DISEASE CONTROL PRIORITIES • THIRD EDITION

8

Child and Adolescent Health and Development

EDITORS

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WITH A FOREWORD BY

Gordon Brown

VOLUME 8

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Series Editors
Dean T. Jamison
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Disease Control Priorities: Improving Health and Reducing Poverty

DISEASE CONTROL PRIORITIES

Budgets constrain choices. Policy analysis helps decision makers achieve the greatest value from limited available resources. In 1993, the World Bank published *Disease Control Priorities in Developing Countries* (*DCP1*), an attempt to systematically assess the cost-effectiveness (value for money) of interventions that would address the major sources of disease burden in low- and middle-income countries. The World Bank's 1993 *World Development Report* on health drew heavily on *DCP1*'s findings to conclude that specific interventions against noncommunicable diseases were cost-effective, even in environments in which substantial burdens of infection and undernutrition persisted.

DCP2, published in 2006, updated and extended *DCP1* in several aspects, including explicit consideration of the implications for health systems of expanded intervention coverage. One way that health systems expand intervention coverage is through selected platforms that deliver interventions that require similar logistics but deliver interventions from different packages of conceptually related interventions, for example, against cardiovascular disease. Platforms often provide a more natural unit for investment than do individual interventions. Analysis of the costs of packages and platforms—and of the health improvements they can generate in given epidemiological environments—can help to guide health system investments and development.

DCP3 differs importantly from *DCP1* and *DCP2* by extending and consolidating the concepts of platforms and packages and by offering explicit consideration of the financial risk protection objective of health systems. In populations lacking access to health insurance or prepaid care, medical expenses that are high relative to income can be impoverishing. Where incomes are low, seemingly inexpensive medical procedures can have catastrophic financial effects. *DCP3* offers an approach to explicitly include financial protection as well as the distribution across income groups of financial and health outcomes resulting from policies (for example, public finance) to increase intervention uptake. The task in all of the *DCP* volumes has been to combine the available science about interventions implemented in very specific locales and under very specific conditions with informed judgment to reach reasonable conclusions about the impact of intervention mixes in diverse environments. *DCP3*'s broad aim is to delineate essential intervention packages and their related delivery platforms to assist decision makers in allocating often tightly constrained budgets so that health system objectives are maximally achieved.

DCP3's nine volumes are being published in 2015, 2016, 2017, and 2018 in an environment in which serious discussion continues about quantifying the sustainable development goal (SDG) for health. *DCP3*'s analyses are well-placed to assist in choosing the means to attain the health SDG and assessing the related costs. Only when these volumes, and the analytic efforts on which they are based, are completed will we be able to explore SDG-related and other broad policy conclusions and generalizations. The final *DCP3* volume will report those conclusions. Each individual volume will provide valuable, specific policy analyses on the full range of interventions, packages, and policies relevant to its health topic.

More than 500 individuals and multiple institutions have contributed to *DCP3*. We convey our acknowledgments elsewhere in this volume. Here we express our particular

gratitude to the Bill & Melinda Gates Foundation for its sustained financial support, to the InterAcademy Medical Panel (and its U.S. affiliate, the National Academies of Science, Engineering, and Medicine), and to the External and Corporate Relations Publishing and Knowledge division of the World Bank. Each played a critical role in this effort.

Dean T. Jamison
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Foreword

HEALTH AND EDUCATION DURING THE 8,000 DAYS OF CHILD AND ADOLESCENT DEVELOPMENT: TWO SIDES OF THE SAME COIN

Today, there is comfort to be found in returning to the inspired words of others. Until H. G. Wells' time machine is made, words are our emotional anchor to the past and, one hopes, our window to a brighter future. Speaking before the 18th General Assembly of the United Nations in 1963, it was President John F. Kennedy who noted that the "effort to improve the conditions of man, however, is not a task for the few." Development is a shared, cross-cutting mission I know well. For the breakthroughs we witness—from Borlaug's wheat to a vaccine for polio—are the products of cooperation, a clean break from siloed thinking, and a courage to work at the sharp edges of disciplines.

Working as a lecturer for five years in the 1970s and early 1980s, I came to see—in a way I never had as a student—that education unlocks talent and unleashes potential. And as Chancellor, Prime Minister, and most importantly a parent, education has remained a centerpiece in my life because of the hope it delivers. For when we ask ourselves what breaks the weak, it is not the Mediterranean wave that submerges the life vest, nor the food convoy that does not make it to the besieged Syrian town. Rather, it is the absence of hope, the soul-crushing certainty that there is nothing ahead to plan or prepare for—not even a place in school.

Two years ago, the International Commission on Financing Global Education Opportunity, composed of two dozen global leaders and convened by the Prime Minister of Norway and the Presidents of Chile, Indonesia, and Malawi, as well as the Director-General of UNESCO, set out to make a new investment case for global education. What resulted was a credible yet ambitious plan capable of ensuring that the Sustainable Development Goal of an inclusive and quality education for all is met by the 2030 deadline. While we continue to work today to ensure our messages become action—from increased domestic spending on schooling to an International Finance Facility for Education—we sought to produce an authoritative, technically strong report that would spend more time being open on desks than collecting dust on a shelf.

The *Disease Control Priorities* (*DCP*) series established in 1993 shares this philosophy and acts as a key resource for Ministers of Health and Finance, guiding them toward informed decisions about investing in health. The third edition of *DCP* rightly recognizes that good health is but one facet of human development and that health and education outcomes are forever intertwined. The Commission report makes clear that more education equates with better health outcomes. And approaching this reality from the other direction, this year's volume of *DCP* shows that children who are in good health and appropriately nourished are more likely to participate in school and to learn while there. The Commission report raises the concept of progressive universalism or giving greatest priority to those children most at risk of being excluded from learning. Here, too, the alignment with *DCP* is clear as health strides are most apparent when directed to the poorest and sickest children, as well as girls.

It is fitting that one of the Commission's background papers appears as a chapter in this volume. The Commission showed that education spending, particularly for adolescent girls, is a moral imperative and an economic necessity. Indeed, girls are the least likely to go to primary school, the least likely to enter or complete secondary school, highly unlikely to matriculate to college, and the most likely to be married at a young age, to be forced into domestic service or trafficked. And with uneducated girls bearing five children against two children for educated girls, the vicious cycle of illiterate girls, high birth rates, low national incomes per head, and migration in search of opportunity will only worsen so long as we fail to deliver that most fundamental right to an education.

Here is a projection to remember. If current education funding trends hold, by 2030, 800 million children—half a generation—will lack the basic secondary skills necessary to thrive in an unknowable future. In calling for more and better results-based education spending, the Commission estimated that current total annual education expenditure is US$1.3 trillion across low- and middle-income countries, an anemic sum that must steadily rise to US$3 trillion by 2030. A rising tide must lift all ships, and so as education spending at the domestic and international levels sees an uptick, the same must be witnessed for health. The numbers may seem large, but the reality is that this relatively inexpensive effort would do more than unlock better health and education outcomes; it would bring us closer to achieving all 17 Sustainable Development Goals and unlocking the next stage of global growth.

A key message of this volume is that human development is a slow process; it takes two decades—8,000 days—for a human to develop physically and mentally. We also know a proper education requires time. So the world needs to invest widely, deeply, and effectively—across education, health, and all development sectors—during childhood and adolescence. And while individuals may have 8,000 days to develop, we must mobilize our resources today to secure their tomorrow. Let us not forget that the current generation of young people will transition to adulthood in 2030, and it will be their contribution that will determine whether the world achieves the Sustainable Development Goals.

We have, to again draw on Kennedy's words, "the capacity to control [our] environment, to end thirst and hunger, to conquer poverty and disease, to banish illiteracy and massive human misery." We have this capacity, but only when we work together. Both the Commission report and this latest *Disease Control Priorities* volume seek to elevate cross-sector initiatives on the global agenda. In human development, health and education are two sides of the same coin: only when we speak as one will this call be heard.

Gordon Brown
United Nations Special Envoy for Global Education
Chair of the International Commission on
Financing Global Education Opportunity
Prime Minister of the United Kingdom, 2007–2010
Chancellor of the Exchequer, 1997–2007

Preface

More children born today will survive to adulthood than at any time in human history. This is true both in terms of the proportion of live births and of absolute numbers. The current cohort of children who have survived to age 5 years will transition to adulthood around 2030 and will be the Sustainable Development Goals (SDGs) generation. The health, nutrition, and education of these young people as they develop from ages 5 to 19 years will have lifelong consequences for the adults they become and for their role in the development of the next generation. Will the world have prepared them well for this task?

Our analyses in this volume show that although the education of this age group is the primary focus of public sector investment, their health is a much lower priority. Indeed, middle childhood and adolescence has historically received the least attention of any age group.

Health and development in middle childhood and adolescence is a new focus of the *Disease Control Priorities* series, which was first published in conjunction with the World Bank's *World Development Report 1993: Investing in Health*, and which has become a key reference for health policy makers in low- and middle-income countries (box 1.1). The earlier editions touched on human development; this third edition is the first to give a specific focus beyond health to issues of human development, including the special role of the education sector, and the first to give prominence to health in this age group. This volume complements volume 2, *Reproductive, Maternal, Newborn, and Child Health*, which focuses on health in the under-five age group.

This volume presents its analyses and conclusions in 30 chapters grouped into five parts:

- **Part 1. Estimates of Mortality and Morbidity in Children (Ages 5 to 19 Years)** explores mortality and morbidity in this age group, with a focus on low- and lower-middle-income countries. A new analysis of mortality is presented, with surprising conclusions, and morbidity is examined with respect to three selected issues: nutrition, education, and health in adolescence.
- **Part 2. Impact of Interventions during the Life Course (Ages 5–19 Years)** reviews development issues at different stages in the life course and presents a conceptual framework for health and development from birth, through middle childhood and adolescence, to young adulthood.
- **Part 3. Conditions and Interventions** describes the evolving age distribution of disease and how new understanding of interventions and epidemiology has transformed the ways in which health systems can contribute to health and development objectives.
- **Part 4. Packages and Platforms to Promote Child and Adolescent Development** explores how novel approaches to policy that deliver health and development interventions to children and adolescents are slowly being implemented in low-income countries. In many cases, the focus is on vertical programs as part of underdeveloped primary health care systems, with a particular emphasis on school-based delivery. Current health systems often fail children and adolescents, especially in the low-income countries and communities that most need them.
- **Part 5. The Economics of Child Development** assembles economic data and seeks to prioritize interventions within three age classes: early childhood, school-age, and adolescence. Each age group is considered in a separate chapter, and each chapter prioritizes interventions on the basis of cost-effectiveness, extended cost-effectiveness, benefit-costs, and returns on investment. Part 5 also includes age-specific economic analysis of important areas of development, including the role of education in delaying

pregnancy and marriage, as well as public financing for mass deworming as an example of school-based intervention.

We would like to acknowledge the many thoughtful people who contributed to the content and conclusions of this volume. The 110 authors from 19 countries contributed most directly to the preparation of the 30 chapters presented here; the volume simply could never have happened without their substantial investment of time and effort in crafting and writing the chapters. We, and they, thank the more than 60 independent reviewers, selected and commissioned by the National Academy of Science, Engineering, and Medicine, who provided peer reviews of all of the chapters (see the section entitled "Reviewers" at the end of the volume for a detailed listing of these individuals).

As a further check on the policy implications of the conclusions, we sought input from those more directly involved in health policy making. A policy consultation was held in Geneva under the leadership of the Regional Director of the World Health Organization (WHO) Eastern Mediterranean Regional Office, with representation from 10 countries.[1] The African Union hosted a regional consultation of Ministry of Health representatives from five countries in Sub-Saharan Africa.[2] We also presented the main conclusions at a variety of fora, seeking feedback from practitioners—including the annual meeting of the European Society for Paediatric Infectious Diseases, in Brighton, United Kingdom; and the Bill & Melinda Gates Foundation, in Seattle, Washington, United States. We are grateful for the many thoughtful responses that we received.

We would also like to recognize our debt to all those who contributed to The *Lancet* Commission on Adolescent Health and Wellbeing. This volume was written in parallel with the report of the Commission and shares some common editors and authors. We support the conclusions of the Commission's report, published in May 2016 (Patton and others); we extend them in this volume to include further economic analysis, as well as an exploration of the health and development needs of children in middle childhood, an age group that may be even more neglected than adolescents in public health policy and planning.

The main conclusion of this volume is that human development is a process that extends over the first two decades of life; for individuals to achieve their full potential, there is a need for age- and condition-specific interventions throughout this 20-year period. The current focus on the "first 1,000 days" represents a failure to recognize the critical importance of subsequent development during middle childhood and adolescence. Although intervention during the first 1,000 days is indeed the essential foundation for subsequent development, it cannot serve as a substitute for continuing intervention during three key phases:

- The middle childhood phase of growth and consolidation (ages 5–9 years), when infection and malnutrition remain key constraints on development, and mortality rates are much higher than previously realized
- The adolescent growth spurt (ages 10–14 years), when the increase in muscle, bone, and organ mass approaches rates not seen since age 2 years, and there are commensurate demands for good diet and health
- The adolescent phase of growth and consolidation (ages 15–19 years), when major restructuring of the brain is associated with behavioral and social experimentation that has lifelong consequence.

We note the asymmetry between the public investment in formal education versus health during the age range of 5–19 years, and the lack of recognition that the developmental returns from education are themselves dependent on concurrent good health and diet. We argue that current policy on health and development has substantially neglected and underserved children in this age range, and that there is too little research on how to respond to the needs of middle childhood and adolescence. We propose packages of interventions for these crucial later phases of development that are in the same range of cost-effectiveness as interventions in the early years of life but of substantially lower cost. We also call for significantly increased investment in research into the health and development needs during middle childhood and adolescence.

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NOTES

1. Participants are listed at the end of this volume.
2. Participants are listed at the end of this volume, as well as online: http://www.dcp-3.org/CAHDEthiopia.

REFERENCE

Patton, G. C., S. M. Sawyer, J. S. Santelli, D. A. Ross, R. Afifi, and others. 2016. "Our Future: A *Lancet* Commission on Adolescent Health and Wellbeing." *The Lancet* 387 (10036): 2423–78.

Abbreviations

AIDS	acquired immune deficiency syndrome
AQ	amodiaquine
AS	artesunate
BCR	benefit-cost ratio
BMI	body mass index
CCT	conditional cash transfer
CHERG	Child Health Epidemiology Reference Group
CME	Child Mortality Estimation
CT	cash transfer
DALY	disability-adjusted life year
DCP1	*Disease Control Priorities in Developing Countries,* first edition
DCP2	*Disease Control Priorities in Developing Countries,* second edition
DCP3	*Disease Control Priorities*, third edition
DHS	Demographic and Health Surveys
DMFT	decayed, missing, and filled teeth
DOHaD	Developmental Origins of Health and Disease
DP	dihydroartemisinin-piperaquine
ECD	early child development
ECE	early childhood education
EFA	Education for All
EGRA	Early Grade Reading Assessment
ESP	education sector plan
FA	fractional anisotropy
FRESH	Focusing Resources on Effective School Health
FRP	financial risk protection
GBD	Global Burden of Disease
GDP	gross domestic product
GHE	Global Health Estimates
GIZ	German Development Cooperation
GNI	gross national income
GYTS	Global Youth Tobacco Survey

HAZ	height-for-age z-scores
Hb	hemoglobin
HBSC	Health Behaviour in School-Aged Children
HEADSS	home, education, activities/employment, drugs, suicidality, sex
HICs	high-income countries
HIV	human immunodeficiency virus
HIV/AIDS	human immunodeficiency virus/acquired immune deficiency syndrome
HLM	hierarchical linear model
HPV	human papillomavirus
HSV-2	herpes simplex virus-2
ICF	International Classification of Functioning, Disability and Health
IEA	International Association for the Evaluation of Educational Achievement
IEC	information, education, and communication
IHME	Institute for Health Metrics and Evaluation
INCAP	Institute of Nutrition for Central America and Panama
IPCs	intermittent parasite clearance in schools
IPT	intermittent preventive treatment
IQ	intelligence quotient
IRS	indoor residual spraying
IST	intermittent screening and treatment
ITN	insecticide-treated bednet
KMC	kangaroo mother care
LBW	low birth weight
LICs	low-income countries
LMICs	low- and middle-income countries
MDA	mass drug administration
MDGs	Millennium Development Goals
m-health	mobile health
MICs	middle-income countries
MICS	Multiple Indicator Cluster Survey
NCDs	noncommunicable diseases
NTD	neglected tropical diseases
OECD	Organisation for Economic Co-operation and Development
OOP	out of pocket
OTL	opportunity to learn
PDV	present discounted value
PIAAC	Programme for the International Assessment of Adult Competencies
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
PFC	prefrontal cortex
PRIMR	Primary Mathematics and Reading
PT	planum temporale
QALY	quality-adjusted life year
RCT	randomized controlled trial
RDT	rapid diagnostic test
RMNCH	reproductive, maternal, newborn, and child health
RoR	rate of return
RSC	Rockefeller Sanitary Commission
RTI	road traffic injury

SABER	Systems Approach for Better Education Results
SSBs	sugar-sweetened beverages
SBM	school-based management
SDGs	Sustainable Development Goals
SES	socioeconomic status
SHN	school health and nutrition
SMC	seasonal malaria chemoprevention
SP	sulphadoxine-pyrimethamine
SR	self-regulation
STHs	soil-transmitted helminths
STI	sexually transmitted infection
TFR	total fertility rate
TIMSS	Trends in International Mathematics and Science Study
TT	tetanus toxoid
U5MR	under-5 mortality rate
UCT	unconditional cash transfer
UMICs	upper-middle-income countries
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
VLY	value of a life year
VSL	value of a statistical life
VWFA	visual word form area
WASH	water, sanitation, and hygiene
WAZ	weight-for-age
WG	Washington Group
WHO	World Health Organization
WHZ	weight-for-height
WPP	World Population Prospects
WRA	women of reproductive age
YLD	years lost to disability
YOURS	Youth for Road Safety

Chapter 29

Economics of Mass Deworming Programs

Amrita Ahuja, Sarah Baird, Joan Hamory Hicks, Michael Kremer, and Edward Miguel

INTRODUCTION

Soil-transmitted helminth (STH) and schistosomiasis infections affect more than 1 billion people, mainly in low- and middle-income countries, particularly school-age children. Although light infections can be fairly asymptomatic, severe infections can have significant health effects, such as malnutrition, listlessness, organ damage, and internal bleeding (Bundy, Appleby, and others 2017).[1]

Low-cost drugs are available and are the standard of medical care for diagnosed infections. Because diagnosis is relatively expensive, and treatment is inexpensive and safe, the World Health Organization (WHO) recommends periodic mass treatments in areas where worm infections are greater than certain thresholds (WHO 2015). A number of organizations, including the Copenhagen Consensus, GiveWell, and the Abdul Latif Jameel Poverty Action Lab, which have reviewed the evidence for, and comparative cost-effectiveness of, a wide range of development interventions, have consistently ranked deworming as a priority for investment.[2] However, Taylor-Robinson and others (2015) challenge this policy, accepting that those known to be infected should be treated but arguing that there is substantial evidence that mass drug administration (MDA) has no impact on a range of outcomes.[3]

This chapter discusses the economics of policy choices surrounding public investments in deworming and considers policy choices under two frameworks:

- *Welfare economics or public finance approach.* Individuals are presumed to make decisions that maximize their own welfare, but government intervention may be justified in cases in which individual actions create externalities for others. These externalities could include health externalities from reductions in the transmission of infectious disease, as well as fiscal externalities if treatment increases long-term earnings and tax payments. Evidence on epidemiological and fiscal externalities from deworming will be important for informing decisions under this perspective.
- *Expected cost-effectiveness approach.* Policy makers should pursue a policy if the statistical expectation of the value of benefits exceeds the cost. Future monetary benefits should be discounted back to the present. Policy makers may also value nonfinancial goals, such as weight gain or school participation; they should pursue a policy if the statistical expectation of the benefit achieved per unit of expenditure exceeds that of other policies that policy makers are considering.

Under either framework, the case for government subsidies will be stronger if demand for deworming is sensitive to price. If everyone would buy deworming medicine on their own, without subsidies, then subsidies would yield no benefits; they would generate a deadweight loss of taxation.

The first perspective focuses on individual goals and assumes that consumers will maximize their own welfare. It treats them as rational and informed, and it

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abstracts from intrahousehold conflicts. The second perspective does not make these assumptions and seeks simply to inform policy makers about expected benefit-cost ratios or cost-effectiveness metrics, rather than making welfare statements.

This chapter summarizes the public finance case for deworming subsidies, given the evidence on epidemiological externalities[4] and high responsiveness of household deworming to price. It reviews the evidence on the cost-effectiveness of mass school-based deworming and associated fiscal externalities. It argues that the expected benefits of following the WHO's recommendation of mass presumptive deworming of children in endemic regions exceed the costs, even given uncertainty about the magnitude and likelihood of impacts in given contexts.[5] This benefit is realized even when only the educational and economic benefits of deworming are considered. Finally, the chapter maintains that between the two leading policy options for treatment in endemic areas—mass treatment versus screening and treatment of those found to be infected—the former is preferred under both public finance and cost-effectiveness approaches. Definitions of age groupings and age-specific terminology used in this volume can be found in chapter 1 (Bundy, de Silva, and others 2017).

EPIDEMIOLOGICAL EXTERNALITIES

STHs—including hookworm, roundworm, and whipworm—are transmitted via eggs in feces deposited in the local environment, typically through open defecation or lack of proper hygiene after defecating. Schistosomiasis is spread through contact with infected fresh water. School-age children are particularly vulnerable to such infections and prone to transmitting infection (Bundy, Appleby, and others 2017). Treating infected individuals kills the parasites in their bodies and prevents further transmission. Three studies provide evidence on such epidemiological externalities from deworming school-age children and suggest these externalities can be substantial.

Bundy and others (1990) studied a program in the island of Montserrat, West Indies, where all children between ages 2 and 15 years were treated with albendazole, four times over 16 months, to eliminate STH infections. The authors found substantial reductions in infection rates for the targeted individuals (more than 90 percent of whom received treatment), as well as for young adults ages 16–25 years (fewer than 4 percent of whom were treated). These findings suggest large positive epidemiological externalities, although only one geographic unit was examined.

Miguel and Kremer (2004) studied a randomized school-based deworming program in rural western Kenya from 1998 through 1999, where students in treatment schools received albendazole twice a year; in addition, some schools received praziquantel for schistosomiasis infections annually. The authors found large reductions in worm infections among treated individuals, untreated individuals attending treatment schools, and individuals in schools located near treatment schools. The authors estimated an 18 percentage point reduction after one year in the proportion of moderate-to-heavy infections among untreated individuals attending treatment schools, and a 22 percentage point reduction among individuals attending a school within 3 kilometers of a treatment school.[6]

Ozier (2014) studied this same randomized program in Kenya but focused on children who were ages zero to two years and living in catchment areas of participating schools at the time of program launch. These children were not treated, but they could have benefited from positive within-community externalities generated by the mass school-based deworming. Indeed, 10 years after the program, Ozier estimated average test score gains of 0.2 standard deviation units for these individuals. Consistent with the hypothesis that these children benefited primarily through the reduced transmission of worm infections, the effects were twice as large among children with an older sibling in one of the schools that participated in the program.

Bobonis, Miguel, and Puri-Sharma (2006), in contrast, found small and statistically insignificant cross-school externalities of deworming and iron supplementation on nutritional status and school participation of children in India. The authors noted that this finding is unsurprising in this context, given both the lower prevalence and intensity of worm infections and the small fraction of treated individuals.

Together, these studies provide strong evidence for the existence of large, positive epidemiological externality benefits to mass treatment in endemic areas, especially in areas with higher infection loads.[7] Such externality benefits are important to consider in both the public finance and cost-effectiveness decision-making frameworks. Under the first perspective, such benefits cannot be fully internalized by household decision makers and thus provide a potential rationale for government subsidies. Under the second perspective, externalities increase the cost-effectiveness of the intervention by increasing the total benefit achieved for a given amount of expenditure.

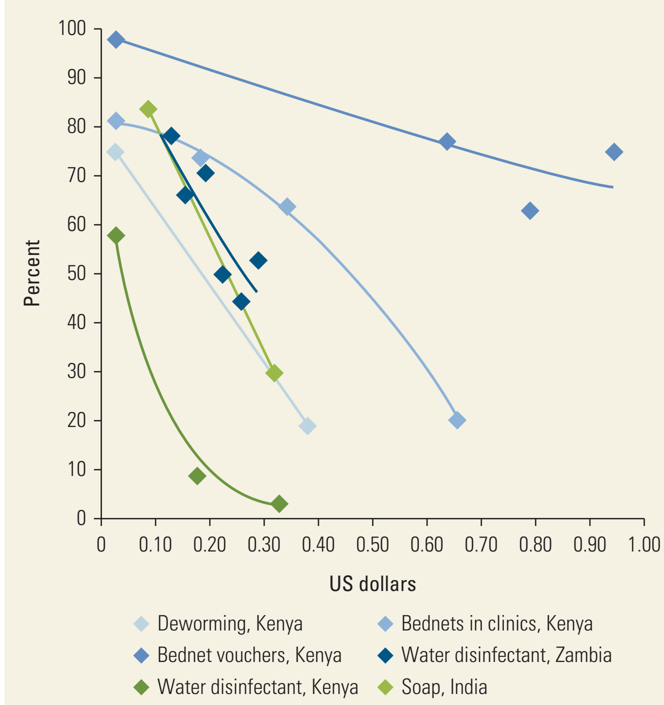
IMPACTS OF THE PRICE OF DEWORMING ON TAKE-UP

Assuming that a behavior generates positive externalities—or that under a cost-effectiveness approach, it is valued by policy makers—public finance theory emphasizes that the attractiveness of a subsidy depends on the ratio of marginal consumers (those who will change their behavior in response to a subsidy) to inframarginal consumers (those who would have engaged in the behavior even in the absence of a subsidy). The higher this ratio, the more attractive the subsidy.

Kremer and Miguel (2007) studied the behavioral response to a change in the price of deworming treatment in the Kenyan deworming program. Starting in 2001, a random subset of participating schools was chosen to pay user fees for treatment, with the average cost of deworming per child set at US$0.30, which was about 20 percent of the cost of drug purchase and delivery through this program. This cost-sharing reduced take-up (the fraction of individuals who received treatment) by 80 percent, to 19 percent from 75 percent.

This result is consistent with findings observed for other products for disease prevention and treatment of non-acute conditions, such as bednets for malaria and water treatment. Figure 29.1 displays how the demand for a range of health care products decreases as price increases.[8] Moreover, Kremer and Miguel (2007) found 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 medications. These results suggest low costs and large benefits from deworming subsidies, important for both the cost-effectiveness and welfare economics perspectives.

Figure 29.1 Response of Consumer Demand to Increase in the Price of Health Products



Source: Abdul Latif Jameel Poverty Action Lab 2011.

IMPACTS OF DEWORMING ON CHILD WEIGHT

In this and subsequent sections we examine the cost-effectiveness of mass deworming in affecting various outcomes potentially valued by policy makers. We focus primarily on economic outcomes rather than health outcomes because the impact of deworming on health is covered in chapter 13 in this volume (Bundy, Appleby, and others 2017). However, we would like to briefly expand upon that discussion to address the cost-effectiveness of deworming in improving child weight. Bundy, Appleby, and others (2017) discuss recent work of Croke and others (2016), who reviewed the literature on the impact of multiple-dose deworming on child weight. Overall, they estimated that MDA increases weight by an average of 0.13 kilograms, with somewhat larger point estimates among populations in which prevalence is greater than the WHO's 20 percent prevalence threshold for MDA, or the 50 percent threshold for multiple-dose MDA.[9] Assuming that an MDA program with two treatments per year costs US$0.60 per person (Givewell 2016), Croke and others (2016) estimated that the cost of deworming MDA per kilogram of weight gain is US$4.48. For comparison with another policy option, a review of school feeding programs by Galloway and others (2009) found that the average of the range associated with a 1 kilogram weight increase for school feeding from evidence from randomized controlled trials is US$182. This finding implies that per dollar of expenditure, mass deworming produces a weight increase 40.62 times that of school feeding. This finding on weight gain suggests that evidence of education and economic impact should not be rejected out of hand based on concern for lack of evidence about mechanisms by which such impacts could be achieved.

IMPACTS OF DEWORMING ON EDUCATION AND LABOR MARKETS

Evidence on the impact of deworming on education and labor market outcomes directly informs the cost-effectiveness perspective, while the fiscal externalities resulting from labor market impacts are important from a welfare economics perspective.

We review publicly available studies of the impact of mass deworming that do the following:

- Use experimental or quasi-experimental methods to demonstrate causal relationships
- Incorporate a cluster design to take into account the potential for infectious disease externalities
- Minimize attrition that could lead to bias.

Most existing studies on deworming randomize at the individual level; they fail to consider the potential for treatment externalities (Bundy and others 2009) and likely underestimate the impact of treatment. We review evidence from three deworming campaigns in different times and contexts—one in the United States in the early twentieth century and two in East Africa at the turn of the twenty-first century.[10]

The first program was launched by the Rockefeller Sanitary Commission (RSC) in 1910 to eradicate hookworm infections in the U.S. South. With baseline hookworm infection rates at 40 percent among school-age children, traveling dispensaries administered treatment to infected individuals in endemic areas and educated local physicians and the public about prevention. The RSC reported a 30 percentage point decrease in infection rates across affected areas 10 or more years after launch of the program (Bleakley 2007).[11]

The second program was a school-based treatment program sponsored by a nongovernmental organization that was phased into 75 schools in a rural district of western Kenya from 1998 through 2001. Baseline helminth infection rates were greater than 90 percent among school children in this area. The nongovernmental organization provided deworming drugs to treat STHs twice per year and schistosomiasis once per year, as well as educational materials on worm prevention. Schools were phased into the program in three groups over four years; each school was assigned to a group through list-randomization, resulting in a cluster randomized stepped-wedge research design.

The third program was delivered by community--based organizations during 2000–03 across 48 parishes in five districts of eastern Uganda.[12] Baseline infection rates were greater than 60 percent in children ages 5–10 years (Kabatereine and others 2001). Treatment was provided during child health days, in which parents were offered multiple health and nutrition interventions for children ages one to seven years. Using a cluster randomization approach, parishes were randomly assigned to receive either the standard intervention of vitamin A supplementation, vaccines, growth monitoring, and feeding demonstrations, or to deworming treatment in addition to the standard package (Alderman and others 2006; Croke 2014).

School Participation

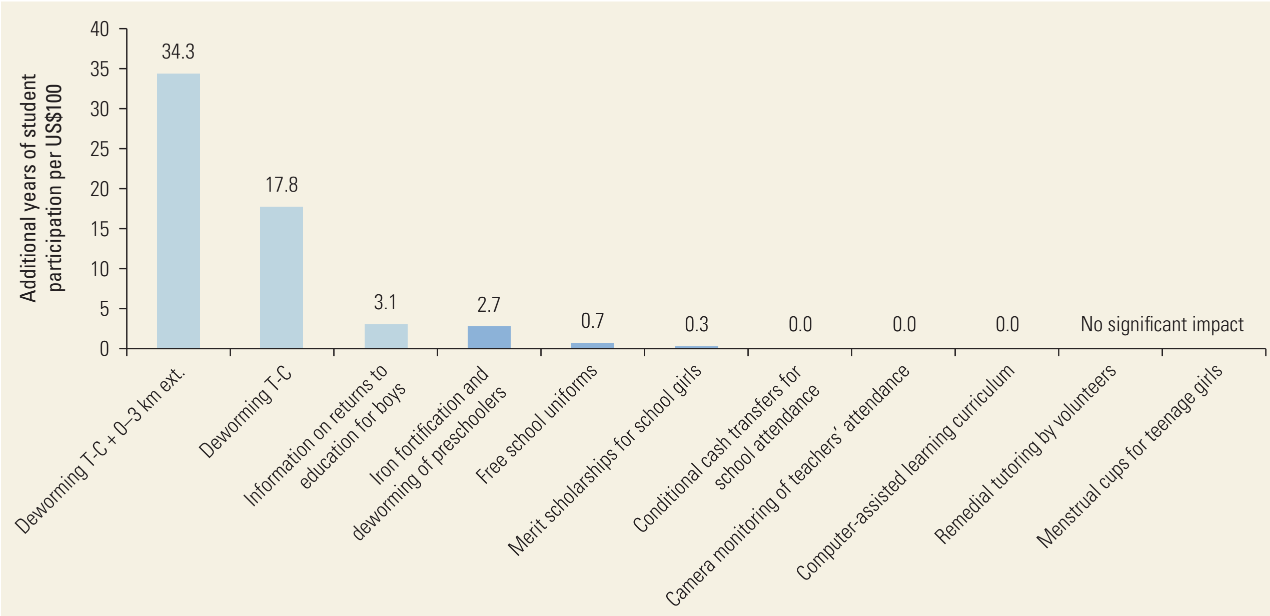
Using a difference-in-difference methodology in his study of the RSC program, Bleakley (2007) compared changes in counties with high baseline worm prevalence to changes in low baseline prevalence counties over the same period. Findings indicate that from 1910 through 1920, counties with higher worm prevalence before the deworming campaign saw substantial increases in school enrollment, both in absolute terms and relative to areas with lower infection rates. A child infected with hookworm was an estimated 20 percentage points less likely to be enrolled in school than a noninfected child and 13 percentage points less likely to be literate. Bleakley's estimates suggest that because of the deworming campaign, a county with a 1910 infection rate of 50 percent would experience an increase in school enrollment of 3 to 5 percentage points and an increase in attendance of 6 to 8 percentage points, relative to a county with no infection problem. This finding remains significant when controlling for a number of potentially confounding factors, such as state-level policy changes and the demographic composition of high- and low-worm load areas. In addition, the author found no significant effects on adult outcomes, which, given the significantly lower infection rates of adults, bolsters the case that deworming was driving these findings.

Miguel and Kremer (2004) provide evidence on the impact of deworming on school participation through their cluster randomized evaluation of the Kenyan school-based deworming program. The authors found substantially greater school participation in schools assigned to receive deworming than in those that had not yet been phased in to the program. Participation increased not only among treated children but also among untreated children in treatment schools and among pupils in schools located near treatment schools. The total increase in school participation, including these externality benefits, was 8.5 percentage points.[13] These results imply that deworming is one of the most cost-effective ways of increasing school participation (Dhaliwal and others 2012). Figure 29.2 shows the cost-effectiveness of deworming in increasing school attendance across a range of development interventions.[14]

Academic Test Scores

In their study of the Kenyan deworming program, Miguel and Kremer (2004) did not find short-term effects on academic test scores.[15] However, the long-term follow-up evaluation of the same intervention (Baird and others 2016) found that among girls, deworming increased the rate of passing the national primary school exit exam by almost 25 percent (9.6 percentage points on

Figure 29.2 Cost-Effectiveness of Development Interventions in Increasing School Attendance



Sources: Hicks, Kremer, and Miguel 2015 based on data from Abdul Latif Jameel Poverty Action Lab.
Note: T–C = the difference between outcomes for those allocated to the deworming treatment group and those allocated to the deworming comparison group; km = kilometers; ext. = externality benefits. Some values are adjusted for inflation but the deworming costs are not. Deworming is costed at US$0.49 per child in Kenya. Some of these programs create benefits beyond school attendance. For example, conditional cash transfers provide income to poor households. The Jameel Poverty Action Lab cost-effectiveness calculations for school participation include conditional cash transfers as program costs.

a base of 41 percent). Ozier (2014) found test-score gains for children younger than age two years at the time of the program.

In the long-term follow-up of the cluster randomized Uganda deworming program, Croke (2014) analyzed English literacy, numeracy, and combined test scores, comparing treatment and control. The study found that children in treatment villages have significantly higher numeracy and combined test scores compared with those in control villages; effect sizes across all three outcomes range from 0.16 to 0.36 standard deviations. The effects were significantly larger for children who were exposed to the program for multiple years.[16]

Labor Market Effects

Bleakley (2007) used data from the 1940 U.S. census to compare adult outcomes among birth cohorts who entered the labor force before and after the deworming campaign in the U.S. South. Adults who had more exposure to deworming as children were significantly more likely to be literate and had higher earnings as adults. The author found a 43 percent increase in adult wages among those exposed to the campaign as children. Given initial infection rates of 30 percent to 40 percent, hookworm eradication would imply a long-term income gain of 17 percent (Bleakley 2010).[17]

Children who were treated for worms in Kenya also had better labor market outcomes later in life. Baird and others (2016) considered women and men separately, given the different set of family and labor market choices they face. They found that Kenyan women who received more deworming treatment are more likely to grow cash crops and reallocate labor time from agriculture to nonagricultural self-employment. Treated men work 17 percent more hours per week, spend more time in entrepreneurial activities, and are more likely to work in higher-wage manufacturing jobs.

Baird and others (2016) estimated the net present value of the long-term educational and economic benefits to be more than 100 times the cost, implying that even policy makers who assume a small subjective probability of realizing these benefits would conclude that the expected benefits of MDA exceed their cost.

Based on these increased earnings, the authors computed an annualized internal rate of return to deworming of 32 percent to 51 percent, depending on whether health spillovers are included. This finding is high relative to other investments, implying that deworming is cost-effective on economic grounds, even without considering health, nutritional, and educational benefits.

Furthermore, because deworming increases the labor supply, it creates a fiscal externality though its impact on tax revenue. Baird and others (2016) estimated that the net present value of increases in tax revenues likely exceeds the cost of the program. The fiscal externalities are sufficiently strong that a government could potentially reduce tax rates by instituting free mass deworming.

EVIDENCE AND POLICY DECISION RULES

This section argues that available evidence is sufficient to support deworming subsidies in endemic regions, even if the magnitude and likelihood of program impacts realized in a given context are uncertain.

When assessing evidence, there will always be some uncertainty about whether an intervention will have benefits in a given context. First, any body of research risks two types of errors: identifying an impact that does not exist (type 1 error), and missing an impact that does exist (type 2). The risk of making a type 1 error is captured by the confidence level (*P*-value) on estimates of impact. The risk of making a type 2 error is captured by the power of the study. Second, questions about the extent to which a body of research applies to the specific context of interest to policy makers will always arise.

Some (for example, Taylor-Robinson and others 2015) contend that the evidence does not support investments in mass deworming. One area of disagreement is the decision rule used. The decision rule the *Cochrane Review* seems to implicitly apply is that programs should not be implemented unless a meta-analysis (with all its associated assumptions) of randomized controlled trials shows benefits and indicates that the risk of a type 1 error is less than 5 percent. This approach is inconsistent with policy making from both a cost-effectiveness and a public finance perspective.

This decision rule puts no weight on the risk of making a type 2 error, which may be quite important for policy makers who do not want to deny a potentially highly beneficial program to their constituents. Given the statistical tradeoff between type 1 and type 2 errors, the desire to avoid withholding treatment with potentially very high benefits will necessitate being comfortable with less-than-definitive proof about program impact. Note that Taylor-Robinson and others (2015) did not report power, but that Croke and others (2016) found that Taylor-Robinson and others (2015) did not have adequate power to rule out effects that would make deworming cost-effective.

A more reasonable policy rule under uncertainty would be to compare expected costs with expected benefits. Suppose that the costs of the program are known to be *C*. Suppose policy makers are uncertain about the benefits of the program (relative to not implementing the program) in their circumstances. For simplicity, consider an example in which they believe that the total benefits may be B_1 with probability P_1, B_2 with probability P_2, or B_3 with probability P_3. This framework encompasses the case in which policy makers believe that there is some chance of zero impact because B_3 could equal zero. A risk-neutral policy maker will undertake the program if[18]

$$P_1 \times B_1 + P_2 \times B_2 + P_3 \times B_3 - C > 0.$$

With this framework in mind, from a cost-effectiveness perspective, deworming would still be warranted in many settings on educational and economic grounds alone, even if its benefits were only a fraction of those estimated in the studies discussed. Policy makers would be warranted in moving ahead with deworming, even if they thought benefits were likely to be smaller in their own context or had some uncertainty about whether benefits would be realized at all. In particular, even if the policy maker believes the impact of deworming on school participation is only 10 percent of that estimated in Miguel and Kremer (2004), or equivalently, if the policy maker believes there is a 10 percent chance of an impact of the magnitude estimated by Miguel and Kremer (2004), and a 90 percent chance of zero impact, it would still be among the most highly cost-effective ways of boosting school participation (Ahuja and others 2015). If the impact on weight is even 3 percent of that estimated by Croke and others (2016), then deworming is cost-effective relative to school feeding in increasing weight. If the labor market impact were even 1 percent of that found by Baird and others (2016), then the financial benefits of deworming would exceed the cost. Of course, to the extent that deworming may affect multiple outcomes, deworming will be even more cost-effective.

An analogous expected-value approach would be natural in a welfare economics framework. Labor market effects half as large as those estimated in Baird and others (2016) would be sufficient for deworming to generate enough tax revenue to fully cover its costs.[19] Standard welfare economics criteria for programs being welfare improving are much weaker than for the tax revenue fully covering costs.

From either a cost-benefit or a welfare economics perspective, a sophisticated analysis would be explicitly Bayesian, taking into account policy makers' previous assumptions and their best current assessment of their specific context. Under a Bayesian analysis that places even modest weight on evidence discussed here, mass school-based deworming would be justified in areas with worm prevalence greater than the WHO thresholds.

It is worth noting that a Bayesian policy maker will make current policy decisions based on current information. However, the policy maker would also continue research if the expected benefits outweigh its costs; as new evidence becomes available, it would be systematically combined with the existing best information when making decisions about continuing or modifying the program.

COST OF MASS TREATMENT PROGRAMS VERSUS SCREENED TREATMENT

The WHO recommends mass treatment once or twice a year in regions where worm prevalence is greater than certain thresholds (WHO 2015). Screening, followed by treatment of those testing positive for worms, is far less practical and more costly than mass treatment without diagnostic testing.

School-based mass treatment costs approximately US$0.30 per child per treatment, including delivery costs (GiveWell 2016).[20] Diagnosis of worm infections, in contrast, is far more expensive and complicated. Speich and others (2010) estimate that the cost per child of the Kato-Katz test, the most widely used field test for worm infections, is US$1.88 in 2013 dollars. If the test works perfectly, costs would be more than seven times higher with treatment following screening, compared with mass treatment without screening. Even proponents of the test-and-treat approach acknowledge this huge differential; Taylor-Robinson and others (2015) stated that screening is not recommended by the WHO because screening costs 4–10 times the cost of treatment. Mass treatment is clearly preferred on cost-effectiveness and public finance grounds.

These figures ultimately underestimate the cost of screening, however.[21] First, tests for worms do not identify all infections. Estimates of the specificity for the Kato-Katz method range from approximately 52 percent to 91 percent (Assefa and others 2014; Barda and others 2013). With a specificity of 52 percent, the cost per infection treated would be much higher for screened treatment compared with mass treatment. Second, a large number of infections would remain untreated. With low specificity, many existing infections would be missed; additionally, screened treatment programs need to reach infected children a second time to treat them, and it is unlikely they can reach each child who was tested—making screening even less cost-effective.

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

This chapter considers the cost of school-based mass deworming programs, which are particularly inexpensive per person reached. We do not consider the cost-effectiveness of more expensive community-based programs that would include extensive outreach efforts beyond schools. One reasonable hypothesis might be that these more intensive efforts may be most warranted in areas with either high prevalence, and thus likely high intensity, of STHs, or where multiple diseases, such as lymphatic filariasis, onchocerciasis, trachoma, and schistosomiasis, that can be addressed by MDA are endemic (Hotez and others 2007).

CONCLUSIONS

Recent estimates suggest that nearly one-third of children in low- and middle-income countries are treated for worms, many via school- or community-based programs (Uniting to Combat Neglected Tropical Diseases 2014). The most commonly used deworming drugs—albendazole, mebendazole, and praziquantel—have been approved for use by the appropriate regulatory bodies in multiple countries, have been shown to be efficacious against a variety of worm infections, and have minimal side effects (Bundy, Appleby, and others 2017).

The impact of deworming will vary 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 decision to expend resources on deworming should be based on a comparison of expected benefits and costs, given the available evidence. Our analysis of evidence from several contexts on the nutritional, educational, and economic impact suggests that the WHO recommendations for mass treatment are justified on both welfare economics and cost-effectiveness grounds. Additional studies will generate further evidence to inform future decisions.

DISCLAIMERS

USAID and the Douglas B. Marshall, Jr. Family Foundation support deworming. Michael Kremer is a former board member of Deworm the World and is currently Scientific Director of Development Innovation Ventures at USAID. Also, Amrita Ahuja is a board member of Evidence Action, a nonprofit organization that supports governments in scaling mass school-based deworming programs; this is a voluntary position with no associated remuneration. None of these organizations had any influence on this chapter.

NOTES

This chapter draws significantly on Ahuja and others (2015).

World Bank Income Classifications as of July 2014 are as follows, based on estimates of gross national income (GNI) per capita for 2014:

- Low-income countries (LICs) = US$1,045 or less
- Middle-income countries (MICs) are subdivided:
  a) lower-middle-income = US$1,046 to US$4,125
  b) upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

1. For further discussion of biological differences across worms, as well as a broader discussion of deworming, please refer to Bundy, Appleby, and others (2017).
2. See, for example, Hall and Horton (2008), GiveWell (2013), and Abdul Latif Jameel Poverty Action Lab (2012).
3. Bundy, Appleby, and others (2017) provide a discussion of Taylor-Robinson and others (2015).
4. Epidemiological externalities are benefits that accrue to individuals who did not necessarily receive the treatment, for instance, a drug that cures treated individuals, thereby reducing transmission of the disease to others.
5. We do not address the optimality of the WHO prevalence thresholds for MDA.
6. Miguel and Kremer (2014) provide an updated analysis of the data in Miguel and Kremer (2004), correcting some errors in the original paper. Throughout this chapter, we cite Miguel and Kremer (2004) but use the updated numbers, where appropriate.
7. Although they do not explicitly explore externality impacts, several medical studies also show decreases in infection rates among untreated individuals (Miguel and Kremer 2004).
8. See Dupas (2014), Kremer and Glennerster (2011), Kremer and Holla (2009), and Abdul Latif Jameel Poverty Action Lab (2011) for reviews of the literature on the impact of prices on adoption of health interventions.
9. As discussed in more detail in Bundy, Appleby, and others (2017), Croke and others (2016) argued that an influential earlier study (Taylor-Robinson and others 2015) was underpowered to reject the hypothesis that MDA is cost-effective in increasing weight. Croke and others (2016) doubled the sample of 11 estimates of the effect of multiple-dose MDA for worms on weight and updated some of the estimates in Taylor-Robinson and others (2015), for example, by using micro-data provided by the original trial authors.
10. Hall and others (2006) conducted a cluster randomized study of the impact of deworming on health and test score outcomes in Vietnam. Because there is no publicly available version of this paper, we do not discuss this study in detail.
11. This measure includes the direct impact on the treated, as well as indirect impacts accruing to the untreated, population.
12. A parish is an administrative division in Uganda comprising several villages.
13. A two-part reanalysis (Aiken and others 2015; Davey and others 2015) questioned some aspects of this study. However, several independent analysts have cast doubt on the methods and conclusions of the reanalyses, and concluded that the studies leave the case for deworming fundamentally unchanged (see, for instance, Berger 2015; Clemens and Sandefur 2015; Healthcare Triage 2015; and Ozler 2015).
14. Several early studies assessed the impacts of deworming on school attendance, using individually randomized evaluations. For example, Simeon and others (1995) studied treatment among Jamaican children ages 6–12 years; Watkins, Cruz, and Pollitt (1996) studied treatment of children ages 7–12 years in rural Guatemala; and Kruger and others (1996) studied treatment of children ages 6–8 years in South Africa. None of these studies found an impact on school attendance. However, any gains are likely to be underestimated since these are individually randomized studies that do not consider treatment externalities. In addition, attendance in the Watkins, Cruz, and Pollitt (1996) study was measured through the use of school register data, which is unreliable in many low-income countries and which excluded any students who 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. There is also the potential for school officials to overstate attendance because of their awareness of the program and the data collection.
15. Hall and others (2006) similarly found no impact on test scores of deworming in Vietnam. As noted previously, there is no publicly available version of this paper, so we do not discuss this study further.
16. The original deworming trial was conducted in 48 communities in five districts in Eastern Uganda. Croke (2014) used educational data collected by the Uwezo project. The Uwezo survey randomly sampled communities and households from all five of these districts, creating in effect a random subsample of communities from the original trial. Croke (2014) provided evidence that the sampling of communities by Uwezo was effectively a random sample of the original trial clusters by showing that the communities have no statistically significant differences across a wide range of variables related to adult outcomes. To further support his econometric identification strategy, Croke (2014) explored 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 years, would have never received the program. One would expect that if effects are truly from the deworming intervention, the impacts would be lower at the two extremes and higher for children in the middle age group, which is what the study found.

17. Two earlier studies looked at the relationship between deworming and labor market outcomes using nonrandomized methods. Using a first-difference research design, Schapiro (1919) found wage gains of 15 percent to 27 percent on Costa Rican plantations after deworming. Weisbrod and others (1973) observed little contemporaneous correlation in the cross-section between worm infections and labor productivity in St. Lucia.
18. This abstracts from curvature of the utility function. Because deworming is inexpensive, and there is no evidence that deworming has serious side effects; because there is evidence for large effects in some cases; and because those with the highest-intensity infections are likely to be poorer than average, risk-averse policy makers or those concerned with equity would be more willing to institute mass deworming than this equation implies.
19. This estimate is conservative, only taking into account direct deworming benefits and ignoring positive externality benefits.
20. GiveWell (2016) calculates the cost of deworming for STHs in India to be US$0.30 per child per treatment, which includes both drug and delivery costs, including the value of staff time.
21. Another screening approach could be to simply ask individuals if they have experienced any of the common side effects of worm infections. Although this screening method is cheaper and potentially useful in environments where stool testing is not practical, it is likely to be very imprecise.

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