Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities

Edward Miguel[a] Michael Kremer [b]

[a]University of California, Berkeley

[b]University of Chicago

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- **Authors:**

EDWARD MIGUEL

Faculty profiles

Members of the Economics Department

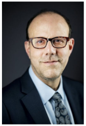
Curriculum Vitae

Homepage

Edward Miguel

Oxfam Professor in Environmental and Resource Economics

Fields:	Development Economics
Current Research:	Long-run impacts of child health investments; Research transparency methods in social science research; Links between extreme climate and violent conflict.
Current Status:	Teaching
PhD:	Ph.D. Harvard University, 2000
Research Interests:	African economic development, including work on the economic causes and consequences of violence; the impact of ethnic divisions on local collective action; and interactions between health, education, environment, and productivity for the poor.
Office:	653 Evans
Phone:	(510) 642-7162



Michael Kremer is the University Professor in the Kenneth C. Griffin Department of Economics. He is the 2019 co-recipient of the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel. He is a Member of the National Academy of Sciences, a recipient of a MacArthur Fellowship and a Presidential Faculty Fellowship, and was named a Young Global Leader by the World Economic Forum. Kremer's recent research examines education, health, water, and agriculture in developing countries.

Introduction

- **Intestinal helminths**—including **hookworm**, **roundworm**, **whipworm**, and **schistosomiasis**—infect more than one-quarter of the world's population.
- **Studies in which medical treatment** is **randomized at the individual level** potentially doubly **underestimate** **the benefits of treatment**:
  - **missing externality benefits** to the **comparison group** from reduced disease transmission.
  - therefore also underestimating benefits for the **treatment group**.
- We evaluate a **Kenyan project** in which school-based mass treatment with **deworming drugs was randomly phased into schools**, rather than to individuals, **allowing estimation of overall program effects**.

Introduction

- **Main Finds 1:**
  - We **examine the impact of a program** in which 75 rural Kenyan primary schools were phased into deworming treatment in a randomized order.
  - Find that the program **reduced school absenteeism by at least 1/4**, with particularly **large participation gains** among the youngest children, making deworming a highly **effective** way to boost school participation among young children.

Introduction

- **Main Finds 2:**
  - We then **identify cross-school externalities**—the impact of deworming for pupils in **schools located near treatment schools**—using exogenous variation in the **local density of treatment school pupils** generated by the school-level randomization,
  - Find that **deworming reduces worm burdens** and **increases school participation** among children in neighboring primary schools.
  - There is also some evidence of **within-school treatment externalities**, we must rely on **nonexperimental methods** to **decompose** the **overall effect on treatment schools** into a **direct effect** and a **within-school externality effect**.

Introduction

- **Main Finds 3:**
  - Including the externality benefits, the cost per additional year of school participation is only **$3.50**, making deworming considerably more **cost-effective than alternative methods** of increasing school participation, such as school subsidies.
  - Moreover, internalizing these externalities would likely require not only **fully subsidizing deworming**, but actually **paying people to receive treatment**.
  - We **do not find** any evidence that **deworming increased academic test scores**. However, we observed cross-sectional **relationship between school attendance and test scores**.

Overview

1. **Intestinal Helminth (Worm) Infections**
2. **The Primary School Deworming Project in Busia, Kenya**
3. **Estimation Strategy**
4. **Deworming Treatment Effects on Health and Nutrition**
5. **Deworming Treatment Effects on School Participation**
6. **Deworming Treatment Effects on Test Scores**
7. **Cost Effectiveness and Welfare Analysis**
8. **Conclusions and Discussions**

Intestinal Helminth (Worm) Infections

I. Intestinal Helminth (Worm) Infections

- **Symptoms**: Most have **light infections**, which may be asymptomatic(无症状), a minority have **heavy infections**, which can lead to iron-deficiency anemia(营养缺乏性贫血), protein-energy malnutrition(营养不良), abdominal pain(腹痛), and listlessness(精神萎靡). Schistosomiasis can also have more severe consequences, for instance, causing enlargement of the liver and spleen(肝脏和脾脏肿大).
- **Low-cost single-dose oral therapies**(单剂口服疗法) can **kill** the worms, reducing hookworm(钩虫), roundworm(蛔虫), and schistosomiasis(血吸虫病) infections by **99%**, only moderately effective against severe whipworm(鞭虫) infections.
- **Reinfection is rapid**: Geohelminth drugs must be taken **every 6 months** and **schistosomiasis drugs** must be taken **annually**.
- **Drug side effects are minor**, but due to concern about the possibility that the drugs could **cause birth defects**(先天缺陷), deworming programs has been to **not treat girls of reproductive age**.

I. Intestinal Helminth (Worm) Infections

- **School-aged children** likely account for the **bulk of helminth transmission:** children are most likely to spread worm infections because they are less likely to use latrines(公共厕所) and more generally have poor hygiene practices(卫生习惯).
- Treatment externalities for **schistosomiasis** are likely to take place across larger areas than is typical for **geohelminth**(土源性蠕虫) externalities due to the **differing modes of disease transmission**—deposited in the local environment when defecating in the “bush” (在“灌木丛”中排便) surrounding their home or school **v.s.** through contact with infected fresh water, bathing or fishing in Lake Victoria.
- **Infection rates vary** widely **seasonally** and from year to year due to rainfall variation and other factors.

The Primary School Deworming Project in Busia, Kenya

II. The Primary School Deworming Project in Busia, Kenya

- We **evaluate the Primary School Deworming Project (PSDP)**, carried out by Internationaal Christelijk Steunfonds Africa (ICS), in cooperation with the Busia District Ministry of Health office.
- The project took place in **southern Busia**—poor and densely-settled farming region with the highest helminth infection rates.
- 75 project schools, >30,000 pupils(ages 6-18)
- In January 1998, the 75 PSDP schools were randomly divided into **3 groups of 25 schools each**.
- Due to ICS' s administrative and financial constraints, **the health intervention was phased in over several years**.

Group 1 schools received free deworming treatment in both 1998 and 1999, **Group 2** schools in 1999, while **Group 3** schools began receiving treatment in 2001.

	Group 1	Group 2	Group 3
1998	treatment	comparison	comparison
1999	treatment	treatment	comparison

Detailed project timeline:

APPENDIX TABLE AI

Primary School Deworming Project (PSDP) Timeline, 1997–1999

Dates	Activity
1997	
October	Pilot Kenya Ministry of Health, Division of Vector Borne Disease (DVBD) parasitological survey. Pilot Pupil Questionnaire
1998	
January–March	Parent-teacher meetings in Group 1 schools
	Pupil Questionnaire administration in grades 3 to 8, and School Questionnaire administration in all schools
	DVBD parasitological survey for grades 3 to 8 in Group 1 schools
January–May	Heavy precipitation and widespread flooding associated with the El Niño weather system
March–April	First round of 1998 medical treatment (with albendazole, praziquantel) in Group 1 schools
October–November	ICS (NGO) examinations administered in grades 3 to 8 in all schools
November	Second round of 1998 medical treatment (with albendazole) in Group 1 schools
1999	
January–March	Parent-teacher meetings in Group 1 and Group 2 schools
	Pupil Questionnaire administration in grades 3 to 8, and School Questionnaire administration in all schools
	DVBD parasitological and hemoglobin surveys for grades 3 to 8 in Group 1 and Group 2 schools
March–June	First round of 1999 medical treatment (with albendazole, praziquantel) in Group 1 and Group 2 schools
May–July	Deworming drug availability survey of local shops, clinics, and pharmacies
October	ICS (NGO) examinations administered in grades 3 to 8 in all schools
October–November	Second round of 1999 medical treatment (with albendazole) in Group 1 and Group 2 schools

2.1. Baseline Characteristics

TABLE I

1998 Average Pupil and School Characteristics, Pre-treatment[a]

	Group 1 (25 schools)	Group 2 (25 schools)	Group 3 (25 schools)	Group 1 – Group 3	Group 2 – Group 3
Panel A: Pre-school to Grade 8					
Male	0.53	0.51	0.52	0.01	−0.01
				(0.02)	(0.02)
Proportion girls <13 years, and all boys	0.89	0.89	0.88	0.00	0.01
				(0.01)	(0.01)
Grade progression (= Grade – (Age – 6))	−2.1	−1.9	−2.1	−0.0	0.1
				(0.1)	(0.1)
Year of birth	1986.2	1986.5	1985.8	0.4**	0.8***
				(0.2)	(0.2)
Panel B: Grades 3 to 8					
Attendance recorded in school registers (during the four weeks prior to the pupil survey)	0.973	0.963	0.969	0.003	−0.006
				(0.004)	(0.004)
Access to latrine at home	0.82	0.81	0.82	0.00	−0.01
				(0.03)	(0.03)
Have livestock (cows, goats, pigs, sheep) at home	0.66	0.67	0.66	−0.00	0.01
				(0.03)	(0.03)
Weight-for-age Z-score (low scores denote undernutrition)	−1.39	−1.40	−1.44	0.05	0.04
				(0.05)	(0.05)
Blood in stool (self-reported)	0.26	0.22	0.19	0.07**	0.03
				(0.03)	(0.03)
Sick often (self-reported)	0.10	0.10	0.08	0.02**	0.02**
				(0.01)	(0.01)
Malaria/fever in past week (self-reported)	0.37	0.38	0.40	−0.03	−0.02
				(0.03)	(0.03)
Clean (observed by field workers)	0.60	0.66	0.67	−0.07**	−0.01
				(0.03)	(0.03)

				(0.03)	(0.03)
Panel C: School characteristics					
District exam score 1996, grades 5–8[b]	−0.10	0.09	0.01	−0.11	0.08
				(0.12)	(0.12)
Distance to Lake Victoria	10.0	9.9	9.5	0.6	0.5
				(1.9)	(1.9)
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)
Group 1 pupils within 3 km[c]	461.1	408.3	344.5	116.6	63.8
				(120.3)	(120.3)
Group 1 pupils within 3–6 km	844.5	652.0	869.7	−25.1	−217.6
				(140.9)	(140.9)

	Group 1 (25 schools)	Group 2 (25 schools)	Group 3 (25 schools)	Group 1 – Group 3	Group 2 – Group 3
Total primary school pupils within 3 km	1229.1	1364.3	1151.9	77.2	212.4
				(205.5)	(205.5)
Total primary school pupils within 3–6 km	2370.7	2324.2	2401.7	−31.1	−77.6
				(209.5)	(209.5)

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

[b] 1996 District exam scores have been normalized to be in units of individual level standard deviations, and so are comparable in units to the 1998 and 1999 ICS test scores (under the assumption that the decomposition of test score variance within and between schools was the same in 1996, 1998, and 1999).

[c] This includes girls less than 13 years old, and all boys (those eligible for deworming in treatment schools).

Table I:

1. Prior to treatment, 3 groups were **similar** on most demographic, nutritional, and socioeconomic characteristics.
2. **Group 1 pupils appear to be worse off** than Group 2 and 3 pupils along some dimensions, potentially creating a bias against finding significant program effects:
    - Group 1 pupils more self-reported blood in stool(便血), reported being sick more often than Group 3 pupils, and were not as clean as Group 2 and Group 3 pupils.
    - Also had lower average scores on 1996 Kenyan primary school examinations than Group 2 and 3 schools(not significant).

TABLE II

January 1998 Helminth Infections, Pre-treatment, Group 1 Schools[a]

	Prevalence of infection	Prevalence of moderate-heavy infection	Average infection intensity, in eggs per gram (s.e.)
Hookworm	0.77	0.15	426 (1055)
Roundworm	0.42	0.16	2337 (5156)
Schistosomiasis, all schools	0.22	0.07	91 (413)
Schistosomiasis, schools <5 km from Lake Victoria	0.80	0.39	487 (879)
Whipworm	0.55	0.10	161 (470)
At least one infection	0.92	0.37	–
Born since 1985	0.92	0.40	–
Born before 1985	0.91	0.34	–
Female	0.91	0.34	–
Male	0.93	0.38	–
At least two infections	0.31	0.10	–
At least three infections	0.28	0.01	–

[a]These are averages of individual-level data, as presented in Brooker, Miguel, et al. (2000); correcting for the oversampling of the (numerically smaller) upper grades does not substantially change the results. Standard errors in parentheses. Sample size: 1894 pupils. Fifteen pupils per standard in grades 3 to 8 for Group 1 schools were randomly sampled. The bottom two rows of the column "Prevalence of moderate-heavy infection" should be interpreted as the proportion with at least two or at least three moderate-to-heavy helminth infections, respectively.

The data were collected in January to March 1998 by the Kenya Ministry of Health, Division of Vector Borne

Table II:

1. 92% of surveyed pupils had **at least one helminth infection** and 37% had **at least one moderate-to-heavy helminth infection**.(**understate actual infection prevalence** to the extent that the most heavily infected children were more likely to be absent from school on the day of the survey.)
2. Moderate-to-heavy worm infections are more likely among **younger** pupils and among **boys**.
3. Pupils who attend schools near Lake Victoria also have substantially higher rates of **schistosomiasis**.

2.2. The Intervention

- Schools with **geohelminth** prevalence over 50 percent were mass treated with albendazole(阿苯达唑) every 6 months, schools with **schistosomiasis** prevalence over 30 percent were mass treated with praziquantel(吡喹酮) annually.
- All treatment schools met the **geohelminth cut-off** in both 1998 and 1999. 6/25 treatment schools met the **schistosomiasis cut-off** in 1998 and 16/50 treatment schools met the cut-off in 1999.
- Not for treating girls 13 years of age and older.
- In addition, treatment schools received worm prevention education: stressed the importance of hand washing, wearing shoes, not swimming,...

- ICS 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 who did not want their child to participate in the project were asked to inform the school headmaster**.
- Beginning in January 1999 ICS required **signed parental consent for all children** to receive medical treatment; consent typically took the form of parents **signing their name in a notebook kept at school by the headmaster**.
- Note: travelling to school to sign the book may be **time-consuming**, and some parents may be **reluctant to meet the headmaster** when behind on school fees, a common problem in these schools.

2.3. Assigned and Actual Deworming Treatment

TABLE III

PROPORTION OF PUPILS RECEIVING DEWORMING TREATMENT IN PSDP[a]

	Group 1		Group 2		Group 3	
	Girls <13 years, and all boys	Girls ≥ 13 years	Girls <13 years, and all boys	Girls ≥ 13 years	Girls <13 years, and all boys	Girls ≥ 13 years
	Treatment		*Comparison*		*Comparison*	
Any medical treatment in 1998	0.78	0.19	0	0	0	0
(For grades 1–8 in early 1998)						
Round 1 (March–April 1998), Albendazole	0.69	0.11	0	0	0	0
Round 1 (March–April 1998), Praziquantel[b]	0.64	0.34	0	0	0	0
Round 2 (Oct.–Nov. 1998), Albendazole	0.56	0.07	0	0	0	0
	Treatment		*Treatment*		*Comparison*	
Any medical treatment in 1999	0.59	0.07	0.55	0.10	0.01	0
(For grades 1–7 in early 1998)						
Round 1 (March–June 1999), Albendazole	0.44	0.06	0.35	0.06	0.01	0
Round 1 (March–June 1999), Praziquantel[b]	0.47	0.06	0.38	0.06	0.01	0
Round 2 (Oct.–Nov. 1999), Albendazole	0.53	0.06	0.51	0.08	0.01	0
Any medical treatment in 1999 (For grades 1–7 in early 1998), among pupils enrolled in 1999	0.73	0.10	0.71	0.13	0.02	0
Round 1 (March–June 1999), Albendazole	0.55	0.08	0.46	0.08	0.01	0
Round 1 (March–June 1999), Praziquantel[b]	0.53	0.07	0.45	0.07	0.01	0
Round 2 (Oct.–Nov. 1999), Albendazole	0.65	0.09	0.66	0.11	0.01	0

Table III:

- **78%** of those pupils assigned to receive treatment (i.e., girls under 13 years old and all boys in the treatment schools) received at least some medical treatment through the program **in 1998**.
- **19%** of girls thirteen years of age or older also received medical treatment **in 1998**.(confusion in the field about pupil age; Particularly common in schools near the lake where schistosomiasis was more of a problem).
- **72% v.s. 78%**: **process of selection into treatment** was fairly similar **in the 2 years** despite the change in consent rules.
- Among girls under 13 years of age and all boys in treatment schools **from the baseline sample**, approximately **57%** received medical treatment at some point in 1999, while only 9% of the girls older.

- Although pupils assigned to comparison schools could also **potentially have transferred to treatment schools to receive deworming medical treatment** through the program, there is **no evidence of large asymmetric flows** of pupils into treatment schools, which could bias the results.

TABLE IV

PROPORTION OF PUPIL TRANSFERS ACROSS SCHOOLS

School in early 1998 (pre-treatment)	1998 transfer to a Group 1 school	1998 transfer to a Group 2 school	1998 transfer to a Group 3 school	1999 transfer to a Group 1 school	1999 transfer to a Group 2 school	1999 transfer to a Group 3 school
Group 1	0.005	0.007	0.007	0.032	0.026	0.027
Group 2	0.006	0.007	0.008	0.026	0.033	0.027
Group 3	0.010	0.010	0.006	0.022	0.036	0.022
Total transfers	0.021	0.024	0.021	0.080	0.095	0.076

- The transfer rates **from early 1998 through the end of 1999** are substantially higher than rates **through the end of 1998** because most transfers occur between school years.
- **Potential transfer bias**

2.4. Health Outcome Differences Between Group 1 and Group 2 Schools

TABLE V

January to March 1999, Health and Health Behavior Differences between Group 1 (1998 Treatment) and Group 2 (1998 Comparison) Schools[a]

	Group 1	Group 2	Group 1 – Group 2
Panel A: Helminth Infection Rates			
Any moderate-heavy infection, January–March 1998	0.38	–	–
Any moderate-heavy infection, 1999	0.27	0.52	−0.25*** (0.06)
Hookworm moderate-heavy infection, 1999	0.06	0.22	−0.16*** (0.03)
Roundworm moderate-heavy infection, 1999	0.09	0.24	−0.15*** (0.04)
Schistosomiasis moderate-heavy infection, 1999	0.08	0.18	−0.10* (0.06)
Whipworm moderate-heavy infection, 1999	0.13	0.17	−0.04 (0.05)
Panel B: Other Nutritional and Health Outcomes			
Sick in past week (self-reported), 1999	0.41	0.45	−0.04** (0.02)
Sick often (self-reported), 1999	0.12	0.15	−0.03** (0.01)
Height-for-age Z-score, 1999 (low scores denote undernutrition)	−1.13	−1.22	0.09* (0.05)
Weight-for-age Z-score, 1999 (low scores denote undernutrition)	−1.25	−1.25	−0.00 (0.04)
Hemoglobin concentration (g/L), 1999	124.8	123.2	1.6 (1.4)
Proportion anemic (Hb < 100g/L), 1999	0.02	0.04	−0.02** (0.01)
Panel C: Worm Prevention Behaviors			
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)

Table V:

- Present **simple differences in health outcomes between treatment and comparison schools**, these differences **understate** overall treatment effects if there are deworming treatment externalities across schools.
- **27%** of pupils in Group 1 (1998 treatment) schools had a **moderate-to-heavy helminth infection** in early 1999 compared to **52%** in Group 2 (1998 comparison) schools.
- The prevalences of moderate-to-heavy hookworm, roundworm, schistosomiasis, and whipworm infections were **all lower** in Group 1 (1998 treatment) schools than in Group 2.
- Group 1 pupils also reported **better health outcomes** after the first year of deworming treatment.
- Health education had a **minimal impact on behavior**, so to the extent the **program improved health** through the effect of anthelmintics rather than through health education.

Estimation Strategy

III. Estimation Strategy

3.1. Econometric Specifications

- We first estimate program impacts in treatment schools, as well as **cross-school treatment externalities**:

$$Y_{ijt} = a + \beta_1 \cdot T_{1it} + \beta_2 \cdot T_{2it} + X'_{ijt}\delta + \sum_d \left(\gamma_d \cdot N^T_{dit}\right) + \sum_d \left(\phi_d \cdot N_{dit}\right) + u_i + e_{ijt}.$$

- Y_{ijt} is the individual health or education outcome, where i refers to the school, j to the student, and $t \in \{1, 2\}$ to the year of the program;
- T_{1it} and T_{2it} are indicator variables for school assignment to the first and second year of deworming treatment, respectively;
- X_{ijt} are school and pupil characteristics.
- N_{dit} is the **total number of pupils** in primary schools at distance d from school i in year t.
- N^T_{dit} is the **number of these pupils** in schools **randomly assigned to deworming treatment**. $d = 03$ denotes schools that are located within 3 kilometers of school i, and $d = 36$ denotes schools that are located between three to 6 kilometers away.
- **Individual disturbance** terms are assumed to be independent across schools, but are allowed to be correlated for observations within the same school.
- The school effect is captured in the u_i term.

- γ_d—measure the deworming treatment externalities across schools.
- $\beta_1 + \sum_d \left(\gamma_d \bar{N}^T_{dit}\right)$—average effect of the first year of deworming treatment on overall infection prevalence in treatment schools.
- $\beta_2 + \sum_d \left(\gamma_d \bar{N}^T_{dit}\right)$—average effect of the second year of deworming treatment on overall infection prevalence in treatment schools.
- β_1 and β_2 capture both **direct effects** of deworming treatment on the treated, as well as any **externalities on untreated pupils within the treatment schools**.
- X_{ijt} **controls** for those pre-treatment differences across schools.
  - the average school score on the 1996 Kenya government district exams for grades 5 to 8;
  - prevalence of moderate-to-heavy helminth infections in the pupil’ s grade;
  - geographic zone; indicators for school involvement in other nongovernmental organization assistance projects;
  - time controls(indicator variables for each six-month period capture the downward trend in school participation due to dropouts);
  - grade cohort indicator variables)

3.2. Estimating Within-School Externalities

- We must rely on **nonexperimental methods** to decompose the effect on treated schools into a **direct effect** and **with-in school externality effect**.
- It is worth bearing in mind that there is **no evidence** that **sicker pupils were more likely to obtain deworming treatment**(less likely to be in school on the day of treatment or because their households were less willing and able to invest in health).
- **Table VI:**
  - Prior to the intervention,**the children who would remain untreated** more likely to be moderately to heavily infected **those who ultimately obtained treatment**. （0.44¿0.39 for Group1; 0.55¿0.51 for Group2）

TABLE VI

Deworming Health Externalities within Schools, January to March 1999[a]

	Group 1, Treated in 1998	Group 1, Untreated in 1998	Group 2, Treated in 1999	Group 2, Untreated in 1999	(Group 1, Treated 1998) – (Group 2, Treated 1999)	(Group 1, Untreated 1998) – (Group 2, Untreated 1999)
Panel A: Selection into Treatment						
Any moderate-heavy infection, 1998	0.39	0.44	–	–	–	–
Proportion of 1998 parasitological sample tracked to 1999 sample[b]	0.36	0.36	–	–	–	–
Access to latrine at home, 1998	0.84	0.80	0.81	0.86	0.03 (0.04)	−0.06 (0.05)
Grade progression (= Grade – (Age – 6)), 1998	−2.0	−1.8	−1.8	−1.8	-0.2^{**} (0.1)	−0.0 (0.2)
Weight-for-age (Z-score), 1998 (low scores denote undernutrition)	−1.58	−1.52	−1.57	−1.46	−0.01 (0.06)	−0.06 (0.11)
Malaria/fever in past week (self-reported), 1998	0.37	0.41	0.40	0.39	−0.03 (0.04)	−0.01 (0.06)
Clean (observed by field worker), 1998	0.53	0.59	0.60	0.66	−0.07 (0.05)	−0.07 (0.10)
Panel B: Health Outcomes						
Girls <13 years, and all boys						
Any moderate-heavy infection, 1999	0.24	0.34	0.51	0.55	-0.27^{***} (0.06)	-0.21^{**} (0.10)
Hookworm moderate-heavy infection, 1999	0.04	0.11	0.22	0.20	-0.19^{***} (0.03)	-0.09^{*} (0.05)
Roundworm moderate-heavy infection, 1999	0.08	0.12	0.22	0.30	-0.14^{***} (0.04)	-0.18^{**} (0.07)
Schistosomiasis moderate-heavy infection, 1999	0.09	0.08	0.20	0.13	-0.11^{*} (0.06)	−0.05 (0.06)
Whipworm moderate-heavy infection, 1999	0.12	0.16	0.16	0.20	−0.04 (0.16)	−0.05 (0.09)
Girls ≥13 years						
Any moderate-heavy infection, 1998	0.31	0.28	–	–	–	–
Any moderate-heavy infection, 1999	0.27	0.43	0.32	0.54	−0.05 (0.17)	−0.10 (0.09)
Panel C: School Participation						
School participation rate, May 1998 to March 1999[c]	0.872	0.764	0.808	0.684	0.064^{**} (0.032)	0.080^{**} (0.039)

- Assume children **obtain treatment** if the **net gain from treatment is more than a cut-off cost**.
- $D_{1ij} = 1\left(S\left(X_{ijt}, e_{ijt}\right) + \varepsilon_{ijt} > C_t\right)$
- $D_{1ij} = 1$ if individual j in school i **received treatment in the first year** that her school was **eligible for treatment** (1998 for Group 1, 1999 for Group 2).
- C_t is the total cost to the household of obtaining treatment in year t (which varies between the two years due to the changing consent requirements)
- ε_{ijt} is an **unobserved random variable** that could depend on the **distance of the pupil' s home** from school, or whether the pupil was **sick** on the treatment day.
- Deal with **selection bias** : (Group 1, Untreated 1998)-(Group 2, Untreated 1999).

$$
\begin{aligned}
&E\left(Y_{ij1} \mid T_{1i1}=1, X_{ij1}, D_{1ij}=0\right)-E\left(Y_{ij1} \mid T_{1i1}=0, X_{ij1}, D_{1ij}=0\right) \\
&=\beta_1+\sum_d \gamma_d \cdot\left[E\left(N_{di1}^T \mid T_{1i1}=1, D_{1ij}=0\right)\right. \\
&\quad\left.-E\left(N_{di1}^T \mid T_{1i1}=0, D_{1ij}=0\right)\right] \\
&\quad+\sum_d \gamma_d \cdot\left[E\left(N_{di1} \mid T_{1i1}=1, D_{1ij}=0\right)-E\left(N_{di1} \mid T_{1i1}=0, D_{1ij}=0\right)\right] \\
&\quad+\left[E\left(e_{ij1} \mid T_{1i1}=1, X_{ij1}, D_{1ij}=0\right)-E\left(e_{ij1} \mid T_{1i1}=0, X_{ij1}, D_{1ij}=0\right)\right],
\end{aligned}
$$

- T_{1i1} is the treatment assignment of the school in 1998 (t = 1), and this takes on a value of one forGroup 1 and zero for Group 2 schools.
- β_1 is the **within-school externality effect**.
- The second and third terms are effects due to differing local densities of primary schools between treatment and comparison schools; these are approximately 0 (as we show in Table I).

Key final term captures any **unobserved differences** between **untreated pupils in the Group 1 and Group 2 schools:**

$$E\left(e_{ij1} \mid T_{1i1}=1, X_{ij1}, C_1 - S\left(X_{ij1}, e_{ij1}\right) > \varepsilon_{ij1}\right) \\ - E\left(e_{ij1} \mid T_{1i1}=0, X_{ij1}, C_2 - S\left(X_{ij2}, e_{ij2}\right) > \varepsilon_{ij2}\right)$$

- If C1 = C2, then by randomization this term equals zero and (2) can be used to estimate β_1.
- However, it is likely that C2>C1 due to **imposition of the signed parental consent requirement in 1999**.
- In our sample, **infected people are less likely to be treated**—and this is robust to conditioning on the full set of X_{ij1} variables described above.
- If S is in fact nondecreasing in e_{ij2}(unobserved characteristics associated with good health outcomes), then C2>C1 implies that the final term will be 0 or -, so **underestimate the within-school externality**.
- Due to changes in the **process of selection** into treatment, **some Group 2 pupils who would have been treated had they been in Group 1 were in fact not treated in 1999**.
- That average unobservables e_{ijt} will be at least as great among the **untreated in Group 2** as among the **untreated in Group 1** (and also that average e_{ijt} will also be at least as great among the **treated Group 2** as among the **treated Group 1**)(no statistically significant differences in 5 baseline characteristics in Table VI, Panel A).

(1) $Y_{ijt} = a + \beta_1 T_{1it} + \beta_2 T_{2it} + X'_{ijt}\delta + \sum_d (\gamma_d \cdot N^T_{dit}) + \sum_d (\phi_d \cdot N_{dit}) + u_i + e_{ijt}$

$t = 1$

(2) $E(Y_{ij1} | T_{1i1}=1, X_{ij1}, D_{1ij}=0) - E(Y_{ij1} | T_{1i1}=0, X_{ij1}, D_{1ij}=0)$

$= (a - a)$

$+ E(\beta_1 T_{1i1} | T_{1i1}=1, X_{ij1}, D_{1ij}=0) - E(\beta_1 T_{1i1} | T_{1i1}=0, X_{ij1}, D_{1ij}=0)$ β_1

$+ E(X'_{ij1} | T_{1i1}=1, X_{ij1}, D_{1ij}=0) - E(X'_{ij1} | T_{1i1}=0, X_{ij1}, D_{1ij}=0) \to 0$

$+ \sum_d \gamma_d [E(N^T_{di1} | T_{1i1}=1, D_{1ij}=0) - E(N^T_{di1} | T_{1i1}=0, D_{1ij}=0)] \to 0$

$+ \sum_d \gamma_d [E(N_{di1} | T_{1i1}=1, D_{1ij}=0) - E(N_{di1} | T_{1i1}=0, D_{1ij}=0)] \to 0$

$+ E(e_{ij1} | T_{1i1}=1, X_{ij1}, D_{ij}=0) - E(e_{ij1} | T_{1i1}=0, X_{ij1}, D_{ij}=0)$

$D_{ij} = 1(S(X_{ijt}, e_{ijt}) + \varepsilon_{ijt} > C_t)$

$t=1.$ $D_{ij} = 1(S(X_{ij1}, e_{ij1}) + \varepsilon_{ij1} > C_1) \to 1998.$ Group 1

$(S(X_{ij2}, e_{ij2}) + \varepsilon_{ij2} > C_2) \to 1999$ Group 2

$E(e_{ij1} | T_{1i1}=1, X_{ij1}, C_1 - S(X_{ij1}, e_{ij1}) > \varepsilon_{ij1})$

$- E(e_{ij1} | T_{1i1}=0, X_{ij1}, C_2 - S(X_{ij2}, e_{ij2}) > \varepsilon_{ij2})$ $\to > 0$? < 0 ?

$C_2 > C_1$

(3) $Y_{ijt} = a + \beta_1 T_{1it} + b_1 \cdot D_{ij} + b_2 \cdot (T_{1it} * D_{ij}) + X'_{ijt}\delta$

$+ \sum_d (\gamma_d \cdot N^T_{dit}) + \sum_d (\phi_d \cdot N_{dit}) + u_i + e_{ijt}$

$Y_{ijt} = a + \beta_1 T_{1it} + X'_{ijt}\delta + \sum_d (\gamma_d N^T_{dit}) + \sum_d (\phi_d N_{dit})$

$+ \sum_d (\theta_d T_{1it} * N^T_{dit}) + u_i + e_{ijt}$

If the expectation of e_{ijt} is the same for the Group 1 pupils who missed their first year of treatment in 1998, and the Group 2 pupils who missed treatment in 1999, then we can estimate both **within-school** and **cross-school treatment externalities** in 1998:

$$
\begin{aligned}
Y_{ijt} = & a + \beta_1 \cdot T_{1it} + b_1 \cdot D_{1ij} + b_2 \cdot (T_{1it} * D_{1ij}) + X'_{ijt}\delta \\
& + \sum_d \left(\gamma_d \cdot N^T_{dit}\right) + \sum_d \left(\phi_d \cdot N_{dit}\right) + u_i + e_{ijt}
\end{aligned}
$$

- β_1 within-school externality effect on the untreated.
- $(\beta_1 + b_2)$ **within-school externality effect** + the additional **direct effect** of treatment on the treated.
- If **the final term in equation (2) is negative**, as we suggest above, this specification **underestimates within-school externalities** and **overstates the impact on the treated within treatment schools**.
- In certain specifications we **interact the local pupil density terms with the treatment school indicator** to estimate potentially **differential cross-school externalities** in treatment and comparison schools.

3.3. Initial Evidence on Within-School Deworming Externalities

- rates of moderate-to-heavy infections were **21%** lower among Group 1 pupils who did not receive medical treatment in 1998.
- By way of contrast, Group 1 pupils who were treated in 1998 had a 24% chance of moderate-to-heavy infection in January to February 1999, while Group 2 pupils who would obtain treatment later in 1999 had a 51% chance of infection, for a difference of 27 %.
- **Difference in the prevalence of moderate-to-heavy infections among the untreated** was approximately three-quarters **the difference in prevalence for the treated** (21%-27%).

Deworming Treatment Effects on Health and Nutrition

IV. Deworming Treatment Effects on Health and Nutrition

- **Table VII:**
  - regression 1, this implies the estimated **average cross-school externality reduction** in moderate-to-heavy helminth infections is $\left[\gamma_{03} * \bar{N}^{T}_{03,1} + \gamma_{36} * \bar{N}^{T}_{36,1}\right]$ =[0.26 ∗ 454 + 0.14 ∗ 802]/1000 = 0.23;
  - The average cross-school externality reduction in moderate-to-heavy infections for comparison school (Group 2) pupils is 9%, while the effect for treatment school (Group 1) pupils is considerably larger, at nearly 29% (Table VII, regression 3).
  - 0.35=0.25(Group1's within-school externality)+0.09(Group1's cross-school externality).
  - The estimated number of moderate-to-heavy helminth infections eliminated through the program is thus (0.35)*%(9817 pupils in Group 1 schools) +(0.09)*(19493 Pupils in Group 2 and 3 schools) = 5190 infections.
  - Consistent with the **differing modes of disease transmission**, **geohelminth externalities** were **primarily within schools**, while **schistosomiasis externalities** were primarily **across schools**.

TABLE VII

Deworming Health Externalities within and Across Schools, January to March 1999[a]

	Any moderate-heavy helminth infection, 1999			Moderate-heavy schistosomiasis infection, 1999			Moderate-heavy geohelminth infection, 1999		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Indicator for Group 1 (1998 Treatment) School	−0.25***	−0.12*	−0.09	−0.03	−0.02	−0.07	−0.20***	−0.11**	−0.03
	(0.05)	(0.07)	(0.11)	(0.03)	(0.04)	(0.06)	(0.04)	(0.05)	(0.09)
Group 1 pupils within 3 km (per 1000 pupils)	−0.26***	−0.26***	−0.11	−0.12***	−0.12***	−0.11**	−0.12*	−0.12*	−0.01
	(0.09)	(0.09)	(0.13)	(0.04)	(0.04)	(0.05)	(0.06)	(0.07)	(0.07)
Group 1 pupils within 3–6 km (per 1000 pupils)	−0.14**	−0.13**	−0.07	−0.18***	−0.18***	−0.27***	0.04	0.04	0.16
	(0.06)	(0.06)	(0.14)	(0.03)	(0.03)	(0.06)	(0.06)	(0.06)	(0.10)
Total pupils within 3 km (per 1000 pupils)	0.11***	0.11***	0.10**	0.11***	0.11***	0.13***	0.03	0.04	0.02
	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Total pupils within 3–6 km (per 1000 pupils)	0.13**	0.13**	0.12*	0.12***	0.12***	0.16***	0.04	0.04	0.01
	(0.06)	(0.06)	(0.07)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
Received first year of deworming treatment, when offered (1998 for Group 1, 1999 for Group 2)		−0.06*			0.03**			−0.04**	
		(0.03)			(0.02)			(0.02)	
(Group 1 Indicator) * Received treatment, when offered		−0.14*			−0.02			−0.10***	
		(0.07)			(0.04)			(0.04)	
(Group 1 Indicator) * Group 1 pupils within 3 km (per 1000 pupils)			−0.25*			−0.04			−0.18**
			(0.14)			(0.07)			(0.08)
(Group 1 Indicator) * Group 1 pupils within 3–6 km (per 1000 pupils)			−0.09			0.11			−0.15
			(0.13)			(0.07)			(0.10)
Grade indicators, school assistance controls, district exam score control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	2328	2328	2328	2328	2328	2328	2328	2328	2328
Mean of dependent variable	0.41	0.41	0.41	0.16	0.16	0.16	0.32	0.32	0.32

[a]Grade 3–8 pupils. Probit estimation, robust standard errors in parentheses. Disturbance terms are clustered within schools. Observations are weighted by total school population. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The 1999 parasitological survey data are for Group 1 and Group 2 schools. The pupil population data is from the 1998 School Questionnaire. The geohelminths are hookworm, roundworm, and whipworm. We use the number of girls less than 13 years old and all boys (the pupils eligible for deworming in the treatment schools) as the school population for all schools.

Deworming Treatment Effects on School Participation

V. Deworming Treatment Effects on School Participation

- Deworming increased school participation in treatment schools by at least 7% points, a one-quarter reduction in total school.(**By** allowing previously weak and listless children to attend school regularly or by improving children's ability to concentrate) absenteeism.
- As with the health impacts, deworming creates **externalities** in school participation both within and across schools.
- after accounting for externalities we estimate that **overall school participation** in this area likely increased by at least **0.14** years of schooling **per pupil actually** treated through the program.
- Considered a participant if she or he is present in school on a given day, and a nonparticipant if she or he is not in school on that day. The days of medical treatment were pre-announced, do not include attendance on these days(调查的这些天)，due to children coming to school in the hope of receiving medicine。

5.1. School Participation Differences across Treatment and Comparison Schools

TABLE VIII

School Participation, School-Level Data[a]

	Group 1 (25 schools)	Group 2 (25 schools)	Group 3 (25 schools)		
Panel A:					
First year post-treatment (May 1998 to March 1999)	*1st Year Treatment*	*Comparison*	*Comparison*	*Group 1 – (Groups 2 & 3)*	*Group 2 – Group 3*
Girls <13 years, and all boys	0.841	0.731	0.767	0.093*** (0.031)	−0.037 (0.036)
Girls ≥13 years	0.864	0.803	0.811	0.057** (0.029)	−0.008 (0.034)
Preschool, Grade 1, Grade 2 in early 1998	0.795	0.688	0.703	0.100*** (0.037)	−0.018 (0.043)
Grade 3, Grade 4, Grade 5 in early 1998	0.880	0.789	0.831	0.070*** (0.024)	−0.043 (0.029)
Grade 6, Grade 7, Grade 8 in early 1998	0.934	0.858	0.892	0.059*** (0.021)	−0.034 (0.026)
Recorded as "dropped out" in early 1998	0.064	0.050	0.030	0.022 (0.018)	0.020 (0.017)
Females[b]	0.855	0.771	0.789	0.076*** (0.027)	−0.018 (0.032)
Males	0.844	0.736	0.780	0.088*** (0.031)	−0.044 (0.037)
Panel B:					
Second year post-treatment (March to November 1999)	*2nd Year Treatment*	*1st Year Treatment*	*Comparison*	*Group 1 – Group 3*	*Group 2 – Group 3*
Girls <13 years, and all boys	0.713	0.717	0.663	0.050* (0.028)	0.055* (0.028)
Girls ≥14 years[c]	0.627	0.649	0.588	0.039 (0.035)	0.061* (0.035)
Preschool, Grade 1, Grade 2 in early 1998	0.692	0.726	0.641	0.051 (0.034)	0.085** (0.034)
Grade 3, Grade 4, Grade 5 in early 1998	0.750	0.774	0.725	0.025 (0.023)	0.049** (0.023)
Grade 6, Grade 7, Grade 8 in early 1998	0.770	0.777	0.751	0.020 (0.027)	0.026 (0.028)
Recorded as "dropped out" in early 1998	0.176	0.129	0.056	0.120* (0.063)	0.073 (0.053)
Females[b]	0.716	0.746	0.648	0.067** (0.027)	0.098*** (0.027)
Males	0.698	0.695	0.655	0.043 (0.028)	0.041 (0.029)

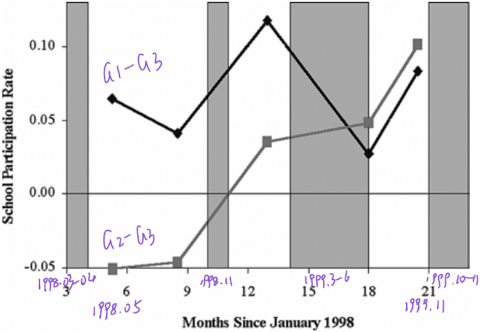


FIGURE 1.—School participation rate May 1998 to November 1999 for girls under 13 years old and for all boys (difference between Group 1 and Group 3 (diamonds), and difference between Group 2 and Group 3 (squares)).[a]

[a]The shaded regions are periods in which medical treatment was being provided (in March–April and November 1998 to Group 1 schools, and March–June and October–November 1999 to Group 1 and Group 2 schools).

5.2. Estimating Overall School Participation Impacts

TABLE IX

School Participation, Direct Effects and Externalities[a]
Dependent Variable: Average Individual School Participation, By Year

	OLS (1)	OLS (2)	OLS (3)	OLS (4) May 98– March 99	OLS (5) May 98– March 99	OLS (6) May 98– March 99	IV-2SLS (7) May 98– March 99
Moderate-heavy infection, early 1999						−0.028*** (0.010)	−0.203* (0.094)
Treatment school (T)	0.051*** (0.022)						
First year as treatment school (T1)		0.062*** (0.015)	0.060*** (0.015)	0.062* (0.022)	0.056*** (0.020)		
Second year as treatment school (T2)		0.040* (0.021)	0.034* (0.021)				
Treatment school pupils within 3 km (per 1000 pupils)			0.044** (0.022)		0.023 (0.036)		
Treatment school pupils within 3–6 km (per 1000 pupils)			−0.014 (0.015)		−0.041 (0.027)		
Total pupils within 3 km (per 1000 pupils)			−0.033** (0.013)		−0.035* (0.019)	0.018 (0.021)	0.021 (0.019)
Total pupils within 3–6 km (per 1000 pupils)			−0.010 (0.012)		0.022 (0.027)	−0.010 (0.012)	−0.021 (0.015)
Indicator received first year of deworming treatment, when offered (1998 for Group 1, 1999 for Group 2)					0.100*** (0.014)		
(First year as treatment school Indicator) ∗ (Received treatment, when offered)					−0.012 (0.020)		
1996 district exam score, school average	0.063*** (0.021)	0.071*** (0.020)	0.063*** (0.020)	0.058 (0.032)	0.091** (0.038)	0.021 (0.026)	0.003 (0.023)

TABLE IX
(Continued)

	OLS (1)	OLS (2)	OLS (3)	OLS (4) May 98–March 99	OLS (5) May 98–March 99	OLS (6) May 98–March 99	IV-2SLS (7) May 98–March 99
Grade indicators, school assistance controls, and time controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.23	0.23	0.24	0.33	0.36	0.28	–
Root MSE	0.273	0.272	0.272	0.223	0.219	0.150	0.073
Number of observations	56487	56487	56487	18264	18264	2327	49 (schools)
Mean of dependent variable	0.747	0.747	0.747	0.784	0.784	0.884	0.884

total effect of deworming on school participation:

in treatment school: $0.075 = \frac{1}{2} \times (0.06 + 0.034 + 0.044 - 0.014)$

in comparison shool: 0.02 給定人數計算

treatments schools $\frac{1}{3} + \frac{2}{3} = \frac{1}{2}$

comparison shools $\frac{2}{3} + \frac{1}{3} = \frac{1}{2}$

3组 $\times \frac{1}{2} = 1.5$

treating one child led to increase in school participation:

$0.075 \times 1.5 + 0.02 \times 1.5 = 0.14$ years

5.3. Comparing Experimental and Nonexperimental Estimates

- OLS(6): This nonexperimental estimate is restricted to the subsample of 2327 pupils in grades three to eight for whom there is 1999 parasitological data.
- OLS(7): IV—Group 1 (treatment) indicator variable, treatment school pupils within 3 km, and treatment school pupils within 3–6 km.
- There are at least 3 reasons why the **IV estimates** of the impact of moderate-heavy infection on school participation are substantially **larger** than **OLS estimates**.
  - The parasitological exam data almost certainly **understates** the total number of moderate to heavy infections eliminated as a result of the program immediately after treatment（处理之后立刻调查）.
  - Exclusion restriction—the program only affects pupils’ school attendance by changing their health—may not hold, due to complementarities in school participation（e.g.stay home sick，their older sisters may also stay home to take care of them.
  - Attenuation bias due to error in measuring the severity of disease.

Deworming Treatment Effects on Test Scores

VI. Deworming Treatment Effects on Test Scores

- **Positive mechanisms**: Deworming could improve test scores both by increasing time spent in school and by improving learning while pupils are in school
- **Negative mechanisms**: but could also potentially reduce test scores through congestion or negative peer effects.
- The results could potentially have been affected by **differential attrition across treatment and comparison schools**, if the additional treatment school pupils who participated in the exam after deworming were below-average performers.(we **restrict 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 **nearly identical proportions of these pupils took the ICS exam in treatment and comparison schools**.)

TABLE X

ACADEMIC EXAMINATIONS, INDIVIDUAL-LEVEL DATA[a]

	Dependent variable: ICS Exam Score (normalized by standard)		
	(1)	(2)	(3) Among those who filled in the 1998 pupil survey
Average school participation (during the year of the exam)	0.63***		
	(0.07)		
First year as treatment school (T1)		−0.032	−0.030
		(0.046)	(0.049)
Second year as treatment school (T2)		0.001	0.009
		(0.073)	(0.081)
1996 District exam score, school average	0.74***	0.71***	0.75***
	(0.07)	(0.07)	(0.07)
Grade indicators, school assistance controls, and local pupil density controls	Yes	Yes	Yes
R^2	0.14	0.13	0.15
Root MSE	0.919	0.923	0.916
Number of observations	24958	24958	19072
Mean of dependent variable	0.020	0.020	0.039

Cost Effectiveness and Welfare Analysis

VII. Cost Effectiveness and Welfare Analysis

We explore the controversy over **whether mass school-based deworming treatment should be a public policy priority** for the poorest countries using **four different approaches**.

- **Health Cost Effectiveness**: health projects are considered cost-effective up to some threshold cost per Disability- Adjusted Life Year (DALY) saved, perhaps $25 to $100 per DALY in the poorest countries.
- **Educational Cost Effectiveness**: promoting school participation through deworming rather than through alternative educational interventions.
- **Deworming as Human Capital Investment**: estimates the rate of return to deworming in future earnings.
- **Externalities and Optimal Deworming Subsidies**: identify the subsidy that would lead individuals to fully internalize treatment externalities.

Conclusions and Discussions

VIII. Conclusions and Discussions

- A school-based deworming programin Kenya led to a **7.5% average gain in primary school participation** in treatment schools, reducing overall school absenteeism by at least one-quarter.
- Treatment created **positive health and school participation externalities** for untreated students.
- A rough calculation suggests that **these spillovers alone are sufficient** to justify not only fully **subsidizing deworming treatment**, but perhaps even **paying people to receive treatment**.
- **However**, this multi-level design may not be practical in all contexts:
  - Randomization at the level of clusters of schools also dramatically **increases the sample size needed for adequate statistical power**, raising project cost.
  - Our results also suggest that **microeconomic and macroeconomic studies** that estimate the impact of health on income conditional on educational attainment are likely to **systematically underestimate**.