_{ij} = a + \beta_1 \cdot T_{1i} + \beta_2 \cdot T_{2i} + \beta_3 \cdot E_{ij} + \beta_4 \cdot (T_{1i} * E_{ij}) + \beta_5 \cdot (T_{2i} * E_{ij}) + X_{ij}' \beta_6 + u_i + e_{ij} \qquad (2)$$

The deworming treatment effect for pupils eligible for the first year of medical treatment is $\beta_1 + \beta_4$ (second year, $\beta_2 + \beta_5$), where β_1 represents the average gain among older girls ineligible for medical treatment. Omitting the *T*E* interaction terms from equation 2 yields the individual data analogue of equation 1.

Existing studies (discussed in section 3) indicate that children with mild helminthic infections may not show significant improvement in cognitive performance and other education outcomes after deworming; intuitively, pupils who experience the greatest improvement in health status after deworming

[8] Average school scores from 1996 - two years before the first year of the project - were employed since the district mock exam was not offered in 1997 due to a national teacher strike in Kenya. Average school exam scores are used because individual exam results are not available for 1996.

[9] Twenty-seven of the sample schools were also receiving assistance from the ICS School Assistance Program during 1998 and 1999. Since this assistance varied across years, school assistance indicators interacted with the year are also included as controls.

may also show the largest educational treatment effects. Identifying students likely to gain from treatment may be important for the evaluation of treatment effects in this case. Parasitological surveys were not conducted in Group 2 and Group 3 schools in 1998, so there is no measure of initial individual infection status for these pupils. Instead, equation 3 includes the proportion of moderate to heavy helminthic infections among pupils in the same geographic zone and grade as a measure of infection likelihood, P_{ij}, as well as including all treatment interaction terms.

$$Y_{ij} = a + \beta_1 \cdot T_{1i} + \beta_2 \cdot T_{2i} + \beta_3 \cdot E_{ij} + \beta_4 \cdot (T_{1i} * E_{ij}) + \beta_5 \cdot (T_{2i} * E_{ij}) + X_{ij}' \beta_6$$
$$+ \beta_7 \cdot P_{ij} + \beta_8 \cdot (E_{ij} * P_{ij}) + \sum_{t=1}^{2} \left[\beta_{9t} \cdot (T_{ti} * P_{ij}) + \beta_{10t} \cdot (T_{ti} * E_{ij} * P_{ij}) \right] + u_i + e_{ij} \qquad (3)$$

The treatment effect coefficients are β_1, β_2, β_4, β_5, β_{9t} and β_{10t} for $t \in \{1, 2\}$. Although P_{ij} may be correlated with individual disturbance terms due to omitted variables, the coefficient estimates on the interaction terms *(T *P)* and *(T *E*P)* are unbiased due to the random assignment of treatment. Once the effect of *P* on outcomes is controlled for with the *P* and *E*P* terms, the conditional covariance $Cov(T_i * E_{ij} * P_{ij}, e_{ij}) \mid E_{ij} * P_{ij} = (E_{ij} * P_{ij}) * Cov(T_i, e_{ij}) = 0$.

4.2. Average Treatment Effect on the Treated (TOT)

Assignment to deworming treatment is used as an instrumental variable for actual treatment status to estimate the average treatment effect on the treated (TOT). This method estimates the average treatment effect for "compliers", individuals whose actual treatment status is affected by treatment assignment (Angrist et al. [1996]). Assignment to treatment is imperfectly correlated with actual treatment due to non-compliance (Table 4); for example, some students in treatment schools were absent on the day of drug administration, while some comparison students received medical treatment independently of the program. Regressions 1 and 2 in Table 9 present the first-stage regressions, and indicate that assignment to treatment is a statistically significant predictor of actually receiving both the first year and the second year of medical treatment. Since survey evidence indicates that only a small

fraction of comparison pupils obtained anthelminthics outside of the program in 1998 and 1999, we assume that comparison school pupils did not receive medical treatment unless they are recorded as having received treatment through the program. The potential bias that may result from this assumption is discussed below.

4.3. Estimation Biases

There are several potentially important biases in the estimation of deworming treatment effects. Unobserved non-compliance with medical treatment assignment does not introduce bias in intention to treat (ITT) estimates since these are defined as the average reduced-form treatment effect of the program taking into account non-compliance. However, unobserved non-compliance in comparison schools – when comparison school pupils obtain deworming treatment from local clinics or shops – may produce a downward bias in estimated treatment effects on the treated (TOT) by improving outcomes among comparison school pupils. The estimated treatment effects on the treated can thus be seen as lower bounds on the actual effects. However, as noted above, survey evidence indicates that few pupils in rural Kenya purchase medical treatment for helminthic infections, suggesting that this bias is likely to be small. Transfers across schools do not bias estimates of the average treatment effect on the treated in the instrumental variable specification, since the medical treatment status of all pupils in treatment schools – including transfers – is recorded.

Pupil attrition may lead to estimation bias in certain outcomes if the distribution of academic quality among treatment school drop-outs differs from the distribution of quality among comparison school drop-outs. Attrition bias does not affect the estimation of either school participation or promotion rate treatment effects due to the definition of these outcomes,[10] but may be important in the estimation of test score treatment effects. A downward bias is generated in both ITT and TOT estimates of test score

[10] Drop-outs are counted as school non-participants in the estimation of the participation rate, and are counted as non-promoted pupils in the estimation of the promotion rate.

effects if a higher drop-out rate in comparison schools is associated with higher average academic quality in these schools, as the worst pupils drop out. This issue is addressed in section 5.3.

5. Empirical Results

5.1. School Participation

Medical treatment for deworming is associated with dramatic gains in school participation among pupils in treatment schools after both one year and two years of medical treatment. The school participation treatment effect for treated pupils is approximately eight percent, reducing total school non-participation by approximately one-third. Deworming may improve school participation by allowing previously ill children to attend school regularly, or by sufficiently improving children's ability to concentrate to make attending school more worthwhile than other activities, such as agricultural labor at home.[11]

School participation was measured during up to five unannounced NGO visits to schools per year in 1998 and 1999. Pupils who were present on the day of an unannounced visit are considered school participants. Considering participation as an outcome measure is more appealing than considering drop-outs and attendance separately, since the distinction between an absent pupil and a drop-out is often not clearly made in school records. Moreover, measuring pupil attendance conditional on not dropping out is unattractive since dropping out is endogenous.

All pupils listed in the school register during the first term in 1998 are included in the analysis of participation rates, including pupils who are recorded as drop-outs at the start of the study. Since many pupils recorded as drop-outs in early 1998 re-enrolled in school at some point during the 1998 or 1999 school years, it is desirable to consider them in the sample.[12] Other pupils have missing year of birth information due to absence from school on the days of questionnaire or exam administration. Although

[11] Many Kenyan children regularly face a choice between school and work: World Bank (1999) data indicate that approximately forty percent of Kenyan children aged 10 to 14 years work at least part-time.

[12] Many initial drop-outs were not assigned a grade by the NGO field staff, complicating the analysis of participation rates by grade. Such pupils are assigned their own grade fixed effect in the regressions in Tables 8 and 9.

boys with missing age information are all assigned to be eligible for deworming treatment, certain assumptions need to be made regarding the treatment eligibility status of girls with missing age information. Girls in pre-school and grades 1, 2, and 3 are assigned to be eligible, and girls in grades 7 and 8 are assigned to be ineligible for treatment, since all but a small fraction of girls in these grades meet the respective eligibility criterion. Girls with missing ages in grades 4, 5, and 6 and those recorded as drop-outs are assigned missing eligibility status, eliminating 277 girls from the sample of approximately 30,000 children. Another 152 pupils are dropped from the sample due to missing both age and sex information.

Average school participation rates in treatment and comparison schools are presented in Table 7. Although the difference in average participation across eligible Group 1 and Group 3 pupils in early 1998 before and immediately after the first round of medical treatment is small (3.1 percent) and insignificantly different than zero, the participation rate for the five post-treatment participation observations is 7.6 percent and is significantly different than zero at 95 percent confidence. The average difference in participation post-treatment is even larger across Group 1 and Group 2 schools (11.0 percent). The treatment effect is larger among pupils eligible for medical treatment than for the ineligible older girls (5.6 percent); moreover, the ineligible girls participation rate after treatment 1998 is only slightly higher than the rate in early 1998 (5.6 percent to 5.0 percent). The 1999 treatment effects are also large and significantly different than zero at high levels of confidence for Group 1 schools (4.9 percent for eligible pupils in the second year of treatment) and Group 2 schools (5.3 percent eligible pupils in the first year of treatment). Ineligible pupils again show large participation gains in both groups of schools in 1999.

The participation gains among ineligible girls in treatment schools in 1998 appear to be driven in part by the high rates of medical treatment among these pupils (Table 4). Large improvements in average participation among the ineligible girls are likely if treatment gains are concentrated among a subset of girls, and if the ineligible girls likely to gain from deworming managed to receive treatment. The compliance data suggest that moderately to heavily infected older girls were in fact six percent more likely to be treated than older girls without a moderate to heavy infection in 1998 (regressions not shown).

However, there were also large participation gains among ineligible older girls in 1999 despite the fact that only 8 percent of ineligible girls received medical treatment, as opposed to 22 percent in 1998. The gains among ineligible girls suggests that there may be important externality benefits for untreated pupils in treatment schools, perhaps due to lower worm burdens as suggested by Table 6. Untreated pupils could also possibly benefit from an improved learning atmosphere in treatment schools.

Three other important patterns are evident in Table 7. First, pupils in lower grades consistently show larger treatment effects than older pupils. For example, in 1998 the average treatment effect for pre-school through grade 2 was 9.2 percent (significantly different than zero at 95 percent confidence) while for pupils in grades 6 to 8 it was 4.2 percent, and in 1999 the comparable gains for Group 2 pupils are 8.3 percent and 2.5 percent, respectively. This may result from higher rates of moderate to heavy infection among younger pupils (Table 2). It is also plausible that school participation is more elastic with respect to health for younger pupils: many pupils drop out of school before reaching the upper grades, which may mean that older pupils are more academically serious and determined to remain in school despite illness.

Second, girls show larger treatment gains than boys: girls in Group 2 schools gained 9.8 percent over girls Group 3 schools in 1999, while the comparable gain for boys is 3.9 percent. This result suggests that school participation may be more elastic with respect to health status for girls than for boys in rural Kenya. Finally, pupils initially recorded as drop-outs have significantly higher school participation rates in treatment schools than in comparison schools, presumably because more such "marginal" pupils return to school after deworming treatment.

Figure 5 presents the participation rates observed during unannounced NGO school visits from May 1998 to November 1999 among eligible pupils (all boys, and girls born since 1985 in 1998 and girls born since 1986 in 1999). Both the differences between Group 1 and Group 3 schools and between Group 2 and Group 3 schools are presented. Pre-treatment participation observations in 1998 were only collected for 27 of the 75 sample schools (for another assistance project) and are not included in the figure. School participation rates for Group 1 schools are consistently higher than rates in Group 3

schools in both 1998 and 1999, and the gap stands at nearly ten percent by November 1999. Group 2 schools have lower school participation than Group 3 schools in 1998 (when both groups were comparison schools), but begin to show participation gains in early 1999. Gains in Group 2 schools increase in the months after treatment, presumably since it takes time for health and nutritional status to improve after deworming. This time series pattern of gradually increasing treatment effects in Group 2 schools suggests that Hawthorne or placebo effects are unlikely to be driving the results, since such effects would presumably become evident immediately after the receipt of medical treatment.

Figure 6 presents histograms of average pupil school participation rates from May 1998 to November 1999 in Group 1 and Group 3 schools, and indicates that the school participation gains resulted from both improved attendance – a higher density in treatment schools at participation rates near one – as well as reduced drop-out rates – a lower density at participation rates near zero.

School participation treatment effect estimates using individual level data are presented in Tables 8 and 9. School assistance controls, grade indicators, and time indicator variables (for each six month interval following the start of the project) are included in all specifications. Table 8 presents the reduced-form (intention to treat) estimates, which can be interpreted as the average impact of assignment to medical treatment on school participation. Probit (regression 1) and linear probability (regressions 2) specifications produce similar estimates: the average school participation gain is approximately seven percent after one year of treatment and four percent after two years, and both are significantly different than zero at 95 percent confidence.[13] The coefficient estimates on other explanatory variables have the predicted signs: the school average exam score in 1996 is positively related to participation rates, and the proportion of moderate to heavy infections in the pupil's standard and geographic zone is negatively (though insignificantly) associated with participation. In all specifications, disturbance terms across

[13] These treatment effects appear plausible in light of the health gains generated by the deworming intervention: 26 percent fewer pupils had moderate to heavy helminthic infections in Group 1 schools than in Group 2 schools in early 1999 (Table 6). If only these seriously infected pupils gained from the medical treatment, their average participation gain would need to be approximately twenty percent in order to generate the overall average participation gain.

observations in the same school are allowed to be correlated, while errors across schools are assumed to be independent. The inclusion of the treatment school-eligibility interaction term *T*E* in regression 3 yields nearly identical treatment effect estimates of a 6.8 percent gain in the first year of treatment and 5.0 percent in the second year of treatment. The *T*E* interaction terms are both significantly different than zero at over 95 percent confidence and account for most of the treatment effect.

Regression 4 examines if pupils in more heavily infected areas gain more from deworming treatment. The estimated participation treatment effects among eligible pupils at mean pupil characteristics are 7.6 percent and 5.1 percent in this case, but the coefficient estimates on the interaction terms *T*P* and *T*E*P* are not significantly different than zero (and unexpectedly take on negative signs). The distribution of zonal infection levels may partially explain this result. The proportion of moderate to heavy infection is quite high in most zones and grades, suggesting that the coefficient estimates on the *T*P* and *T*E*P* may not apply to a case with more variation in local infection levels: the rate of moderate to heavy infection (pre-treatment, for pupils in 1998 and 1999) is over 48 percent, and the interquartile range is (0.33, 0.54). The treatment effect may be non-monotonic with respect to infection intensity if areas with many serious infections also suffer disproportionately from other health problems that lead to persistently low school attendance. Local rates of moderate to heavy helminthic infections are in fact strongly positively correlated with self-reported malaria across geographic zones in this area (regressions not shown).

Regression 5 in Table 8 includes actual infection status from the 1999 parasitological survey as an explanatory variable, and indicates that pupils who were moderately or heavily infected in early 1999 had significantly lower participation rates in 1998 and early 1999 (before the first 1999 round of medical treatment). Regression 5 is restricted to the random subsample of Group 1 and Group 2 pupils selected for the 1999 parasitological survey.

Table 9 presents the two-stage instrumental variable estimates of the treatment effect on the treated (TOT). The sample in Table 9 is restricted to pupils for whom there is non-missing medical treatment information, reducing the sample from school participation 217,331 observations to 201,201

observations. Regressions 1 and 2 present the first stage, and indicate that assignment to a treatment school is a powerful predictor of actual treatment status, especially for eligible pupils. The full set of instruments captures approximately 60 percent of the variation in actual first and second year treatment status. Regression 3 reproduces the reduced form treatment effect estimates for the sample of pupils with non-missing medical treatment information. Regression 4 includes an indicator for actual treatment status rather assignment to treatment, and suggests that treated pupils exhibited 12.0 percent higher participation than non-treated pupils in first the year of medical treatment and 15.6 percent higher participation in the second year. These coefficients reflect both deworming treatment effects, as well as differences in unobserved characteristics across treated and untreated pupils in treatment schools.

Regression 5 presents the instrumental variable estimates. These can be interpreted structurally as the average effects of deworming medical treatment – rather than assignment to treatment – on school participation. The treatment school indicators (T) and the treatment school-eligibility interaction terms ($T*E$) are employed as instrumental variables for actual treatment status in the first stage (regressions 1 and 2). The treatment effect estimates are 8.4 percent in the first year of medical treatment (significantly different than zero at 99 percent confidence) and 7.6 percent in the second year (significantly different than zero at 95 percent confidence). These are likely to represent a lower bound on the actual treatment effect on the treated due to unobserved non-compliance in comparison schools, as discussed above.

5.2. Related Anthropological and Survey Evidence

The treatment effect estimates in Tables 7, 8 and 9 corresponds closely with independent medical anthropological evidence from a nearby region of western Kenya (Geissler et al. 2000). Geissler et al. conducted weekly interviews over the course of seven months in 1998 with a random sample of 57 school children aged 11 to 17 years, and found that children complained of abdominal pains – which are likely to be associated with intestinal infections – in 12 percent of the weekly interviews. In 44 percent of these abdominal pain episodes – or five percent of all interviews – the child claimed that she did not attend school due to the abdominal problems, which is similar to the deworming treatment effect estimates

obtained in Table 8. Geissler et al also find that the children self-treated 84 percent of abdominal illness episodes with local herbs – including leaves, roots, and bark – that were collected and made into herbal tea. In no case did Geissler et al. find that a child or her parent purchased deworming drugs in a local store or clinic. [14]

Surveys with fifteen headmasters of PSDP treatment schools – conducted by ICS field officers and one of the authors in 1999 and 2000 – provide further evidence that deworming treatment was associated with improvements in school participation and health. Thirteen of the fifteen interviewed headmasters stated that deworming treatment in 1998 had a positive effect on pupil attendance. One headmaster asserted that "the attendance rate in general is above average, and particularly for lower classes," which is consistent with the results presented in Table 7. Eleven of the fifteen headmasters also stated that deworming treatment was associated with substantial improvements in the general health and well-being of pupils.

5.3. Academic Test Scores

Deworming is not significantly associated with academic test score gains in 1998 and 1999 after accounting for both pre-treatment differences in academic quality across schools, as well as potential exam participation (selection) bias. One possible explanation for the weak test results is the relative infrequency of severe anemia in western Kenya (Table 6), which eliminates the most commonly proposed mechanism linking worm infections to cognitive performance. A second explanation is the relatively weak observed relationship between average school attendance and test scores, which suggests that the deworming school participation gains (Table 9) would not produce test score treatment effect estimates significantly different than zero at traditional confidence levels; this explanation is explored in greater

[14] Beliefs about disease and malnutrition may partially explain the reluctance of some residents to treat the symptoms of worm infections with western medicine. A team of Kenyan anthropologists write about Funyula division: "Traditionally malnutrition … is thought to be an affliction induced by a breach of or deviation from a social norm, particularly adultery on the part of either of the child's parents. Such a disorder may not be treated by modern medicine or food but by local herbs, *amanyasi kaekhira*. In the case of kwashiorkor, the swelling of the body is attributed to witchcraft and certain local herbs are administered to … reduce the child's size" (Government of Kenya 1986).

detail below. An additional possibility is that increased congestion, as well as negative human capital externalities – as more academically marginal pupils attend school more frequently in treatment schools – had a negative impact on the learning environment for other pupils in treatment schools.

Two sets of examinations were administered in 1998 and 1999: the ICS exams in English, Mathematics, and Science-Agriculture – which are modelled on Kenyan Ministry of Education exams – and government District Mock exams in English, Maths, Science-Agriculture, Kiswahili, Geography-History, Home Science, and Arts-Crafts. The average score across all subjects is employed as the principal test score outcome measure for each set of tests, although the basic results are unchanged if subjects are examined separately (regressions not shown). Although treatment effect estimates are similar for both exams, the empirical analysis focuses on the ICS exams for two reasons. First, exam participation was higher on the ICS exam than on the District Mocks – for example, 84 percent of enrolled pupils in the relevant standards took the ICS exam in 1998 while the corresponding rate for the Mocks was 66 percent – since pupils must pay an exam fee to sit for the Mocks and taking the ICS exam was free. This implies that the ICS exam estimates contain treatment effect information for a larger proportion of pupils. Treatment schools also showed far higher participation than comparison schools on the District Mocks, potentially exacerbating selection biases. Second, the ICS exam provides information on a larger age range of students since the ICS exams were administered to pupils in grades 3 to 8, and the District Mocks were only administered to grades 4 to 8. Finally, follow-up ICS tests (identical to the ICS test administered in school) were administered among a subsample of pupils who did not take the ICS exam (including school drop-outs) in 1998 and 1999, providing additional information on the distribution of the ICS test; follow-up District Mock tests were not administered in either year.

Although the ICS tests for 1998 and 1999 are similar in content, they differ in two important ways. First, the 1998 exam features multiple-choice questions while the 1999 test featured short answers, since short answers were thought to potentially better capture pupil understanding and eliminate correct answers due to guessing. Second, while each grade in 1998 was administered a different exam, in 1999 the same exam – featuring questions across a range of difficulty levels – was administered to all pupils in

grades 3 to 8. Administering a single exam to all pupils is particularly useful if grade promotion rates differ across treatment and comparison schools. In both 1998 and 1999, test scores are normalized among pupils initially enrolled in the same grade in early 1998.

Tables 10 and 11 present treatment effect estimates using individual-level test score data. The 1996 average school scores on District Mocks are included in all regressions as a control for pre-treatment school quality. The estimated treatment effects are -0.047 standard deviations for the first year post-treatment and -0.068 standard deviations for the second year, though neither is significantly different than zero at traditional levels of confidence.[15] Including the treatment school-eligibility (*T*E*) interaction term in regression 2 yields similar results, although the average treatment effect estimates become slightly more negative. Regression 3 includes the interaction of treatment status and average infection intensity for each zone-grade combination, and suggests that pupils in more heavily infected areas did not experience additional gains from deworming treatment.

Differential exam participation across treatment and comparison schools may contribute to the test score gap: for example, 85 percent of eligible pupils in Group 1 schools sat for the 1998 ICS exams compared to 82 percent in the comparison Group 2 and Group 3 schools. A downward bias in ITT and TOT treatment effect estimates would result if the additional marginal treatment school pupils participating in the exam were below average performers. Regression 4 restricts the sample to pupils who were administered the 1998 pupil questionnaire, eliminating over twenty percent of the sample and much of the potential exam participation bias, since pupils present on the day of questionnaire administration (pre-treatment) are likely to have similar characteristics in both treatment and comparison schools. However, this restriction also removes an important subsample of pupils from the analysis. The estimated exam score treatment effects using this restricted sample are nearly identical to those estimated using the complete sample, and remain insignificantly different than zero at traditional confidence levels.

[15] Tests scores are often normalized to *N(0,1)* distributions and expressed in units of standard deviations in the education literature to facilitate the comparison of results across studies.

Regression 5 in Table 10 includes average school participation during the year of the exam as an explanatory variable and excludes the school treatment indicators. The coefficient estimate on average school participation is 0.633; a ten percent gain in attendance is associated with a 0.063 standard deviations higher score on the ICS exam. The coefficient estimate on average school participation in this regression captures both the causal impact of higher participation on test scores, as well as unobserved pupil characteristics correlated with both test scores and school participation. The coefficient estimate also suffers from attenuation bias due to measurement error, since the school participation measure is the average of only up to five participation observations per year (the average pupil was observed 3.84 times per year). It is straightforward to correct this coefficient estimate for attenuation bias since the average participation rate and the number of participation observations are known[16]: the corrected coefficient estimate is 1.96. If deworming leads to test score gains solely through improvements in attendance, and average attendance increases by approximately six percent in treatment schools (Table 8), the estimated "effect" of deworming on test scores in the absence of omitted variable bias would only be (0.06)(1.96) = 0.12 standard deviations. However, if a substantial fraction of the attendance "effect" is due to omitted variable bias – which seems plausible given the limited set of individual controls – the true causal impact of higher attendance on test scores would fall within the 95 percent confidence intervals of the deworming treatment effect estimates in Table 10.

Table 11 presents treatment effect estimates using imputed test score data based on the results of the 1998 ICS follow-up exams; similar follow-up exams were administered in 1999 but the data has not yet been processed for analysis, so Table 11 restricts analysis to the 1998 exams. Pupils who did not take the 1998 ICS exam (including drop-outs) were followed up in twenty of the seventy-five deworming schools and encouraged to sit for the exam several weeks after the actual ICS exam was administered.

[16] The average participation rate among this subsample of pupils is 0.886, which implies that the variance of a single participation observation is (0.886)(1-0.886) = 0.101. Pupils are observed 3.84 times per year on average, which implies that the sampling variance of average annual participation (σ^2_S) is approximately 0.026; the total variance in average annual school participation (σ^2_T) is 0.039. The true coefficient estimate on average annual attendance β is related to the coefficient estimate b by the standard attenuation bias formula: $\beta = b(\sigma^2_T/\sigma^2_T - \sigma^2_S) = 1.96$.

Among grade three through eight pupils with missing ICS exams in these schools, similar proportions were administered the follow-up exam in Group 1 (treatment) schools – 34 percent – and Group 2 and Group 3 (comparison) schools – 32 percent – suggesting that a selection bias is unlikely to be driving the results. In total, 214 pupils were administered the follow-up exam in these twenty schools.

Missing 1998 ICS test score data is imputed in two steps. First, the normalized test scores of the follow-up pupils are regressed on a set of indicator variables for their grade, geographic zone, and school assistance group (assistance from other NGO projects) separately for Group 1, Group 2, and Group 3 schools. It is unfortunately not possible to condition on a broader set of covariates, since many of the pupils with missing exam data are missing pupil questionnaires. Second, the missing test score values for other pupils are imputed as predicted values of this regression, again separately for Group 1, Group 2, and Group 3 schools. The imputation increases the sample size of 1998 ICS exam scores from 14995 to 17768 pupils.

The results employing this imputed data are presented in Table 11. Regression 1 contains that 1998 test score results with only the actual (non-imputed data) and produces a treatment effect estimate similar to that in Table 10, regression 1 (-0.038 standard deviations). Regression 2 includes the imputed test score data and yields a slightly less negative first year treatment effect estimate (-0.018 standard deviations). Regressions 3 through 6 perform quantile regressions on this augmented sample, to determine whether worse academic performers benefited disproportionately from deworming; standard errors in the quantile regression specifications are computed using a bootstrap technique, and are clustered for each school. The treatment effect estimate for the lowest quintile is in fact positive (0.041 standard deviations) although not significantly different than zero at traditional confidence levels. The treatment effect estimates for the remaining quintiles decline monotonically for each quintile, but remain small and are not significantly different than zero.

5.4. Promotion Rates

Table 12 indicates that there is a positive, though statistically insignificant, relationship between deworming treatment and promotion rate increases after one year of medical treatment. It is not possible to compute two-year promotion treatment effect since enrollment data for early 2000 has not yet been processed for analysis. Promotion rates are not conditional on continued school enrolment in 1999: pupils who dropped out by the start of the 1999 school year are counted as not promoted. Unfortunately, there is no pre-treatment data on promotion rates to control for pre-existing promotion patterns across the treatment and comparison schools. Although pupils in pre-school and grades 1 and 2 in Group 1 schools appear to have substantially higher promotion rates than pupils in Group 3 schools – 4.7 percent – the difference is not significantly different than zero at traditional confidence levels. Regression results using individual level data also indicate that there is no significant statistical association between deworming and promotion rates (regressions not shown).

5.5. Project Costs and Benefits

Detailed program costs for the treatment of 15,000 school children in the fifty Group 1 and Group 2 schools in 1999 were collected.[17] The cost of parasitological examinations are not included in this estimate since individual screening is not recommended in areas with high infection prevalence (WHO [1988]), which includes most of sub-Saharan Africa (Brooker et al. 2000a). The total deworming cost per pupil treated in 1999 is 1.46 U.S. dollars – with nearly half the cost of the deworming drug purchases – which is similar to existing cost estimates for similar school-based helminth control projects in other less developed countries (World Bank 1993, PCD 1998). However, this cost constitutes a relatively large health expense in Kenya; by way of contrast, total annual government expenditures on health per capita in Kenya were approximately 5 U.S. dollars from 1990 to 1997, implying that public provision of deworming treatment to all Kenyan schoolchildren aged 6 to 14 years would comprise over ten percent of

[17] The 1998 costs were slightly lower since cheaper generic drugs were used.

national health spending in Kenya if the government administered the program as efficiently as the PSDP (World Bank 1999).

Mass deworming is only one of many worthy health interventions competing for the scarce resources of health ministries in Kenya and other less developed countries, and some authors have recently questioned whether mass deworming ought to be accorded priority for public funds (Dickson et al. 2000). The 1993 World Development Report includes school-based mass treatment for parasitic worm infections among the most highly cost-effective public health interventions for poor countries: measuring cost effectiveness in terms of U.S. dollars per disability adjusted life year (DALY), a standard measure of disease burden, the Report suggested that mass deworming costs approximately 15 to 30 U.S. dollars per DALY, and recent estimates suggest that mass deworming may be even more cost-effective, at only 8 U.S. dollars per DALY in high prevalence communities (Chan 1997).[18] However, vaccination against measles and DPT (diptheria, pertussis, and tetanus) is a potentially even more cost-effective health intervention, at 12 to 17 U.S. dollars per DALY, and yet the vaccination rate for measles and DPT among Kenyan infants of less than one year of age was only 32 percent in 1997 (World Bank 1999).

The following speculative calculation suggests that the labor market benefits of the Primary School Deworming Project alone may far outweigh its cost, providing additional information for an overall deworming benefit-cost estimate. Restricting attention to labor market benefits excludes sizeable health and nutritional gains, understating the true benefits of deworming. Knight and Sabot (1987) estimate that the average labor market return to an additional year of primary schooling in Kenya is 17 percent. Assuming that this gain is log-linear implies that an additional fraction of a year of schooling increases wages by that fraction times 17 percent. Knight and Sabot decompose the returns to education into a return to cognitive performance (on tests of literacy, numeracy, and reasoning) and a direct return to years of schooling, and find that years of schooling alone account for approximately 40 percent of the

[18] By contrast, clinical treatment of leukaemia is significantly less cost effective according to the same criteria, at over 1,000 U.S. dollars per DALY.

total return to education.[19] If deworming leads to increased school participation but minimal cognitive gains – as suggested by the test score results – the direct return to an additional year of primary education would be approximately 7 percent.

Income per worker in Kenya is 570 USD (World Bank 1997), and Table 8 indicates that the average increase in primary school participation after one year of treatment is at least 6 percent of one year. If the wage gains from higher school participation are earned over forty years in the workforce, and future wages are discounted at an annual rate of ten percent, the average individual wage benefit from one year of deworming treatment is 25.8 U.S. dollars, or nearly twenty times the estimated cost of treatment. These cost estimates do not include the opportunity cost of schooling, as children may choose to work rather than attend school. If the average primary school child in Kenya is half as productive as the average adult – which may represent an upper bound on child productivity[20] – the opportunity cost of increased school participation is what a child could earn by working for an additional five percent of a school year, or approximately 9.50 U.S. dollars.[21] The labor market rate of return to deworming treatment in this case remains over 100 percent.

6. Conclusion

To summarize the empirical results, a school-based deworming program conducted by a Kenyan non-governmental organization had a significant positive impact on school participation. The estimated average gain in primary school participation among treated pupils is eight percent, reducing overall pupil non-participation in schools by approximately one-third. This large school participation effect points to the role that tropical diseases such as intestinal worms may play in reducing educational attainment in

[19] This decomposition is for returns to secondary education, but it serves as a useful approximation in the absence of similar estimates for primary education.

[20] Udry [1996] finds that children's agricultural labor is several times less productive than adult labor in another rural African setting (Burkina Faso).

[21] The school year is approximately eight months in Kenya, so 5 percent of the school year is 3.3 percent of a year. 9.50 U.S. dollars represents 3.3 percent of the average annual Kenyan wage of 570 U.S. dollars, divided by two to reflect the lower labor productivity of schoolchildren.

sub-Saharan Africa, the region with the highest prevalence of helminths and other tropical diseases (World Bank 1993). Given the evidence that human capital investment is associated with higher levels of subsequent economic growth, the results may also provide microeconomic support for the claim, advanced by Bloom and Sachs (1998) among others, that the high tropical disease burden is a causal factor contributing to slower African economic development. However, despite the evidence of large school participation gains, there is no convincing evidence of treatment effects on academic test scores or grade promotion rates.[22]

Additional issues that will be explored in future research include why parents in this area of endemic helminthic infections are not currently purchasing deworming drugs for their children – given the moderate costs of the drugs and its potentially important health, educational, and labor market benefits – and why a large minority of children did not receive deworming drugs through the program. The planned study will investigate the role that rural social networks play in the transmission of knowledge about health; the randomized provision of the deworming treatment intervention among households through the project may allow for an unusually convincing examination of information diffusion and social learning. In 2001, the NGO will also introduce a parent user fee for participation in the deworming project, and will explore which parents participate in cost-sharing, and their reasons for participating. Taken together, these findings may provide new insights into the design of successful public health interventions in less developed countries.

[22] Future work will also examine the impact of deworming on cognitive performance, such as memory tests.

7. References

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Table 1: 1998 Average Pupil and School Characteristics, Pre-treatment[23]

	Group 1 (25 schools)	Group 2 (25 schools)	Group 3 (25 schools)	Group 1 – Group 3	Group 2 – Group 3
Pre-primary to Grade 8					
Year of birth	1986.1	1986.3	1985.7	0.4***	0.7***
				(0.2)	(0.2)
Male	0.53	0.51	0.52	0.01	-0.01
				(0.02)	(0.02)
Eligible for medical treatment	0.88	0.89	0.88	0.00	0.01
				(0.01)	(0.01)
Grade progression, Grade – (Age – 6)	-2.1	-2.0	-2.1	-0.0	0.1
				(0.1)	(0.1)
Grades 3-8					
Access to latrine at home	0.82	0.81	0.82	0.00	-0.01
				(0.03)	(0.03)
Cement floor at home	0.21	0.24	0.21	-0.01	0.03
				(0.03)	(0.04)
Have cows at home	0.47	0.47	0.46	0.01	0.01
				(0.03)	(0.03)
Weight-for-age Z-score	-1.39	-1.40	-1.44	0.05	0.04
				(0.05)	(0.05)
Blood in stool	0.26	0.22	0.19	0.07**	0.03
				(0.03)	(0.03)
Clean (observed by field workers)	0.60	0.66	0.67	-0.07**	-0.01
				(0.03)	(0.03)
Sick often (self-reported)	0.10	0.10	0.08	0.02	0.02
				(0.01)	(0.01)
Stomach ache in past week (self-reported)	0.62	0.61	0.58	0.04	0.02
				(0.03)	(0.03)
Malaria/fever in past week (self-reported)	0.37	0.38	0.40	-0.03	-0.02
				(0.03)	(0.03)
School characteristics					
District mock exam score 1996, normalized grade average (grades 5-8)	-0.20	0.18	0.02	-0.22	0.15
				(0.23)	(0.23)
Distance to Lake Victoria	10.0	9.9	9.5	0.6	0.5
				(1.9)	(1.9)
Local school spending per pupil (1997), KSh[24]	95.8	108.6	123.0	-27.1	-14.3
				(41.5)	(42.4)
Pupil population	392.7	403.8	375.9	16.8	27.9
				(57.6)	(57.6)
School latrines per pupil	0.007	0.006	0.007	0.001	-0.000
				(0.001)	(0.001)
Proportion moderate-heavy infections in zone	0.37	0.37	0.36	0.01	0.01
				(0.03)	(0.03)
Proportion moderate-heavy infections in zone, schools < 5km from Lake Victoria	0.46	0.44	0.42	0.03	0.01
				(0.05)	(0.04)

[23] Standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Data from the 1998 ICS Pupil Namelist, and 1998 Pupil Questionnaire and School Questionnaire.

[24] This excludes two outliers greater than 1000 Kenyan Shillings per pupil; the difference remains insignificantly different than zero when they are included. The exchange rate in 1997 was roughly 50 Kenya Shillings = 1 USD.

Table 2: January 1998 Helminthic Infections, Group 1 (1998 Treatment) schools, grades 3 to 8[25]

	Prevalence of infection	Prevalence of moderate to heavy infection	Average infection intensity, in eggs per gram (epg)
Hookworm	0.77	0.15	426 (1055)
Roundworm	0.42	0.16	2337 (5156)
Whipworm	0.55	0.10	161 (470)
Schistosomiasis	0.22	0.07	91 (413)
At least one infection	0.92	0.37	-
Born since 1985	0.92	0.40	-
Born before 1985	0.91	0.34	-
Female	0.90	0.34	-
Male	0.93	0.39	-
At least two infections	0.31	0.10	-
At least three infections	0.28	0.01	-

[25] Sample size: 1894 pupils. Fifteen pupils per standard in grades 3 to 8 for Group 1 schools were sampled. These are the raw averages, as presented in Brooker, et al (2000b); correcting for the oversampling of the smaller upper grades does not lead to substantial changes in these figures. The moderate infection thresholds for the various intestinal helminths are: 250 epg for *S. mansoni*, and 5,000 epg for Roundworm, both the WHO standard, and 750 epg for Hookworm and 400 epg for Whipworm, both somewhat lower than the WHO standard. Refer to Brooker, et al (2000b) for a discussion of this parasitological survey and the infection cut-offs. Standard errors in parentheses. The data were collected in January to March 1998 by the Kenya Ministry of Health, Division of Vector Borne Diseases (DVBD). All cases of schistosomiasis are *S. mansoni*. The bottom two rows should be interpreted as the proportion of individuals with at least two and three moderate to heavy helminthic infections, respectively.

Table 3: January 1998 characteristics correlated with a moderate-heavy helminthic infection among Group 1 (1998 Treatment) schools, grades 3 to 8[26]

	Dependent variable: 1998 moderate-heavy infection Probit
Proportion of moderate-heavy infections in geographic zone	0.81***
	(0.20)
<5 km from Lake Victoria	0.11***
	(0.04)
District mock exam score 1996, normalized grade average (grades 5-8)	-0.028
	(0.021)
Year of birth	0.037***
	(0.011)
Male	0.022
	(0.028)
Grade progression, Grade – (Age – 6)	-0.037***
	(0.011)
Access to latrine at home	-0.075**
	(0.036)
Cement floor at home	-0.052
	(0.031)
Have cows at home	-0.040
	(0.033)
Weight-for-age (Z-score)	-0.037**
	(0.018)
Blood in stool	0.030
	(0.027)
Malaria/fever in past week (self-reported)	0.030
	(0.024)
Clean (observed by field worker)	-0.011
	(0.019)
Number of pupils	1739
Mean of dependent variable	0.37

[26] Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Disturbance terms are assumed to be independent across schools, but are allowed to be correlated within schools. Coefficient estimates can be interpreted as the marginal change in the likelihood of infection with a marginal change in the explanatory variable. Data are the from 1998 PSDP Pupil questionnaire and 1998 parasitological surveys. The definition of moderate-heavy infections follows (Brooker et al 2000b). The sample size in Table 3 is smaller than in Table 2 since some pupils either left certain questions on the pupil questionnaire blank, or were not administered a questionnaire.

Table 4: Proportion of pupils (in initial sample) receiving medical treatment through the ICS Primary School Deworming Program in 1998 and 1999, grades 1 to 8[27]

	Group 1		Group 2		Group 3	
	Eligible pupils	Ineligible pupils	Eligible pupils	Ineligible pupils	Eligible pupils	Ineligible pupils
	Treatment		*Comparison*		*Comparison*	
Any medical treatment in 1998	0.77	0.22	0	0	0	0
Round 1 (March-May 1998), Albendazole	0.60	0.11	0	0	0	0
Round 1 (March-May 1998), Praziquantel	0.64	0.35	0	0	0	0
Round 2 (Oct.-Nov. 1998), Albendazole	0.63	0.12	0	0	0	0
	Treatment		*Treatment*		*Comparison*	
Any medical treatment in 1999	0.58	0.06	0.55	0.08	0.01	0
Round 1 (March-June 1999), Albendazole	0.44	0.05	0.35	0.05	0.01	0
Round 1 (March-June 1999), Praziquantel	0.45	0.05	0.37	0.05	0.01	0
Round 2 (Oct.Nov. 1999), Albendazole	0.51	0.05	0.51	0.07	0.01	0
Parental consent in 1999	0.51	0.41	0.37	0.28	0.01	0.01

Table 5: Proportion of Transfers across schools, 1998-1999

	1998 transfer to a			1999 transfer to a		
	Group 1 School	Group 2 school	Group 3 school	Group 1 school	Group 2 school	Group 3 school
Group 1 school (early 1998)	0.005	0.007	0.007	0.033	0.027	0.027
Group 2 school (early 1998)	0.005	0.007	0.007	0.026	0.032	0.025
Group 3 school (early 1998)	0.009	0.010	0.006	0.023	0.037	0.022
Total transfers	0.019	0.024	0.020	0.082	0.096	0.074

[27] There is drug compliance data for treatment schools for grades 1-8. The 1999 data is incomplete: treatment data is missing for three schools, and parental consent information is missing for six schools. These data are currently being cleaned in Kenya and will be included in future versions of the paper. Eligible pupils include all boys, and all girls under thirteen years of age. Since month and date of birth information is missing for most pupils, assignment of eligibility status for girls born during the threshold year is imperfect. The assumption is made that all girls who turn 13 in a given year are eligible for treatment; this may lead to an underestimate of the proportion of eligible pupils who received treatment.

Table 6: January to March 1999 helminthic infections, anemia, and self-reported health outcomes, Grades 3 to 8, Group 1 schools (1998 Treatment) and Group 2 schools (1998 Comparison) [28]

	All Pupils			Eligible Pupils			
	Group 1	Group 2	Group 1 – Group 2	Group 1, Treated 1998	Group 1, Untreated 1998	Group 2	Group 1, Untreated – Group 2
Any moderate-heavy infection, 1998	0.38	-	-	0.39	0.41	-	-
Any moderate-heavy infection, 1999	0.27	0.53	-0.26***	0.24	0.36	0.52	-0.16
			(0.06)				(0.15)
Hookworm moderate-heavy infection, 1999	0.06	0.22	-0.16***	0.04	0.10	0.22	-0.11
			(0.03)				(0.08)
Roundworm moderate-heavy infection, 1999	0.09	0.25	-0.16***	0.08	0.11	0.24	-0.12
			(0.05)				(0.11)
Whipworm moderate-heavy infection, 1999	0.13	0.18	-0.05	0.13	0.16	0.17	-0.02
			(0.06)				(0.14)
Schisto. moderate-heavy infection, 1999	0.08	0.18	-0.09	0.08	0.10	0.18	-0.08
			(0.06)				(0.15)
Hemoglobin concentration (g/L), 1999	124.8	123.2	1.6				
			(1.3)				
Proportion anemic (Hb < 120g/L), 1999	0.36	0.40	-0.04				
			(0.05)				
Proportion anemic (Hb < 120g/L), 1999	0.02	0.04	-0.02				
			(0.02)				
Sick in past week (self-reported), 1999	0.41	0.45	-0.05**				
			(0.02)				
Sick often (self-reported), 1999	0.12	0.15	-0.03**				
			(0.01)				
Stomach ache in past week (self-reported), 1999	0.36	0.38	-0.02				
			(0.02)				
Clean (observed by field worker), 1999	0.59	0.60	-0.01				
			(0.02)				
Wears shoes (observed by field worker), 1999	0.24	0.26	-0.02				
			(0.03)				
Days contact with fresh water in past week (self-reported), 1999	2.4	2.2	0.2				
			(0.3)				

[28] Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The moderate-heavy infection thresholds for the various intestinal helminths are: 250 epg for *S. mansoni*, and 5,000 epg for Roundworm, both the WHO standard, and 750 epg for Hookworm and 400 epg for Whipworm, both somewhat lower than the WHO standard. Refer to Brooker, et al (2000b) for a discussion of this parasitological survey and the infection cut-offs. Kenya Ministry of Health officials collected the parasitological from January to March 1998 in Group 1 schools, and from January to March 1999 in Group 1 and Group 2 schools. Anemia data were collected by a Kenya Ministry of Health official and ICS field officers using the portable Hemocue finger-prick machine. Parasitological data were not collected from Group 3 (comparison) schools in either year. The self-reported health outcomes were collected during Pupil Questionnaire administration in January to March 1999 in all three groups. For health indicators from the Pupil Questionnaire, the third column includes average outcomes for both Group 2 and Group 3 schools. Table 6 presents school average outcomes. The number of pupil observations for the parasitological results are: Group 1 (all pupils), 609; Group 2 (all pupils), 1544; Group 1 (eligible, treated 1998), 486; Group 1 (eligible, untreated 1998), 77; Group 2 (eligible), 1226. The number of observations for the hemoglobin results are: Group 1, 292; Group 2, 486. The number of observations for the 1999 Pupil Questionnaire health outcomes are: Group 1, 3562; Group 2 and Group 3, 5540.

Table 7: 1998-1999 School participation rates in Busia, Kenya primary schools[29]

	Group 1 (25 schools)	Group 2 (25 schools)	Group 3 (25 schools)	Group 1 – Group 3	Group 2 – Group 3
Before treatment and immediately post-treatment (January to May 1998)					
Eligible pupils	0.826	0.789	0.795	0.031	-0.007
				(0.064)	(0.064)
Ineligible pupils	0.946	0.878	0.896	0.050	-0.019
				(0.036)	(0.036)
First year post-treatment (May 1998 to March 1999)	*1st Year Treatment*	*Comparison*	*Comparison*		
Eligible pupils	0.840	0.730	0.765	0.076**	-0.034
				(0.036)	(0.036)
Ineligible pupils	0.868	0.803	0.812	0.056	-0.009
				(0.034)	(0.034)
Pre-school, Grade 1, Grade 2 in early 1998 (among eligible pupils)	0.795	0.688	0.703	0.092**	-0.014
				(0.044)	(0.043)
Grade 3, Grade 4, Grade 5 in early 1998 (among eligible pupils)	0.880	0.789	0.832	0.048*	-0.043
				(0.029)	(0.029)
Grade 6, Grade 7, Grade 8 in early 1998 (among eligible pupils)	0.934	0.859	0.892	0.042*	-0.032
				(0.025)	(0.026)
Recorded as "dropped out" in early 1998 (among eligible pupils)	0.062	0.042	0.029	0.033*	0.013
				(0.019)	(0.016)
Females[30]	0.855	0.770	0.787	0.069**	-0.016
				(0.032)	(0.032)
Males	0.843	0.735	0.778	0.065*	-0.043
				(0.037)	(0.037)
Second year post-treatment (March to November 1999)	*2nd Year Treatment*	*1st Year Treatment*	*Comparison*		
Eligible pupils	0.711	0.714	0.662	0.049*	0.053*
				(0.029)	(0.029)
Ineligible pupils	0.672	0.679	0.619	0.053*	0.060**
				(0.030)	(0.030)
Pre-school, Grade 1, Grade 2 in early 1998 (among eligible pupils)	0.689	0.722	0.639	0.050	0.083**
				(0.035)	(0.034)
Grade 3, Grade 4, Grade 5 in early 1998 (among eligible pupils)	0.749	0.773	0.727	0.023	0.046*
				(0.023)	(0.023)
Grade 6, Grade 7, Grade 8 in early 1998 (among eligible pupils)	0.770	0.776	0.751	0.019	0.025
				(0.027)	(0.028)
Recorded as "dropped out" in early 1998 (among eligible pupils)	0.163	0.117	0.055	0.108*	0.062
				(0.063)	(0.052)
Females	0.714	0.745	0.647	0.067**	0.098***
				(0.027)	(0.027)
Males	0.696	0.691	0.653	0.043	0.039
				(0.029)	(0.030)

[29] Notes: Standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The participation rate is computed among all pupils enrolled in the school at the start of 1998. Pupils who are present in school on the day of an unannounced NGO visit are considered participants. Pupils had up to five participation observations per year. Pupils eligible for treatment include all boys, and girls under age 13.

[30] 396 pupils in the sample are missing information on gender. For this reason, the average of the female and males participation rates does not equal the overall average.

Table 8: School Participation, Intention-to-treat (reduced-form) estimates[31]

	Dependent variable: School participation (indicator variable)				
	Probit (1)	OLS (2)	OLS (3)	OLS (4)	OLS (5) 5/98-3/99
First year as treatment school (T1)	0.069***	0.063***	0.029*	0.034	
	(0.016)	(0.014)	(0.015)	(0.039)	
Second year as treatment school (T2)	0.040**	0.037*	-0.030	-0.012	
	(0.018)	(0.021)	(0.020)	(0.047)	
Moderate-heavy infection, early 1999					-0.027**
					(0.013)
Eligible for treatment (E)	0.070***	0.053***	0.029***	0.038	-0.011
	(0.009)	(0.006)	(0.010)	(0.030)	(0.008)
Rate of moderate-heavy infections in geographic zone by grade[32] (P)	-0.030	-0.023	-0.023	0.046	
	(0.058)	(0.053)	(0.054)	(0.069)	
1996 District Mock exam score, school average	0.041***	0.037***	0.037***	0.037***	0.008
	(0.012)	(0.011)	(0.011)	(0.010)	(0.010)
T1*E			0.039**	0.100	
			(0.019)	(0.061)	
T2*E			0.080***	0.090	
			(0.024)	(0.067)	
E*P				-0.029	
				(0.068)	
T1*P				-0.013	
				(0.085)	
T2*P				-0.047	
				(0.104)	
T1*E*P				-0.121	
				(0.141)	
T2*E*P				-0.012	
				(0.140)	
School assistance controls, grade controls, and time controls	Yes	Yes	Yes	Yes	Yes
R^2	-	0.12	0.13	0.13	0.08
Root MSE	-	0.407	0.407	0.407	0.308
Number of observations	217331	217331	217331	217331	11397
Mean of dependent variable	0.746	0.746	0.746	0.746	0.883
Estimated first year effect (eligible pupil at mean characteristics)	0.069***	0.063***	0.068***	0.076***	-
	(0.016)	(0.014)	(0.016)	(0.015)	
Estimated second year effect (eligible pupil at mean characteristics)	0.040**	0.037*	0.050**	0.051**	-
	(0.018)	(0.021)	(0.023)	(0.025)	

[31] Notes: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Disturbance terms are assumed to be independent across schools, but are allowed to be correlated within schools. Participation is computed among all pupils enrolled at the start of the 1998 school year. Pupils present during an unannounced NGO school visit are considered participants. The results are for up to five observations from 1998 and up to five from 1999. Eligible pupils include all boys, and girls under age 13. Regression 5 includes pupils with parasitological information from early 1999, restricting the sample to a random subset of Group 1 and Group 2 pupils.

[32] Zonal infection rates among grade 3 and 4 pupils are used for pupils in grades 4 and below and for pupils initially recorded as drop-outs (there is no parasitological data for pupils below grade 3); zonal infection rates among grade 5 and 6 pupils are used for pupils in grades 5 and 6, and zonal infection rates among grade 7 and 8 pupils are used for pupils in grades 7 and 8.

Table 9: School Participation, Instrumental variable estimates

	Dependent variable:				
	Received first year medical treatment	Received second year medical treatment	School participation (indicator variable)		
	OLS 1st stage	OLS 1st stage	OLS Reduced form	OLS	IV-2SLS
	(1)	(2)	(3)	(4)	(5)
Received first year medical treatment				0.120***	0.084***
				(0.016)	(0.021)
Received second year medical treatment				0.156***	0.076**
				(0.019)	(0.035)
First year as treatment school (T1)	0.202***	0.0002	0.032**		
	(0.025)	(0.002)	(0.014)		
Second year as treatment school (T2)	0.046***	0.066***	-0.018		
	(0.011)	(0.009)	(0.019)		
Eligible for treatment (E)	-0.016***	-0.004*	0.030***	0.018**	0.031***
	(0.004)	(0.002)	(0.010)	(0.008)	(0.009)
Rate of moderate-heavy infections in geographic zone by grade[33] (P)	-0.020	-0.045**	-0.020	-0.006	-0.014
	(0.029)	(0.022)	(0.059)	(0.060)	(0.058)
1996 District Mock exam score, school average	0.001	-0.000	0.036***	0.040***	0.037***
	(0.004)	(0.002)	(0.011)	(0.011)	(0.011)
T1*E	0.596***	0.0002	0.034*		
	(0.027)	(0.0005)	(0.020)		
T2*E	0.060***	0.559***	0.073***		
	(0.011)	(0.020)	(0.023)		
School assistance controls, grade controls, and time controls	Yes	Yes	Yes	Yes	Yes
R^2	0.67	0.58	0.13	0.14	-
Root MSE	0.237	0.169	0.401	0.398	0.399
Number of observations	201201	201201	201201	201201	201201
Mean of dependent variable	0.204	0.055	0.754	0.754	0.754
Estimated first year effect, eligible pupil at mean characteristics	-	-	0.066***	0.120***	0.084***
			(0.017)	(0.016)	(0.021)
Estimated second year effect, eligible pupil at mean characteristics	-	-	0.055**	0.156***	0.076**
			(0.023)	(0.019)	(0.035)

[33] Zonal infection rates among grade 3 and 4 pupils are used for pupils in grades 4 and below and for pupils initially recorded as drop-outs (there is no parasitological data for pupils below grade 3); zonal infection rates among grade 5 and 6 pupils are used for pupils in grades 5 and 6, and zonal infection rates among grade 7 and 8 pupils are used for pupils in grades 7 and 8.

Table 10: Academic exam scores 1998 and 1999, Intention-to-treat (reduced-form) estimates[34]

	Dependent variable: ICS Exam Score (normalized by standard) OLS				
	(1)	(2)	(3)	(4) Restricted sample (fill 1998 survey)	(5)
First year as treatment school (T1)	-0.047	0.005	-0.004	0.020	
	(0.050)	(0.057)	(0.150)	(0.150)	
Second year as treatment school (T2)	-0.068	0.013	-0.066	-0.075	
	(0.075)	(0.088)	(0.250)	(0.294)	
Average school participation (during the year of the exam)					0.633*** (0.070)
Eligible for treatment (E)	0.230**	0.269***	0.212**	0.210**	0.228***
	(0.025)	(0.041)	(0.100)	(0.097)	(0.025)
Rate of moderate-heavy infections in geographic zone by grade[35] (P)	0.005	0.004	-0.113	0.019	0.053
	(0.242)	(0.241)	(0.345)	(0.352)	(0.240)
1996 District Mock exam score, school average	0.393**	0.393***	0.392***	0.408***	0.389***
	(0.036)	(0.036)	(0.036)	(0.037)	(0.037)
E*P					
T1*E		-0.066	-0.010	-0.044	
		(0.053)	(0.144)	(0.151)	
T2*E		-0.105	-0.127	-0.105	
		(0.069)	(0.187)	(0.206)	
T1*P			0.020	-0.103	
			(0.365)	(0.369)	
T2*P			0.189	0.131	
			(0.528)	(0.651)	
T1*E*P			-0.123	0.032	
			(0.322)	(0.347)	
T2*E*P			0.023	0.057	
			(0.390)	(0.455)	
Grade indicators And school assistance controls	Yes	Yes	Yes	Yes	Yes
R^2	0.13	0.13	0.13	0.14	0.14
Root MSE	0.927	0.927	0.927	0.921	0.921
Number of observations	25014	25014	25014	19120	24829
Mean of dependent variable	0.019	0.019	0.019	0.039	0.011
Estimated first year effect (eligible pupil at mean characteristics)	-0.047	-0.061	-0.051	-0.059	-
	(0.050)	(0.053)	(0.059)	(0.065)	
Estimated second year effect (eligible pupil at mean characteristics)	-0.068	-0.092	-0.090	-0.104	-
	(0.075)	(0.077)	(0.084)	(0.096)	

[34] Notes: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Disturbance terms are assumed to be independent across schools, but are allowed to be correlated within schools. The restricted sample includes pupils who completed the 1998 pupil questionnaire, to address potential exam participation bias. Regression 6 includes pupils with parasitological information from early 1999, restricting the sample to a random subset of Group 1 and Group 2 pupils.

[35] Zonal infection rates among grade 3 and 4 pupils are used for pupils in grades 4 and below (there is no parasitological data for pupils below grade 3); zonal infection rates among grade 5 and 6 pupils are used for pupils in grades 5 and 6, and zonal infection rates among grade 7 and 8 pupils are used for pupils in grades 7 and 8.

Table 11: Academic exam scores 1998, imputing missing data[36]

	(1) OLS, (non-missing)	(2) OLS, (imputed data)	(3) Quantile regression, 1st quintile (imputed data)	(4) Quantile regression, 2nd quintile (imputed data)	(5) Quantile regression, 3rd quintile (imputed data)	(6) Quantile regression, 4th quintile (imputed data)
First year as treatment school (T1)	-0.038	-0.018	0.041	-0.008	-0.018	-0.044
	(0.063)	(0.055)	(0.056)	(0.057)	(0.078)	(0.073)
Eligible for treatment (E)	0.278***	0.249***	0.111***	0.189***	0.246***	0.329***
	(0.028)	(0.023)	(0.021)	(0.020)	(0.032)	(0.038)
Rate of moderate-heavy infections in geographic zone by grade[37] (P)	-0.056	0.021	-0.070	-0.133	-0.105	0.075
	(0.027)	(0.218)	(0.181)	(0.285)	(0.370)	(0.312)
1996 District Mock exam score, school average	0.415***	0.378***	0.338***	0.363***	0.396***	0.431***
	(0.040)	(0.033)	(0.036)	(0.044)	(0.058)	(0.047)
Grade indicators and school assistance controls	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.15	0.12	-	-	-	-
Root MSE	0.914	0.917	-	-	-	-
Number of observations	14995	17768	17768	17768	17768	17768
Mean of dependent variable	0.026	-0.049	-0.049	-0.049	-0.049	-0.049

Table 12: 1998 School promotion rates in Busia, Kenya primary schools[38]

	Group 1 *1998 Treatment*	Group 2 *1998 Comparison*	Group 3 *1998 Comparison*	Group 1 – Group 3	Group 2 – Group 3
Eligible pupils	0.628	0.609	0.606	0.023	0.004
				(0.026)	(0.026)
Ineligible pupils	0.478	0.519	0.507	-0.030	0.012
				(0.035)	(0.035)
Pre-school, Grade 1, Grade 2 (among eligible pupils)	0.678	0.652	0.631	0.047	0.021
				(0.030)	(0.029)
Grade 3, Grade 4, Grade 5 (among eligible pupils)	0.643	0.674	0.667	-0.024	0.007
				(0.026)	(0.026)
Grade 6, Grade 7, Grade 8 (among eligible pupils)	0.574	0.599	0.599	-0.025	-0.002
				(0.031)	(0.033)
Females[39]	0.610	0.628	0.591	0.019	0.038
				(0.026)	(0.026)
Males	0.607	0.589	0.578	0.028	0.011
				(0.029)	(0.030)

[36] Notes: Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Disturbance terms are assumed to be independent across schools, but are allowed to be correlated within schools in all regressions. Standard errors in the quantile regressions are computed using a bootstrap technique (with twenty iterations).

[37] Zonal infection rates among grade 3 and 4 pupils are used for pupils in grades 4 and below (there is no parasitological data for pupils below grade 3); zonal infection rates among grade 5 and 6 pupils are used for pupils in grades 5 and 6, and zonal infection rates among grade 7 and 8 pupils are used for pupils in grades 7 and 8.

[38] Notes: Standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Pupils eligible for treatment include all boys, and girls under age 13.

[39] Among pupils with non-missing eligibility information.

Figure 1: Map of Kenya

Figure 2: Primary School Deworming Schools, Busia District, Kenya

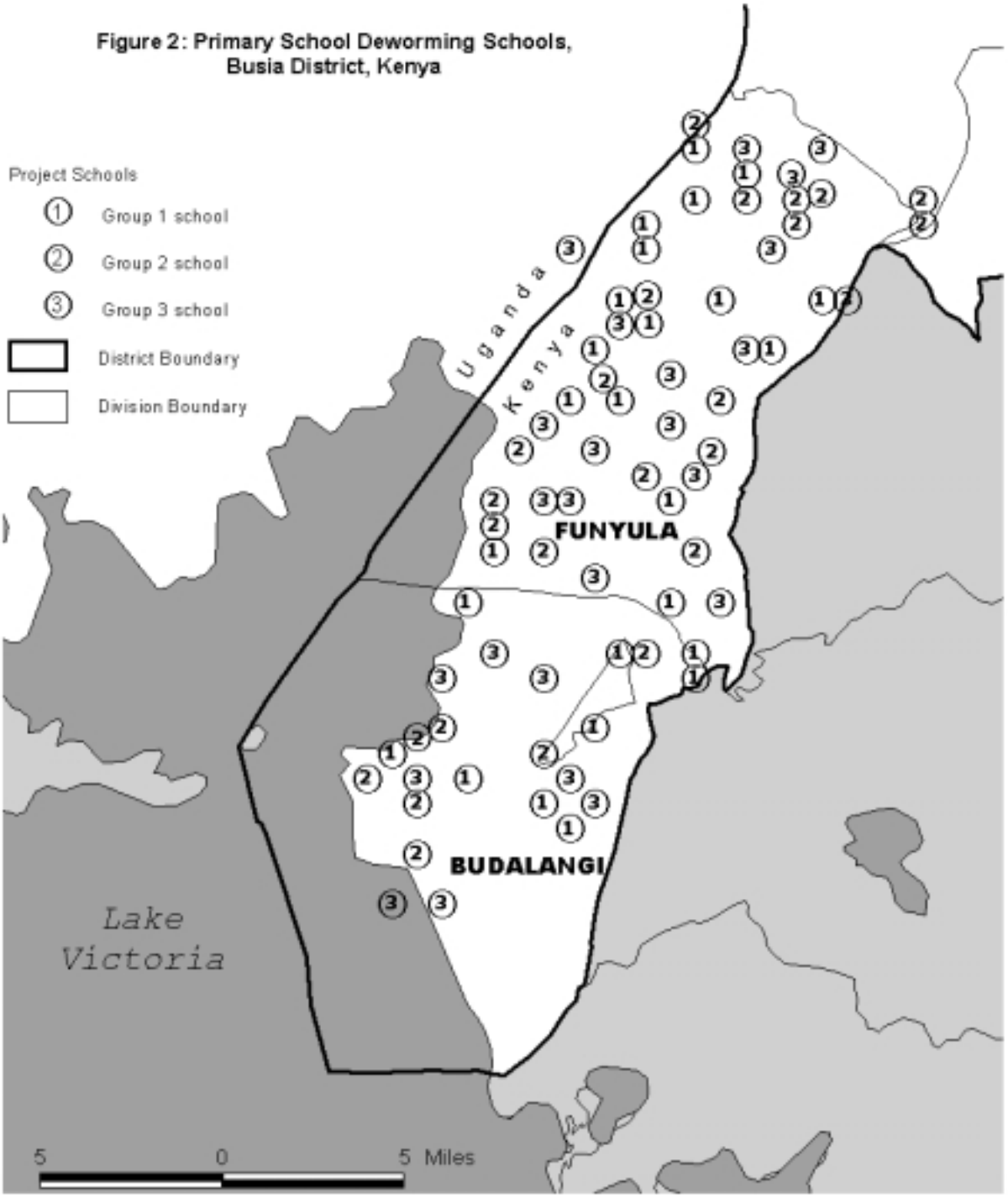


Figure 3: Proportion of Treatment (Group 1) pupils receiving any PSDP medical treatment for helminthic infections in 1998, among boys (circles) and girls (triangles)

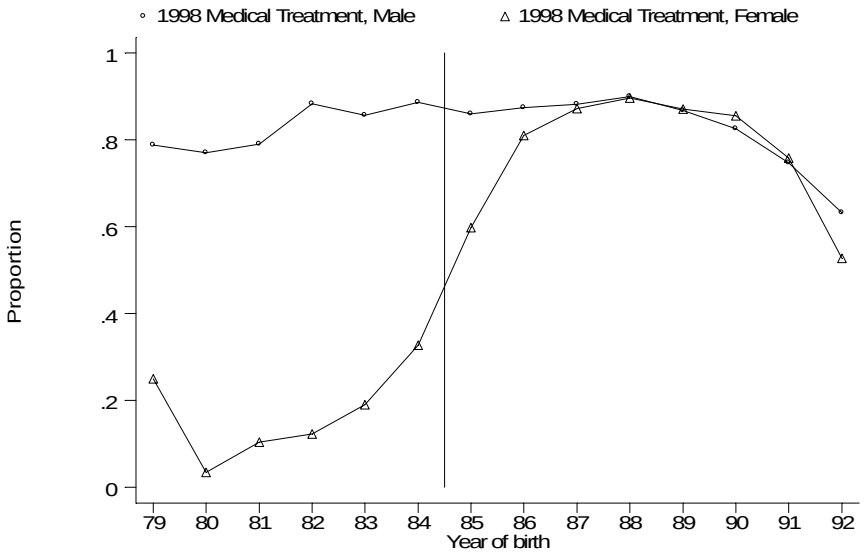


Figure 4: Proportion of Treatment (Group 1, Group 2) pupils receiving any PSDP medical treatment for helminthic infections in 1999, among boys (circles) and girls (triangles)

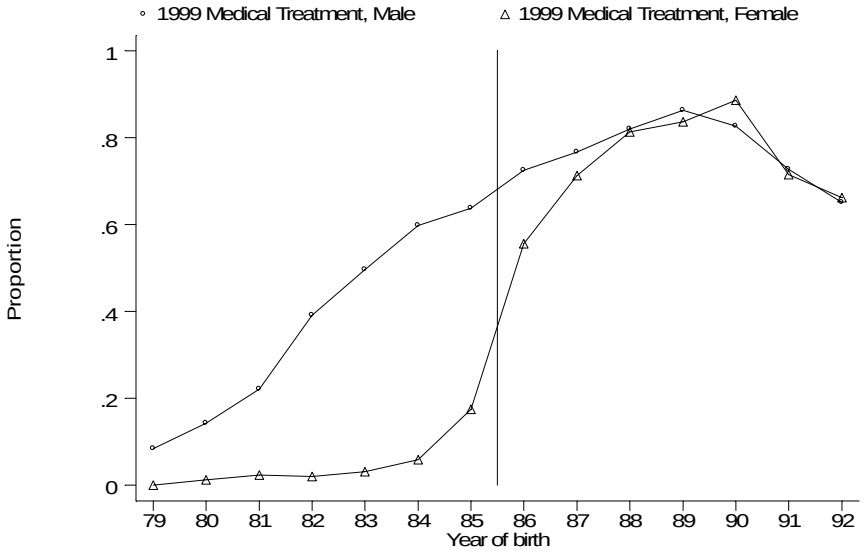


Figure 5: School participation rate May 1998 to November 1999, among pupils eligible for treatment, difference between Group 1 and Group 3 (triangles), and difference between Group 2 and Group 3 (circles) [40]

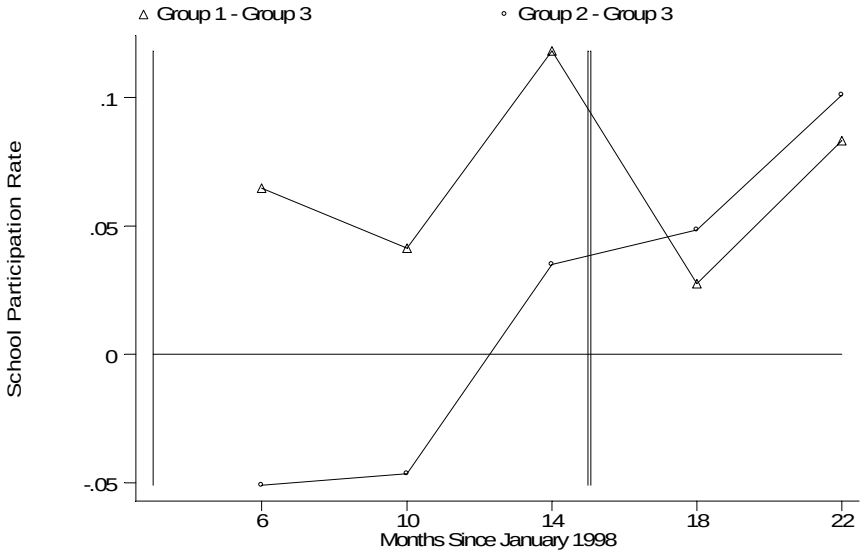
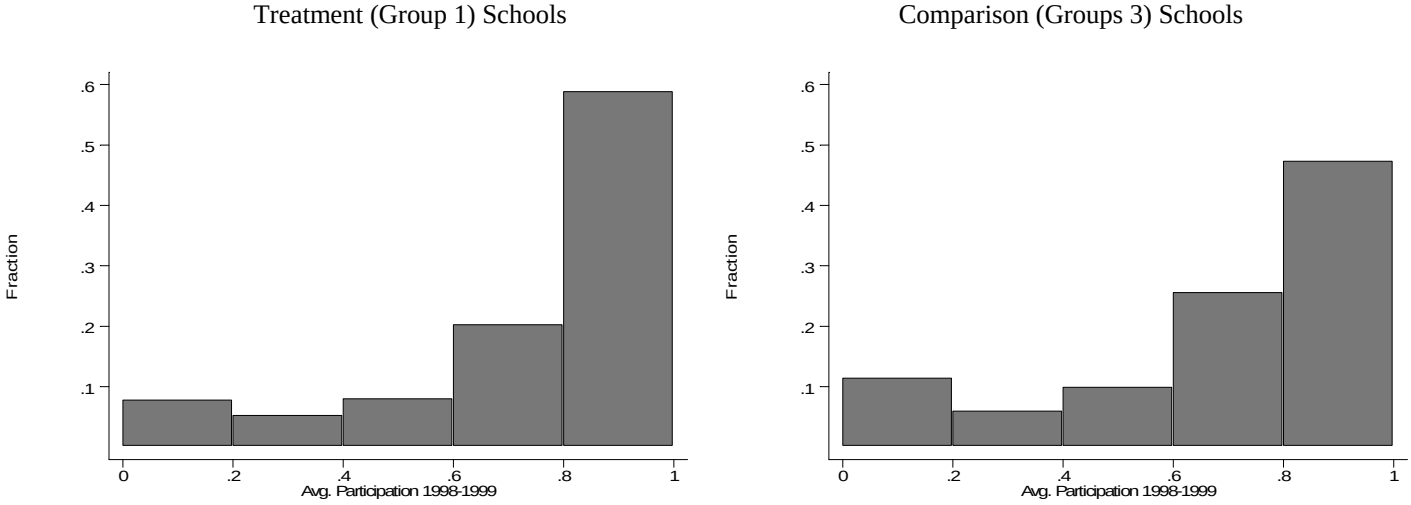


Figure 6: Average school participation rate from May 1998 to November 1999 among eligible pupils, histograms for Treatment (Group 1) schools (left) and Comparison (Group 3) schools (right)



[40] Vertical lines denote approximate start dates for 1998 medical treatment (Group 1 schools) and 1999 medical treatment (Group 1 and Group 2 schools).