INVITED PAPERS

When Should Governments Subsidize Health? The Case of Mass Deworming

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We discuss how evidence and theory can be combined to provide insight on the appropriate subsidy level for health products, focusing on the specific case of deworming. Although intestinal worm infections can be treated using safe, low-cost drugs, some have challenged the view that mass school-based deworming should be a policy priority. We review well-identified research which both uses experimental or quasi-experimental methods to demonstrate causal relationships and adequately accounts for epidemiological externalities from deworming treatment, including studies of deworming campaigns in the Southern United States, Kenya, and Uganda. The existing evidence shows consistent positive impacts on school participation in the short run and on academic test scores, employment, and income in the long run, while suggesting that most parents will not pay for deworming treatment that is not fully subsidized. There is also evidence for a fiscal externality through higher future tax revenue, which may exceed the cost of the program. Our analysis suggests that the economic benefits of school-based deworming programs are likely to exceed their costs in places where worm infestations are endemic. This would likely be the case even if the benefits were only a fraction of estimates in the existing literature. JEL codes: H2, H51, I1, I12, I15, I2, I20, I25, I3, O1

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I. Introduction

Moving from empirical evidence to policy judgments requires the implicit or explicit use of theory, both in order to assess the relevance of evidence on existing policy and to make normative judgments. For example, randomized trials have established that take-up of mosquito nets, water treatment products, and deworming pills are very sensitive to price in particular contexts. Theory is needed to make reasonable inferences about price sensitivity of demand for the same goods in other contexts, let alone for other health goods. Kremer and Glennerster (2011), for example, argue that price sensitivity is often the case for goods used to prevent disease or treat nonacute disease. Even if one is willing to make this generalization, however, determining whether subsidies are justified requires a normative analysis.

In this paper, we discuss how evidence and theory might be combined to provide insight on appropriate subsidies for the prevention and treatment of communicable diseases, focusing on the case of deworming. Intestinal worm infections are among the most widespread diseases globally, affecting over a billion people mainly in low income countries (Hotez et al. 2006). School-age children have particularly high infection rates and play an important role in spreading disease (Hotez et al. 2006). Infections can lead to malnutrition, listlessness, organ damage, and internal bleeding (de Silva et al. 2003; Crimmins and Finch 2005). Safe, low-cost drugs are available to treat intestinal worm infections and are the standard of medical care. In fact, because treatment is inexpensive and safe but diagnosis is relatively expensive, the World Health Organization (WHO) recommends periodic mass treatments in areas where worm infections are above certain thresholds. However, some have challenged this WHO policy, accepting that those who are known to be infected should be treated, but questioning whether the existing evidence base is strong enough to support mass treatment (Taylor-Robinson et al. 2012).

What evidence could one gather to shed light on the question of what public policy is appropriate? That may depend in part on one's normative theoretical perspective, and one could imagine a range of such perspectives. For example:

(1) A strong *libertarian view* might be that families have different needs and that parents should decide how to spend resources themselves, so that it is inappropriate for the state to take their money in taxes and then decide to subsidize one particular type of expenditure over another.
(2) In a *welfare economics/public finance approach*, individuals are presumed to make decisions that maximize their own welfare, but government intervention may be justified in cases where individual actions create externalities for others. In particular, subsidies may be appropriate if use of the good creates positive externalities. This could include health externalities from reductions in the transmission of infectious disease, as well as fiscal

externalities if treatment of children increases their long-run earnings and tax payments.

(3) A third approach focuses on *cost effectiveness in achieving policymaker goals* (and need not assume that the policy maker's goal is to maximize a weighted sum of household utilities). For example, policy makers may seek to achieve universal primary education (as in the Millennium Development Goals) or to maximize GNP growth subject to constraints, which in turn will lead them to undertake investments with high rates of return. The standard welfare economics/public finance approach assumes that consumers will maximize their own welfare, treats them as rational and informed, and abstracts from conflicts within the household (e.g., between parents and children). This cost effectiveness approach does not do that, but of course it potentially risks efficiently achieving goals that are not those of most citizens.

(4) From a *human rights perspective*, individuals might be seen as having a right to good health care. Under this approach, one might argue that children have a basic right to treatment for easily and cheaply treated medical conditions.

Note that under the first approach, there may not be any evidence that would make deworming subsidies appropriate, and under a strong enough form of the final perspective, subsidies for mass deworming might be appropriate under any evidence that does not challenge the medical appropriateness of deworming for infected individuals and its safety for those without infections. In this article we will review the evidence on deworming to try to shed light on what might be normatively appropriate under perspectives 2 through 4.

We will argue first that deworming is highly responsive to price. Second, we will review evidence showing that mass school-based deworming is a highly cost-effective educational investment and a high-return economic investment even in the absence of any other health benefits from deworming. We will discuss evidence suggesting that the epidemiological and fiscal externalities associated with deworming are large enough to support the WHO's position advocating mass presumptive deworming treatment of children in endemic regions, even under a relatively restrictive welfare economics/public finance perspective. Finally, we will compare the costs associated with the two leading policy options in endemic areas, namely, mass treatment versus the screening and treatment of those found to be infected.

The rest of the article is structured as follows. Section 2 provides background information on worm infections, and describes the studies we draw upon to inform our argument. Section 3 summarizes evidence on the impact of price on take-up of deworming treatment. Section 4 reviews evidence on the educational and economic impacts of deworming treatment and discusses fiscal externalities. Section 5 compares the costs of mass treatment to the costs of screening and then treatment of the infected. Section 6 concludes.

II. Background on Intestinal Worms

Roughly one in four people are infected with soil transmitted helminthes (STH) in endemic countries (Pullan et al. 2014), and a further 187 million individuals are infected with schistosomiasis, mostly in Africa (Hotez et al. 2006). These two types of worms follow different modes of disease transmission. STH (which include hookworm, whipworm, and roundworm) are transmitted via eggs deposited in the local environment when individuals defecate in their surroundings or do not practice proper hygiene after defecating, while the schistosomiasis parasite is spread through contact with infected fresh water. Due to their transmission mechanisms, school-aged children are especially vulnerable to these worm infections (Hotez et al. 2006).

The potential health consequences of worm infections are generally agreed to depend on the number of worms in the body, rather than a simple binary indicator of infection status, but there is no scientific consensus on the functional form of this relationship. Some have argued that treating worm infections once or twice per year can improve child appetite, growth, and physical fitness (Stephenson et al. 1993), and reduce anemia (Stoltzfus et al. 1997; Guyatt et al. 2001). Deworming may also strengthen the immunological response to other infections, such as malaria (Kirwan et al. 2010) and human immunodeficiency virus (HIV; Kjetland et al. 2006). Furthermore, chronic parasitic infections in childhood generate inflammatory (immune defense) responses and elevated cortisol levels that lead energy to be diverted from growth, and this may produce adverse health consequences throughout the life course, including organ damage, atherosclerosis, impaired intestinal transport of nutrients, and cardiovascular disease (Crimmins and Finch 2005).

Safe, low-cost drugs are available to treat worm infections and are the standard of medical care (Horton 2000; Keiser and Utzinger 2008; Perez et al. 2012). Because treatment is inexpensive and safe but diagnosis is relatively expensive (requiring lab analysis of a stool sample), the WHO recommends periodic mass school-based treatments in areas where worm infections are above certain thresholds (WHO 2014). Mass school-based deworming involves administering deworming drugs to all children at a school in an area where worms are endemic, without individual diagnosis. The Copenhagen Consensus, the Disease Control Priorities Project, Givewell, and the Abdul Latif Jameel Poverty Action Lab (J-PAL) have reviewed the evidence for, and comparative cost-effectiveness of, a wide range of development interventions and have consistently ranked deworming as a priority for investment.[1]

Despite this recommendation, some have challenged the view that mass deworming of school-children should be a policy priority, contending that the evidence on mass treatment programs is of poor quality or inconclusive and is

1. See, for instance, Disease Control Priorities Project (2008), Hall and Horton (2008), J-PAL Policy Bulletin (2012), and Givewell (2013).

therefore insufficient to justify these programs (Taylor-Robinson et al. 2012; Hawkes 2013), although they do not dispute that those known to be infected with worms should be treated.

By randomizing at the individual level, most studies on deworming in the public health literature fail to consider the potential for epidemiological externalities from treatment, where treatment can improve outcomes not only for the person treated but also others by reducing the chance of disease transmission (Bundy et al. 2009). The underlying biological mechanisms suggest that treating infected people can prevent them from spreading infection, and existing evidence suggests that such externalities can be substantial.

Bundy et al. (1990) examine a case in which all 2–15 year-olds on the island of Montserrat, West Indies, were treated with single dose albendazole four times over a 16-month period. At the end of the trial, the authors find substantial reductions in infection rates not only for the targeted individuals (where greater than 90% of the target population received treatment) but also for adults aged 16–25 (even though less than 4% received treatment), suggesting large positive epidemiological externalities.

More recently, Miguel and Kremer (2004) study a cluster-randomized school-based deworming program in rural western Kenya during 1998–1999, where students were treated with albendazole twice per year (and some schools were additionally treated with praziquantel once per year). The authors find large reductions in worm infection prevalence among treated individuals, untreated individuals attending treatment schools, and individuals in schools located near treatment schools. In particular, after just one year of treatment the authors estimate an 18 percentage point reduction in the proportion of moderate-to-heavy infections among untreated individuals attending treatment schools (P-value $< .05$), and a 22 percentage point reduction among individuals attending a school within 3 kilometers of a treatment school (P-value $< .05$) (Miguel and Kremer 2004).[2]

Ozier (2014) studies this same school-based deworming program in Kenya but focuses on children who were 0 to 2 years old when the program was launched and who lived in the catchment areas of the participating schools. These children were not directly treated themselves but could have benefited from the positive within-community externalities generated by mass school-based deworming. Ten years after the program, Ozier (2014) estimates average test score gains of 0.3 standard deviation units (P-value $< .01$). These children likely benefited primarily through reduced transmission of worm infections, and consistent with this hypothesis, the effects were twice as large among children with an older sibling in one of the schools that received the program.

2. Miguel and Kremer (2014) provide an updated analysis of the data in Miguel and Kremer (2004), correcting some errors in the original analysis. Throughout this paper we still cite Miguel and Kremer (2004), but use the updated numbers where appropriate.

Together, these three studies provide strong evidence for the existence of large, positive, and statistically significant deworming externality benefits within the communities that received mass treatment. Because of this, studies that are randomized at the individual level—rather than the cluster level, which provides geographic separation between treatment and control groups, thereby allowing for a study of treatment externalities—likely greatly underestimate the impacts of treatment.

In what follows, we consider findings from well-identified studies that investigate the effect of deworming on educational and economic outcomes. We consider a study to be well-identified if it both (1) uses experimental or quasi-experimental methods to demonstrate causal relationships and (2) incorporates a cluster design to take into account the potential for infectious disease externalities. In particular, we review evidence from three deworming campaigns in widely different times and contexts—one in the US South in the early 20th century and two in East Africa at the turn of the 21st century.

Bleakley (2007) analyzes the impact of hookworm eradication in the US South, exploiting a program launched by the nongovernmental Rockefeller Sanitary Commission in 1910. After detecting hookworm infection rates of 40% among school-aged children in the region, the Commission sponsored traveling dispensaries that administered treatment to infected individuals in affected areas and educated local physicians and the public about prevention. In their own follow-up analysis, the commission reports a 30 percentage point decrease in infection rates across the infected areas (Bleakley 2007).[3] To assess the impact of this intervention on educational and economic outcomes, Bleakley (2007) uses quasi-experimental methods, comparing changes in counties with high baseline worm prevalence to changes in low baseline prevalence counties over the same period.

The second deworming campaign we discuss is an NGO-sponsored school-based treatment program which was phased into 75 schools in a rural district of western Kenya during 1998–2001. This area was characterized by high baseline helminth infection rates, at over 90% among school-children. The program entailed provision of deworming drugs to treat STH (twice per year) and schistosomiasis (once per year), as well as provision of educational materials on worm prevention. Due to administrative constraints of the NGO, schools were phased into the program in three groups, where each school was assigned to a group through list-randomization. The first group began deworming treatment in 1998, the second group in 1999, and the final group in 2001.

Several papers have explored various aspects of this Kenyan program. In what follows, we focus on the Miguel and Kremer (2004) paper mentioned above, which analyzes the short-run impact of the program on education and health outcomes, and Baird et al. (2014), which follows up with participants a decade

3. This measure includes the direct impact on the treated as well as indirect impacts accruing to the untreated population.

later to assess the long-run impact of the program. We also discuss Kremer and Miguel (2007), which studies the behavioral response to a change in the price of deworming treatment in this program.

The third campaign we consider was a program delivered by community-based organizations during 2000–2003 across 48 parishes in five districts in eastern Uganda. This program area was also characterized by high worm prevalence, with an infection rate of over 60% in children aged between five and ten years old (Kabatereine et al. 2001). Treatment was provided during "child health days," in which parents were offered multiple health and nutrition interventions for children aged 1 to 7. Using a cluster-randomization approach, parishes were randomly assigned to receive either the standard intervention, which included Vitamin A supplementation, vaccines, growth monitoring and feeding demonstrations, or to receive deworming treatment in addition to the standard package (Croke 2014).

Alderman et al. (2006) explore the short-run impacts of this program on child health, and find that mass treatment led to improvements in child weight. Croke (2014) studies the longer term educational impacts on these children 7–8 years after the program. In particular, he exploits data on academic test scores that were collected as part of an unrelated set of national learning assessments by an NGO. These data exist for 22 of the 48 parishes in the original randomized study, of which 12 received the standard treatment and 10 received deworming in addition to the standard package.

III. Impact of Pricing on Take-Up

Before turning to the evidence on the educational and economic impacts of deworming, we first discuss evidence on the impact of pricing on take-up. Under standard welfare economics, the ratio of intramarginal to marginal consumers will be important in determining optimal tax and subsidy policy, since the fiscal costs of increasing subsidies are proportional to the number of inframarginal consumers, while the benefits of any positive epidemiological or fiscal externalities depend on the number of marginal consumers who will be induced to deworm by subsidies. Such considerations will also be important from a cost effectiveness perspective. From a human rights perspective, if parents are not willing to pay for treatment, then the larger society may have an obligation to make treatment free and convenient so children can be treated.

Kremer and Miguel (2007) study the behavioral response to a change in the price of deworming treatment in the context of the Kenyan school-based deworming program. The implementing NGO had a policy of using community cost-recovery in its projects to promote sustainability and confer project ownership on its beneficiaries. Thus, starting in 2001, a random subset of participating schools were allocated to pay user fees for the deworming treatment, with the average cost of deworming per child set at US$0.30 (about one-fifth of the cost of drug purchase and delivery through this program). The authors find that this cost-sharing reduced take up by 80%, from 75% to 19%. This result is consistent with findings observed for other products for disease prevention and treatment of nonacute conditions such as bednets for malaria and water treatment.[4]

A more detailed examination of the data on the observed price elasticity of demand suggests that insights from behavioral economics may be important in explaining these results. Cost-sharing came in the form of a per-family fee, so that families with more children effectively faced a lower per-child price. Kremer and Miguel (2007) find no evidence that adoption is sensitive to these variations in positive price, despite the high sensitivity to there being a positive price at all.[5] Moreover, the authors find that user fees did not help target treatment to the sickest students: students with moderate to heavy worm infections were not more likely to pay for the drugs in the cost-sharing schools. In standard models of human capital investment, people weigh the opportunity costs of an investment against the discounted value of returns (Becker 1993). Small fees should not make much difference unless people happen to be right at the margin of whether or not to make the investment. In fact, relatively small short-run costs (e.g., $0.30 per deworming pill) appear to generate large movements in adoption, consistent with models of time inconsistent preferences (Laibson 1997). To the extent that people are subject to behavioral biases, there may be a stronger rationale for policymakers basing decisions on deworming programs on their educational and economic cost-effectiveness rather than on conventional public finance criteria.

IV. Education and Labor Market Impacts of Deworming

In this section we summarize the existing evidence on the impact of deworming on education and labor market outcomes. These direct benefits will help inform the cost-effectiveness perspective, while the fiscal externalities resulting from labor market impacts will be important from a welfare economics perspective. The combination of the findings that many parents will not purchase deworming medication for their children and that deworming affects children's educational and economic outcomes raises concerns from the perspective of the human rights of the child. To the extent that governments are committed to ensuring that the rights of children are protected, there may be a stronger case for free mass deworming.

School Participation

Early work on the links between deworming and education focuses on simple correlations between worm infection levels and school participation, and finds a significant positive relationship between infection rates and school absenteeism

4. See Kremer and Holla (2009), JPAL Policy Bulletin (2011), Kremer and Glennerster (2011), and Dupas (2014) for reviews of the literature of the impact of prices on adoption of health interventions.

5. Other studies (e.g., Banerjee et al. 2010) also suggest that adoption of health interventions may be particularly sensitive to prices near zero.

($P < .001$; Nokes and Bundy 1993). More recently, clustered evaluations have tried to carefully identify the causal effect of deworming on school participation, and avoid issues of confounding that may underlie simple correlations (Bundy, Walson, and Watkins 2013).[6]

In his difference-in-difference study of the US South, Bleakley (2007) finds that between 1910 and 1920 counties characterized by higher worm prevalence prior to the deworming campaign saw substantial increases in school enrollment, both in absolute terms and relative to areas with lower infection rates. The author estimates that a child infected with hookworm would have been 20 percentage points less likely to be enrolled in school than a noninfected child and was also 13 percentage points less likely to be literate. His estimates suggest that due to the deworming campaign, a county with a 1910 infection rate of 50% would experience an increase in school enrolment of 3–5 percentage points and an increase in attendance of 6–8 percentage points, relative to a county with no infection problem. Because his analysis is performed at the county (and state) level, these results encompass any within-county (state) externality effects but not spillovers across counties (states).

Since Bleakley (2007) is not randomized, one concern is that something other than deworming is driving the difference in outcomes detected for children. However, the finding remains significant when controlling for a number of potentially confounding factors, such as state-level policy changes during that period and the demographic composition of high- and low-worm load areas. In addition, Bleakley (2007) finds no significant differences in adult outcomes, including literacy and labor force participation, across counties with higher and lower prevalence over the period of the deworming campaign. Since adults had much lower infection rates and hence were unlikely to benefit as much from deworming, the lack of a difference in adult outcomes bolsters the case that deworming, and not something else, was driving the enrollment surge in areas that previously had high hookworm prevalence.

Miguel and Kremer (2004) also provide evidence on the impact of deworming on school participation through their cluster-randomized evaluation of the school-based deworming program in Busia, Kenya. The authors find substantially greater school participation in schools that had been assigned to receive deworming than in those that had not yet been phased in to the program.

6. There are also a number of early studies that assessed impacts on school attendance using individually randomized evaluations. For example, Watkins, Cruz, and Pollitt (1996) study deworming treatment of children aged 7–12 years in rural Guatemala and find no impact on school attendance. However, this study is not cluster randomized, thus limiting the ability to interpret the results. Furthermore, attendance in this study is measured through the use of school register data, which excludes any students who have dropped out during the study. Since dropping out is very likely correlated with treatment status, there is a high risk that this gives a biased picture of school participation over time. We might also be concerned about the potential for school officials to overstate attendance due to their awareness of the program and the data collection. Simeon et al. (1995) studies deworming treatment among Jamaican children aged 6–12, and also finds no impact on school attendance. However, this study is also randomized at the individual level.

Participation increased not only among treated children but also among untreated children in the treatment schools (e.g., girls of reproductive age, who at that time were not approved for mass drug administration) and among pupils in schools located near treatment schools. The total increase in school participation, including these externality benefits, was 8.5 percentage points (Miguel and Kremer 2004). As discussed in Dhaliwal et al. (2012), these results imply that deworming is one of the most cost-effective ways of increasing school participation.

Academic Test Scores

In their study of the Kenyan deworming program, Miguel and Kremer (2004) do not find effects on cognition or a short-run effect on academic test scores. However, the long-run follow-up evaluation of the same intervention (Baird et al. 2014) finds that among females, deworming increased the rate of passing the national primary school exit exam, by almost 25% (9.6 percentage points on a base of 40%). One hypothesis is that the children receiving treatment were too old for any potential gains in cognitive function but learned more simply through increased school participation.

In the long-run follow-up of the cluster-randomized Uganda deworming program, Croke (2014) analyzes the English, math, and combined test scores comparing treatment and control, as well as looking at whether the impact is greater for those who received multiple deworming treatments as compared those who were dewormed once. The study finds that children in treatment villages have significantly higher scores as compared to those in control villages, with effect sizes ranging from 0.15 to 0.36 standard deviations. Effect sizes also more than double for children who were dewormed more than once, but the difference in coefficients is only significant for math scores.[7]

Employment and Income

Bleakley (2007) uses data from the 1940 US census to compare adult outcomes among birth cohorts who entered the labor force before and after the deworming campaign in the US South. Adults who had more "exposure" to deworming as children were significantly more likely to be literate and had higher earnings as adults. He finds a 43% increase in adult wages among those infected as children.

7. Since the 22 communities included in the Croke (2014) analysis were not randomly selected, although the original assignment was random, there may be concern that the results are driven by long-term differences in these communities as opposed to the deworming treatment. Croke (2014) addresses this issue by showing that the communities are similar on many variables related to adult outcomes (e.g., ownership of phones and televisions, access to water and electricity, and measures of female empowerment). To further support his econometric identification strategy, Croke (2014) also explores the pattern of test scores of all children tested in these parishes. The youngest children would have been too young to receive more than two rounds of deworming, while the oldest children, at age 16, would have never received the program. Thus, one would expect that if effects are truly from the deworming intervention, then the impacts would be lower at the two extremes and higher for children in the middle age group, which is what the study finds.

This effect is large enough to suggest that hookworm infections could have explained as much as 22% of the income gap between the US North and South at the time. Given initial infection rates of 30%–40%, hookworm eradication would therefore imply a long-run income gain of 17% (based on 43% increase in wages and a 40% infection rate) (Bleakley 2010).

Children who were treated for worms in Kenya also had better outcomes later in life. Baird et al. (2014) consider females and males separately, given the different set of family and labor market choices they face in this context (Pitt, Rosenzweig, and Hassan 2012). They find that Kenyan females who received more deworming treatment have higher school enrollment and are more likely to pass the national primary school exit exam. They are also more likely to grow cash crops and reallocate labor time from agriculture to entrepreneurship. Treated males work 3.5 more hours per week, spend more time in entrepreneurial activities, and are more likely to work in higher-wage manufacturing jobs.

The increases in earnings allow Baird et al. (2014) to compute an annualized internal rate of return (IRR) of 32%–52% to deworming, depending on whether health spillovers are included. This is high relative to other investments, implying deworming is cost effective on economic grounds, even without counting any health benefits.

Furthermore, because deworming increases labor supply, it creates a fiscal externality though its impact on tax revenue. In fact, Baird et al. (2014) estimate that the net present value (NPV) of increases in tax revenues greatly exceed the cost of the program. The fiscal externalities are thus sufficiently strong that a government could potentially reduce tax rates by instituting free mass deworming. Deworming thus easily satisfies the weaker conditions required for the benefit to exceed the costs to taxpayers.

V. The Cost of Mass Treatment Programs versus Screened Treatment

The WHO recommends mass treatment once or twice a year in regions where worm prevalence is above certain thresholds (WHO 2014). Screening followed by treatment of those testing positive for worms is far less practical and more costly than mass treatment of infected and uninfected children without diagnostic testing. From a practical perspective, screening programs are also logistically difficult, requiring collection of stool samples, and more than 20 minutes of health worker time per sample collected (Speich et al. 2010). For a national program like the current one in Kenya, this would result in the need for approximately 1,200 health workers focused full time on such testing each year.

Turning attention to costs, delivering deworming medicine for soil-transmitted helminths through school-based programs is estimated to cost approximately US$0.35 per child per round of treatment, including delivery costs (Givewell 2014). Diagnosis of worm infections, on the other hand, is far more expensive and complicated, requiring skilled staff. Taylor-Robinson et al. (2012) state that screening for worm infections is not recommended by the WHO because the cost of screening is 4–10 times that of the treatment itself. Speich et al. (2010) estimate that the cost per child of testing via the Kato-Katz test, the most commonly used method for testing for worms in the field, is US$1.88 in 2013 dollars. Assuming that the test has a specificity of 100% (i.e., identifies 100% of infections) and that all the children who are screened are also present on the day that treatment is provided, the cost per infection treated would be more than six times higher with treatment following screening as compared to mass treatment without screening. Mass treatment is hence clearly preferred on cost-effectiveness and public finance grounds.

The numbers above, however, ultimately underestimate the cost of screening.[8] First, tests for worms do not identify all infections. Estimates of the specificity for the Kato-Katz method range from about 91% to about 52% (Barda et al. 2013; Assefa et al. 2014). With a specificity of 52%, the cost per infection treated would be about 12 times higher for screened treatment as compared to mass treatment. Second, a large number of infections would remain untreated. The fact that screened treatment programs need to reach infected children a second time to treat them, and that it is unlikely they can reach each child who was tested, makes screening even less cost-effective and leaves even more infections untreated.

The vast majority of the 870 million children at risk of worm infections (Uniting to Combat Neglect Tropical Diseases 2014) could be treated each year via mass deworming programs at a cost of approximately 300 million dollars a year, which is feasible given current health budgets. The cost of treating them via screened programs would likely be closer to 2 billion dollars annually, if not higher.

VI. Conclusion

The WHO recommends mass treatment once or twice a year in regions where worm prevalence is above 20% and above 50%, respectively (WHO 2014). Deworming is currently being implemented as policy in many parts of the developing world, with recent estimates suggesting that 280 million children (out of 870 million in need) are treated for worms, many via school-based and community based integrated neglected tropical disease programs (Uniting to Combat Neglect Tropical Diseases 2014).

Our analysis suggests that the WHO recommendations are justified on human rights, welfare economics, and cost-effectiveness grounds. Of course, more evidence would be useful and some uncertainty remains.[9] Although our conclusions

8. Another screening approach could be to simply ask individuals if they have experienced any of the common side effects of worm infections. While cheaper and potentially useful in environments where stool testing is not practical, this screening method would likely be very imprecise.

9. While we believe that subsidizing deworming is worthwhile given currently available evidence, this should not be taken to imply that we see no role for additional studies generating further evidence to inform future decisions.

are based on evidence from two radically different contexts (East Africa at the turn of the 21st century and the US South at the turn of the 20th century), the impact of deworming will of course vary to some degree with the local context, including circumstances such as type of worm, worm prevalence and intensity, comorbidity, the extent of school participation in the community, and labor market factors.

The most commonly used deworming drugs—albendazole, mebendazole and praziquantel—have all been through clinical trials, have been approved for use by the appropriate regulatory bodies in multiple countries, and have shown to be efficacious against a variety of worm infections and also to have minimal side effects (Horton 2000; Fenwick et al. 2003; Keiser and Utzinger 2008; Perez del Villar et al. 2012). This means that the decision of whether to expend resources on deworming is one that can be made based on comparing expected benefits and costs, given the available evidence.

It is worth noting that deworming would be highly cost effective in many settings on educational and economic grounds alone, even if its benefits were to be only a fraction of those estimated in Kenya, Uganda, and the southern United States. Thus, policy makers would be warranted in moving ahead with deworming even if they thought its benefits were likely to be substantially smaller in their own context, or even if they had some uncertainty about whether benefits would be realized at all. In particular, even if the impact of deworming on school participation is only 1/10th of that estimated in Miguel and Kremer (2004), it would still be among the most highly cost effective ways of boosting school participation. Furthermore, labor markets effects half as large as those estimated in Baird et al. (2014) would be sufficient for deworming to generate enough tax revenue to fully cover its costs.[10] A sophisticated welfare analysis would be explicitly Bayesian, taking into account policy makers' priors and their assessment of their specific context, and we believe that under a Bayesian analysis that placed even modest weight on evidence discussed here, mass school-based deworming would be justified in areas with worm prevalence above the WHO cutoffs.

Conflict of Interest

In the interests of transparency around potential conflicts of interest, the authors note that the U.S. Agency for International Development (USAID) and the Douglas B. Marshall, Jr. Family Foundation support deworming. Kremer is the Scientific Director of Development Innovation Ventures at the U.S. Agency for International Development. Also, Ahuja is the chair of the board of Evidence Action, a nonprofit organization which supports governments in scaling mass

10. Note that this estimate is conservative, only taking into account direct deworming benefits, and ignoring positive externality benefits.

school-based deworming programs; this is a voluntary position with no associated remuneration. The content of this article is solely the responsibility of the authors, and does not necessarily represent the official views of the Eunice Kennedy Shriver National Institute of Child Health & Human Development, the U.S. National Institutes of Health, USAID, the Douglas B. Marshall, Jr. Family Foundation, or Evidence Action.

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