Social Networks and Learning about Health in Kenya

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Abstract: The spread of many seemingly beneficial technologies is slow in less developed countries. We provide empirical evidence on social learning about health in the context of a project designed to reduce intestinal worm infections among Kenyan school children. Intestinal worms infect one in four people worldwide, yet can be safely treated with drugs at pennies per dose. This paper uses an experimental methodology to estimate social effects, avoiding the well-known econometric critiques that plague non-experimental studies. Those who were randomly exposed to more information about deworming drugs through their social networks were significantly *less* likely to take them. They are also significantly more likely to believe that the drugs are "not effective" – direct evidence on the evolution of their beliefs. A rational learning model in which individuals have overly optimistic priors about private drug benefits is consistent with these main findings, though we also discuss other potential explanations.

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1. Introduction

Technology adoption is central to economic growth and development. An extensive empirical literature has examined technology adoption decisions for health, family planning, and agriculture and finds that the spread of many seemingly beneficial technologies is often remarkably slow.[2] Many such health-related anomalies have been studied, including slow adoption of the flu vaccine and beta-blockers in the United States (Schneider et al. 2001, Krumholz et al. 1998), water boiling in Peru, the use of well water rather than stream water in Egypt (Rogers 1995), and condom use during the AIDS epidemic in Africa (Philipson and Posner 1995).

In this paper, we provide empirical evidence on social learning about a new health technology in the context of a public health project designed to reduce intestinal worm infections among Kenyan school children. Intestinal worms infect one in four people worldwide, yet can be safely treated with drugs at pennies per dose through school-based mass deworming programs. Such programs were identified as among the most cost-effective health interventions in the 1993 World Development Report (World Bank 1993). In prior work, we examined the impact of deworming on child health, nutrition, and school outcomes (Miguel and Kremer 2003): after two years, school absenteeism among the deworming treatment group fell by approximately one-quarter, or seven percentage points, on average (although there were no significant academic or cognitive test scores gains), and there were significant gains in several measures of health status, including reductions in worm infection, child growth stunting and anemia, and gains in self-reported health.[3]

The other main finding of previous research is that deworming significantly reduced worm infection and increased school participation among untreated children in the treatment schools, and among children in neighboring primary schools: the drop in moderate-heavy infection rates among untreated children in treatment schools was 80 percent as large as the drop among the treated, and they

[2] Conley and Udry (2000), Foster and Rosenzweig (1995), and Munshi and Myaux (2001) are three notable studies that examine social learning in less developed countries. Griliches (1957) and Rogers (1995) are classic references in the social learning literature.

[3] Refer to Appendix Tables A1-A3 for a summary of the main results of Miguel and Kremer (2003).

also showed large school participation gains. Cross-school externalities were also large for schools located within six kilometers of treatment schools, at over 25 percent of the effect in treatment schools, on average.[4] Thus observed differences across the treated and untreated children within treatment schools – in other words, the private treatment benefit beyond the externalities benefits – are substantially smaller than the overall program effect, and the same is true for differences across treatment and comparison schools due to cross-school externalities. In fact, 76 percent of the reduction in worm burden was due to externalities, suggesting that spillovers are extremely important in this scenario.

This paper uses an experimental methodology to estimate social effects in the adoption of deworming, thus avoiding well-known identification problems – especially omitted variable bias and endogeneity – that plague non-experimental learning social learning studies (see Manski 1993 for a discussion).[5] We address another weakness of many existing studies by collecting information directly from survey respondents on their closest friends and relatives – or "reference group" – an approach also recently adopted by Conley and Udry (2000). Taken together, this detailed information on self-defined social networks, the relatively large sample size (nearly 1700 households), and experimental empirical methodology make ours a useful setting to examine the nature of social learning about a new health technology.

In the original deworming program mentioned above, the "early treatment" and "late treatment" schools were randomly selected, producing exogenous local variation in the proportion of children in program schools, thus allowing estimation of social effects. We collected survey data on individual social networks to explore how variation in their social contacts' program exposure affected these individuals' own adoption decisions, for instance, by providing these individual with better information about the

[4] However, note that the ratio of private benefits to social benefits is almost certainly larger in the short-run, since it takes time for local environmental contamination with worm larvae – and thus re-infection – to fall following mass deworming. The 1999 health survey data presented in Appendix Tables A1, A2, and A3 were conducted up to one year after initial 1998 deworming treatment.

[5] Several recent papers also use experimental methods to identify social effects. Studies that examine *group-level randomization of treatment* to estimate social effects, along the lines of this paper, include Miguel and Kremer (2003) – our previous study of health externalities – and Duflo and Saez (2002). Katz et al (2001), Kremer and Levy (2001), and Sacerdote (2001) employ *random variation in peer group composition* to estimate social effects.

drugs. We find that children whose parents have (randomly) more social links to early treatment schools are themselves significantly *less* likely to take deworming drugs: for each additional social link a parent has to an early treatment school, her child is 3.1 percentage points less likely to take the drugs – an apparent case of failed social learning about an effective new health technology. Social learning effects are especially large for individuals with more schooling. Additional *child* social links to early treatment schools also lead to lower drug take-up. We find major differences between the experimental and non-experimental social effect estimates, suggesting that omitted variable bias in many existing non-experimental studies may be large.

One way to reconcile this seemingly anomalous finding on social learning with a rational model is if individuals have prior beliefs about drug benefits that are overly "optimistic" – in the sense of expecting unrealistically large deworming health gains – in which case additional information lowers posterior beliefs and thus drug take-up. In essence, people with additional information about the treatment learned through their social networks that private deworming benefits were smaller than expected, and thus they "learned" to free-ride. People may have had overly optimistic priors about the private benefits of treatment for several reasons, for instance, if they thought that taking treatment permanently eliminated worms from the body, rather than realizing that private treatment benefits were only temporary (and that longer-run benefits are due to the reduction in infection transmission caused by others taking the medicine). Another plausible explanation is that project organization field workers effectively "over-sold" the benefits of the drugs to communities at the start of the project.

However, we do not rule out the possibility that possible that take-up was in fact below the privately optimal level that would have been chosen by Bayesian learners, due to the fact that health gains from deworming take time to be realized (contrasted with the immediacy and salience of drug side effects), and the widely-held traditional view in western Kenya that moderate worm infections are not a health problem – as well as several other explanations we return to in Section 6 below.[6]

The remainder of the paper is structured as follows. Section 2 discusses worm infections, and Section 3 describes the Primary School Deworming Project. Section 4 lays out a simple social learning model, and Section 5 discusses the estimation of social effects and presents the main empirical results, and Section 6 examines non-Bayesian explanations for the results. The final section concludes.

2. Intestinal Worm (Helminth) Infections

Over 1.3 billion people worldwide are infected with hookworm, 1.3 billion with roundworm, 900 million with whipworm, and 200 million with schistosomiasis (Bundy 1994). Most have light infections, which are often asymptomatic, but more severe worm infections can lead to iron deficiency anemia, protein energy malnutrition, stunting (a measure of chronic undernutrition), wasting (a measure of acute undernutrition), listlessness, and abdominal pain, and heavy schistosomiasis infections can have even more severe consequences.[7]

Helminths do not reproduce within the human host, so high worm burdens are the result of frequent re-infection. The geohelminths (hookworm, roundworm, and whipworm) are transmitted through ingestion of, or contact with, infected fecal matter, which can occur, for example, if children do not use a latrine and instead defecate in the fields near their home or school, areas where they also play.[8] Schistosomiasis is acquired through contact with infected freshwater; for example, in our Kenyan study area people often walk to nearby Lake Victoria to bathe and fish. Medical treatment for helminth infections creates externality benefits by reducing worm deposition in the community and thus limiting re-infection among other community members (Anderson and May 1991).

[6] In a related paper, we examine the effect of a deworming drug cost-recovery program, worm prevention health education, and an individual "mobilization" technique from psychology on drug take-up in the same settings (see Kremer and Miguel 2003).

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

[8] Note that individuals are likely to have at least some knowledge of their infection status, since they can observe certain worms in their stool, and may also see them being expelled from their body after treatment.

3. The Primary School Deworming Project (PSDP) in Busia, Kenya

We study the Primary School Deworming Project (PSDP), a school health program carried out by a Dutch non-governmental organization (NGO), ICS Africa, in cooperation with the Kenyan Ministry of Health. The project took place in Busia district, a poor and densely-settled farming region in western Kenya, and the 75 project schools include nearly all rural primary schools in this area, with over 30,000 enrolled pupils between the ages of six and eighteen, over 90 percent of whom suffer from intestinal worm infections. In January 1998, the PSDP schools were randomly divided into three groups (Groups 1, 2 and 3) of twenty-five schools each: the schools were first divided by administrative sub-unit (zone) and by involvement in other non-governmental assistance programs, and were then listed alphabetically and every third school assigned to a given project group.[9]

Due to administrative and financial constraints, the health intervention – which included both deworming medicine and health education on worm prevention behaviors – was phased in over several years. Group 1 schools received treatment in 1998-2001, and Group 2 schools in 1999-2001, while Group 3 began participating in 2001. This design implies that in 1998, Group 1 schools were treatment schools, while Group 2 and Group 3 schools were the comparison schools; and in 1999 and 2000, Group 1 and 2 schools were the treatment schools and Group 3 schools were comparison schools. Starting in 1999, signed individual parental consent was required for deworming, while in 1998 only "community consent" (meetings at which parents were informed of – and could opt out of – the program) had been required. At each school, the project started out with a community meeting of parents, teachers, and the school committee, which included a discussion of worm infections, the nature of medical deworming treatment, and worm prevention measures. All school communities agreed to participate in the project.

The project provided periodic treatment with deworming drugs in all schools where prevalence of the disease was sufficiently high. The geohelminths and schistosomiasis can be treated using the low-cost

[9] Appendix Table A4 presents a detailed project timeline.

single-dose oral therapies of albendazole and praziquantel, respectively. The World Health Organization has endorsed mass school-based deworming in areas with prevalence over fifty percent, since mass treatment eliminates the need for costly individual screening (Warren et al. 1993, WHO 1987), and drugs delivered through a large-scale school program may cost as little as 0.49 USD per person per year in East Africa (PCD 1999). Side effects are minor and transient, rarely lasting more than one day, but may include stomach ache, diarrhea, dizziness, fever and even vomiting in some cases (WHO 1992). Side effects are more severe for children with heavier schistosomiasis infections[10], and in our data parents of children with more severe infections are in fact somewhat more likely to claim that the drugs had side effects (although this effect is not statistically significant).

The project followed the standard practice at the time in mass deworming programs of not treating girls of reproductive age, due to concern about the possibility that albendazole could cause birth defects (WHO 1992, Bundy and Guyatt 1996, Cowden and Hotez 2000). (The WHO recently called for this policy to be changed to allow older girls to be treated, due to a recent record of safe usage by pregnant women – see Savioli, Crompton and Neira 2003). In addition to medical deworming treatment, the project included intensive health education on worm prevention behaviors, mainly focusing on hand washing, wearing shoes, and avoiding infected fresh water.

The NGO has a general policy of introducing community cost-recovery in all its rural development programs, to promote "sustainability" and to confer project "ownership" on the beneficiaries. In this case, the NGO temporarily waived this policy initially, and then decided to phase it in gradually. The fifty Group 1 and Group 2 schools were stratified by treatment group and geographic location, and then twenty-five were randomly selected to pay user fees for medical treatment in early 2001, while the remaining twenty-five continued to receive free medical treatment; all Group 3 schools received free treatment. The average cost of deworming per child was slightly more than 0.30 U.S.

[10] The manufacturer of praziquantel (Bayer) states that "Side effects are usually mild and temporary and include abdominal pain, nausea, vomiting, headache, fever, pruritus, drowsiness. Side effects may be more severe in heavy infestations." (home.intekom.com/pharm/bayer/)

dollars – still a heavily subsidized price, about one-fifth the cost of drug purchase and delivery through the NGO program.[11] We find that the introduction of a small cost for deworming led to a dramatic reduction in treatment rates. Children in 75 percent of households in the free treatment schools received deworming drugs in 2001 (Table 1, Panel A), while the rate was only 18 percent in cost-sharing schools – providing evidence on the low value most households attach to deworming.[12] These cost-sharing results, and their policy implications, are discussed in detail in Kremer and Miguel (2003).

4. A Simple Model of Learning about a Health Technology

It is possible that once people gain experience with a new medical technology, they will learn about its effectiveness and then spread this information on to others. Below we consider a theoretical model of the spread of technology through social learning, and then empirically examine the spread of deworming drug adoption and worm infection knowledge. We first examine how far we can go toward explaining take-up patterns in a rational framework with Bayesian learning (Section 5), and then discuss remaining anomalies and possible non-rational explanations (Section 6).

Imagine an individual *i* in school *j* deciding whether to adopt a new technology (or health practice), where an indicator variable for take-up is represented by $T_{ij} \in \{0, 1\}$. With homogeneous individuals, we represent the expected overall private benefit of adoption by $\phi = E[U(T_{ij} = 1) - U(T_{ij} = 0)]$, which may include benefits in health, education, and other dimensions, where *U* is individual utility, the private benefit conditional on the treatment choices of other individuals. For simplicity, we do not explicitly model the expected treatment benefit as a function of others' treatment choices (although we slightly modify this below).[13]

[11] Annual Kenyan per capita income is $340 (World Bank 1999), but incomes are thought to be lower in Busia.
[12] The data is described below.
[13] The effect of other people's treatment choices on the magnitude of private treatment benefits is unclear *a priori*, and we do not formally model these externalities. As a benchmark case, if helminth re-infection rates are independent of current worm load, and if the health burden of infection is linear in worm load, then the private health benefits of treatment are independent of others' treatment decisions. However, the epidemiological literature suggests that linearity is unlikely. If instead the health costs of infection are convex (concave) in worm load, then deworming treatment benefits will be greater (smaller) in an environment that is expected to have high exposure to

At the moment the new technology is introduced, individuals share a common prior on the expected private benefits, denoted ϕ_0, which may be greater or less than the actual expected benefit, ϕ. ϕ_0 could be less than ϕ due to traditional beliefs about worms, that emphasize their health benefits rather than their costs (Geissler 1998a), or greater than the true ϕ if people have overly optimistic estimates of the private benefits of treatment. If people estimate their own expected benefits by comparing individuals in treatment and comparison schools, they will be likely to overestimate the private benefits of treatment; specifically, to the extent that there are positive within-school treatment externalities, they will assign some of the externality value to private benefits, making priors overly optimistic. If people estimate the private benefit of treatment by simply comparing the health status of infected and uninfected people, they could similarly overestimate the effect of treatment. Another potential explanation for overly optimistic priors regarding deworming could be that NGO field officers exaggerated its benefits during the community meetings held to publicize the program; although an examination of the scripts used in their standard thirty minute talk to parents suggests that the field officers presented a reasonably balanced view of deworming, we cannot rule out this possibility. In any case, priors about the impact of deworming may well have been noisy, since people had little experience with mass treatment with deworming drugs before the program and since treatment spillovers were not emphasized by field workers during the community informational meetings.

These priors are based on *n* independent signals about treatment benefits, and individuals combine this prior information with additional information they receive from their social links in the early treatment schools. Individuals are randomly assigned N_{ij}^{E} early treatment links, and each such link yields one additional signal about private benefits, a noisy signal based on the link's own experiences as

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worms in the future – and thus the private benefits of treatment will be *lower* (*higher*) if others are also treated. In a previous study (Miguel and Kremer 2003) we estimate overall deworming treatment spillovers, but are unable to estimate an externality health benefits function of the sort described above.

[15] For simplicity, we focus on the social learning aspect of the adoption decision and do not consider the case where individuals experiment today in order to gain more information about the technology for future rounds, although this could be important in certain contexts.

well as their observations of others. Individuals then compute the naïve sample average of private signals, from their prior and their social links, and the posterior belief on expected treatment benefits for an individual with N_{ij}^E early treatment links becomes:

$$E[U(T_{ij}=1)-U(T_{ij}=0)\,|\,N_{ij}^E]=\alpha(N_{ij}^E)\cdot\phi_0+(1-\alpha(N_{ij}^E))\cdot\phi \qquad (1)$$

where $\alpha(N_{ij}^E)=\frac{n}{n+N_{ij}^E}$, which goes to zero as individuals accumulate information through their social network, and as posterior beliefs approach the true expected benefit.[15] Note that it is reasonable to assume there is also some individual heterogeneity in perceived adoption benefits, in which case the likelihood of adoption increases continuously in the expected treatment benefits (we model this explicitly in Section 5 below).

We assume that individuals use a simple updating rule, and compare observed outcomes across treated and untreated children in order to estimate the private treatment benefit in this setting – the variable of immediate interest to them – and they do not learn about the complicated underlying epidemiological model of treatment spillovers (this may be contributing to overly optimistic priors, as mentioned above). Although individuals would be better able to react optimally to changes in public policy or the disease environment in an alternative theoretical framework where they learn about the underlying epidemiology, we do not think that such a model is realistic in this context, since the epidemiological model is complicated and few individuals in this area have even basic knowledge about worm infections: as we discuss below, the median resident is able to name just one of ten common worm infection symptoms, and fewer still can accurately describe transmission mechanisms.

The solution of the model is intuitive: when the prior is greater than the actual expected benefit ($\phi_0 > \phi$), those with more early treatment social links have lower posterior beliefs about expected benefits on average, and thus the likelihood of adoption declines in the number of early links. From Equation 1, the decline in the expected benefit of treatment with respect to early links will be convex, as in Figure 1, as the posterior asymptotically approaches the true expected benefit. Similarly, when the prior is less than the true expected benefit, the posterior asymptotically approaches the true expected benefit from below.

4.1 Heterogeneous Prior Beliefs, Information, and Treatment Effects

We extend the model by allowing heterogeneous prior beliefs, information, and treatment effects.

The prior is now a function of an individual characteristic X_{ij}, such that $\phi_{0,ij} = \phi_0(X_{ij})$, and we assume $\phi_0' > 0$ without loss of generality. For an illustration in the context of rural Kenya, formal schooling is considered an important predictor of receptiveness to new health technologies (Akwara 1996, Kohler et al 2001), and more educated individuals are thus likely to have more "optimistic" priors about technologies advocated by representatives of an NGO.[16] (Note that this could reflect either the impact of education, or simply that those people who are more open to "modernity" are likely to obtain more education.) When $\phi_0(X_{ij}) > \phi$ for all X_{ij}, individuals with more education generally have higher adoption rates, but additional early links lead to sharper drops in their adoption. Formally,

$$\frac{\partial^2 E[U(T_{ij}=1) - U(T_{ij}=0) \mid N_{ij}^E]}{\partial N_{ij}^E \partial X_{ij}} = -\phi_0'(X_{ij}) \cdot \frac{n}{(n + N_{ij}^E)^2} < 0 \qquad (2)$$

Certain early links may also provide more (or less) favorable information regarding deworming; for instance, individuals may have certain links who report that the technology has a high payoff (ϕ_H) and others who report it has a low payoff (ϕ_L), where $\phi_H > \phi_L$. High (low) payoff links might be those that experienced large (small) benefits themselves, or those who observed large (small) average benefits in their community. It is straightforward to show that people with additional high payoff links are thus more likely to adopt.

Treatment benefits may also be a function of an individual health characteristic, $W_{ij} = W(N_{ij}^E)$, such that $\phi_{ij} = \phi(W(N_{ij}^E))$, where health is allowed to be a function of early social links. For this study,

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[16] We thus depart from the standard assumption of common priors. For theoretical examinations of how different beliefs on political and health issues can persist, refer to Piketty (1995) and Das (2000), respectively.

W_{ij} should be thought of as the individual worm infection level, where those with higher infection levels typically have greater treatment benefits, $\phi' > 0$. Infection levels are also a function of social links due to epidemiological externalities: children whose families have close social interactions with households in early treatment schools may experience lower helminth re-infection rates and thus reductions in infection intensity, so in this setting $W' < 0$. The impact of early treatment links on the likelihood of adoption is presented in Equation 3 (where we make the algebraically convenient, but substantively inessential, assumption that $\phi_0' = \phi'$ and $\phi_0'' = \phi'' = 0$ at all infection levels):

$$\frac{\partial E[U(T_{ij}=1, W(N_{ij}^E)) - U(T_{ij}=0, W(N_{ij}^E)) \mid N_{ij}^E]}{\partial N_{ij}^E} \qquad (3)$$

$$= \left\{ \left[\phi(W(N_{ij}^E)) - \phi_0(W(N_{ij}^E))\right] \cdot \frac{n}{(n+N_{ij}^E)^2} \right\} + \left\{ W'(N_{ij}^E) \cdot \phi' \right\}$$

The first right hand side term is the *information social effect*, and is negative when priors are overly optimistic, as above. The second term is the *infection social effect*, which should also be negative because having more early treatment links can lead to lower infection levels (due to epidemiological externalities) and this in turn reduces treatment benefits. We argue below that the infection social effect is very small empirically, largely because child infection levels only weakly affect deworming take-up, and thus that the impact of early links on take-up is overwhelmingly driven by information rather than infection externalities.

5. Social Learning about Deworming

5.1 Data and Measurement

The empirical results employ two new micro-datasets, the 2001 PSDP Parent Questionnaire and 2001 PSDP Pupil Questionnaire, which were administered by experienced enumerators under the close supervision of NGO field managers. Parent Questionnaires were collected during household visits among a random subsample of parents with children currently enrolled in Group 2 and Group 3 schools. A subsample of children (age ten and older) actually in school on the day of survey administration were administered the Pupil Questionnaire. Survey refusal rates were very low for both surveys, as is typical for this region.

Parent Questionnaire respondents were asked for personal information on their closest social links: the five friends they speak with most frequently, the five relatives they speak with most frequently, additional social contacts whose children attend local primary schools, and individuals with whom they speak specifically about child health issues. These relatives, neighbors, and friends are referred to collectively as the respondent's set of "social links". The Parent Questionnaire also collected information on the deworming treatment status of social links' children and the effects of treatment on their health; how frequently the respondent speaks with each social link; which primary schools links' children attend; the global positioning system (GPS) location of the respondent's home; and the respondent's knowledge of worm infections and attitudes toward deworming drugs. The Parent Questionnaire was administered in two rounds in 2001, with households randomly allocated between the rounds; the main difference between the survey rounds is that the Round 2 survey collected more detailed information on the impact of deworming on links' children. The 2001 Pupil Questionnaire collected similar information on social networks and attitudes toward deworming, but this time from the schoolchildren themselves.

There are three main samples used in the analysis. Sample I is the main sample, and contains 1678 parents surveyed in Rounds 1 or 2 with complete child treatment and social network data.[17] Sample II contains the 886 parents surveyed in Round 2, and we use this sample to analyze the impact of links' deworming experiences on respondent's choices. Sample III contains information for the 3164 children with complete 2001 Pupil Questionnaire data on social links and drug take-up, and who were eligible for treatment in 2001. On average, parent respondents have 10.2 social links with children in primary school, of whom 4.4 attend the respondent's child's own school, 2.8 attend other project schools (Groups 1, 2 or 3), and 1.9 attend nearby "early treatment schools" (Groups 1 and 2 – refer to Table 1, Panels B and C).

[17] Eleven percent of surveyed households were dropped due to child ineligibility for deworming (i.e., the child was an older girl excluded from treatment), and a reasonably modest thirteen percent due to either missing parent network information, child treatment information, household characteristics, or difficulty matching observations across the 2001 surveys and early PSDP datasets.

There is considerable variation across individuals in the number of early treatment links – the standard deviation is 2.0 – and approximately one-third of respondents have no social links to Group 1 or 2 schools at all, one-third have one or two links, and one-third have three or more links. Child social networks show similar patterns (Table 1, Panel D).

5.2 Estimating Social Effects

We test whether households with more social links to early treatment schools were more likely to take deworming drugs in 2001, conditional on the total number of social links they have to all project schools. The experimental design of the PSDP created exogenous random variation in the proportion of individuals whose children attend "early treatment" schools (Groups 1 and 2) and "late treatment" schools (Group 3). To validate the identification strategy, we confirm that the deworming project randomization succeeded in creating "treatment" and "comparison" groups that are similar along a range of characteristics. The number of social links to early treatment schools, as well as the Group 2 indicator variable and the cost-sharing indicator, are generally not significantly associated with observable characteristics (Table 2), including with parent years of education, community group membership (e.g., women's or farmers' groups), the total number of children in the household, asset ownership (iron roof at home), and the distance from home to the primary school (although the number of early links is positively and significantly associated with iron roof ownership in one specification – Table 2, regression 4), or with household ethnic group or religious affiliation (results not shown). The number of child social links to early treatment schools is not significantly related to any of these characteristics, among the subsample of children with both complete 2001 Parent Questionnaire and Pupil Questionnaire data (results not shown).

The main analysis with parent social network data is conducted at the household level using probit estimation, and the outcome measure takes on a value of one if any child in the household received treatment with deworming drugs in 2001, and zero otherwise (though results are similar if the analysis is conducted using the child as the unit of observation, results not shown).[18] T_{ij} is the main dependent variable, the 2001 treatment indicator described above, where *i* is a household in school *j*. The idiosyncratic deworming benefit term, ε_{ij}, captures unobserved variation in parent beliefs about deworming or costs to obtaining treatment (for instance, whether the pupil was sick on the treatment day, which increases the cost of attending school). The individual treatment decision becomes T_{ij} = $1(\lambda N_{ij}^{E} + X_{ij}{'}\beta + \varepsilon_{ij} > 0)$, where N_{ij}^{E} is the number of parent social links to early treatment schools (not including the respondent's own school), and "early treatment schools" in 2001 are the Group 1 and 2 schools. (We also examine the *proportion* of social links to early treatment schools as a robustness check below.) A parallel analysis is conducted using information on child social networks.

Among the explanatory variables, X_{ij}, we include total links to all program schools other than the respondent's own school, as well as the number of links to non-program schools (represented by the vector N_{ij}); given the experimental design of the original deworming program, the number of social links to early treatment schools is randomly assigned conditional on total links to other program schools. The cost-sharing indicator variable, C_j, takes on a value of one for schools participating in the cost-sharing project. Z_{ij} includes additional household socioeconomic characteristics (parents' education and asset ownership), demographic characteristics (respondent fertility), and other controls (respondent membership in community groups and a Group 2 indicator) that may affect real or perceived deworming benefits and costs. Idiosyncratic disturbance terms are allowed to be correlated within each school as a result of common influences, such as headmaster efforts in promoting deworming take-up. Equation 4 presents the main probit specification:

$$\Pr(T_{ij} = 1) = \Phi\{\lambda_1 N_{ij}^{E} + N_{ij}{'}\lambda_2 + \gamma C_j + Z_{ij}{'}\theta + \varepsilon_{ij}\} \qquad (4)$$

[18] Treatment choices across children in the same family are highly correlated due to the common parent decision that underlies them, as expected, and hence the focus is on the household as the unit of observation.

We also include interaction terms between household characteristics and the number of links in some specifications to explore the possibility of heterogeneous treatment effects, for example, for individuals with different levels of education.

We discuss additional econometric identification issues in Section 5.4 below.

5.3 Social Learning Results

Each additional parent social link to an early treatment school is associated with 3.1 percentage points lower likelihood that the respondent's children received medical treatment in 2001, and this effect is significantly different than zero at over 95 percent confidence (Table 3, regression 1).[19] This suggests that the respondent's relatively small, self-defined reference group has a major impact on health choices: having two additional early treatment social links (roughly a one standard deviation increase) reduces take-up by six percentage points, a reduction of ten percent of average take-up. Figure 2 graphically presents the non-parametric social effect estimates – using a Fan local regression and Epanichnikov kernel – and indicates that the relationship between the number of early treatment links and take-up, conditional on the explanatory variables in regression 1, is negative and convex, consistent with our learning model.[20]

None of the demographic or socioeconomic controls is significantly associated with 2001 take-up except for distance from home to school, which is negatively related to take-up; this finding makes sense since walking to school to provide written parental consent is more costly for geographically distant households. The effect of early links is nearly identical for cost-sharing and non-cost-sharing schools (results not shown). Social effects are more negative for Group 3 schools (point estimate –0.041, Table 3, regression 2) than for Group 2 schools (point estimate –0.018), although the difference is not statistically significant. This result is consistent with the theoretical model: Group 2 parents have observed the impact

[19] Marginal probit coefficient estimates evaluated at mean values are presented.
[20] However, we cannot completely rule out the possibility that individuals are learning about an underlying epidemiological model when making their treatment choices, rather than the model presented in Section 4.

of deworming treatment in their own household and community, and should therefore be less influenced than Group 3 parents by early links (i.e., in Equation 1, *n* is larger for Group 2 parents than Group 3 parents). Nonetheless, the persistent influence of early links on the behavior of Group 2 households after two years of treatment is noteworthy; one plausible explanation is that initial pieces of information about a new technology carry disproportionate weight in subsequent decision-making (Rabin and Schrag 1999), although this is a departure from the Bayesian learning framework presented above.[21] The results are robust to including the proportion of links with children in early treatment schools, rather than the number of such links (regression 3).

This framework is extended to include different types of parent social links – "close" friends (with whom the respondent speaks at least twice per week) versus "distant" friends, for example – shedding light on their relative importance in information transmission. Each additional "close" link to an early treatment school is associated with 0.036 lower probability of deworming treatment in 2001, while the effect of "distant" links is negative but only marginally statistically significant (Table 3, regression 4, estimate -0.020, standard error 0.016), although we are unable to reject the hypothesis that social effects are the same for "close" and "distant" links (p-value=0.22). Similarly, the social effect on take-up is nearly identical for links to relatives and friends (results not shown).

Social effects are more strongly negative for respondents with more education (regression 5), which is consistent with the prediction that those with the most optimistic priors experience the largest drops in take-up when they receive more information. Other social learning studies in development – most notably Foster and Rosenzweig (1995) – find that educated individuals are most responsive to information regarding new technologies, although in other cases this has led more educated individuals to be early adopters, unlike our case where they are the first to learn *not* to adopt.[22]

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[21] One finding that casts some doubt on this explanation, however, is the fact that links to Group 1 schools (phased in during 1998) have nearly identical effects as links to Group 2 schools (phased in during 1999).

[22] The social effect results are robust to a specification without socioeconomic controls (Appendix Table A5, regression 1), and to the inclusion of additional ethnic and religious controls and indicators for whether individuals are members of the dominant local ethnic and religious group (regression 2); none of the six ethnic group indicator variables is significantly related to take-up. The results are similar when the local density of early treatment school

Social links' experiences with deworming may also affect the information individuals receive. In particular, we test whether take-up is higher when links had "good" experiences with deworming. This non-experimental analysis complements the experimental estimates, but may suffer from omitted variable bias: people with favorable reactions to deworming may move in the same social circles, and, moreover, individuals who themselves have more positive views toward treatment may also be more likely to report that their links had good effects, even if the links experiences were not that good. Social links' actual take-up choices may also provide information for the respondent on treatment benefits, or may affect adoption through imitation effects (Munshi 2002). Similarly, the deworming experiences and choices of people in social links' communities may affect respondent take-up. For each early treatment school, we compute the average difference in school attendance between treated and untreated pupils in 1999, and use this to classify schools into "large treated minus untreated difference" schools (those above the median difference) and "small treated minus untreated difference" schools. The treated minus untreated difference measures the average observed private benefit to deworming in that school. Finally, we also categorize links' schools into "high deworming take-up" schools in 1999 (those above the median take-up rate) and "low deworming take-up" schools, and estimate whether social links to schools with a "good" reception to deworming have a different impact than links to schools that had a "bad" reception.

We find no evidence that the treatment choices and experiences of the social links themselves, or the experiences of children in links' schools, affect take-up decisions. Links to early treatment schools with low take-up do have a somewhat more negative effect on respondent treatment rates (Table 4, regression 2, point estimate –0.032) than links to schools with high take-up (point estimate –0.030), but the difference between these estimates is not significantly different than zero. Similarly, there is no

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pupils (located within three kilometers of the respondent's school), and the density of all local primary school pupils, are included as controls (regression 3), but the point estimate on early links falls by about one-third and becomes insignificant, possibly because the local density measures are in part also picking up the effect of interactions with individuals not included in the roster of social links; still an F-test indicates that the early treatment social links and local density of early treatment pupils terms are jointly significant at 99 percent confidence. Similar social effects prevailed in the first year of the project as in 2001: more social links to Group 1 schools (the early treatment schools in 1999) is also significantly associated with lower 1999 take-up rates among Group 2 households, statistically significant difference between the effect of links to early treatment schools where the difference in school participation between treated and untreated pupils was large (and thus the observed private treatment benefit large) versus those where this difference was small (regression 3). There is no evidence that social links' treatment choices themselves have an impact on individual adoption (regression 4).[23] These non-experimental estimates are markedly different from the experimental estimates – which are consistently negative – implying that the omitted variable bias in this context is likely to be large and positive. There is some evidence that having more links whose children had "good effects" from deworming is associated with higher take-up, while those with more links who had "side effects" are less likely to be treated (regression 5) – the p-value on the hypothesis test that the two coefficient estimates are equal is 0.22 – but this result is ultimately inconclusive.

We next examine the impact of early treatment social links on deworming attitudes and knowledge, and find that respondents with more early links are significantly more likely to claim that deworming drugs are "not effective" (Table 5, row 1). This is consistent with the hypothesis that some people thought deworming would provide long-term protection against worms but learned otherwise from their contacts at early treatment schools. The existence of large within-school externalities from mass deworming may also partially explain these results: in the presence of externalities, people who observe children in their community – some of whom received deworming drugs, and some of whom did not – should infer that the private benefits to deworming are relatively small. We do not find a significant impact of additional early links on the belief that deworming drugs are "very effective", although the point estimate is negative (row 2), nor that the drugs have "side effects" (row 3). We do find that individuals with more years of schooling are much more likely than less educated individuals to believe

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1.7 percentage points lower for each additional link (regression 4). However, the effect of links to Group 1 and 2 schools on take-up among Group 2 parents in 2000 is negative but not statistically significant (results not shown).

[23] One drawback of our dataset is that we only have information on social links' deworming choices provided by the respondent herself (we did not collect the full names of social links for privacy reasons, and are thus unable to match the social links to the main database).

that deworming is “very effective” (an increase of 0.018 per year of schooling, standard error 0.003, regression not shown), a finding of more “optimistic” beliefs among the better educated, as expected.

Although early treatment links do affect deworming attitudes, they do not affect beliefs that “worms and schistosomiasis are very bad for child health” (Table 5, row 4), although of course, it is possible that parents simply say what they believe that the enumerator wants to hear regarding the health consequences of worms, as suggested by Geissler (1998a): 92 percent of the respondents claimed that helminth infects are “very bad” for child health. The number of early treatment links has no effect on parents’ self-reported claim to “know about the ICS deworming program” (row 5), to “know about the effects of worms and schistosomiasis” (row 6), nor on their objective knowledge of worm infection symptoms (rows 7-10). However, parent education and community group membership are both strongly positively correlated with all of these knowledge measures (results not shown). Most respondents lack even basic knowledge about worm infections, and they were only able to name 1.8 common symptoms on average. Thus not only did a substantial expenditure in worm prevention health education through the program not affect recipients’ behavior directly (as discussed in Kremer and Miguel 2003), but these messages also failed to spread to other community members.

In contrast, the actual number of treated social links, and the number of social links with whom the respondent speaks about deworming, are both positively and significantly related to most deworming attitudes and knowledge outcomes, once again highlighting important differences between the experimental and non-experimental estimates (Table 5). It appears that individuals with unobservably more interest in child health more frequently discuss worms with their social links, who are themselves more likely to have their own children receive treatment. In short, the positive observed correlation in outcomes within social networks in this context appears to be due to omitted variables rather than social effects – a finding that casts doubt on the reliability existing studies that estimate positive peer effects using non-experimental methods in this region of Kenya (for instance, Kohler et al 2001) and elsewhere.

We next turn to child social networks. As expected, the proportion of pupil links to early treatment schools is strongly correlated with the proportion of parent links (correlation coefficient 0.46).

We find that child early treatment links are also negatively and marginally significantly related to drug take-up in the full sample of 3164 children (point estimate -0.018, standard error 0.010 – Table 6, regression 1). The result is robust to the inclusion of the proportion of social links in early treatment schools (regression 2). Unlike for parents, each additional child social link to a “close” relative or friend (with whom the child speaks at least twice per week) is somewhat *less* influential than a link with whom the child speaks less than twice per week (Table 6, regression 3), although this difference is not statistically significantly different than zero at traditional confidence levels.

The child results are also similar when we condition on the parent social link variables, using the subsample of 1239 children with both complete parent and child social networks data, although the effect of an additional early treatment link is not statistically significant (point estimate -0.015, standard error 0.014 – regression not shown). We would ideally estimate the impact of parent and child social networks on drug take-up simultaneously in the same regression specification. However, forty-six percent of the 1678 parents from the sample used in the above analysis (Tables 2-5) are dropped when we are restricted to the subsample of 1239 children with complete data (note that there are multiple children in some households), and sixty-one percent of children in the complete Pupil Questionnaire sample are dropped. Not all children were administered the 2001 Pupil Questionnaire, some because of limited financial resources for the research (which forced us to interview a representative subsample of children present in school on the day of survey administration rather than all children), and others because of their absence from school on that day. The estimated parent social effect remains negative but becomes smaller and statistically insignificant using reduced sample (point estimate -0.017, standard error 0.018 – regression not shown), whether or not the child social link controls are included as explanatory variables, although the dramatic reduction in sample size complicates interpretation of these results.

The child social effects links differ sharply by the age of the child: for teenagers (at least 13 years of age), each additional early treatment social link is associated with a drop of -0.028 percentage points (standard error 0.012) in take-up (Table 6, regression 4), while the effect for younger children is small and statistically insignificant (point estimate -0.006, standard error 0.014 – regression 5). Thus parent social links appear much more influential than child links in affecting deworming take-up for the youngest children – which should perhaps not be surprising given the age of the children and the fact that parent consent is required for treatment – while for teenagers the point estimate on additional social links is negative and nearly as large as the point estimate on parent links (for instance, in Table 3, regression 1). This suggests that teenagers often play a central role in their own health care choices – a point made forcefully by Geissler (2000) in his study of a nearby district in western Kenya. There is no significant difference in the impact of additional early treatment links by gender (results not shown). There are no statistically significant effects of early treatment social links on any measure of child knowledge of worm infections or attitudes toward deworming drugs (results not shown), unlike for adults.

To summarize this sub-section, the social effect estimates are broadly consistent with a learning model in which individuals' prior beliefs on the private benefits of deworming are overly "optimistic" – in this case, at least in part because deworming externalities in mass treatment areas reduce the private returns to adoption, or because NGO field workers "over-sold" the benefits of treatment. Several pieces of evidence support the model. First, non-parametric regression suggests that the relationship between additional early treatment social links and drug take-up is negative and convex. Second, educated individuals – who have more optimistic priors toward new technologies – show the sharpest negative effects of additional early links on take-up. Third, parents with more links to the early treatment schools are significantly more likely to believe that deworming drugs are "not effective" – direct evidence on the evolution of their beliefs. Fourth, there are somewhat more negative social effect estimates among parents whose children had just begun receiving deworming in 2001 (Group 3) compared with parents whose children had already experienced two years of deworming (Group 2).

These results, together with the cost-sharing findings, indicate that most parents in this area do not place much value on deworming drugs, despite high worm infection rates and the demonstrated effectiveness of the drugs, and there are a number of plausible explanations for this seeming anomaly. First, note that the traditional view in this area is that worms either have no effect on health, or may even be positive agents of digestion, and many parents in the area approached deworming with this prior.

Once free deworming treatment was introduced, most parents did in fact provide consent for their children to be treated – 75 percent of parents in free treatment schools had children treated in 2001 – indicating there was not widespread opposition to the drugs. Yet parents and children observed only moderate private benefits, due in part to the large deworming treatment externalities, and as a result, those parents with exogenously more information about the program through their social network were significantly less likely to have their children participate in the program (Table 3), and were more likely to believe that deworming drugs are "not effective" (Table 5). Given this, most parents opted *not* to pay for the drugs when asked to do so.

5.4 Econometric Identification Issues

Even though the randomizations were largely successful, social links to early treatment schools could potentially affect adoption through the infection social effects described in Section 4.1. We find that having additional social links to early treatment schools is in fact associated with somewhat lower rates of moderate-heavy helminth infection, as expected (Table 2, regression 6), but the effect is relatively small and not statistically significant (coefficient estimate –0.012, standard error 0.017, relative to a mean moderate-heavy infection rate of 0.27). Note that the relatively weak relationship between early treatment social links and child infection status does not contradict the strong infection externality findings in Miguel and Kremer (2003): the children of parents' named social links constitute only a small fraction of all people that the respondents' own children interact with at school, church, in nearby fields, and when they bathe or fish in Lake Victoria, so it is reasonable that links' children would only have a moderate effect on their infection status.

These infection effects are driven entirely by early treatment links with whom the respondent has a "close" social relationship, speaking at least twice per week (Table 2, regression 7, coefficient estimate –0.018), while additional early links with whom the respondent speaks less frequently do not affect infection status (estimate 0.004). Thus "distant" social links do have a sizeable negative impact on individual adoption decisions (Table 3, regression 4), but have no effect on infection status – further bolstering the claim that information rather than infection externalities is driving the overall social effect.

In terms of the second step – from infection status to treatment decisions – we find that prior infection status is not significantly associated with drug treatment for either Group 1 in 1998 or Group 2 in 1999 (Appendix Table A1, Panel A), or for Groups 2 and 3 in 2001 (results not shown) and the point estimates suggest that moderate-to-heavy worm infection is actually somewhat *negatively* related to treatment rates.[24] Of course, the cross-sectional correlation between infection and treatment cannot be interpreted as causal due to omitted variable bias: children from unobservably low socio-economic status households may both have high infection rates and low take-up, for example. However, the treated and untreated look remarkably similar along many observable baseline socioeconomic and health characteristics (Appendix Table A1, Panel C), weakening the case for strong selection effects into treatment. Evidence on the effect of changes in infection status on drug take-up is provided by the 1999 cross-school infection externality estimates, which are identified using exogenous variation in the local density of early treatment schools (Miguel and Kremer 2003): although we find large average reductions in moderate-heavy worm infection rates as a result of cross-school externalities (23 percentage points, Appendix Table A3), proximity to early treatment schools leads to an average reduction in drug take-up of only 2 percentage points, which has the expected sign but is near zero and statistically insignificant (standard error 3 percentage points, results not shown). Taken together, a variety of evidence thus indicates that child infection levels affect take-up only weakly, if at all.

Moreover, the relationship between infection and treatment would have to be implausibly large and positive for changes in health status to explain anything more than a tiny fraction of the overall social effect: for example, if eliminating a moderate-heavy infection reduced the likelihood of drug take-up by a massive fifty percentage points on average, health externalities could only account for a

[24] The 2001 worm infection results are for a subsample of only 575 children who were randomly sampled for stool collection, and were present in school on the day of the parasitological survey. Due to the small sample size, we do not focus on the parasitological data in the main empirical analysis above.

(0.5)*(0.012)=0.006 reduction in take-up, less than one-fifth of the overall social effect (Table 3, regression 1). We conclude, then, that the social effects are overwhelmingly driven by information.

Pupil transfers among local primary schools during the course of the study are another potential identification concern. For example, parents with more health-conscious social links – whose children may have been more likely to transfer to early treatment schools to receive deworming – may themselves also be more health-conscious and eager to have their own children receive treatment, biasing the estimated social effect upward. However, the rate of pupil transfers between treatment and comparison schools in 1998 and 1999 was low and nearly symmetric in both directions, suggesting that the transfer bias is likely to be small regardless of its direction (Miguel and Kremer 2003). Moreover, the hypothesized transfer bias is *positive*, so it cannot account for our negative estimated social effects; in fact, such bias would imply that our estimates constitute upper bounds on the true (negative) effects.

A related identification issue concerns whether social networks measured in 2001 – three years after the program started – were themselves affected by the program. Social effect estimates would be biased to the extent that health-conscious individuals tended to become socially "closer" to individuals with children in early treatment schools, and thus more likely to name them as social links in the 2001 survey, but we feel this is also unlikely. The number of social links to early treatment schools is exactly two-thirds of the total number of links to project schools, and respondents were statistically no more likely to name early treatment links than links to other schools;[25] although not definitive, this strongly suggests that the program did not lead to substantial shifts in network composition. Further, any bias from endogenous network formation would again be positive, and thus cannot explain our findings.

6. Non-Bayesian Factors Affecting Deworming Drug Take-up

While the above analysis suggests that people seem to have learned over time that the benefits of treatment were less than they had anticipated, some mystery remains as to why people are still not more

[25] The average number of links to early treatment schools is 1.92, while (Total number of links to project schools) * (Total # Group 1 and 2 pupils / Total # Group 1, 2 and Group 3 pupils) =1.91.

likely to take the drugs than we find – given that the dates of drug treatments were announced in advance and that more than 90 percent of children have worm infections of some sort.[26] Beyond this, it is surprising that more of a market for drugs has not developed in this area independently of the project. As noted above, albendzole and praziquantel are cheap to produce. While many medicines, such as aspirin and anti-malarials, are cheaply available in nearly all local shops, deworming is available in very few and only at high mark-ups (where mark-ups are high presumably because the market is quite thin).[27]

It is possible that people simply did not recognize the benefits of deworming. In the traditional view, worms are an integral part of the human body and necessary for digestion, and many infection symptoms – including abdominal pain and malnutrition – are attributed to malevolent occult forces ("witchcraft") or breaking taboos (Government of Kenya 1986).[28] Geissler (1998a, 1998b, 2000) studies deworming take-up in a Kenyan district that borders our study area, with a nearly identical worm infection profile, and finds that, while the Western bio-medical paradigm is making inroads into traditional health views (especially among the younger and better educated), most people do not place much value on deworming treatment because worms are not seen as a pressing health problem - especially compared to malaria and HIV/AIDS.[29] As a result, there was essentially no deworming outside the school health program Geissler studies, and most children instead relied on herbal remedies to alleviate the abdominal discomfort caused by worms.

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[26] The 2001 take-up data (collected by field officers) indicates that nearly 80 percent of non-treatment was due to pupil absence from school on the treatment day, with the remainder due to no parental consent; there were very few cases of child refusal to take the drugs (less than one percent). A small number of respondents in the 2001 Parent Questionnaire stated that they opposed deworming (1 percent), although it remains possible that more parents do in fact oppose treatment but were reluctant to state this confrontational view to the enumerator.

[27] We conducted a survey in 1999 of all hospitals, health clinics, dispensaries, and pharmacies, as well as many local shops (*dukas*) in this area to assess the availability of deworming drugs. We found that none of the 64 local shops surveyed had either albendazole (or its close substitute, mebendazole) or praziquantel in stock, though a minority of shops carried less effective deworming drugs (levamisole hydrochloride and piperazine).

[28] Although serious worm infection levels had fallen substantially in Group 1 and 2 schools by 2001 – several years after mass deworming began in these communities – leaving fewer heavily infected children who would gain the most from treatment (Miguel and Kremer 2003a), the vast majority of children still have some level of infection.

[29] Geissler studies an ethnically Luo area (Luos speak a Nilotic language), while the majority of our sample are ethnically Luhya (a Bantu-speaking group) though Luos are a sizeable minority in our sample. However, traditional Luo views toward worms are closely related to views found among Bantu-speaking groups in other parts of Africa, including Mozambique (Green et al. 1994, Green 1997) and South Africa (Zondi and Kvalsig 1987).

The existence of frequent health shocks from many sources (e.g., malaria, typhoid, cholera) also complicates learning about new health treatments in this area, especially given the timing of deworming costs and benefits: deworming entails immediate costs (i.e., the effort needed to obtain treatment and possible drug side effects) while benefits emerge only gradually as individual nutritional status improves in the months after treatment, potentially obscuring health gains. The immediate drug side effects may be particularly salient for many individuals. In contrast, social learning patterns could conceivably have led to higher take-up for diseases like malaria for which health impacts are more acute.

To the extent that many people in this area believed that worms were not a serious health problem at the start of the program, and there are psychological fixed costs to "re-categorization" along the lines of Mullainathan (2002) – in other words, to begin believing that worms in fact are a serious problem – the modest observed private deworming benefits might not be large enough to justify shifting one's beliefs, further dampening take-up. A final factor is that the individuals (parents) who provide consent for treatment, and pay for treatment in cost-sharing schools, are not the same people who directly benefit from treatment (their children). This further reduces drug take-up to the extent that there is imperfect altruism and inefficient bargaining within households, which may be especially likely for the parent-child relationship.[30]

7. Conclusion

We find there are large social effects regarding the adoption of a new health technology – deworming drugs – in rural Kenya. Individuals' narrow self-defined reference groups had a truly major impact on their health behavior, though it appears that, unexpectedly, those with exogenously more social links in program schools were significantly *less* likely to take deworming drugs. Consistent with this finding, they are more likely to believe that deworming drugs are not effective – direct evidence on the evolution

[30] Udry (1996) and Dercon and Krishnan (2000) present evidence on inefficient within-household resource allocation in other rural African settings. Note, however, that child orphan status is not related to take-up (results not shown).

of their beliefs regarding the new technology. We also find major differences between experimental and non-experimental social effect estimates, suggesting that the results of existing non-experimental studies should be interpreted with caution due to the likelihood of substantial omitted variable bias.

Our empirical results together with the results of a related project (Kremer and Miguel 2003), also have important implications for the design of successful public health projects in less developed countries – especially for treatments characterized by large positive treatment externalities. Foreign aid donors have increasingly moved away from traditional economic analysis of development projects to the concept of "sustainability," where we focus on financial sustainability. Whereas orthodox public finance analysis suggests that governments should indefinitely fund public goods and activities that generate positive externalities, advocates of sustainability promote interventions that can be funded and maintained locally without external support, and they also emphasize the importance of local "ownership".

In Kremer and Miguel (2003) we evaluate the usefulness of the sustainability approach utilizing a series of randomized evaluations of interventions to fight worms in the Kenyan setting, and draw implications for the design of public health programs. We find that those elements of the deworming project seeking to promote "sustainable" health gains through health education and community mobilization completely failed. In particular, we find that intensive school health education had no impact on child worm prevention behaviors, and thus child health is likely to be worsened to the extent scarce funds are diverted from medical treatment into health education in this setting. A verbal commitment "mobilization" intervention – which asked people to commit in advance to adopt the drugs, taking advantage of a finding from psychology that individuals strive for consistency in their statements and their actions – led to significantly *lower* treatment rates.

Another "sustainability" issue relates to social spillovers in knowledge about the new health technology. If treating (or educating) children in certain families leads to higher deworming rates among their social contacts, this would suggest that social learning might eventually lead to higher take-up rates without the need for large subsidies. However, the findings of this paper indicate that children whose parents have more social links to treatment schools are *less* likely to take deworming drugs, so the social learning channel also appears unpromising. Thus large indefinite subsidies may be necessary to sustain high drug take-up for diseases characterized by positive treatment externalities, like deworming – a finding especially important for Africa, where half the disease burden is associated with infectious and parasitic diseases (WHO 1999).

8. References

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9. Tables and Figures

Figure 1: Expected Benefits of Adoption and Early Treatment Links (N_{ij}^{E}) for $\phi_0 > \phi$

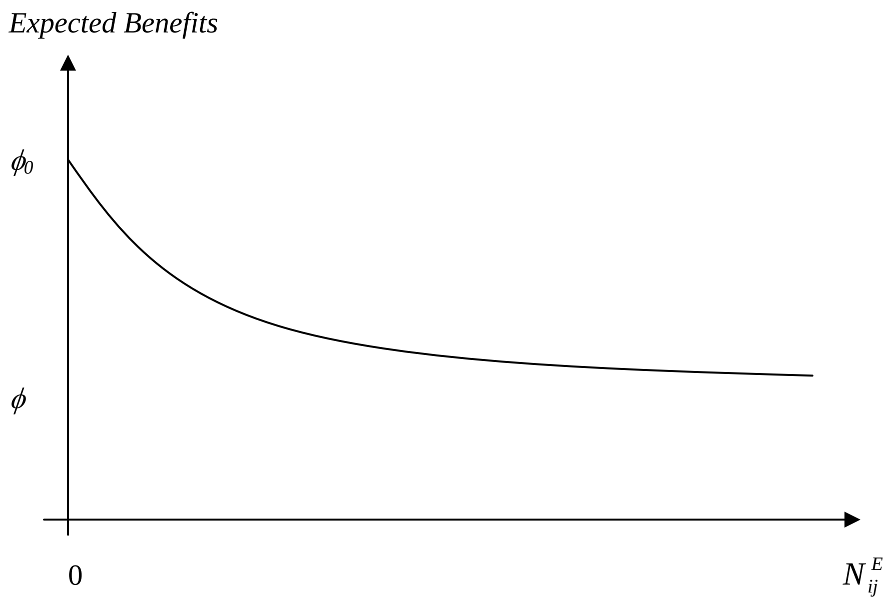

Figure 2: Non-parametric Fan regression (Epanechnikov kernel):
Effect of social links to early treatment schools (Group 1,2, not own school)
on 2001 Deworming Drug Take-up (residuals conditional on other covariates)

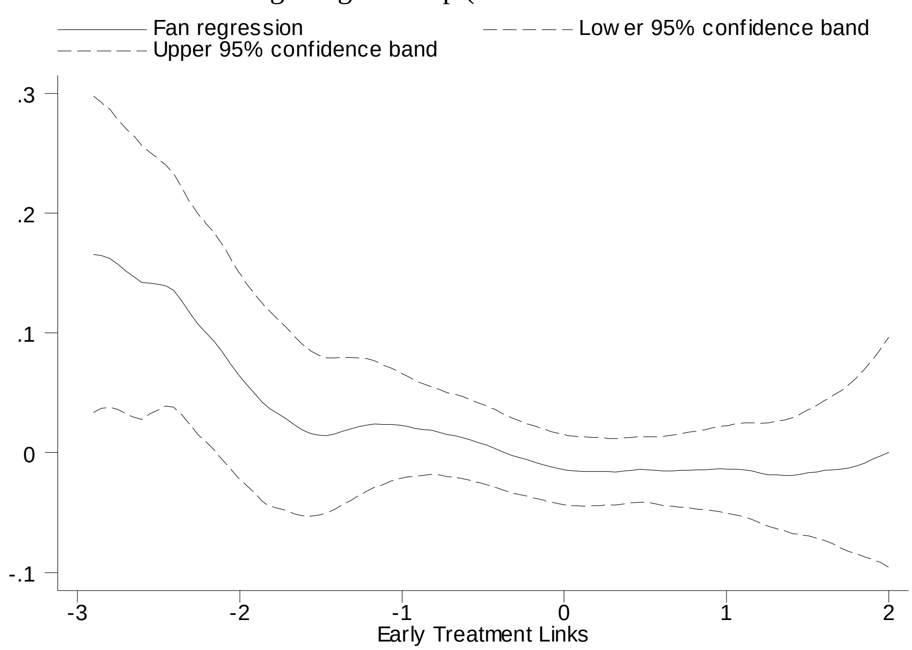

Table 1: Summary Statistics

	Mean	Std dev.	Obs.
Panel A: Deworming Treatment Take-up			
Took deworming drugs in 2001 (Group 2 and 3)	0.61	0.49	1678
Took deworming drugs in 2001, free treatment schools (Group 2 and 3)	0.75	043	1251
Took deworming drugs in 2001, cost-sharing schools (Group 2 and 3)	0.18	0.38	419
Panel B: Parent Social Links (Round 1 and Round 2 Data)			
Total	10.2	3.4	1678
With children in own school	4.4	2.8	1678
With children not in Group 1, 2, or 3 schools	3.0	2.4	1678
With children in Group 1, 2, 3 schools – not own school	2.8	2.4	1678
With children in Group 1, 2 schools – not own school ("early treatment")	1.9	2.0	1678
With children in Group 1 schools – not own school	0.9	1.4	1678
Proportion with children in early treatment schools	0.66	0.37	1358
With children in early treatment schools, with whom respondent speaks at least twice per week ("Close Links")	1.2	1.6	1678
With children in early treatment schools, with whom respondent speaks less than twice per week ("Distant Links")	0.7	1.1	1678
With children in early treatment schools, high deworming take-up 1999	0.95	1.41	1678
With children in early treatment schools, low deworming take-up 1999	0.96	1.47	1678
With children in early treatment schools, large difference in attendance between treated and untreated 1999	0.99	1.47	1678
With children in early treatment schools, small difference in attendance between treated and untreated 1999	0.90	1.36	1678
Panel C: Parent Social Links (Round 2 Data)			
With children in early treatment schools who received deworming	0.39	1.02	886
With children in early treatment schools who received deworming and had "good effects" (according to respondent)	0.26	0.90	886
With children in early treatment schools who received deworming and had "side effects" (according to respondent)	0.02	0.20	886
With children in early treatment schools who received deworming, respondent does not know effects	0.09	0.39	886
With children in early treatment schools who did not receive deworming	0.16	0.57	886
With children in early treatment schools, respondent does not know whether they received deworming	1.89	2.06	886
Panel D: Child Social Links			
Total	10.8	3.1	3164
In Group 1, 2, or 3 schools	0.6	1.1	3164
In Group 1, 2, 3 schools – not own school	3.2	2.5	3164
In Group 1, 2 schools – not own school ("early treatment")	2.1	2.0	3164
Proportion in early treatment schools	0.65	0.37	2673

In early treatment schools, with whom respondent speaks at least twice per week ("Close Links")	1.3	1.6	3164
In early treatment schools, with whom respondent speaks less than twice per week ("Distant Links")	0.7	1.1	3164

Notes for Table 1: From 2001 Parent and 2001 Pupil Questionnaires, and NGO administrative records. The "Proportion in early treatment schools" excludes respondents with no links to program schools (other than their own), hence the reduced sample.

Table 2: Validating the randomizations (Group 2 and Group 3 households)

	Dependent variable:						
	Respondent years of education	Community group member	Total number of children	Iron roof at home	Distance home to school (km)	Moderate-heavy infection, 2001	
	OLS	Probit	OLS	Probit	OLS	Probit	Probit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
# Links with children in early treatment schools (Group 1, 2, not own school)	0.07 (0.08)	-0.008 (0.012)	-0.01 (0.06)	0.025** (0.012)	-0.18 (0.12)	-0.012 (0.018)	
# Links with children in early treatment schools, with whom respondent speaks **at least twice/week**							-0.018 (0.023)
# Links with children in early treatment schools, with whom respondent speaks **less than twice/week**							0.004 (0.021)
Cost-sharing school indicator	0.12 (0.30)	0.00 (0.04)	0.07 (0.23)	0.02 (0.06)	1.3 (0.9)	0.07 (0.11)	0.07 (0.11)
Group 2 school indicator	-0.46 (0.29)	-0.03 (0.04)	0.13 (0.19)	0.01 (0.05)	-0.03 (0.28)	-0.22*** (0.07)	-0.22*** (0.07)
# Links with children in Group 1, 2, or 3 schools, not own school	0.11 (0.07)	0.013 (0.011)	-0.029 (0.054)	-0.009 (0.012)	0.14 (0.11)	-0.001 (0.015)	-0.002 (0.014)
# Links with children not in Group 1, 2, or 3 schools	0.07** (0.03)	0.018*** (0.006)	-0.043 (0.030)	0.009 (0.006)	0.02 (0.03)	-0.010 (0.009)	-0.009 (0.009)
# Links, total	0.13*** (0.04)	0.007 (0.006)	0.059** (0.028)	-0.011* (0.006)	-0.01 (0.03)	0.003 (0.008)	0.003 (0.007)
Socio-economic controls (excluding dependent var.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.06	-	0.01	-	0.10	-	-
Root MSE	3.8	-	2.3	-	1.9	-	-
Number of observations (parents)	1678	1678	1678	1678	1678	575	575
Mean (s.d.) of dependent variable	4.6 (3.9)	0.58 (0.49)	5.5 (2.3)	0.61 (0.49)	1.7 (2.0)	0.27 (0.45)	

Notes for Table 2: Uses Parent and Pupil Sample. Data from 2001 Parent Survey, 2001 Pupil Survey, 2001 Parasitological Survey, and 2001 administrative records. Robust standard errors in parentheses. Disturbance terms are clustered within schools. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The socioeconomic controls include Respondent years of education, Community group member, Total number of children, Iron roof at home, and Distance from home to school (but when any of these is the dependent variable, it is not included as an explanatory variable).

Table 3: Experimental Social Effect Estimates (Groups 2 and 3) – Parent Networks

	Dependent variable: Child took deworming drugs in 2001				
	(1)	(2)	(3)	(4)	(5)
# Links with children in early treatment schools (Groups 1 and 2, not own school)	-0.031** (0.014)	-0.041** (0.017)			-0.002 (0.018)
# Links with children in early treatment schools *** Group 2 school indicator**		0.018 (0.029)			
Proportion links with children in early treatment schools			-0.098** (0.045)		
# Links with children in early treatment schools, with whom respondent speaks **at least twice/week**				-0.036** (0.015)	
# Links with children in early treatment schools, with whom respondent speaks **less than twice/week**				-0.020 (0.016)	
# Links with children in early treatment schools *** Respondent years of education**					-0.0062* (0.0032)
# Links with children in Group 1, 2, or 3 schools, not own school	0.013 (0.011)	0.013 (0.017)	-0.006 (0.009)	0.013 (0.011)	-0.014 (0.014)
# Links with children not in Group 1, 2, or 3 schools	-0.008 (0.007)	-0.008 (0.009)	-0.005 (0.007)	-0.007 (0.007)	-0.008 (0.011)
# Links, total	0.019*** (0.005)	0.029*** (0.007)	0.021*** (0.007)	0.018*** (0.005)	0.013 (0.008)
Respondent years of education	0.003 (0.003)	0.003 (0.003)	0.002 (0.004)	0.003 (0.003)	-0.016 (0.012)
Community group member	0.029 (0.025)	0.033 (0.026)	0.038 (0.029)	0.030 (0.026)	0.025 (0.025)
Total number of children	0.005 (0.006)	0.006 (0.006)	0.005 (0.007)	0.005 (0.006)	0.006 (0.006)
Iron roof at home	0.010 (0.027)	0.007 (0.027)	0.010 (0.032)	0.011 (0.027)	0.008 (0.027)
Distance home to school (km)	-0.018** (0.009)	-0.018** (0.009)	-0.014 (0.010)	-0.018** (0.009)	-0.018** (0.009)
Group 2 school indicator	0.01 (0.05)	0.20** (0.09)	0.01 (0.05)	0.01 (0.05)	0.01 (0.05)
Cost-sharing school indicator	-0.62*** (0.08)	-0.62*** (0.08)	-0.62*** (0.09)	-0.63*** (0.08)	-0.63*** (0.08)
Number of observations (parents)	1678	1678	1358	1678	1678
Mean of dependent variable	0.61	0.61	0.61	0.61	0.61

Notes for Table 3: Data from 2001 Parent Survey, and 2001 administrative records. Marginal probit coefficient estimates are presented. Robust standard errors in parentheses. Disturbance terms are clustered within schools. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Regression 2 also includes interaction terms (# Social links with children in Group 1, 2, or 3 schools, not own school)*(Group 2) and (# Social links with children not in Group 1, 2, or 3 schools)*(Group 2); similarly, in Regression 5 there are analogous interaction terms with Years of Education. Regression 3 excludes parents for which (# Social links with children in Group 1, 2, or 3 schools, not own school) = 0, since the proportion of links is undefined in that case. In Regression 4, we cannot reject the hypothesis that the coefficient estimates on (# Links with whom respondent speaks at least twice/week) and on (# Links with whom respondent speaks less than twice/week) are equal (p-value=0.22).

Table 4: The Effect of Different Types of Social Links – Parent Networks

	Dependent variable: Child took deworming drugs in 2001				
	(1)	(2)	(3)	(4)	(5)
# Links with children in early treatment schools (Groups 1 and 2, not own school)	-0.031** (0.014)				
# Links with children in early treatment schools, **high deworming take-up**		-0.030* (0.016)			
# Links with children in early treatment schools, **low deworming take-up**		-0.032* (0.016)			
# Links with children in early treatment schools, **large difference in participation between treated, untreated**			-0.024 (0.017)		
# Links with children in early treatment schools, **small difference in participation between treated, untreated**			-0.032** (0.015)		
# Links with children in early treatment schools whose children **received deworming**				-0.004 (0.022)	
# Links with children in early treatment schools whose children **did not receive deworming**				-0.014 (0.027)	-0.007 (0.028)
# Links in with children in early treatment schools, **respondent does not know whether they received deworming**				-0.014 (0.016)	-0.013 (0.016)
# Links with children in early treatment schools whose children **received deworming and had "good effects"**					0.004 (0.021)
# Links with children in early treatment schools whose children **received deworming and had "side effects"**					-0.112 (0.082)
# Links with children in early treatment schools whose children **received deworming and respondent does not know effects**					0.006 (0.046)
Social links, other controls	Yes	Yes	Yes	Yes	Yes
Number of observations (parents)	1678	1678	1678	886	886
Mean of dependent variable	0.61	0.61	0.61	0.56	0.56

Notes for Table 4: Data from 2001 Parent Survey, 2001 Parasitological Surveys, and 2001 administrative records. Marginal probit coefficient estimates are presented. Robust standard errors in parentheses. Disturbance terms are clustered within schools. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Social links controls include total number of links, number of links to Group 1, 2, 3 schools (not own school), and number of links to non-program schools. Other controls include respondent years of education, community group member indicator variable, total number of children, iron roof at home indicator variable, and distance from home to school in km, as well as the Group 2 indicator and Cost-sharing school indicator. "High (low) deworming take-up" schools are those with take-up greater than (less than) median school take-up, and "Large (small) differences in participation between treated, untreated" schools are defined similarly.

Regression 1 reproduces the result in Table 3, Regression 1. In Regression 2, we cannot reject that the two coefficient estimates are equal (p-value=0.93). In regression 3, we cannot reject that the two coefficient estimates are equal (p-value=0.63). In regression 4, we cannot reject that the coefficient estimates on (# Links with children in early treatment schools whose children received deworming) and on (# Links with children in early treatment schools whose children did not receive deworming) are equal (p-value=0.77). In regression 5, we cannot reject that the coefficient estimates on (# Links with children in early treatment schools whose children received deworming and had good effects) and on (# Links with children in early treatment schools whose children received deworming and had side effects) are equal (p-value=0.22).

Table 5: Experimental and Non-Experimental Social Effect Estimates on Deworming Attitudes and Knowledge – Parent Networks

Dependent variable	Estimate on # Links with children in early treatment schools [Experimental]	Estimate on # Links with children in early treatment schools **whose children received deworming** [Non-experimental]	Estimate on # Links with children in early treatment schools **with whom respondent spoke about deworming** [Non-experimental]	Mean of dependent variable
Panel A: Attitudes				
1) Parent thinks deworming drugs "not effective"	0.017** (0.007)	0.013 (0.008)	0.009** (0.004)	0.12
2) Parent thinks deworming drugs "very effective"	-0.007 (0.010)	0.026** (0.013)	0.040*** (0.007)	0.43
3) Parent thinks deworming drugs have "side effects"	0.000 (0.003)	-0.001 (0.003)	0.003* (0.002)	0.04
4) Parent thinks worms, schistosomiasis "very bad" for child health	-0.001 (0.006)	-0.004 (0.006)	-0.006* (0.003)	0.92
Panel B: Knowledge				
5) Parent "knows about ICS deworming program"	0.004 (0.011)	0.050*** (0.014)	0.055*** (0.011)	0.70
6) Parent "knows about the effects of worms and schistosomiasis"	-0.001 (0.013)	0.045*** (0.013)	0.039*** (0.009)	0.68
7) Number of infection symptoms parents able to name (range 0-10)	-0.006 (0.005)	0.018** (0.008)	0.010** (0.005)	1.8
8) Parent able to name "fatigue" as symptom of infection	-0.004 (0.010)	0.028*** (0.009)	0.021*** (0.006)	0.20
9) Parent able to name "anemia" as symptom of infection	0.005 (0.009)	-0.003 (0.011)	0.010** (0.005)	0.22
10) Parent able to name "weight loss" as symptom of infection	0.002 (0.006)	0.004 (0.005)	-0.001 (0.004)	0.06

Notes for Table 5: Data from 2001 Parent Survey, and 2001 administrative records. Marginal probit coefficient estimates are presented, and each entry is the result of a separate regression. Robust standard errors in parentheses. Disturbance terms are clustered within schools. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The ten possible infection symptoms include fatigue, anemia, weight loss, stunted growth, stomach ache, bloated stomach, blood in stool, worms in stool, diarrhea, and fever. Social links controls and other controls are included in all specifications. Social links controls include total number of links, number of links to Group 1, 2, 3 schools (not own school), and number of links to non-program schools. Other controls include respondent years of education, community group member indicator variable, total number of children, iron roof at home indicator variable, and distance from home to school in km, as well as the Group 2 indicator and Cost-sharing school indicator. The number of observations (parents) across regressions ranges from 1656 to 1678, depending on the extent of missing survey data for the dependent variable.

Table 6: Experimental Social Effect Estimates (Groups 2 and 3) – Child Networks

	Dependent variable: Child took deworming drugs in 2001				
	(1)	(2)	(3)	(4) Children ≥ Age 13	(5) Children < Age 13
# Links in early treatment schools (Groups 1 and 2, not own school)	-0.018 (0.011)			-0.028** (0.012)	-0.006 (0.014)
Proportion links in early treatment schools		-0.073* (0.044)			
# Links in early treatment schools, with whom respondent speaks **at least twice/week**			-0.014 (0.011)		
# Links in early treatment schools, with whom respondent speaks **less than twice/week**			-0.026** (0.013)		
# Links in Group 1, 2, or 3 schools, not own school	-0.014 (0.009)	-0.029*** (0.008)	-0.014 (0.009)	-0.010 (0.011)	-0.019* (0.012)
# Links not in Group 1, 2, or 3 schools	-0.021* (0.012)	-0.020* (0.013)	-0.020 (0.012)	-0.014 (0.017)	-0.031** (0.014)
# Links, total	0.030*** (0.006)	0.030*** (0.007)	0.030*** (0.006)	0.031*** (0.080)	0.029*** (0.009)
Control variables	Yes	Yes	Yes	Yes	Yes
Number of observations (children)	3164	2673	3164	1653	1511
Mean of dependent variable	0.54	0.55	0.54	0.54	0.54

Notes for Table 6: Data from 2001 Pupil Survey, and 2001 administrative records. Marginal probit coefficient estimates are presented. Robust standard errors in parentheses. Disturbance terms are clustered within schools. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. The control variables include: pupil age; pupil sex; the cost-sharing school indicator; Group 2 school indicator; and the pupil verbal commitment intervention indicator (discussed in Kremer and Miguel 2003). Regression 2 excludes children for which (# Social links with children in Group 1, 2, or 3 schools, not own school) = 0, since the proportion of links to treatment schools is undefined in that case. Note that we cannot reject the hypothesis that the effect of early treatment links on take-up is the same for Children ≥ Age 13 and for Children < Age 13 (p-value=0.19) – regression not shown.

10. Appendix

Table A1: PSDP Health and Education Treatment Effects and Externalities (1998-1999)

	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: Health Outcomes						
Any moderate-heavy infection, 1998	0.39	0.44	-	-	-	-
Any moderate-heavy infection, 1999	0.24	0.34	0.51	0.55	-0.27***	-0.21**
					(0.06)	(0.10)
Panel B: School Participation						
School participation rate, May 1998 to March 1999	0.872	0.764	0.808	0.684	0.064**	0.080**
					(0.032)	(0.039)
Panel C: Selection into Treatment						
Access to latrine at home, 1998	0.84	0.80	0.81	0.86	0.03	-0.06
					(0.04)	(0.05)
Grade progression (=Grade – (Age – 6)), 1998	-2.0	-1.8	-1.8	-1.8	-0.2**	-0.0
					(0.1)	(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	-0.01
					(0.04)	(0.06)
Clean (observed by field worker), 1998	0.53	0.59	0.60	0.66	-0.07	-0.07
					(0.05)	(0.10)

Notes for Table A1: These results use the data from Miguel and Kremer (2003). These are averages of individual-level data for grade 3-8 pupils in the parasitological survey subsample; disturbance terms are clustered within schools. Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Obs. for the 1999 parasitological survey: 670 Group 1 treated 1998, 77 Group 1 untreated 1998, 873 Group 2 treated 1999, 352 Group 2 untreated 1999. The data are for all boys, and for girls age 13 years and under (older girls are ineligible for deworming in mass treatment programs due to the potential embryotoxicity of the drugs).

School participation averages are weighted by pupil population. The participation rate is computed among pupils enrolled in the school at the start of 1998. Pupils present in school during an unannounced NGO visit are considered participants. Pupils had 3.8 participation observations per year on average. Participation rates are for grades 1 to 7; grade 8 pupils are excluded since many graduated after the 1998 school year, in which case their 1999 treatment status is irrelevant. Preschool pupils are excluded since they typically have missing take-up data. Characteristics in Panel C are for grades 3 to 7, since younger pupils were not administered the Pupil Questionnaire.

Table A2: PSDP Health and Nutrition Impacts (1999)

	Group 1	Group 2	Group 1 – Group 2
Panel A: 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	-1.13	-1.22	0.09*
(low scores denote undernutrition)			(0.05)
Weight-for-age Z-score, 1999	-1.25	-1.25	-0.00
(low scores denote undernutrition)			(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)

Notes for Table A2: These results use the data from Miguel and Kremer (2003). These are averages of individual-level data for grade 3-8 pupils; disturbance terms are clustered within schools. Robust standard errors in parentheses. Significantly different than zero at 99 (***), 95 (**), and 90 (*) percent confidence. Obs. for hemoglobin results: 778 (292 Group 1, 486 Group 2).

Obs. for 1999 Pupil Questionnaire health outcomes: 9,102 (3562 Group 1, 5540 Group 2 and Group 3).

Hb data were collected by Kenya Ministry of Health officials and ICS field officers using the portable Hemocue machine. The self-reported health outcomes were collected for all three groups of schools as part of 1999 Pupil Questionnaire administration.

Table A3: Deworming health externalities within and across schools, January to March 1999

	Any moderate-heavy helminth infection, 1999 (1)	Moderate-heavy schistosomiasis infection, 1999 (2)	Moderate-heavy geohelminth infection, 1999 (3)
Indicator for Group 1 (1998 Treatment) School	-0.25***	-0.03	-0.20***
	(0.05)	(0.03)	(0.04)
Group 1 pupils within 3 km (per 1000 pupils)	-0.26***	-0.12***	-0.12*
	(0.09)	(0.04)	(0.06)
Group 1 pupils within 3-6 km	-0.14**	-0.18***	0.04
(per 1000 pupils)	(0.06)	(0.03)	(0.06)
Total pupils within 3 km (per 1000 pupils)	0.11***	0.11***	0.03
	(0.04)	(0.02)	(0.03)
Total pupils within 3-6 km (per 1000 pupils)	0.13**	0.12***	0.04
	(0.06)	(0.03)	(0.04)
Grade indicators, school assistance controls, district mock exam score control	Yes	Yes	Yes
Number of observations (children)	2328	2328	2328
Mean of dependent variable	0.41	0.16	0.32

Notes for Table A3: 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. The local densities are constructed using GPS data on program schools.

Appendix Table A4: Primary School Deworming Project (PSDP) timeline, 1998-2001

Dates	Activity
1998	
January	75 Primary schools first stratified by geographic zone, and then randomly divided into three groups of 25 schools (Group 1, Group 2, Group 3)
March-April	First round of 1998 treatment (albendazole, praziquantel) in Group 1 schools
November	Second round of 1998 treatment (albendazole) in Group 1 schools
1999	
March-June	First round of 1999 treatment (albendazole, praziquantel) in Group 1, Group 2 schools
October-November	Second round of 1999 treatment (albendazole) in Group 1, Group 2 schools
2000	
March-June	First round of 2000 treatment (albendazole, praziquantel) in Group 1, Group 2 schools
October-November	Second round of 2000 treatment (albendazole) in Group 1, Group 2 schools
2001	
January-March	2001 Parent Survey (Wave 1) data collection in Group 2, Group 3 schools
	2001 Pupil Survey (Wave 1) data collection in Group 2, Group 3 schools. Verbal commitment intervention carried out during Pupil Survey, among a random subsample of pupils.
March-June	First round of 2001 treatment (albendazole, praziquantel) in Group 1, Group 2, Group 3 schools. Cost-sharing in 25 (randomly selected) Group 1, Group 2 schools
May-September	2001 Parent Survey (Wave 2), and household GPS data collection in Group 2, Group 3 schools.
	2001 Pupil Survey (Wave 2) data collection in Group 2, Group 3 schools. Verbal commitment intervention carried out during Pupil Survey, among a random subsample of pupils.
October-November	Second round of 2001 treatment (albendazole) in Group 1, Group 2, Group 3 schools. Cost-sharing continues in 25 (randomly selected) Group 1, Group 2 schools

Appendix Table A5: Robustness of Social Effect Results – Parent Networks

	Dependent variable:			
	Child took deworming drugs in 2001			Child took deworming drugs in 1999 (Group 2)
	Probit (1)	Probit (2)	Probit (3)	Probit (4)
# Links with children in early treatment schools (Group 1, 2, not own school)	-0.027* (0.014)	-0.029** (0.014)	-0.016 (0.014)	
# Pupils in early treatment schools < 3 km from home (per 1000 pupils)			-0.20*** (0.07)	
# Pupils in all schools < 3 km from home (per 1000 pupils)			0.14** (0.07)	
# Links with children in early treatment schools (Group 1 in 1999, not own school)				-0.017** (0.007)
Social links	Yes	Yes	Yes	Yes
Other household controls	No	Yes	Yes	Yes
Ethnic, religious controls	No	Yes	No	No
Number of observations (parents)	1678	1678	1678	755
Mean of dependent variable	0.61	0.61	0.61	0.83

Notes for Appendix Table A5: Data from 2001 Parent Survey, and 1999 and 2001 administrative records. Social links controls include total number of links, number of links to Group 1, 2, 3 schools (not own school), and number of links to non-program schools. Other household controls include respondent years of education, community group member indicator variable, total number of children, iron roof at home indicator variable, and distance from home to school in km, as well as the Group 2 indicator and Cost-sharing school indicator. Ethnic controls include indicators for Samia, Nyala, Luo, Khayo, Marachi, and Teso groups, and an indicator for being a member of the largest ethnic group in the school (which is near zero and statistically insignificant). Religion controls include indicators for Catholic, Anglican, Pentecostal, Apostolic, Legio Mario, Roho, and Muslim faiths, and an indicator for being a member of the largest religious group in the school (which is negative and marginally statistically significant). In regression 1, no household controls are included as explanatory variables, other than the standard social link controls.