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IS MASS DEWORMING A VIABLE AND COMPETITIVE METHOD TO IMPROVE WELFARE IN DEVELOPING COUNTRIES?

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ABSTRACT

Recently, school-based mass deworming programs have been increasingly employed in developing countries as a tool to improve health, education, and prosperity. With international support from the World Health Organization, these initiatives have attempted to reduce the detrimental developmental threat that intestinal worms pose to nearly one billion school-aged children. The body of research focused upon the future welfare impacts on countries and individuals subjected to these programs has surged in the new millennium. Economists have utilized the various health and labor market outcomes associated with deworming programs in an attempt to estimate their effect on developing economies. This paper attempts to provide a comprehensive review of the literature surrounding mass deworming programs. Bringing together studies of various time periods and locations, the question of whether these programs are feasible and effective across the range of circumstances found in developing regions is explored. Beyond their own evaluation, school-based mass deworming programs are then compared to like-minded policies undertaken in developing regions, in an attempt to understand the relative cost-efficiency with which mass deworming achieves its goals. This review aggregates the findings of many studies to support the notion that mass deworming programs are a viable and comparatively efficient method to improve welfare in developing countries.

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Chapter 1

Introduction: Why Worms?

Intestinal worms (also known as intestinal helminths) infect approximately 2 billion people worldwide, of which more than 850 million are school-aged children (Ahuja et al., 2015; Baird et al., 2016). The World Bank ranks helminth infection as causing more ill health in children aged 5–15 years than any other infection (Taylor-Robinson, Jones, and Garner, 2009). These parasitic infections are among the most common infections worldwide, and affect the poorest and most deprived countries. Whether they are soil-transmitted helminths (STHs) or transmitted through infected water sources (schistosomiasis), these worm infections fall under the category of 'Neglected Tropical Diseases' (NTDs) and constitute the majority of the billions of NTD cases worldwide (Hotez et al., 2007). NTDs are a diverse group of communicable diseases that are prevalent in tropical and subtropical countries and constitute large burdens on the health and economic development of low-income countries (Hotez et al., 2007). Traditionally, NTDs have carried a low priority on donor agendas compared to more well-known diseases such as malaria, although the benefits of preventing these diseases are similar (examined in Chapter 4).

The economic significance of these intestinal worm infections will be explored in this paper, and a basic understanding of the symptoms of helminth infection is helpful in connecting the health consequences to the related economic shortcomings. Studies have shown associations between helminth infection with under nutrition and iron deficiency anemia, as well as long-run negative impacts such as stunted growth, poor school attendance, and cognitive development

(Hotez et al., 2007; Ozier, 2014). While short-run symptoms are unpleasant, very few people die as a direct result of helminth infection (Hotez et al., 2006). Instead, the true consequences of infections are realized in the long-run, as physical and cognitive development are stunted and productivity is lowered. While their lives are usually not endangered, helminth-infected individuals face serious reductions in their future earnings and quality of life (Baird et al., 2016).

To attempt to prevent such reductions, programs designed to control and eliminate intestinal worm infections in developing countries have been established, focused on guidelines set by the World Health Organization (WHO). Explored later in this paper, the process of widespread community treatment through ‘preventative chemotherapy’ has been favored by the WHO over other methods of treatment, such as a ‘screened treatment’ method which requires individual diagnosis before treatment. These widespread treatment programs are labeled ‘mass deworming’ programs, and beyond the direct alleviation of symptoms, thse programs enjoy the added benefit of positive externalities (Miguel & Kremer, 2004). For example, in one study where only schoolchildren were dewormed, the authors found large spillovers within the community; in terms of school attendance, children in dewormed areas who were not actually given medication still received around 60% of the benefits of direct deworming (Ozier, 2014). Such externalities provide powerful benefits to developing economies, and while they may be difficult to quantify, estimations have shown their effectiveness in magnifying labor market outcomes and future earnings for mass-dewormed economies (Baird et al., 2016).

WHO-endorsed programs target school-aged children (or younger) for three main reasons. The first reason is that the most severe long-run consequences of infection are magnified in young children’s ‘sensitive period’ of physical and cognitive development (Ozier, 2014). Health shocks incurred from helminths in early childhood can permanently transform an individual's potential lifetime health, earnings, and cognition (Ozier, 2014). Beyond the youngest children, the long-run detrimental effects of infection are minimized. The second reason for targeting school-aged children is that they are the most at-risk group, due to comparatively worse hygiene habits and higher exposure to infection sources than older individuals (Ozier, 2014). The final factor in focusing on school-aged children is that schools provide existing infrastructure and a skilled workforce (in nurses) for these programs, as children are congregated in one place to ease the delivery of treatment. In preventing the adverse effects of helminth infections, the health benefits of mass deworming programs have been shown to translate to quantifiable economic benefits (Bleakley, 2010; Baird et al., 2016).

To best understand the economic importance of mass deworming programs, the concept of a 'poverty trap' must first be understood. A poverty trap is a self-reinforcing mechanism which causes poverty to persist. These traps can span generations, are commonly found in the developing world, and can arise as a result of many different factors – health, education, governance, location, and more. Poor education systems coupled with poor health and nutrition can leave children to grow up worse off than their parents, and eventually raise children that will be worse off than themselves. Intestinal parasites serve as a health barrier in Sub-Saharan Africa and other developing regions, and are one of many factors in these poverty traps, as they cripple the productivity of entire nations. Not only is Africa the poorest region in the world, but it was also the only major developing region with negative growth in income per capita during 1980-2000 (Sachs et al., 2004). As these African countries' economies stagnated, their populations continued to grow, resulting in a lower quantifiable quality of life for each citizen.

In health-barrier poverty traps, sick and fatigued individuals find themselves unable to go to school or work, which stunts their potential for economic prosperity, which leaves them unable to afford treatment for their diseases, which leaves them unable to go to school or work. To escape this individual and societal stagnation, laborers require both intellectual and physical skills that favor higher productivity that infected people cannot attain. One step towards escaping such poverty traps may be to control the high levels of worm infection rates in developing countries.

Addressing this, the studies explored in this paper have found evidence that such deworming programs can have direct fiscal benefits for governments as well as their citizens (Baird et al., 2016). Through positive externalities, mass deworming programs benefit every member of a treated community, whether they have received drugs or not. Such externalities and governmental budget growth can help to ensure a higher quality of individual cognitive development and health, which creates more educated and productive workers that can then give back to their economy, which can result in a government being able to ensure basic health. With each treated generation, these poverty-trapped economies could climb out of destitution and potentially become attractive for outside investment, such as becoming the destination for outsourced manufacturing jobs. At this milestone, a developing economy can become globalized and escape a poverty trap once perpetuated by health barriers.

In the face of such optimistic outcomes, there are definitely dubious aspects to such a productive program. Along with the economic benefits of deworming that will be explored, many behavioral economics-related and policy-related barriers that complicate the implementation of mass deworming programs will be considered. High sensitivity to the cost of treatment, difficulty in instilling habitual worm prevention behaviors, and low individual valuation associated with deworming are all problems that a government may face when attempting to implement a nationwide program (Kremer & Miguel, 2007). These barriers further complicate the escape from poverty, as people have shown their disinterest in contributing to sustaining deworming programs. This results in governments bearing the full cost of initiating and upholding treatment programs.

Even if programs are implemented, their sustainability must be ensured to reap the full long-term benefits of deworming. Sustainability entails funding, which many of these trapped countries cannot afford to allot. Organizations such as the World Health Organization and pharmaceutical companies such as GlaxoSmithKline currently donate money and medications to sustain these programs, yet the cost-effectiveness in achieving goals such as school participation and increased labor outcomes must be ensured to entice others (WHO, 2011). The WHO has stated that its goal of deworming 75% of school-aged children across the world has not been met (~58% STH and 28% schistosomiasis coverage as of 2015), and other organizations have admitted that they would benefit from more funding (WHO, 2016; Deworm the World Initiative, 2016). With each country afflicted by worm infection comes different policy and economic barriers, which must be considered in depth before installing deworming programs. The nature of poverty traps ensures that aid efforts will fail unless they are fully enforced and sustained until the country can provide the services themselves, which suggests that full confidence must be attained before outside commitment to fund deworming programs.

A thorough analysis of mass deworming, from theory to policy implementation to economic impact, will shed light on the viability of these programs as a tool to increase welfare, productivity, and possible future nationwide progress towards escaping poverty traps. Expanding on their economic impact, the evaluation of mass deworming programs' cost-effectiveness will serve as evidence for or against the implementation and sustenance of programs by outside organizations and governments. Finally, such evidence can be used as a comparative tool to gage the effectiveness of mass deworming programs in achieving various goals in comparison to other like-minded policies.

Chapter 2

Background on Mass Deworming

With an issue such as intestinal worms, where the epidemic encompasses cultures and communities around the world, there is the potential to test the effects of mass deworming across a multitude of different environments. Many economists and sociologists have done just this, and have either built upon existing work or replicated studies in different settings. A prime example of this is the work of Miguel and Kremer (2004), cited by 1,587 articles at the time of this writing, including those discussed in depth throughout this paper. In order to present a thorough background of the research involving deworming, I will present a brief history of mass deworming programs that have preceded work such as Miguel and Kremer (2004). Afterwards, I will review this study first and proceed to subsequent literature that rests upon or replicates this "foundation" study.

Chapter 2.1 - A Brief History of Deworming

While the formal study of deworming programs has mainly developed within the past century, the consequences of intestinal worms have been recorded for millennia. A confirmed infection with intestinal worms dates back to Egypt over 3,000 years ago, and the parasites have been suspected of influencing biblical happenings, such as the cursing and desertion of Jericho over 3,400 years ago (Sandbach, 1976). While history has noted the existence and possible impact of intestinal worms, true study into these worms obviously could not commence until they began to be discovered in the early 19th century (Sandbach, 1976). At this point, the importance of these worms was understood and they became some of the most intensely studied parasites. Once schistosomiasis, a disease caused by intestinal worms which is targeted by modern deworming programs, was discovered in 1852, over 10,280 citations of the disease were recorded in the following 110 years (Sandbach, 1976).

Beyond the history of the worms themselves, the timeline of mass deworming initiatives is comparatively short. Although mass deworming programs had been initiated in 1910, one of the first studies devoted to the economic benefits of intestinal worm eradication was Schapiro (1919). The study focused upon a plantation in Costa Rica on which almost every laborer was infected with hookworm, a helminth targeted by modern deworming programs as well. After treatment, approximately 10% remained infected, and after six months, laborer productivity had increased by 15-30% and the amount of land cultivated increased by 50% the following year (Schapiro, 1919).

The first widely studied mass deworming program was implemented by the Rockefeller Sanitary Commission (RSC) in the United States at the beginning of the 20th century, funded by a $1 million donation from John D. Rockefeller. The RSC aimed to examine the truth behind claims that the wealth disparity in the North and South was accompanied by a similar disparity in health, with worm infection being a specific cause of such inequality. Hookworm infected 40% of Southern schoolchildren, and was labeled as the “Germ of Laziness”, due to the infected person’s reduced ability to work or study (Bundy, 2013).

The RSC initiated large-scale treatment (with now-outdated drugs), and monitored resulting health and education outcomes over the span of the 5-year intervention. The records kept by the RSC were so well-kept that a re-analysis of the data was performed by Bleakley

(2007) over 100 years later. Explored later in this paper, Bleakley (2007) uses the RSC data along with 1940 US Census data (30 years after RSC's initiative) to find that hookworm infection may have accounted for around half of the literacy gap and 20% of the income gap between the North and South at the time. After successfully eradicating hookworm infection in the South, the RSC became the Rockefeller International Health Division (IHD), with a primary goal of reducing diseases that stunted developing countries' economic growth by reducing the productive capacity of its citizens. This led to a rapid eradication of hookworm in British Guiana by the IHD, yet a change in leadership in the following years saw the IHD shift towards research rather than aid.

The RSC deworming campaign in the US was among the last to be conducted in a high-income country, and was followed by a lull in interest in worms and other 'diseases of the poor', until interest resurged after World War II (Bundy, 2013). In 1947, the President of the American Society of Parasitology titled his inaugural address "This Wormy World" to address the post-WWII phenomenon of soldiers returning home to the US and Europe with worms acquired overseas. With 'diseases of the poor' arriving in the home of the rich, worms were 'important' again, yet the available outdated treatments were labeled with "poor efficacy and worrisome toxicity" (Bundy, 2013).

In the 1980's, several drugs developed for veterinary use would be found to be highly effective against worms in humans; these drugs included albendazole and praziquantel, the two drugs used in the deworming studies reviewed in subsequent chapters (Olds, 2013). These drugs were safe enough to be delivered without individual diagnosis of worms, highly effective in curing and reducing transmission of worms, and cheap enough (around $0.22 per combined dosage) for the World Health Organization (WHO) to endorse mass school-based deworming programs in highly infected areas (WHO, 1987). In the following years, programs following guidelines recommended by the WHO were undertaken in various developing countries, such as Kenya and Uganda. These programs would then be studied by economists and sociologists in an attempt to finally be able to research the effects of mass deworming programs.

Chapter 2.2 - Mass Deworming Studies

The first such study is a 2004 paper by Miguel and Kremer, in which they analyze data garnered from the Primary School Deworming Project (PDSP). Carried out in 1998 by a nonprofit Dutch organization (ICS), the project took place in Busia, Kenya, a region described as a poor and densely-settled farming area in western Kenya. Encompassing 75 schools with a total enrollment of over 30,000 students aged six to eighteen, the project split the schools into three equal groups and offered free deworming treatments. Due to financial constraints, ICS had to phase in the treatment program over a period of several years, in which Group 1 received free treatment alone in 1998, with Groups 1 and 2 receiving treatment in 1999, and finally all three groups enjoying free treatment in 2001. This phasing-in allowed for Miguel and Kremer to use the program in a stepped-wedge trial, which is a form of a randomized control trial where there is a sequential but random rollout of an intervention over multiple time periods. In 1998, Group 1 was the treatment group with Groups 2 and 3 being controls, while in 1999, Group 1 and 2 were both treatment groups with Group 3 remaining a control group. When considering the three groups, Miguel and Kremer (2004) found no statistically significant differences in the school groups' enrollment numbers, infection rates in surrounding areas, sanitation facilities, or other numerous variables that could have interfered with analyzing the treatment results. Therefore, any subsequent results could not be attributed to preexisting characteristics of the students.

After a year of treating only Group 1, the students in the treatment group experienced a lower infection prevalence of almost every tracked parasite when compared to their non-treated Group 2 counterparts, significant at a 99% confidence interval (Miguel & Kremer, 2004). Also relevant was the finding of no statistically significant difference between the three groups' major worm prevention behaviors – observed pupil cleanliness, proportion of pupils wearing shoes, or self-reported exposure to fresh water. This lack of significantly different behaviors lends support to the assumption that non-treatment factors, such as prevention education, were irrelevant compared to the effect of the drugs themselves.

In addition to this, they reason that the treatment programs were not necessarily 'efficient', because they did not treat based on intensity of infection. Due to the fact that treatment was administered at school, and heavy infection was a leading cause of school absenteeism, those that received treatment were not necessarily students most heavily infected, as those students were more likely to be absent during treatment (Miguel & Kremer, 2004). In the same vein, Miguel and Kremer (2004) estimates a cut-off cost of treatment, where students will only receive treatment if the benefit of treatment outweighs the associated costs, which are not necessarily monetary costs. For example, even in the case of free treatment, parents of poor students may be reluctant to give consent to treatment if they have not paid school fees and do not want to visit the school (Miguel & Kremer, 2004). These poor pupils may also be financially unable to maintain the same level of cleanliness as their peers, and may be more severely infected as a result.

With these findings in mind, Miguel and Kremer (2004) arrives at the hypothesis that gives the paper the relevancy needed to be the foundation for future research – the quantification of positive externalities associated with mass deworming programs. Beyond the direct treatment of students, the authors assert the existence of indirect and positive effects both within each school and extending across schools. This idea is the reasoning behind the widespread policy push for mass deworming as opposed to a much costlier case-by-case treatment of intestinal worms. As previously discussed, because the more severely infected children are no more likely to receive treatment through mass deworming, the program appears to not increase the attendance, health, and education of those that miss school the most. Miguel and Kremer (2004) combats this thought with their assertion of a spillover effect of positive benefits garnered from treatment.

Citing a parasitological survey of 557 children entering preschool (and therefore without any opportunity to receive treatment) in 2001, before Group 3 began treatment, Miguel and Kremer (2004) report that children entering preschool in Group 1 and 2 schools had a forty percent reduction in the proportion of moderate-to-heavy worm infections compared to Group 3 schools. Although none of the children had received treatment, their infection rates were lower if they were about to attend schools that had undergone mass deworming.

From a geographical perspective, the authors found a large radius for positive externality benefits across schools. If a school was not in Group 1 yet was within 3 to 4 kilometers of a Group 1 school, a statistically significant (at a 95% confidence interval) reduction in moderate-to-heavy infections of students in non-Group 1 schools was found (Miguel & Kremer, 2014). Miguel and Kremer (2004) estimates that by treating the Group 1 pupils, over nine percent of the pupils from the remaining groups would experience an elimination of infection. The estimation assumes that externalities only reach 3 to 4 kilometers due to scarcity of data in further locales, so the authors presume the externality effect to be even slightly greater than estimated.

Finally, the paper's last major point that has been built upon in following research is the tangible effect of mass deworming on school participation rates. Miguel and Kremer (2004) finds that deworming resulted in one quarter fewer absences throughout the year, by "allowing previously weak and listless children to attend school regularly or by improving children's ability to concentrate, which may have made attending school increasingly worthwhile relative to other activities, such as agricultural labor, staying at home, or fishing". In decreasing the amount of absences by one quarter, the authors deduce that with each treated pupil, there is an increase of at least 0.14 total years of schooling (between treated and untreated students) in the location studied (Miguel & Kremer, 2004). This finding is the basis of multiple subsequent studies, in which increased education is the foundation for more specific research concerning the benefits of mass treatment policies (Bleakley, 2010), (Baird et al., 2016).

Equipped with this value, Miguel and Kremer (2004) estimates the impact of mass deworming on future wage increases in children, and also explores the relationship between mass deworming and cognition (measured via test scores). Once again, they build further upon these estimations by extending the analysis to a cost and welfare evaluation, with attention to policy implementation. Much of the deworming research that came after this study has focused upon one or more of these findings. Many of these estimations made by Miguel and Kremer will be reviewed along with the research that has been done to support or refute them since 2004.

Focusing on test scores, many factors come into play when introducing a mass deworming treatment. Healthier students may enjoy a higher return to education per unit of time spent in class, as a result of decreased incidence of anemia, which negatively effects cognitive ability. Miguel and Kremer (2004) argues that this was most likely not influential in their Kenyan study, and that deworming may even have a negative impact on test scores due to increased class size. After reviewing their data, they come to the conclusion that the treatment did not have a strong effect, positive or negative, on the efficiency of learning per unit of time spent in school. In later studies done by Kevin Croke (2014) and Owen Ozier (2014), this position is challenged with assertions that deworming positively impacts cognition in the long-run. While Miguel and Kremer (2004) found that no immediate influence on test scores was present, later research found an impact that did not manifest until many years later.

Employing the same data as Miguel and Kremer (2004), Ozier (2014) reanalyzed the cognitive changes resulting from deworming. In 2009 and 2010, a field team in Kenya conducted cognitive assessments on 2,400 children that were infants during 1998 and 1999 mass deworming programs in their communities. Due to the randomized design the study in Miguel and Kremer (2004), Ozier (2014) was able to use the 2009-2010 data to act as an extension of the original study. This allowed for an analysis of infants at the time of the original study focused on how the programs came to eventually effect their cognitive development measured through test scores. While Miguel and Kremer (2004) utilized data from English, Mathematics, and Science-Agriculture exams, Ozier (2014) employed extensive tests pertaining to verbal fluency, memory, and reasoning.

In Ozier (2014), evidence is found that for infants under a year old, being raised in a dewormed community has a large and statistically significant (at a 99% confidence interval) long-run positive impact on cognition equivalent to 0.5 to 0.8 additional years of schooling. Through analyzing tests such as Raven's Progressive Matrices, which is a commonly used series of puzzles that tests nonverbal reasoning and general intelligence, Ozier (2014) distinguishes a profound long-term cognitive impact of deworming arising from the positive spillover effects of mass treatment. Ozier (2014) proposes a "sensitive period" in which infants are more receptive to the benefits of being raised in a dewormed community. To reinforce this finding, Ozier (2014) deducts that the positive impact found in infants under age 1 is not found in older children when their community is dewormed.

The Ozier (2014) findings rest upon the externality effects introduced by the 2004 study. While Miguel and Kremer (2004) analyzed the impact of increased school participation on cognition via test scores, they were unable to account for the positive deworming externalities that would influence infants (which were not the focus of the study) over a decade later. Whereas Miguel and Kremer (2004) focused on the more immediate gains from treatment, Ozier (2014) presented an argument focused around long-term benefits to community members, both treated and untreated.

To further illustrate the evidence of deworming positively affecting cognition, other studies have been conducted using different data sets from different regions of the world. Croke (2014) analyzed the long-run impact of a cluster-randomized trial in eastern Uganda that provided mass deworming to preschool aged children from 2000 to 2003. A cluster-randomized trial is a type of randomized controlled trial where groups of subjects are randomized instead of individual subjects. Croke (2014) mirrored the structure of Ozier (2014) by utilizing previous data to evaluate the long-term influence of deworming on cognitive ability. Between 10 treatment parishes and 12 control parishes, children aged 8-15 (who were aged 1-7 at time of treatment) were assessed. The treatment and control parishes were found to have no significant differences over a number of socioeconomic variables, including access to phones, radios, water, and electricity (Croke, 2014). Those raised in treated parishes scored considerably better (explored in Chapter 4.2) on numeracy and literacy tests than their untreated parish counterparts.

The difference between the two studies lies in Croke (2014) asserts a direct ‘treatment on treated (TOT)’ impact on young children being treated to complement the Ozier (2014) indirect ‘spillover’ community benefit. The children in Croke (2014) were treated and impacted individually as opposed to the Ozier (2014) externality effect. By combining the findings of the two studies, it can be reasoned that mass deworming has both direct and indirect positive effects on individuals in communities, and especially infants, in the long-run.

Although Miguel and Kremer (2004) did not uphold a relation between deworming and test scores, future research filled in the gaps by assigning the benefits to the younger generation, which is realized only after multiple years have passed. With the link between deworming and cognitive benefits affirmed, it is possible to continue to review the inquiries about deworming’s impact on future wages.

Ozier (2014) combines two previous studies pertaining to cognition increases and future wage increases to apply the findings to its own. In doing so, Ozier (2014) finds that deworming can increase future wages by 12.5 percent to 83.3 percent. Incorporating dollar terms, Ozier (2014) finds that the net present value of lifetime earnings of a typical western Kenyan individual is $1509.96. Using the most conservative estimate of future wage increase (12.5%), this results in an increase in lifetime earnings of over $180. The significance of this increase goes beyond individual well-being into the realm of government benefit, which will be discussed later in Chapter 3.3. For a brief summarization of the studies presented in this chapter, see Table 1.

Table 1. Summary of Ch. 2 Study Findings

Study	Summary	Key Findings
Miguel & Kremer (2004)	"Foundation" study on 1990's Kenyan program, built upon by later studies.	• Found deworming increased school participation. • Found substantial positive externalities. • Could not find significant impact of deworming on test scores.
Ozier (2014)	Follow-up 10 years later using same data as Miguel & Kremer (2004), studied long-run cognitive impacts of the deworming program and resulting impacts on future earnings. Focused on externality' "spillover" benefits.	• Found significant long-run positive impact from deworming on cognition. • Found 12%-83% increase in future wages by exploiting cognition and externality benefits.
Croke (2014)	Studied early 2000's Ugandan program. Mirrored Ozier (2014) structure to study long-run cognitive impact of deworming programs using follow-up data. Focused on direct benefits instead of "spillovers".	• Found direct "treatment on treated" increases in cognition to complement Ozier (2014) 'spillover' increases.

Chapter 3

Is Mass Deworming a Viable Strategy to Improve Welfare?

While the body of work pertaining to mass deworming continues to grow as different societies and time periods are analyzed, most studies reaffirm the original conclusions asserted about both the effect of intestinal worms and the effectiveness of mass treatment. Intestinal worms induce predictable symptoms that have been shown to be detrimental to young children in both a short and long-term manner. While mass deworming programs have shown to be effective in reducing infections and creating positive externalities, the exact welfare benefits to a specific society may be hard to quantify. In addition, while consequential, these intestinal worm infections rarely cause death, with an estimated 0.0014% to 0.08% of the infected population dying due to these infections each year (Hotez et al., 2006). Finally, mass deworming programs ultimately use money to administer drugs to uninfected individuals as well. These facts leave policymakers (governments and organizations such as the WHO) with the decision to justify the costs of mass deworming programs or opt for alternate means of improving collective welfare.

In this chapter, I will first answer the question: Is mass deworming a viable strategy to improve welfare? This will delve into studies of cost-effectiveness, future welfare analysis, and sustainability. Afterwards, in Chapter 4, I will answer a second question: Is mass deworming a competitive strategy to improve welfare? In doing so, I will explore alternate strategies and their impact on welfare.

In 2008 the Copenhagen Consensus, described as “a think tank that researches the smartest solutions to the world’s biggest problems, advising policy-makers and philanthropists how to spend their money most effectively", sponsored an event (Center, 2008). This event, paneled by 8 distinguished economists, set out to find the most cost-effective ways to advance global welfare with a focus on developing countries. Among 30 considered solutions, mass deworming programs were ranked sixth overall and first in the category of educational solutions (Center, 2008). While saving comparison for Chapter 4, the Consensus asserted the favorable sustainability and benefit-to-cost of mass deworming programs. These characteristics can therefore be assumed to be paramount in determining the viability of welfare-increasing plans, including mass deworming programs.

Chapter 3.1 - Sustainability of Mass Deworming

To be effective, deworming drug treatment must be continued twice per year indefinitely due to the rapid reinfection rates in most communities resulting from constant exposure to infection sources (Kremer & Miguel, 2007). Funding towards efficient mass deworming programs must therefore go towards sustainable long-term plans. As the impact of mass deworming has become more widely understood, much attention has been given towards determining the most efficient usage of funds allocated for treatment programs.

The methods to achieve sustainability in aid programs have been widely debated for decades. In the mid 1900's, emphasis was placed on capital investment and infrastructure development to launch countries into self-sustaining growth (Rostow, 1960). Shortly after, the focus turned to creating better economic environments by reducing tariffs and attempting to keep inflation rates low. In more recent times, this method was discarded in favor of efforts to create "locally sustainable" programs in which start-up funds are supplied by governments or donor organizations, and can then continue without external support (Kremer & Miguel, 2007). This current ideology suggests multiple “sustainable” strategies for deworming communities, such as cost-sharing, health education, and “verbal commitment” plans. For these methods to be effective, a voluntary effort to sustain deworming treatment must be taken on by local communities and governments. In these situations, the benefit of being worm-free must outweigh the cost associated with taking additional voluntary action. Kremer and Miguel (2007) studies the feasibility of such plans, calling upon their previous study in Kenya.

In Kremer and Miguel (2007) the impacts of three different “sustainable” programs for mass deworming are analyzed. The first is a cost-sharing program, in which a small fee is charged for deworming drugs. This program ultimately aims to implement a user fee for treatment by which the local governments can generate revenue, which can then be reinvested into the program to slowly phase out external support. Cost-sharing is a popular practice in many less developed countries’ health sectors, such as Kenya. This is because cost-sharing theoretically raises government revenue and allocates scarce resources to those who need them most, as the most afflicted individuals should be most willing to pay for treatment. Implemented in the Miguel and Kremer (2004) Kenyan study, the program allocated outside non-profit funds towards providing free deworming drug treatment in schools for two to three years, and afterwards had 25 randomly-selected schools undertake cost-sharing.

When cost-sharing was implemented, the effective cost faced by each family in the chosen schools amounted to one fifth of the total price of treatment (Kremer & Miguel, 2007). This amounted to only thirty cents per family, yet reduced the amount of students participating in treatment by 80%, from 75% of children in the schools down to 19% (Kremer & Miguel, 2007). The sensibility to an introduction of a price for treatment is evidently very high, yet Kremer and

Miguel (2007) find that any fluctuation in price is irrelevant; the idea of having to pay anything at all is more of a deterrent for individuals than the actual price itself. In addition, after administrative costs, generated revenue was miniscule and cost-sharing's theoretically efficient allocation of drugs to sick students was not replicated in reality. The drop in treatment participation mirrored similar drops in other chronic disease prevention/treatment products when fees were introduced, such as bed nets for malaria or water treatment (Ahuja et al., 2015). In rural Kenya, Cohen and Dupas (2010) finds that the uptake percentage for fully subsidized malaria bed nets is 99%, but a small reduction to a 90% subsidy decreases uptake to only 10%. Kremer et al. (2009) records only a 10% uptake when water disinfectant was subsidized by 50% in Kenya. These findings suggest that most households in Kenya have a high price elasticity of demand (sensitivity to changes in price) for these goods. The individuals in the 2004 Kenyan study placed little value on deworming drugs, and valued other products and actions above deworming treatment.

To further examine the shortcomings of the cost-sharing method, another explanation for such extreme price elasticity can be found from the concept of "Zero as a Special Price" from Shampanier Mazar, and Ariely (2007), which deals with a behavioral economics evaluation of the true value of free products. Relating to decisions about free (zero price) products, the study proposes that people do not simply subtract costs from benefits (as they would in normal cost-benefit-centered decision-making). Instead, they perceive the benefits associated with free products as higher. The Shampanier et al. (2007) concept states that when humans see the word 'free', the actual value of the product is not considered, including any negative consequences. This results in people appearing to act as if zero pricing of a good not only decreases its cost, but also adds to its benefits (Shampanier et al., 2007). In the case of deworming, individual's cost-benefit analyses may be influenced by this concept as they forget about negative consequences (fears, superstition, cost of traveling to treatment) that might have stopped them when faced with even a miniscule cost for treatment. In addition, they may have an inflated demand for this ‘free’ treatment if they perceive the benefits as being amplified when treatment is ‘free’.

An additional explanation for such objection to any imposed cost of treatment may arise from the notion of a “free rider” problem. A “free rider” problem pertains to public goods in which people do not ‘chip in’ to support the public good, but can still benefit from it, thus they receive a ‘free ride’. These public goods are non-excludable (there is no way to exclude people from using it) and non-rivalrous (one person’s usage does not restrict other individuals’ usage). Examples of such goods are lighthouses, streetlights, and national defense. Pertaining to deworming, the positive externalities are both non-excludable and non-rivalrous, and therefore deworming programs present the incentive for people to not support these programs yet still benefit from them. In their personal cost-benefit analyses, it may be rational for parents to save their money (if asked to pay for their child’s treatment) and simply receive the potent positive externality benefits anyway. Ultimately, if every parent decided this was the rational choice, there would be no funding and no benefit for any member of the community. From a sustainability standpoint, such behavior suggests pessimistic outcomes for seeking community support in funding mass deworming programs.

Another proposed sustainable plan is health education, which was also implemented and analyzed in the Kenyan study. In schools participating in the drug treatment program, students were also educated in worm prevention. Two teachers in each school attended a full-day training session on worm prevention, and were instructed to teach these lessons to students during school. In addition to these lessons, each treatment school was visited several times each year by an experienced nonprofit organization team, led by a trained public health technician. The program emphasized three main worm prevention behaviors: hand washing, wearing shoes, and avoiding infected fresh water (Kremer & Miguel, 2007).

Administrators of the study specifically tasked with behavior observation recorded pupil cleanliness (of hands and uniform), the proportion of pupils wearing shoes, and self-reported pupil exposure to fresh water. After one year, no significant differences in these worm prevention behaviors were found between treatment and control school students, and there was no significant variation in results between ages, genders, or grades. As with cost-sharing, the results indicate a low valuation of deworming among individuals, as new hygiene practices or new shoes were seen as too costly for the purpose of preventing worms (Kremer & Miguel, 2007).

One objection to the assertion made from the education results could be that a moral hazard arises. In economics, moral hazard occurs when one party engages in extra risk because another party bears the cost of such risk. In this case, the moral hazard would be that students neglected worm prevention behaviors (creating higher risk) because they were already receiving drug treatment and felt protected from reinfection (the funding non-profit bore the cost associated with neglecting prevention behaviors). The fact that there was no change in behaviors among older girls who did not receive drug treatment (due to pregnancy concerns) suggests that this belief was not the reason for neglecting of prevention behaviors throughout the schools. If moral hazard were influencing behavior, these untreated girls would not assume the high-risk behavior of neglecting worm prevention behaviors. Additionally, children benefitting from spillover effects of deworming showed no change in behavior as well. These children were enrolled in the control schools and showed large reductions in worm infection levels yet received no health education, and exhibited no significant change in worm prevention behavior. Finally, other research has suggested that health education practice and knowledge depreciation is rapid, regardless of short-run impacts (Haggerty et al., 1994). These findings imply that, once again, the low valuation of deworming each individual holds contributes to the failings of worm prevention behavior education as a sustainable deworming practice.

The final sustainable deworming practice analyzed through the Kenyan study by Kremer and Miguel (2007) was one in which pupils engaged in a verbal commitment. While not necessarily considered a standalone plan, many sustainable-minded programs require local “ownership” in which beneficiaries of the program make an affirmative commitment to the project. Behavioral economics and psychology studies have suggested that individuals can be motivated to engage in socially beneficial, yet individually costly, actions by being asked if they intend to participate. When asked, most agree to participate and then feel motivated to follow through, i.e. a blood donation commitment on a college campus (Cioffi, 1998). Just as giving blood is individually costly yet socially beneficial, a commitment to participate in deworming treatment called a similar cost-benefit analysis into question. Randomly selected pupils in treatment schools were provided information on deworming effects, the date of treatment, and were asked if they were going to participate in treatment. Although 98% answered ‘Yes’, there was no statistically significant impact attributed to the verbal commitment (Kremer & Miguel, 2007).

In each evaluation of strategies geared towards sustainability in the Kenyan study, the underlying notion that individuals do not highly value deworming on a personal level prevails. As with many other lasting, non-deadly health concerns in developing countries, the cost of treatment is individually unjustified even in the face of societal benefit. These results suggest that any deworming sustainability measures centered on personal cost-benefit decisions may fail. As seen by the verbal commitment results, techniques that induce people to take socially beneficial actions in the United States may fail in developing countries such as Kenya (Kremer & Miguel, 2007). Policymakers must therefore give careful consideration to the structure of deworming programs.

Chapter 3.2 - Policy Implementation

In a 2015 study, Ahuja et al. combine empirical evidence garnered from previous research (explored in Chapter 2) and theory to provide appropriate insight on policy implementation regarding mass deworming programs. The evidence shows the same short run (school participation) and long-run (test scores, employment, income) benefits discussed in Chapter 2. In addition, Ahuja et al. (2015) restates that most individuals will not participate in deworming treatment unless it is fully subsidized, and also suggests that there is a fiscal externality in the form of higher future tax revenue that may exceed the cost of the deworming program.

Ahuja et al. (2015) explores the viability of mass deworming treatments by filtering the empirical evidence through three theoretical perspectives that policymakers may hold. In doing so, different characteristics of the deworming program are prioritized under different perspectives. The first perspective is a ‘welfare economics/public finance’ approach, in which individuals are presumed to make decisions maximizing their own welfare, where government subsidies may be appropriate for goods that create positive externalities. In the case of deworming, this could equate to health externalities (reduction in disease transmission) or fiscal externalities (treatment increases long-run earnings and tax payments) (Ahuja et al., 2015). The second perspective is focused on ‘cost-effectiveness in achieving policymaker goals’, where the authors assume the goal is to maximize collective utility. In this approach a goal is set such as universal primary education, and subsequent programs such as deworming are undertaken if they are deemed a cost-effective method to achieve the aforementioned goal. The final approach, a ‘human rights’ perspective, argues that policymakers may have a duty to subsidize programs that ensure a basic human right of good health. As empirical data are presented, each type of policymaker may have different input, which mirrors the complications of justifying a broad mandate for mass deworming programs across varying governing bodies.

Before discussing the cost-effectiveness of a mass deworming program, it must first be ensured that the individuals actually decide to receive the treatment. In order for mass deworming to be an effective treatment, policymakers must have the capital and individuals must receive treatment. For example, under the ‘human rights’ perspective, a fully subsidized treatment would see the highest treatment participation rate, yet such a plan may not be realistic in all situations. In the case of low-budget policymakers unable to bear the full cost of subsidizing treatment, sustainability measures such as the cost-sharing method reviewed by Kremer and Miguel (2007) may impact the treatment participation rate too negatively for the mass treatment to be effective. The conclusions drawn from Kremer and Miguel (2007) relating to an extreme sensitivity to the presence of a price for deworming drugs present significant problems for some of the policymaker views explored by Ahuja et al. (2015).

As mentioned before, the ‘human rights’ perspective that could be adopted by governments and policymakers would make the health and future benefits of schoolchildren paramount. This would entail free mass deworming, aligning with evidence that shows that many parents will not purchase deworming medication for their children. By bearing the full cost of the treatment, policymakers will have an effective way to improve health and future educational and economic outcomes of children. In contrast to a policymaker with more economic-minded goals, the ‘human rights’ policymakers may have an obligation to make treatment free and convenient in order to satisfy their goals (Ahuja et al., 2015). While this approach may not result in the most economically sound outcomes, it ensures that the troubling resistance to paid treatment by parents is nullified. Full subsidization of deworming treatment cannot be deemed viable unless specific details of societies are present, therefore the ‘human rights’ perspective cannot be analyzed beyond the broad idea that it is.

While human rights are considered in policymaker decisions, economic welfare analysis can serve as a more concrete tool to aid in deworming policy choices. Under the Ahuja et al. (2015) ‘welfare analysis/public finance’ approach, individuals are assumed to make decisions that maximize their own welfare, with government subsidization to promote positive externality effects. As previously mentioned, the Kremer and Miguel (2007) assertion contradicts this view’s assumption that individuals will maximize their own welfare. In standard models of human capital investment, people will weigh the opportunity costs of an investment against the discounted value of returns (Ahuja et al., 2015). In other words, under these standard assumptions, the parents of schoolchildren should spend their money on what will bring them the most return. The behavioral economics insights of Kremer and Miguel (2007) have shown that in the face of small costs, the large benefits of deworming treatment are not valued by parents. This crucial finding indicates that policymaker intervention is necessary under the ‘welfare analysis/public finance’ approach. Under these circumstances, people do not make welfare-maximizing decisions when refusing to pay for deworming drugs. The policymaker must therefore intervene and promote treatment to induce positive externality benefits that would otherwise be lost. In the studies included by Ahuja et al. (2015), these benefits include academic test scores, school participation, and employment and income of others. Under this perspective, the subsidization of mass deworming treatment is justified when these benefits are substantial.

Another possible explanation for the inefficient decision-making exhibited by parents of potential deworming patients is the concept of discounting. In economics, discounting is the process by which people determine the present value of future benefits related to a decision made today. Due to the time value of money, which states that a dollar today is more valuable than a dollar tomorrow due to its potential to earn additional revenue before the 'future' period, parents deciding upon deworming treatment may undervalue the magnitude of the long-run benefits of deworming their children. As the amount of time between today and the time when benefits are received increases, the more the value of these benefits are subtracted. In the case of deworming, as these benefits are realized far into the future, people may discount these benefits to the point where they are unjustifiable in the current period, even in the face of miniscule costs. While this process is rational, parents in these communities may over-discount because they do not truly know the value of the long-run benefits of deworming, and consequently make inefficient decisions based on an individual cost-benefit analysis.

In exploring the impact of deworming on test scores, employment, and income, Ahuja et al. (2015) uses the findings to analyze mass deworming from a 'cost-effectiveness' perspective as well. As they employ previous studies' findings on academic scores, school participation, and employment/income, they use health and fiscal externality benefits to justify deworming under the 'welfare analysis/public finance' approach. To justify deworming under the 'cost-effectiveness' perspective, they use deworming's direct effects and fiscal externality benefits to achieve a policy goal.

Citing Miguel and Kremer (2004) and Croke (2014), both explored in Chapter 2, Ahuja et al. (2015) explore the impact of mass deworming on academic test scores. Miguel and Kremer (2004) found no short-run effects on cognition via academic test scores, but with the same initial data, Baird et al. (2016) found a long-run increase in the rate of passing the primary school exit exam for females by almost 25%.

Analyzing the impact of mass deworming on school participation also yields significant justification for mass deworming under a 'cost-effectiveness' and 'welfare analysis/public finance' standpoint. From Miguel and Kremer (2004), the evidence in favor of mass deworming positively affecting school participation is substantial, decreasing the individual number of days absent each year by one quarter. With a 'welfare analysis/public finance' perspective in mind, the positive externality found (where untreated students in treatment schools and in nearby untreated schools enjoyed higher participation) further increased the number of externality benefits of mass deworming. As Miguel and Kremer (2004) found, when accounting for positive externalities, there was a total increase of 0.14 years of schooling gained per pupil treated. The total increase in school participation (measured by attendance during unannounced survey visits), including externality benefits, was 8.5 percentage points, and therefore implies that deworming is one of the most cost-efficient ways of increasing school participation (Ahuja et al., 2015). The 'cost-effectiveness' standpoint sets a goal and aims to achieve it in the most cost-effective method possible, and Miguel and Kremer (2004) justifies mass deworming as a policy to attain an increase in school participation (Dhaliwal et al., 2011). Other like-minded policies include information sessions for parents on returns to education in Madagascar, free primary school uniforms in Kenya, and merit scholarships for girls in Kenya (reviewed in Chapter 4.1).

Another aspect of mass deworming that has been researched in depth is the impact that treatment has on employment and income. While this factor will be explored more thoroughly in Chapter 3.3, it will be utilized here to further justify mass deworming under a 'cost-effectiveness' perspective. In a study employing the 1940 US Census, those with more exposure to deworming when they were children were significantly more likely to be literate and have higher earnings later in life (Bleakley, 2007, 2010). The study compared adult outcomes among different age groups before and after a deworming campaign in the southern United States. The decrease in adult wages among those persistently infected as children was 43%, and was large enough to suggest that worm infections could have explained as much as 22% of the income gap between the less-afflicted North and the South at the time (Ahuja et al., 2015). A later study would imply a long-run income gain of 17% when infection rates were 40% (Bleakley, 2010). For comparison, the infection rate for school-aged children in the region studied by Miguel and Kremer (2004) was estimated to be around 90% (Bleakley, 2007). While the study did not take the costs of deworming treatment into account, the substantial income benefits that Bleakley (2010) finds may be indicative of high cost-effectiveness.

In a long-run follow-up of the same Kenyan deworming intervention studied by Miguel and Kremer (2004), Baird et al. (2016) found that more frequently treated females were more likely to grow cash crops and reallocate labor time from agriculture to entrepreneurship. In the same vein, males who received more treatment worked 3.5 more hours per week, spent more time in entrepreneurial activities, and were more likely to work in higher-wage manufacturing jobs (Baird et al., 2016). These impacts on labor decisions and subsequent increase in earnings allow Baird et al. (2016) to compute a rate of return for mass deworming treatment to be in the range of 32% up to 52% when health externalities are included. From a 'cost-effectiveness' standpoint, this implies that investing in mass deworming treatment programs is an economically effective way to achieve various goals set by policymakers.

From a 'welfare analysis/public finance' perspective, the large impact of externalities on the rate of return for the project lends credence to investment in a deworming program. As deworming increases labor supply, a fiscal externality is created by way of its impact on tax revenue (Ahuja et al., 2015). In addition to this increased labor supply, the marginal product of labor, or the increase in output attributed to one additional unit of labor, will increase as a result of the productivity increases in the more educated and healthy labor. Discussed more in depth in Chapter 3.3, estimations show that the net present value of increases in tax revenues greatly exceeds the costs associated with implementing and operating a mass deworming program (Baird et al., 2016). These fiscal externalities therefore potentially allow a government to reduce tax rates by instituting mass deworming – a concept that is beneficial to policymakers regardless of perspective (Ahuja et al., 2015).

To summarize, the existence of such extreme treatment uptake sensitivity to any price being imposed on deworming drugs causes a large problem in many policymaker approaches. Although Kremer and Miguel (2007) found the societal benefit to outweigh the personal costs of deworming treatment, individuals did not internalize the positive externalities that would benefit their society. As parents will not make the rational welfare-improving decision to purchase treatment drugs, the positive externalities coupled with such high price elasticity provides a strong argument for free distribution of deworming drugs (Tarozzi et al., 2014).

Through a welfare analysis perspective, the substantial positive externalities that arise from mass deworming programs present incentives for policymakers to intervene and provide treatment. In the same vein, a policymaker focused upon human rights may find that a full subsidy is the only effective way to ensure the protection of human rights, regardless of justification through cost-effectiveness or welfare analysis. Lastly, policymakers can employ the direct and external fiscal net benefits of mass treatment to justify implementation of deworming programs as a way to achieve various policy goals in a cost-effectiveness-focused perspective.

When viewed through these three theoretical policymaker ideologies, the suggested action remains mostly the same – large or total subsidization of deworming programs becomes justified as it allows for maximum uptake and therefore maximum benefit. The effectiveness of mass deworming programs relies on the consistent and widespread treatment of individuals, which is maximized through subsidization if Kremer and Miguel (2007) holds true.

In the following sub-chapter, the cost-effectiveness theories described in this sub-chapter will be substantiated with data. While the theoretical 'cost-effectiveness' lens will no longer be referenced, any further consideration of cost-effective aspects of deworming discussed can be used as further justification for (or against) mass treatment from that viewpoint. In addition, any discussion of externality benefits can be used to strengthen (or weaken) the case for implementing a mass treatment program under 'welfare analysis/public finance' policymaker criteria.

Chapter 3.3 - Cost-Effectiveness

In this sub-chapter, different studies of the cost-effectiveness of mass deworming programs will be reviewed. In doing so, the theories explored in Chapter 3.2 can be rationalized on an economic basis. This basis can be utilized as a tool to measure mass deworming programs' feasibility from policymaker points of view when compared to alternative welfare-increasing programs. By exploring the quantitative efficiency of mass deworming programs in achieving various goals, such as improved school participation or increased tax revenue, deworming programs can be assessed and later compared to different programs with the same goals in mind. Such programs include school-participation-minded policies such as uniform provision and merit scholarships. This assessment will be undertaken in this sub-chapter, and the comparison against alternate programs will ensue in Chapter 4.

Before comparison with alternative welfare-increasing programs, mass deworming programs must themselves be economically sound. While the prevalence and effect of intestinal worms are widely agreed upon by researchers, the mass-treatment method must be proven to be more cost-efficient at reducing worm infections, and therefore raising welfare, than other deworming initiatives. One such alternative program is the individualized 'screened treatment' program, where masses are screened and only treated if infected. Ahuja et al. (2015) assesses the two methods of deworming in terms of cost efficiency.

On both a logistical and economic basis, mass treatment is preferred over a screened treatment program (Ahuja et al., 2015). A nationwide screened treatment program in a country such as Kenya would require approximately 1,200 full-time health workers each year. In contrast, the full cost of delivering and administering one round of treatment in a school-based mass deworming program currently costs approximately $0.35 to $0.59 (Baird et al., 2016). With a mass deworming program, drug providers do not require the knowledge needed to screen for worms, therefore full treatment may be undertaken by already-employed nurses in school (Miguel & Kremer, 2004). The high volume and high skilled labor requirements for worm screening contribute to the estimation that screening alone costs 4 to 10 times that of the actual treatment itself (Speich et al., 2010).

The most commonly used method to screen for worms in the field, the Kato-Katz test, is approximately $1.88 per child (Speich et al., 2010). If this test were to identify 100% of infections and every infected child returned for treatment, the cost per infection treated would amount to over 6 times higher than that of a non-screened mass treatment (Ahuja et al., 2015). In reality, the Kato-Katz test's specificity has been estimated to range from 52% to 91%, where 52% specificity entails a per-infection-treated cost nearly 12 times larger than a mass treatment program (Ahuja et al., 2015).

Finally, the cost efficiency of a screened treatment program is further hampered by the necessity of multiple visits by patients (one to screen and one to treat) meaning some patients will go untreated if re-contacting patients is difficult (Ahuja et al., 2015). Such issues are nonexistent in mass deworming programs, as patients are provided drugs with each session. Ahuja et al. (2015) asserts that the nearly 870 million children at risk of worm infections could be treated via mass deworming at a cumulative cost of 300 million dollars per year, compared to 2 billion dollars annually under a screened treatment program.

Despite the difference in cost, due to the nature of cost-benefit analysis, a screened treatment program could be preferred over mass treatment if these large costs were met by even larger benefits. Ultimately, because mass deworming treats the same individuals that would eventually be screened and treated, the benefits resulting from a screened program do not scale with the large costs. Mass deworming achieves the same goals as screened programs at a fraction of the cost, with the added benefits of positive externalities.

Beyond screened and mass deworming programs, one further deworming initiative was studied by Kremer and Miguel (2007) – a health education program. The quantitative outcome (in terms of welfare or treatment success) of such a program was unobtainable due to the fact that simultaneous mass deworming drug treatment was in progress in the studied schools. Discussed in Chapter 3.1, this program is behavior-centered, where teachers impart worm prevention behaviors. Therefore, worm prevention behaviors could not be attributed as the cause of decreased infection rates when students were taking drugs proven to eliminate intestinal worms. Also discussed in Chapter 3.1 is the failure of this program, as no significant worm prevention behavior changes were observed after a year. With no change in behavior, no welfare or deworming benefits could be attributed to the program. Despite this, the approximate costs associated with the health education program were estimated, and an approximate cost-effectiveness analysis can be done using the behavioral outcomes observed. Kremer and Miguel (2007) estimate that the combined cost of teacher training, teacher lessons at school, lectures delivered by outside specialists, and the other educational materials (wall charts, etc.) cost at least $0.44 per pupil per year. While this cost is comparable to the per-treatment cost of a mass deworming program, the health education initiative did not exhibit the same benefit, rendering it less cost-effective. On the other hand, if the study *had* observed a significant improvement in worm prevention behaviors, such an intervention would be difficult to compare to mass deworming on a cost-effectiveness scale.

Given the available data, most studies have reaffirmed that mass deworming programs are the most cost-efficient route to reducing worm infection rates. As discussed in Chapter 2, the welfare benefits realized from deworming manifest themselves through many different channels. Increases in labor supply, academic test scores, and school participation rates have all been attributed to the health benefits experienced when communities undergo mass deworming. Each of these increases has been studied further with a focus on the long-term welfare benefits that they produce, which can then be attributed back to mass deworming. These quantitative values allow deworming health initiatives to be viewed in an economic fashion, where such values can be used to compare it to any other welfare-improving objective. Whether the alternative policy is a trade, educational, environmental, or even another health-related program, deworming can be measured against it on the basis of economic costs and benefits.

Baird et al. (2016) explores the future welfare benefits of deworming patients by analyzing their decisions in the labor market. In doing so, the Baird et al. (2016) study of the labor market also allows them to make macroeconomic welfare estimations about the impact of deworming on tax revenues. The influences found to act upon labor market decisions are educational and health related, with findings consistent to studies summarized in Chapter 2.

Employing the same data set as Miguel and Kremer (2004), Baird et al. (2016) examines young adults aged 19-26 a decade after belonging to either a non-treated control group or treatment group. In assessing health, education, and labor market outcomes between ex-pupils of treated schools and non-treated control schools, Baird et al. (2016) reports findings consistent with deworming's positive cognitive impacts as reported by Croke (2014) and Ozier (2014) and positive future income impacts as reported by Bleakley (2007, 2010). These positive educational impacts coupled with health improvements are used as the driving force behind subsequent positive changes in labor market outcomes.

While Baird et al. (2016) found an increase in primary school enrollment time for men (about 5% longer), the study did not find any significant increase in secondary education enrollment, nor any academic improvement. For women, participation in mass deworming led to an increase in secondary school enrollment time, an increase in secondary school entrance exam performance by 25%, and led to a halving of the gender gap between treated student enrollments in secondary school (Baird et al., 2016). Overall, women's educational attainment increased by 0.354 years (Baird et al., 2016). Such a distinction in benefits between genders falls in line with previous assertions that positive health shocks disproportionately induce women to increase their human capital acquisition (Pitt, Rosenzweig, and Hassan, 2012).

Focusing upon adults aged 22 and 23 (12-13 at time of treatment) due to their majority completion of school and subsequent workforce entrance, dewormed men spent 3.74 hours a week, or 13%, more time working than their same-age control counterparts (Baird et al., 2016). The increase in hours worked per week was not significant for women. Aside from the increase in time spent working, the allocation of work across sectors and occupations changed in the dewormed adults as well. Deworming leads men to increase total work hours, but they did not significantly work in different sectors any more than non-treated males. On the other hand, dewormed women increased weekly nonagricultural self-employment hours by nearly 70% (1.86 hours) and reduced weekly agricultural hours by nearly 15% (1.27 hours) (Baird et al., 2016). In addition, 77% of self-employed women in Kenya work in retail, and there is evidence that retail profits are tied to math skills (Kremer et al., 2013).

Further analysis of the same data showed a shift in occupational choice, as treated individuals were found to be three times more likely to work in manufacturing jobs (Baird et al., 2016). At the same time, a significant decrease in casual labor, defined as not having regular work hours (i.e. construction), was observed for the same group. In the study, the average earnings of individuals in manufacturing jobs almost double those of workers in casual labor (Baird et al., 2016). Manufacturing jobs require more hours per week than other occupations, averaging 53 hours per week compared to an average of 42 hours for all wage-earning jobs considered (Baird et al., 2016). Workers in manufacturing missed an average of 1.1 days due to poor health in the last month of the study, compared to the average 1.5 days among all wage earners (Baird et al., 2016).

Once again considering gender, the positive effect that deworming has on increases in manufacturing is significant for men, while women experience a significant increase in growing cash crops. The combined increases in secondary education, self-employment, and cash crop cultivation may be seen as an attempt by women to move into higher productivity activities despite preexisting social and family constraints (Baird et al., 2016). Such constraints could complicate a woman's move into a male-dominated job such as manufacturing, yet the productivity increases still could indicate higher future earnings for women (Baird et al., 2016).

Utilizing the labor market outcomes explored previously, Baird et al. (2016) estimate ensuing changes in lifetime earnings of Kenyan citizens under a subsidized mass deworming program. They also estimate subsequent costs adopted by the Kenyan government, with a focus on drug administration costs and increased secondary education costs stemming from higher enrollment. Such costs included needing to supply more teachers to maintain the same student-to-teacher ratio in secondary schools that now had a higher number of enrolled students. The estimated policy benefits and costs are found for a program covering two-thirds of primary schools, such as the one studied by Miguel and Kremer (2004). The benefits of fully subsidized and partially subsidized programs are compared against one another.

Due to the fact that the Baird et al. (2016) study only has data found at the time of the follow-up survey and not the entire path of future earnings and labor decisions, their estimations are “somewhat speculative”. Accordingly, they adopt a “reasonably conservative” approach in bounding the effect of deworming on lifetime income (Baird et al., 2016). To elaborate, they base their calculations on differences in hours worked between the treatment and control group, instead of focusing on more abstract positive impacts, such as labor and educational improvements in women. In limiting the positive impacts of deworming considered in their calculations, their estimations are conservative yet less speculative. Calculations are done for two different programs: one program is a fully subsidized mass deworming program, while the other mirrors the cost-sharing program studied in Kremer and Miguel (2007). The following cost and benefit values of each program are both seen as relative to a non-subsidized program where individuals must purchase their own treatment.

Over the average of 2.41 years of deworming in the treatment group, at a 2016 cost of $0.59 per pupil per year in a mass deworming program, Baird et al. (2016) finds that the total direct cost to the government per person treated is $1.42. Taking into account the Kremer and Miguel (2007) 75% take-up rate under a full subsidy, the cost to the government per pupil in a treatment school is $1.07 (Baird et al., 2016). For comparison, over the same 2.41 years, the direct cost to the government with partial deworming subsidies under a cost-sharing program would be $1.15 per person, as individuals paid an average of $0.27 for the drugs (Baird et al., 2016). Due to the decreased Kremer and Miguel (2007) cost-sharing take-up rate of 19%, the cost to the government per pupil in a cost-sharing treatment school is $0.22, as far fewer treatments are administered.

The average increase in schooling costs faced by the Kenyan government in the calculation stem from the government's desire to maintain the same student-to-teacher ratio in secondary school amidst higher enrollment numbers due to deworming. Baird et al. (2016) estimate this cost to be an additional $10.71 per treated pupil in a fully subsidized deworming program, with the cost dropping to $2.71 in a cost-sharing program.

On the other hand, in calculating the lifetime revenues that both individuals and the government would incur, the estimation is completed first without positive externality gains, and then once again with them. Using 2016 values for Kenyan tax rates (16.6%) and real cost of capital (9.85%), government revenue can be deducted after finding individual gains. For reference, the average NPV of per-person lifetime earnings in the no-externality and no-subsidy calculations was $1,509 (Baird et al., 2016). With no externality gains, Baird et al. (2016) find that individuals gain a lifetime NPV average of $119 after taxes under a fully subsidized mass deworming treatment program, dropping to $30 per-person under a partially subsidized cost-sharing program.

For the government, these values imply a NPV increase in per-person government revenue through taxation of $23 and $6 respectively. After subtracting schooling costs, the government would make an estimated $12.90 or $3.27 per individual, respectively. Fully subsidized, such a program is highly cost-effective, as the $12.90 increase in government revenue is far greater than the $1.07 subsidy cost (Baird et al., 2016). If the calculations are changed to include positive externalities, the earning gains of both parties are much larger, with a per capita net increase in government revenue of $102.97 and a NPV increase in individual earnings of $766.81 (Baird et al., 2016). These results are consistent with other studies evaluating the effects of mass deworming on cognition and their subsequent positive influence on future wages (Ozier, 2014).

As the above calculations are for programs that cover two-thirds of all primary schools, Baird et al. (2016) extend their estimations to include a program that would be national, covering all primary schools with full subsidization. Here, the cost per treatment school student would rise to $1.60, while the NPV net increase in government revenue would remain at $12.90, justifying it as a cost-effective nationwide policy (Baird et al., 2016). For the cost-sharing program, the nationwide calculations are not presented. In light of the findings above, a government could even potentially reduce tax rates by instituting fully subsidized mass deworming (Ahuja et al., 2015).

In addition, the Baird et al. (2016) data are used to calculate the internal rate of return (IRR) of a nationwide Kenyan mass deworming program in schools. IRR is used to assess the desirability of investing in a program such as mass deworming, and Baird et al. (2016) calculates the Kenyan mass deworming IRR at a 31.8% with no health spillovers, and a “massive 51.0%” when including such externalities. This implies that deworming is cost-effective on economic grounds, even when ignoring health benefits (Ahuja et al., 2015).

Beyond a broad improvement in labor market decisions and welfare, an added benefit of mass deworming programs may be the changes in labor and education among women. While the overall well-being of individuals may improve from mass deworming, women may also make their own improvements in closing wage differences across genders, depending on societal constraints. The study’s welfare estimations did not include the women-specific educational and labor improvements for accuracy reasons, but Baird et al. (2016) mentions the positive (yet incomplete due to data shortcomings) effect that it would have on their estimations.

Further research on the impact of worm infections on future income gains has shown similar findings. Although the following study does not include the costs associated with deworming, it further solidifies the evidence of future earnings benefits of mass deworming programs with long-run data beyond that of Baird et al. (2016). Referenced in Chapter 2.1, Bleakley (2010) focuses on the eradication of intestinal worms in the US South by way of a mass deworming program initiated in 1910. 40% of school-aged children in the southern United States were found to be infected, with great variation in the infection rate across different counties. Using 1940 US Census data, Bleakley (2010) searches for long-run effects on adults that were school-aged in the 1910 program. By analyzing the differences in data between southern counties with low rates of infection against those with high rates, Bleakley (2010) finds long-run positive income impacts of deworming treatment in areas that were previously highly infected. The long-run benefits enjoyed by school-aged children at treatment time are not mirrored for adults at treatment time, suggesting that these benefits are attributable mostly to the deworming because adults are known to not suffer from severe worm infection (Bleakley, 2010).

Echoing previously discussed findings, Bleakley (2010) finds that children with more exposure to the deworming campaign were more likely to be literate, earn higher incomes as adults, and even work more hours. Children were more exposed if they were younger at the time of the program, and located in an area with higher infection rates. In contrast to Baird et al. (2016), Bleakley (2010) states that the increase in hours worked does not account for a large fraction of increased future earnings. Instead, the large fraction is potentially explained by an increase in quality (not quantity) of schooling, or the return to schooling, for students. In other words, the increase in labor supply (due to more hours worked) could be offset by an equal increase in demand, yet due to the increase in productivity of the same labor supply, the marginal product of labor rises and laborers are more valued and therefore higher paid.

Exploring this, the decrease in return to schooling (on lifetime income) caused by worm infection was found to be almost 50% (Bleakley, 2010). In addition, persistent childhood worm infections were found to have a negative 43% impact on adult earnings, and could explain 22% of the entire income gap between the northern and southern United States at the time of the program (Bleakley, 2010). This means that dewormed children experienced 43% higher wages, and that intestinal worms had a significant macroeconomic impact on an entire country. With the study's 40% infection rate and 43% impact on earnings, total eradication of the intestinal worms implied a long-run income gain across the South of 17% (Ahuja et al., 2015). Bleakley (2010) and the studies in Kenya suggest that intestinal worms have had a significant economic impact across multiple locations and time periods.

Despite these findings, Bleakley (2010) presents doubts that may suggest lesser expectations for benefits of modern day programs in countries such as Kenya, even if these countries experience much higher rates of infection (90% in Miguel and Kremer (2004)). The Bleakley (2010) increases in return to schooling and in future earnings were so large partially due to the United States' already functioning schools and labor markets. As the health benefits from deworming arose in the United States, efficient educational facilities and labor opportunities were already present and ready to translate health benefits into economic and educational ones. Bleakley (2010) admits that expectations for an exact replica of results in Kenya may be optimistic due to the possibility of less established schools and labor markets. For a brief summarization of the studies presented in this chapter, see Table 2.

Table 2. Summary of Ch. 3 Study Findings

Study	Summary	Key Findings
Kremer & Miguel (2007)	Behavioral Economics study into the sustainability of deworming programs when a share of the responsibility/cost is put on the citizens to receive treatment. Focused upon the same program in Kenya as Miguel and Kremer (2004).	• Cost-sharing found an extremely high price sensitivity to treatment (Shampanier et al. (2007) – "Zero as a Special Price") • Health education (hygiene habits) were not upheld • Verbal commitment had no impact • Most parents found any costs associated with treatment to outweigh benefits
Ahuja et al. (2015)	Uses previously discussed studies' empirical evidence and applies the findings to an exploration of different policy implementations. 3 main ideologies with different goals and values: Human rights, welfare/public finance, and cost-effectiveness	• 3 viewpoints all justify the implementation of mass deworming programs • Deworming is cost-effective on economic grounds
	(Continued on next page)	

Baird et al. (2016)	Study of the same data set used by Miguel and Kremer (2004), a decade later. Cost-effectiveness evaluation of deworming. Explores the future welfare benefits of deworming patients by analyzing their decisions in the labor market. These decisions contribute to macroeconomic welfare estimations about the impact of deworming on tax revenues.	• Dewormed men worked 13% more hours, women had significant education increases (mainly secondary) • Men increased manufacturing hours, women decreased self-employment hours • Individuals gain a lifetime NPV average of $119 after taxes, governments make over $11 net per person • When externalities were considered, they increased these estimates greatly • 30%-50% IRR
Bleakley (2007, 2010)	Study of the early 1900's RSC hookworm eradication initiative, using 1940's Census data. The return to schooling constitutes a large increase in future welfare for treated students due to productivity increases.	• Exposed children were more likely to be literate, earn higher incomes, and even work more hours as adults • Childhood worm infections had a negative 43% impact on adult earnings • Eradication = long-run income gain across the South of 17%

Chapter 4

Is Mass Deworming a Competitive Strategy to Improve Welfare?

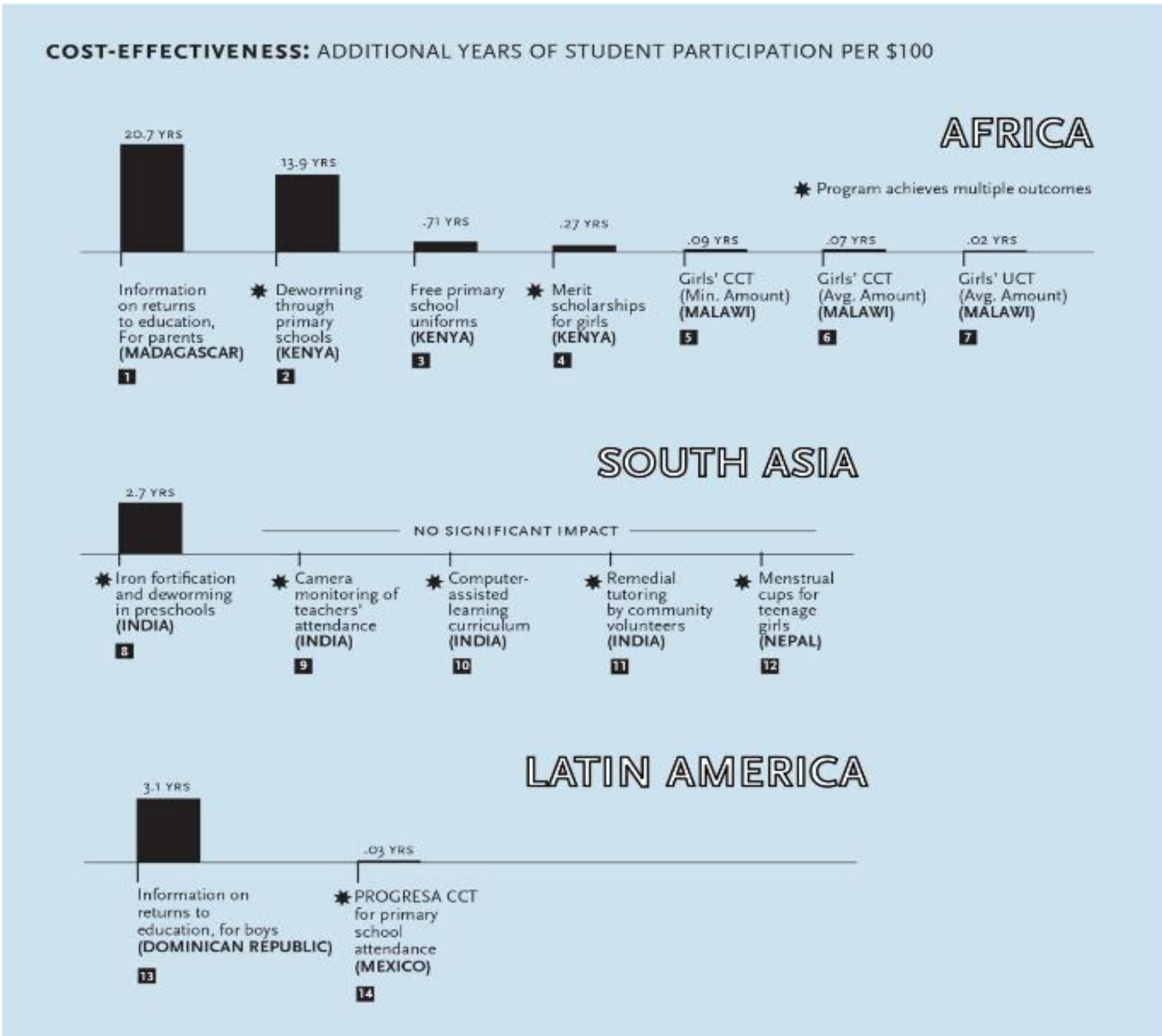
Throughout this paper, mass deworming has been established as a viable method to achieve various policymaker objectives. Such objectives include increased school participation, quality of education, and future earnings (resulting in higher tax revenues). In order to fully review the effectiveness of mass deworming programs, their positive impacts must be measured against those generated by programs designed to achieve similar goals. In this chapter, I will present multiple cost-effectiveness analyses (CEA's) to explore how effectively mass deworming programs achieve policymaker goals when compared to other health, education, and poverty initiatives. These analyses focus on comparing the quantifiable benefit (higher attendance, test scores, earnings) of each program per set unit of cost. When considering evidence-based policy implementation, the interventions that have lower incremental costs per unit of incremental benefit are better candidates for investment. In many developing countries, the scarcity of government resources implies necessity on effective allocation towards such policies.

Obviously, many of the programs discussed in this chapter serve multiple purposes and aim to achieve many different objectives. In this chapter, comparison between initiatives will be solely based upon CEA. The capability to truly rank the effectiveness of these programs requires much more data, and even with this, rankings would still be possibly inaccurate due to the wildly varying characteristics and goals of each developing economy. The analyses presented in this chapter serve the purpose of efficiently summarizing the empirical data of different studies on many different programs.

Chapter 4.1 - School Participation

In following with the progression of modern research on mass deworming, the link between school participation increases and mass deworming programs was established in the foundational Miguel and Kremer (2004) study. This relationship has been confirmed by subsequent studies (Dhaliwal, 2011; Baird et al., 2016). Through alleviation of anemia and fatigue, school-aged children in the Kenyan mass deworming program were able to reduce their absenteeism by 25% (Miguel & Kremer, 2004). This translated to an increase of 0.14 school years (approx. 28 additional days attended) in the area for every student treated. The estimated cost, when accounting for delivery and administration of treatment, was $7.19 per year of additional schooling (J-PAL Policy Bulletin, 2012). This equates to around 13.9 years of additional schooling gained for every $100 dollars spent on the program, as seen in Figure 1 (from Dhaliwal, 2011).

Figure 1. Cost-Effectiveness: School Participation



The estimates in Figure 1 rely on data from the Miguel and Kremer (2004) Kenyan program, which was small-scale and directed by a non-governmental organization. A larger (possibly nationwide) program would likely cost even less per child (J-PAL Policy Bulletin, 2012).

The only program in the Dhaliwal (2011) study found to be more cost-effective than mass deworming was the program to provide information on the returns to education to parents in Madagascar (Nguyen, 2008). This program provided statistics and role models to correct the (underestimated) value that individuals placed on receiving education. As the statistics were presented by already-employed teachers, the cost of providing such information was extremely low. Unpaid, educated speakers of similar economic background to parents effectively remedied the information gap between perceived and actual returns to education by presenting their success stories (Nguyen, 2008). As students and parents readjusted how much they valued schooling, the students exhibited higher scholastic effort and decreased absenteeism. The cost per additional year of school attendance was $4.83, yet Nguyen (2008) theorizes that a program with only the statistical-information element would be more cost-effective.

Chapter 4.2 - Test Scores

Although mass deworming has a relatively cost-effective impact on school attendance, such an increase cannot be taken as concrete evidence for implementation. More time spent in school does not equate to higher human capital accumulation, and increases in attendance may even have minor negative effects on cognition due to more congested classrooms (Miguel & Kremer, 2004). Therefore, it is important to measure how competitively cost-effective mass deworming is at increasing test scores.

While Miguel and Kremer (2004) originally asserted that mass deworming had no significant impact on children's test scores, Ozier (2014) and Croke (2014) later found long-run positive impacts resulting from the benefits of being dewormed as an infant. Test scores have been used to measure cognition and indicate human capital accumulation efficiency, which has been utilized as an estimator for future earnings (Bleakley, 2010). In the literature focused upon test score gains, standard deviation increases are used as a common metric (McEwan, 2012).

Croke (2014) found mass deworming to have a positive impact of 0.16 to 0.36 standard deviations on test scores. Ozier (2014) found the program to have a roughly 0.2 standard deviation increase (significant at the 5% level).

To compare these results with other programs aimed at increasing test scores in the developing world, a cost-effectiveness ratio (CER) can be used. By finding the cost (in dollars) per pupil per 0.10 standard deviation gain in test scores, a common unit for comparison can be employed. McEwan (2012) calculates the CER of various education interventions in Kenya, seen in Table 3. The equation for CER is simply the cost divided by the effect, multiplied by 0.10. The values for the deworming project are found using the Ozier (2014) 0.2 standard deviation increase.

Table 3. Cost-Effectiveness Ratios of Education Interventions in Kenya

Intervention	*Effect*	*Cost*	*CER*
	Avg. test score gain	**Cost per pupil**	**Cost per pupil per 0.10 SD gain**
Girl’s Scholarship Program	0.12	$1.69	$1.41
Teacher Incentives	0.07	$0.95	$1.36
Textbook Provision	0.04	$2.24	$5.61
Deworming Project	**0.20**	**$1.46**	**$0.73**

The three other interventions are school-centered programs similar to mass deworming. The girl’s scholarship program was a merit scholarship provided to girls who scored well on exams; teacher incentives linked their salaries to their own attendance or to students' test scores; textbook provision was simply the increasing of educational resources. As Table 3 implies, when incorporating the Ozier (2014) test score findings, mass deworming was the most cost-effective of the four Kenyan school-based interventions aimed at increasing test scores.

When compared to other popular health interventions in the developing world, such as the provision of Long Lasting Insecticidal Nets (LLINs) to combat malaria, mass deworming has competitive impacts on test scores. Using the same Raven's Progressive Matrices test as Ozier (2014), Venkataramani (2012) studies the impact of infants exposed to the eradication of malaria in Mexico during the 1950's. Similar to Ozier (2014), Venkataramani (2012) explores the impact of malaria on cognitive development during the 'sensitive period' in infancy. Exposure to the program resulted in a 0.10-0.20 standard deviation increase, similar to the findings in the Ozier (2014) Kenyan study. In addition to this, Mueller et al. (2008) found the cost per malaria case averted with LLINs in a 2004 Togolese study to be $3.26. With the relationship between malaria and cognition, and the cost per 'treatment' of malaria via LLINs, a comparative CEA can be used to measure LLIN provision against school-based deworming. Following the previous method of comparing CERs, LLINs cost-effectiveness ratio would equate to $1.63-$3.26 per 0.10 increase in standard deviation. This would imply that mass deworming programs would be slightly more cost-effective in increasing cognition.

Due to the variance in time period, location, and even method of treatment between the Venkataramani (2012) and Mueller et al. (2008) malaria studies, the estimations of a CEA on cognition between school-based mass deworming and LLIN provision cannot be assumed as entirely accurate. Information on LLIN program costs and their cognitive impacts in Kenya (to stay consistent with Ozier (2014)) is unavailable. GiveWell, a non-profit charity evaluation organization, estimated the cost per malaria case averted to be a fraction of the Togolese cost, at $1.36, possibly due to economies of scale (Karnofsky, 2016). With this cost estimate, the CER of malaria and test scores would be $0.68-$1.36 per 0.10 increase in standard deviation. Under this estimation, LLIN distribution would rival mass deworming in terms of cost-effectively increasing cognition.

Lastly, the cost-effectiveness of the Nguyen (2008) Madagascar study in increasing school attendance somewhat translates to increased test scores. When analyzing test scores, Nguyen (2008) opts to only include the statistical information aspect of the study to optimize cost-effectiveness. At a cost of $0.08 per student, the program increased test scores by 0.20 standard deviations; only $0.04 per pupil was required to increase their score by 0.10 standard deviations (Nguyen, 2008). While the program was once again extremely cost-effective in achieving a policy goal, the tests administered were comprised differently. In Madagascar, the tests given to students were achievement rather than ability tests. The material on the tests was supposed to be mastered at that stage in the curriculum, and test material could be learned with effort instead of an increase in innate intelligence. The difference between ability-based tests, such as Raven’s, and the effort-based tests in Madagascar makes the connection between test scores and cognition less relevant.

Chapter 4.3 - Future Earnings

In estimating future earnings, research on mass deworming programs has focused on the increased labor productivity gained through various mechanisms, such as increased cognition or increased school attendance/hours worked (Bleakley, 2010; Baird et al., 2016). Similar to mass deworming, malaria eradication has been researched with the same focus on how much childhood exposure to disease affects labor productivity, and subsequent adult earnings.

In the Bleakley (2010) study on the eradication of hookworm in the US South, estimates are made for the impact of malaria on future earnings as well. While Bleakley (2010) finds that a childhood plagued with persistent hookworm infection has a -43% effect on adult wages, the study's estimations for the effect of a 'malarious childhood' on the same factor equal approximately -50%. Outside of the United States campaign, the same study estimated the impact in Latin American countries to be equally detrimental by focusing on 1950's malaria eradication campaigns in Brazil, Colombia, and Mexico. Given these similar estimates for large-scale programs, the cost-effectiveness of mass deworming and LLIN provision (using GiveWell large-scale costs) to increase future earnings would be similar. As these effects were found for persistent, lifelong infection, Bleakley (2009) alternatively presents impact-per-year values of each disease. For hookworm, each year infected reduced adult income by 2.2%; for malaria, each year infected depressed future income by 2.5% (Bleakley, 2009). Once again, the similar annual cost of averting one helminth infection and one case of malaria would imply that LLIN provision would be slightly more cost-effective when viewed in this annual fashion.

Chapter 5

Conclusion

In this paper, the literature focused upon the health and economic benefits related to mass deworming papers is reviewed. In Chapter 1, the importance of understanding intestinal helminths is stressed by presenting the prevalence and potential impact of worm infections. Chapter 2 provides background information on mass deworming as a whole. A history of deworming and the research surrounding it is presented, and then multiple modern studies are summarized in order to provide knowledge required for the rest of the literature review. In Chapter 3, the viability of school-based mass deworming programs is addressed with literature related to sustainability, policy implementation, and cost-effectiveness. By employing an understanding of the health benefits of school-based mass deworming programs summarized in Chapter 2, the economic implications of mass deworming programs are examined. School-based mass deworming programs must be sustained by policymakers, not individuals. The literature implies that mass deworming can be feasibility implemented and be cost-effective in achieving policymaker goals. Finally, Chapter 4 delves into a comparison of mass deworming with like-minded policies. Three main benefits of mass deworming initiatives are assessed against other policies by focusing on cost-effectiveness analyses. School-based mass deworming seems to be competitively cost-effective in achieving these goals, although definite assertions cannot be made.

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