Intergenerational Child Mortality Impacts of Deworming: Experimental Evidence from Two Decades of the Kenya Life Panel Survey*

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Abstract

We assess the impacts of a randomized Kenyan school-based deworming intervention on the mortality of recipients' children using a 23-year longitudinal data set of over 6,500 original participants and their children. The under-5 mortality rate fell by 22% (17 deaths per 1000 live births) for children of treatment group individuals. We find that a combination of improvements in health and education, living standards, increased urban residence, delayed fertility, and greater use of health care in the parent generation contributed to the reduction. The results indicate that health investments can improve the health outcomes of the next generation.

**Conference version.* *Contributors*: EM and MK conceived the original PSDP study. AS and EO supervised data collection in Kenya. JH, EM, MW, SB, and LF conceived the analysis on the long-run effects of deworming. EO, PS, MNK, and ML engaged in data curation, visualization, and analysis, which involved adapting the statistical methods to the intergenerational child mortality data, with supervision from EM and MW. SK and FH conducted the cost-benefit analysis, with supervision from EM, MW, and AH. AH and MW wrote the original draft, and all authors worked to review and revise the manuscript. ††Denotes joint first authorship.†To whom correspondence should be addressed. *Acknowledgements*: We thank conference audiences at the 2022 Advances with Field Experiments and 2022 NEUDC for helpful suggestions. We gratefully acknowledge funding from the U.S. National Institutes of Health (NIH) (#R01-TW05612, #R01-HD044475, #R01-HD090118, #R03-HD064888), the U.S. National Science Foundation (#SES-0418110, #SES-0962614), the Dioraphte Foundation, Givewell, and the Berkeley Population Center. Human subjects approval was obtained from the University of California, Berkeley and Maseno University in Kenya. This study is registered on the American Economic Association's Randomized Controlled Trials Registry (AEARCTR-0001191).

1 Introduction

Reducing child mortality has long been a major public health priority. Despite substantial progress in reducing child mortality over the last 30 years, rates still remain above target levels set as part of the Sustainable Development Goals (25 deaths per 1000 live births) in numerous low and middle-income countries (LMICs), generating substantial research and policy interest in the determinants of child health and mortality. In particular, research has documented geographic persistence at the national and subnational level (Burstein et al., 2019), as well as intergenerational persistence – women who had siblings die under 5 are more likely to have a child die themselves (Vogl and Lu, forthcoming).

This persistence highlights the importance of understanding the intergenerational transmission of health status – how the health status of the first generation affects the health status of the subsequent generation. Bhalotra and Rawlings (2011) document positive relationships between maternal and child health, with improved maternal health generating persistent benefits for children in some regions. The persistence of health disparities across generations may also directly influence intergenerational economic mobility in society more broadly (Black and Devereux, 2011; Chetty et al., 2014; Jácome et al., 2021; Alesina et al., 2021; Asher et al., 2020).

Despite the intellectual and policy importance, relatively few studies have causally estimated the intergenerational transmission of child health in LMICs and especially in Sub-Saharan Africa (SSA), (with some notable exceptions, e.g., Grépin and Bharadwaj, 2015; Andriano and Monden, 2019), in large part due to challenges with data availability. In particular, causally studying the topic requires i) experimental or exogenous variation in child health status for the first generation (the parents); ii) long-term data linked between parents and their children; and if one wants to investigate mechanisms, iii) data beyond what is typically available in registry and administrative data.

This study examines the intergenerational transmission of health in the context of a school-based deworming intervention (the Primary School Deworming Project, PSDP) in Kenya. Intestinal helminth infections remain one of the most widespread parasitic infections globally and have adverse health and nutritional consequences for children including stunting, anemia, and increased susceptibility to other infections (Pullan et al., 2014; Disease Control Priorities Project, 2008). In particular, recipients of the PSDP were aged 8-15 at baseline, falling within the "adolescent growth spurt" phase with greater requirements on nutrition and good diet (Bundy et al., 2018). At present, the World Health Organization (WHO) recommends providing mass school-based deworming treatments in regions with infection prevalence over 20% at baseline, noting population-wide health gains and cost-effectiveness of this approach

(World Health Organization, 2017). Several previous studies analyze the short- and long-run impacts of deworming (e.g., Miguel and Kremer, 2004; Taylor-Robinson et al., 2012; Croke et al., 2016; Ozier, 2018; Baird et al., 2016; Hamory et al., 2021; Croke and Atun, 2019). Baird et al. (2016) and Hamory et al. (2021) assess the validity of the PSDP's research design and study its long-term effects, using up to four rounds of follow-up data (20 years post-treatment), and document meaningful impacts on a range of adult outcomes – including health, education, and economic living standards – among individuals in the treatment group, who received 2.4 years of additional deworming on average.

This study estimates the effects of deworming treatment on the subsequent generation's mortality outcomes during childhood, and the research design overcomes many of the challenges noted above. The PSDP provides experimental variation in exposure to deworming treatment, and we make use of a unique panel dataset that includes detailed information on both the program participants and their children, the Kenya Life Panel Survey (KLPS). This 23-year longitudinal dataset also contains data that allows us to explore leading mechanisms through which adult life changes may translate into intergenerational survival impacts.

While Kenya has experienced declines in the infant mortality rate (IMR) and under-5 (child) mortality rate (U5MR) in recent decades (similar to many LMICs), infant and child mortality continues to be a significant issue: UNICEF estimates under-5 mortality in Kenya in 2020 at 42 per 1000 live births, which is seven times the level in the US. Trends in child mortality rates amongst the control group in our sample are reassuringly similar to the Kenyan national average. When we turn to treatment effects, we find that being in the deworming treatment group (parent generation) reduced the under-5 mortality of the child generation by 22% (or 17 deaths per 1000 live births), from 76 to 59 deaths per 1000 live births. We see slightly smaller effects for infant mortality (reduction of 15%, 6 deaths per 1000 live births), though these are not significant at traditional confidence levels. Interestingly, there appears to be some evidence of a dose-response relationship – individuals assigned to more years of free deworming (based on the program phase-in and their anticipated primary school grade progression) see larger reductions in under-5 child mortality.

To better understand the direct and indirect processes through which deworming contributes to reductions in intergenerational child mortality, we examine the impact of deworming on five channels that have been highlighted in the existing literature as mechanisms or determinants of child mortality (though some may be interrelated): parent health (Bhalotra and Rawlings, 2011, 2013; Aizer and Currie, 2014); education, especially maternal education (Currie and Moretti, 2003; Breierova and Duflo, 2004; Grépin and Bharadwaj, 2015; Andriano and Monden, 2019; Gakidou et al., 2010); living standards and residence (Amarante et al., 2016; Kennedy-Moulton et al., 2022); fertility patterns (LeGrand and Phillips, 1996; Rutstein, 2005), and child-level use of health care (Bishai et al., 2016). In our data, improved health, greater education, improved living standards, reduced fertility and increased health-care access are all correlated with cross-sectional reductions in child mortality, though the strength of the correlations varies. When estimating treatment effects, we find that deworming leads to improvements across all five channels, with varying impacts by parents' gender and age. Among female parents, deworming significantly increased self-reported health and education: maximum school attainment increased by 0.43 years, they were 7.6 percentage points more likely to attend any secondary school (on a base of 38 percent). Children born to females in the deworming treatment group are also more likely to receive antenatal care (ANC) and have had an institutional delivery, which may improve child survival directly and also serve as a proxy for greater healthcare access. Male parents experience increases in living standards, particularly consumption expenditure, which may provide parents with additional resources to support their children, and are more likely to be in urban areas which may also provide better healthcare access. We do not see effects on total fertility, though age at first birth is 0.4 years higher for the deworming treatment group. While the design makes it challenging to disentangle their relative contributions, we conclude that some combination of these channels contribute to the overall effect of deworming on intergenerational child survival. Notably, finding improvements on multiple mechanisms dovetails with findings in the public health research whereby multiple factors are associated with reductions in child mortality and often multisectoral approaches are most effective in addressing critical health determinants (Kuruvilla et al., 2014; Bishai et al., 2016).

To our knowledge, this study is the first to analyze the intergenerational effects of deworming. A core contribution of this study is to leverage an intergenerational panel dataset combined with experimental variation, which is extremely rare in LMIC settings, to estimate the causal impact of a child health intervention on intergenerational child survival outcomes. Furthermore, due to the richness of the KLPS, we are able to identify plausible mechanisms and combinations of mechanisms that contribute to the observed reductions in child mortality.

Finally, based on the estimated overall effect of deworming on intergenerational child survival, this study quantifies the economic value of increased child survival in terms of its social internal rate of return. We estimate the number of additional surviving children by combining our estimated under-5 mortality reduction (17 per 1000) with the time series of the average number of births per year in our data. We then generate the monetary value of the additional healthy years per child by combining estimates from the WHO's Global Burden of Disease for Kenya with revealed and stated preference estimates for the value of disability-adjusted life years (DALYs) averted. These numbers, plus information on the cost of school-based deworming, allow us to estimate the social internal rate of return for increased child survival as a result of deworming, which we estimate to be over 42%. These high rates of return due to the child survival gains are in addition to prior work that has demonstrated very high cost-effectiveness of dewmorming treatment in terms of adult labor market returns (Hamory et al., 2021).

We contribute to three particular areas of research. First, we provide additional evidence of the long-term effects of child health interventions (Currie and Vogl, 2013; Almond et al., 2018; Daramola et al., 2022). While much of the literature has focused on the effects of in-utero or early childhood interventions, there is growing interest in adolescence as another critical period for development (Bundy et al., 2018; Akresh et al., 2021). We provide further evidence that adolescent interventions can lead to long-term gains, which has further implications for the cost-effectiveness of such programs.

Second, we relate to research documenting intergenerational mobility and persistence in economic and health outcomes (Black and Devereux, 2011; Chetty et al., 2014; Jácome et al., 2021; Alesina et al., 2021; Asher et al., 2020) by providing evidence on the intergenerational transmission of health status (Vogl and Lu, forthcoming; Bhalotra and Rawlings, 2013). Given the importance of early-life health for later-life outcomes (Currie and Vogl, 2013), improved child survival (which implies improved child health) may have implications for intergenerational mobility for the next generation.

Third, we relate to the literature (mainly in public health) that has studied the causes of reduced child mortality. The leading causes of infant mortality (IMR) and under-five mortality (U5MR) in these contexts include preterm birth complications, infectious diseases, and intrapartum-related events, pointing to the importance of parent and household characteristics and behaviors (Liu et al., 2016; Strong et al., 2021). Past studies find that IMR is most strongly correlated with biodemographic factors (e.g., birth order, birth spacing) while U5MR is most strongly correlated with socioeconomic, environmental, and hygienic factors (Omariba et al., 2007; Currie and Moretti, 2003; Kim et al., 2019; Grépin and Bharadwaj, 2015). While many of these look at contemporaneous interventions and factors (i.e., aiding young children or families with young children directly), we provide evidence on how aiding the first generation may influence subsequent generations.

2 Research Design & Data

2.1 The Primary School Deworming Program (PSDP)

The PSDP took place in Busia District (now Busia County) in western Kenya from 1998-2003. This rural, largely agrarian area had high baseline intestinal helminth infection rates (over 90%) (Miguel and Kremer, 2004). In 1998, a non-governmental organization (NGO) launched the PSDP in 75 schools enrolling over 32,000 pupils. Schools were experimentally assigned into one of three groups via list randomization, with 25 schools assigned to each. The schools were first stratified by administrative subunit (zone), zones were listed alphabetically within each geographic division, and schools were ordered by pupil enrollment within each zone, with every third school then assigned to a given program group. Previous studies confirm the validity of the research design and document that the groups were well-balanced along a wide range of baseline characteristics (Miguel and Kremer, 2004; Baird et al., 2016).

The program was phased in across groups: Group 1 schools began treatment in 1998, Group 2 schools in 1999, and Group 3 schools in 2001 (Figure A.1; see also Appendix B). Children in Groups 1 and 2 were thus on average assigned to 2.41 additional years of deworming treatment and serve as the treatment group in this analysis, while Group 3 serves as the control group (as in Baird et al. (2016); Hamory et al. (2021)). Take-up of the deworming drugs was high: around 75% for the treatment group and under 5% for the control group (Miguel and Kremer, 2004).

Two other cross-cutting experiments were implemented in the KLPS sample, but to focus on the intergenerational impacts of deworming, the treatment groups from these experiments are excluded from the present analysis, and the control groups are re-weighted to maintain the representativeness of the original sample. See Appendix B for more details on the PSDP and KLPS.

2.2 Data

The Kenya Life Panel Survey (KLPS) began in 2003 to track a representative sample of approximately 7500 students enrolled in grades 2 to 7 in the PSDP schools at baseline, and is thus largely representative of primary school students in the study area in 1998. Four rounds of KLPS surveys have been collected over the period 1998-2021 (see Figure A.1), as respondents have aged from 8-15 years old at baseline to 28-36 years old. A notable feature of the KLPS is the commitment to tracking all respondents selected at baseline regardless of whether they have relocated within Kenya or beyond, resulting in high overall effective tracking rates, with 86.5% ever surveyed across all rounds (Table A.1).

Each KLPS round has collected information on fertility and child health, and we use self-reported survey data on births and survival status to construct child and infant mortality measures consistent with Demographic and Health Surveys (Croft et al., 2018). The primary infant and child mortality outcomes pool reported live births (for female respondents and the partners of male respondents) across KLPS survey rounds. A child is considered to have experienced under-5 (under-1) mortality if the child was born alive and is reported by the parent to have died before the age of 5 years (1 year), and is only included in the sample if data is collected at least 5 years (1 year) since their birth year.

KLPS data also include measures that allow us to investigate five types of mechanisms for the intergenerational transmission of health: (i) parental health, (ii) education (any secondary school attendance and total years of completed schooling), (iii) living standards and residence choice (namely, consumption, individual earnings and urban residence), (iv) fertility patterns (age at first birth and number of live births), and (v) use of health care (indicators for receiving antenatal care (ANC) and institutional delivery). Summary statistics for these measures and details on their construction are available in Appendix C.

3 Empirical methods

To estimate the effects of deworming on IMR and U5MR, we use a linear probability model where the dependent variable is a child mortality measure; we also estimate logistic and probit regression models to check robustness. Following Baird et al. (2016) and Hamory et al. (2021), our main empirical specification is:

$$Y_{ijkt} = \alpha + \lambda_1 T_j + X'_{ijk}\beta + \gamma_t + \varepsilon_{ijkt}, \tag{1}$$

where Y_{ijkt} is the outcome of interest for child k of individual i in the PSDP school j as measured in interview round t. As described above, the treatment variable T_j is an indicator for whether the parent attended a school in deworming groups 1 or 2, which were assigned to 2.41 more years of deworming than group 3. Regression covariates include a set of respondent and child-level covariates (as in Baird et al. (2016) and Hamory et al. (2021)), namely the PSDP participants' baseline school characteristics (average test score, population, number of students within 6 km, and administrative zone indicators), respondents' baseline characteristics (grade and gender), indicators for KLPS survey calendar month (within wave and round), and indicators for participation in the control group of other randomized interventions implemented later in the panel (see Appendix B). We also include year of birth fixed effects for child mortality estimates. Standard errors are clustered at the school level to allow for correlation in outcomes both within schools and across survey rounds. The estimates are weighted to maintain representativeness of the baseline PSDP population and take into account the tracking design of the KLPS (as in Baird et al. (2016)) (see Appendix B, C, and table notes).

As a secondary analysis, we look further into differences by deworming treatment levels, namely the years of assigned deworming treatment, in a dose-response analysis. The years of assigned deworming is a function of deworming treatment school group and baseline grade, assuming a normal grade progression, which generates additional experimental variation in the amount of deworming treatment received as the program phased in by group, and some individuals aged out of primary school.[1] Individuals are thus assigned to between zero and six years of deworming treatment; we define two-year treatment bins (1-2, 3-4, 5-6) and estimate Equation (1) using this treatment vector.

To study mechanisms, we (i) examine correlations between hypothesized mechanisms and child mortality in our sample and (ii) estimate deworming treatment effects on these mechanisms.We take a similar approach to Equation (1), estimating ordinary least squares regressions of our mechanism of interest on a deworming treatment indicator, with adjustments for the level of of the data (recipient (parent) vs. child) and data availability by survey round (see Appendix C).

We look for heterogeneous effects in two main dimensions that were pre-specified: recipients' (parent) gender and age, based on previous deworming findings. These analyses allow us to estimate heterogeneous effects, which may be of inherent interest, and also to shed light on potential mechanisms, given the differences in estimated deworming effects.

4 Results

4.1 Intergenerational Child Mortality Impacts

Figure A.1 shows the study timeline. As of the 23-year follow-up, we find no statistically significant difference in attrition between the intervention and control groups (Table A.1). High round-specific and overall tracking rates (86.5% surveyed in a follow-up round) also indicate that the results remain largely representative of the original study population.

The gray line in Figure 1, Panel A plots the Kenyan national average for under-5 mortality over time; as in many LMICs, this rate has fallen by almost half since the start of the study. The blue line in this panel plots the U5MR for the deworming control group by year of

[1] Years in which schools were assigned to cost-sharing for deworming medicine are not counted due to the limited take-up (see Kremer and Miguel (2007) for additional details on take-up in cost-sharing schools).

child birth. We see similar trends for the control group as with the national average. The deworming treatment group is plotted in orange: across child year of birth (1998-2016), under-5 mortality is lower among the children of the treated group in most years. We see similar trends for infant (under-1) mortality, though deworming treatment effects are less pronounced. Again, for both the treatment and control groups, children born in later cohorts experienced declines in mortality, reflecting population-level declines in the Kenyan U5MR and IMR over the period.

Table 1 presents these results in regression form. The deworming intervention decreased the U5MR and IMR for the children of beneficiaries by 17 deaths per 1000 births and 6 deaths per 1000 births, respectively. The average treatment effect for deworming on intergenerational child mortality represents a reduction of 22% (p-value = 0.03), relative to the control mean of 76 deaths per 1000 births (Table 1). Effect magnitudes and statistical significance levels are nearly identical using logistic and probit regression models (Table A.4), and with alternative weighting schemes (Figure A.3 and Table C.2). Similarly, deworming leads to an average reduction in intergenerational infant mortality of 15% (p-value = 0.26, not statistically significant), relative to the control mean of 40 deaths per 1000 births (Table 1).

The data allows for analysis of heterogeneous effects by parents' gender and age (specifically, older versus younger than the median baseline age of 12 years old). The deworming effects are somewhat larger in magnitude among female recipient parents, although effects across gender groups are not significantly different (Table 1). Relative to control group females, deworming treatment reduced intergenerational child mortality for treated females by 16 deaths per 1000 births, an average reduction of 21% (Table 1). The effects of deworming on intergenerational child mortality are larger among older parents (Table A.2). Specifically, deworming reduces intergenerational child mortality among treated older parents by 23 deaths per 1000 births, an average reduction of 29% relative to older parents in the control group, and the difference between older and younger parents is statistically significant (Table A.2). As older parents experienced larger living standards gains relative to younger parents, these results highlight interesting contrasts that we explore further in the next section to better understand potential mechanisms.

Furthermore, we document interesting trends in U5MR when we estimate effects by the number of years assigned to free deworming, which are presented graphically in Figure 2. KLPS respondents that were assigned to receive more years of free deworming have both higher consumption expenditure (Panel A, reproduced from Hamory et al. (2021)) and lower under-5 mortality (Panel B). There are not major differences in the number of births per respondent by years of assigned deworming (Panel C), and while the greatest number of births is among those that received 2-3 years of free deworming, we have sizable sample sizes within each cell (Panel D). The fact that under-5 mortality reductions and annual consumption expenditure appear to exhibit a similar trends and some type of dose-response relationship is intriguing and suggestive of improved living standards playing a role in child mortality reductions, a topic we now turn to in more detail.

4.2 Mechanisms

We focus on five main channels that may contribute to the survival of children in the subsequent generation that are prominent in existing research and collected as part of KLPS surveys: parental health, educational outcomes, adult living standards, fertility patterns, and use of health care. (Of course, other mechanisms that are not measured in KLPS may also contribute to the causal impact of deworming on intergenerational child mortality, making it challenging to fully decompose the overall effect across the measured channels.) Childhood deworming treatment may have positively influenced a number of these adult outcomes, and in turn these outcomes may be associated with reductions in child mortality (see Figure A.2 for an illustration). These outcomes may also be inter-related, e.g. improvements in living standards may allow access to better healthcare; Appendix Table A.8 presents correlations between these potential mechanisms.

To explore this empirically, we (i) calculate correlations between these outcomes and child mortality, and (ii) estimate deworming treatment effects on these outcomes. Deworming treatment is positively correlated with each of these five channels (e.g., for fertility patterns, deworming is positively correlated with reductions in total number of children), and these channels are in turn negatively correlated with intergenerational child mortality, although not all correlations are statistically significant.

Table 2 presents the long-run causal impact of deworming on the five main channels in regression form. The top row of Table 2 reports the correlation between the outcome and child mortality at the respondent level for columns 1-9, as these are measured for respondents, and at the child level for columns 10-11. (More complete regression results are presented in Table A.7.)

KLPS surveys collect information on respondent self-reported health in multiple rounds, which we turn into an indicator for whether or not self-reported health is "good" or "very good". We pool data across survey rounds to estimate treatment effects, and find significant increases in the share of female respondents reporting "good" or "very good" health (3 percentage points on a base of 78 percent). Additionally, KLPS surveys collected information about pregnancies (for themselves for female respondents, and for their partners for male respondents), with questions following those in DHS surveys. To look at correlations with under-5 mortality, we generate an indicator equal to one if the respondent (or their partner) ever report having experienced a miscarriage among those that have been pregnant; experiencing a miscarriage is positively correlated with under-5 mortality. To look at the impact of deworming on miscarriage, we analyze the data at a pregnancy level using a probit specification (as pre-specified), where the main outcome is an indicator for pregnancies that ended in miscarriage. As in Baird et al. (2016), we find reductions in miscarriages for female respondents. Taken together, these findings are suggestive that improved maternal health may play a role in reduced child mortality.

Deworming treatment also has positive effects on recipients' education outcomes (see Columns (4-5)). Among the full sample, individuals who received deworming treatment attained 0.25 more years of schooling (p-value = 0.17) and were more likely to have attended secondary school. These estimated effects are somewhat larger among female parent recipients: among treated females, deworming treatment increased school attainment by 0.43 years (p-value = 0.08) and increased the likelihood of secondary school attendance by 7.6% (p-value = 0.05), relative to females in the control group.

The living standard results presented reproduce the longitudinal analysis from Hamory et al. (2021) and pool data across KLPS rounds 2 to 4, when most respondents were between 19 years and 35 years old. Total household per capita consumption expenditures up to 20-years post treatment are higher by USD PPP 305 (p-value = 0.06) among the treated group, which represents a 14% increase relative to the control mean. Column (2) also documents higher annual individual earnings among deworming recipients, although the results are not statistically significant for the full sample. Treated individuals are 4 percentage points (p-value = 0.03) more likely to reside in urban areas as adults, and this effect is particularly large among male parents (a 13% increase in urban residence relative to control male parents).

The data also suggest that deworming treatment leads to some modest changes in fertility patterns, including age of first birth and total number of children (see Columns (7-8)). Among the treated group, age at first birth is higher by 0.42 years (p-value = 0.06), relative to the control mean of 22.7 years. Among male parent recipients, deworming increased the age at first birth by 0.52 years (p-value = 0.05), relative to the mean age of 24.3 years among male parents in the control group. Individuals in the treatment group also had slightly fewer total children on average although this estimate is not statistically significant.

A final measured pathway is use of health care: on average, deworming treatment increases recipient parents' likelihood of receiving ANC by 1.3 percentage points (p-value = 0.01) and institutional delivery (see Columns (9-10)). Treated female parents are 1.7 percentage points more likely to receive ANC and 4 percentage points more likely to use institutional delivery relative to the female parents in the control group.

To further quantify the role that these factors may be playing in child mortality reductions, we estimate correlations between these outcomes and child mortality in a regression framework in Table A.7, and multiply these by our estimated deworming treatment effects on that outcome from Table 2 to generate an "implied" effect on under-5 mortality from each source. While this exercise is somewhat speculative given that deworming has affected numerous plausible channels (Table 2), this does provide a sense of the relative magnitudes of potential effects across outcomes. We also divide these implied effects by our total estimated treatment effect and report this in the bottom row of Table A.7. Effects on living standards, education and fertility all account for notable shares of the overall reduction in under-5 mortality when estimated individually; when estimated jointly, these factors account for about 14% of the overall treatment effect, a non-trivial share given the many potential mechanisms that may contribute to these results and the fact that measurement error may attenuate some estimates.

Through estimating the long-run effects of deworming on various adult outcomes, the findings suggest several potential contributors to intergenerational child health formation. Improved living standards and residence, higher educational attainment particularly among female parent recipients, older maternal age of first birth, and increased access to health care may serve as pathways to reducing the subsequent generations' child mortality risk. Though the experimental variation in deworming is unable causally identify the separate impact of these parental and household factors on intergenerational infant and child mortality, the study does confirm the combined effect of these factors as possible channels, through the causal effect of deworming on both the original recipient's adult outcomes and the intergenerational child survival outcomes.

5 Cost Benefit Analysis

To quantify the monetary value of the reduction in under-5 mortality, we conduct cost-benefit analysis to estimate the internal rate of return (IRR) for deworming. The social rate of return for deworming treatment provides an estimate of the economic value of the benefits of deworming relative to the costs of providing treatment. School-based deworming is relatively inexpensive, and we use recent cost estimates from school-based deworming in Kenya (see D.1 for details). Valuing health gains is more challenging; there is an extensive literature estimating disability-adjusted life years (DALYs). We take two approaches to identify a willingness to pay per DALY averted: the first uses the stated preference of Kenyan households' willingness to pay to avoid child health problems, and the second uses revealed preference measures (which are typically lower than stated preferences). We combine the estimated willingness to pay to avert a DALY figures with information on the time series of births in the sample, the estimated U5MR reduction (from Table 1), and the average value of life in terms of DALYs, to generate benefits over time.

Using stated and revealed preference approaches, the estimated willingness to pay per DALY averted is USD PPP 3611 and 67, respectively. Figure 3 presents the costs and implied intergenerational health benefits graphically, on a log scale. In earlier years, deworming treatment costs are incurred, and child survival benefits are smaller given the low overall birth rates. In later years, higher birth rates lead to increased benefits in terms of child survival, which through 25 years post treatment, amount to USD PPP 394 and 7 on average under the stated and revealed preference approaches, respectively. The annualized social IRR for intergenerational mortality benefits under stated preference and revealed preference is 124.6% and 41.5%, respectively. Assuming a discount rate of 5%, the net present value from intergenerational mortality benefits is positive for both stated and revealed preference approaches, at USD PPP 4658 and 85 respectively, with respect to the deworming drug treatment costs.

These calculated benefits only include the reduction of intergenerational child mortality and do not incorporate other treatment gains (e.g., those in consumption and earnings Hamory et al. (2021)), nor other losses in human welfare associated with bereavement. Furthermore, we assign the intergenerational child survival benefits to five years after the child's birth. For both of these reasons (and others articulated in the appendix), the partial cost-benefit analysis here provides a highly conservative estimate for the overall return to deworming.

6 Discussion

This study provides novel causal evidence on the impact of a randomized child health intervention on intergenerational child survival outcomes. We document that the children of deworming recipients were more likely to survive to age 5. We also estimate deworming impacts on five leading channels potentially linking deworming to intergenerational child mortality–adult health and education, adult living standards and residence choice, fertility patterns, and use of health care–and it seems likely that some combination of these channels, and possibly others, account for the overall child survival effect. The findings on mechanisms also corroborate previously hypothesized channels (e.g., maternal education).

It should also be noted that we do not conduct a full causal mediation analysis due to data limitations and methodological concerns (Lynch et al., 2008). A timing mismatch between the measurement of the mechanisms (sometimes only collected in later KLPS survey rounds) and intergenerational child mortality, for instance, make it difficult to establish tight causal claims. Furthermore, given that the hypothesized mechanisms were not themselves randomized in the original study design, mediation analysis may lead to biased inference.

The point estimate on intergenerational infant (under-1) mortality is negative, and the proportional reduction in infant mortality is broadly in line with the reduction in under-5 mortality, but the infant mortality effect is not statistically significant. Several factors may explain differences between the IMR and U5MR results. Previous studies suggest that different pathways are more important in explaining intergenerational infant versus under-5 mortality. Importantly, deworming led to improvements in adult socioeconomic and education outcomes, which are more commonly associated with U5MR (Omariba et al., 2007). Baird et al. (2016) also finds that deworming reduces the likelihood of miscarriage. Somewhat speculatively, this suggests that additional children who may be less healthy are being born in the treated group; if these children are more susceptible to neonatal infections, the leading cause of infant mortality globally (Liu et al., 2016), this would dampen the treatment effect in infant mortality.

The relative impacts on the various proposed channels linking deworming to intergenerational child survival also differ depending on recipients' gender or age at baseline. For instance, the deworming effects on education outcomes and use of health care are particularly large among female parent recipients, which suggests that for female parents, deworming may reduce intergenerational child mortality predominantly via increases in years of schooling and use of ANC and institutional delivery. Similarly for parent recipients above the median age in the sample, deworming had particularly large positive impacts on economic living standards, and this subgroup also shows more pronounced reductions in under-5 child mortality.

Additionally, cost-benefit analysis for deworming suggests that the benefits of increased intergenerational child survival alone far outweigh the costs of treatment. It should be noted that the high calculated social IRRs here are consistent with previous analysis on the marginal value of public funds invested in numerous child health, education, and nutritional programs (Hendren and Sprung-Keyser, 2020).

In general, rigorous evaluations of the long-term and intergenerational impacts of childhood health investments are rare in LMICs due to a lack of longitudinal data that tracks both adults and their children and the well-known difficulties inherent in designing credible strategies to address omitted variables and confounding. In contrast, this study leverages the unusual combination of experimental evidence and a longitudinal survey among the original respondents and their children.

Limitations of this study include an inability to decompose the overall effect of deworming on intergenerational child survival across the measured channels. While the experimental design allows for the identification of plausible mechanisms, it is difficult to disentangle the relative weight and interaction of these mechanisms in reducing child mortality. Mechanisms matter, because beyond implementing child health interventions (like deworming), it is important to understand where policy should focus to improve child survival and health outcomes. Furthermore, the heterogeneous deworming impacts on potential mechanisms among gender and age subgroups suggests that the study population matters. Thus, an important avenue for future research is to determine which multi-sectoral approaches are most effective, and for whom.

Another factor to consider is external validity: the KLPS is not a nationally-representative sample but rather drawn from students attending rural primary schools in Busia, Kenya in 1998. This smaller sample, however, is the price to pay for experimental variation in the child health intervention. Furthermore, the limited sample size allowed for the gathering of multiple rounds of rich survey data with low rates of sample attrition, which enables us to analyze how adult life changes translate into child survival outcomes, including via the hypothesized mechanisms discussed above. Despite not being nationally-representative, the KLPS sample appears to be fairly typical of other SSA settings (see Appendix B). Furthermore, given the high prevalence of intestinal helminth infections in SSA and globally, the findings on the causal intergenerational impacts of deworming are relevant in many other settings.

These findings suggest that deworming treatment has implications not only for reducing infection rates among the current generation, but also potentially far-reaching implications on improving child survival outcomes of the subsequent generation. Furthermore, transmission of intergenerational child health could occur on multiple fronts, and multi-sectoral public policy approaches may be key to reducing infant and child mortality. Finally, cost-benefit analysis suggests that deworming is highly cost-effective. Taken together, the results provide causal evidence of the intergenerational transmission of health and highlight the wide range of assumptions under which subsidies for deworming would be justified.

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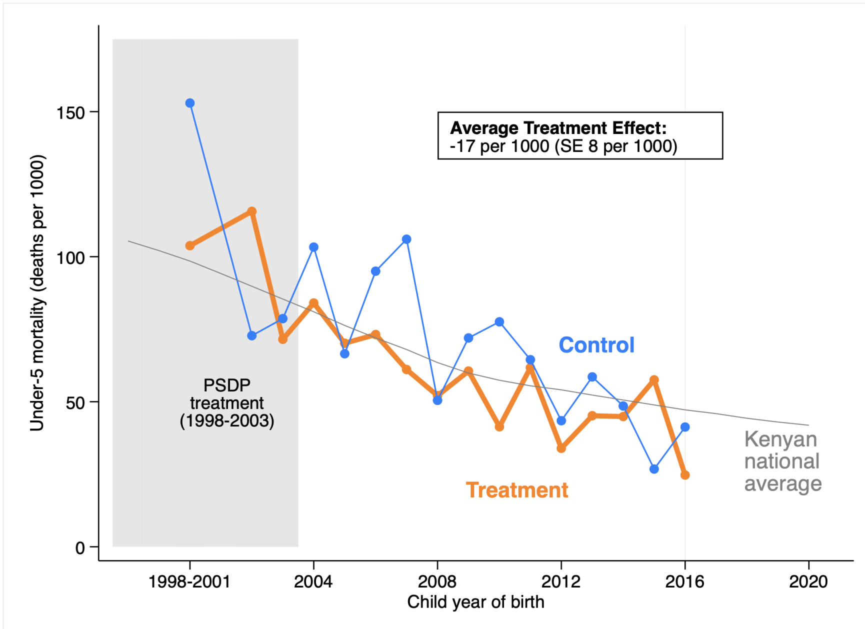
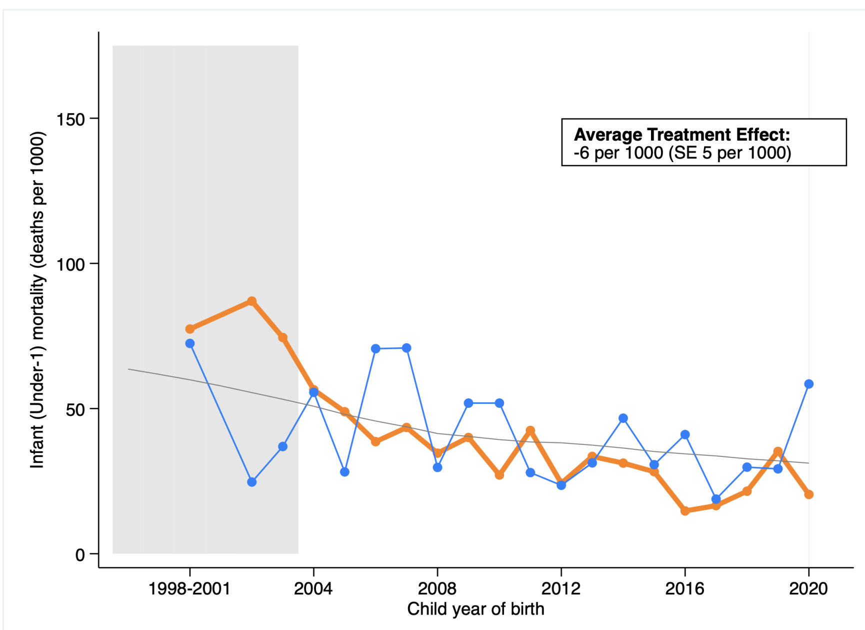
Figure 1: Intergenerational Deworming Impacts on Child Mortality, for Parent Deworming Treatment group vs Control group



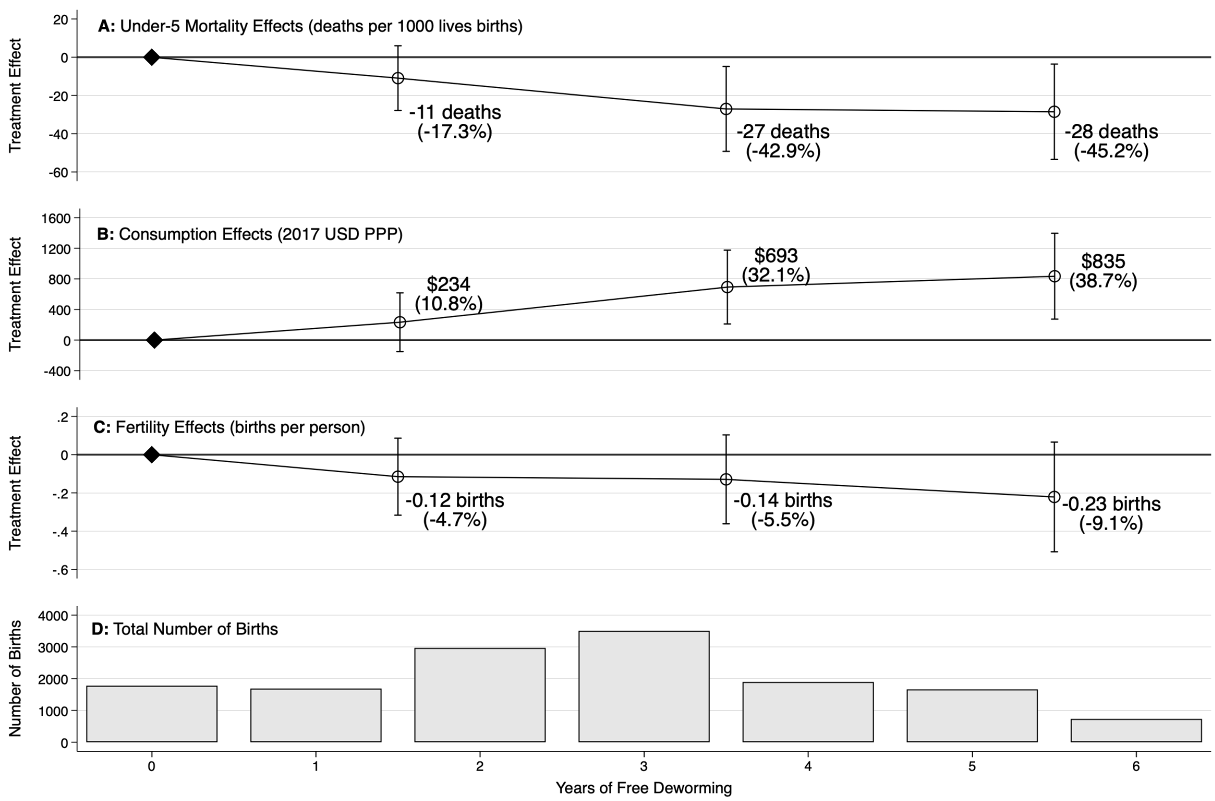
(a) Panel A: Under-5 mortality over time (1998-2016)



(b) Panel B: Infant (under-1) mortality over time (1998-2020)

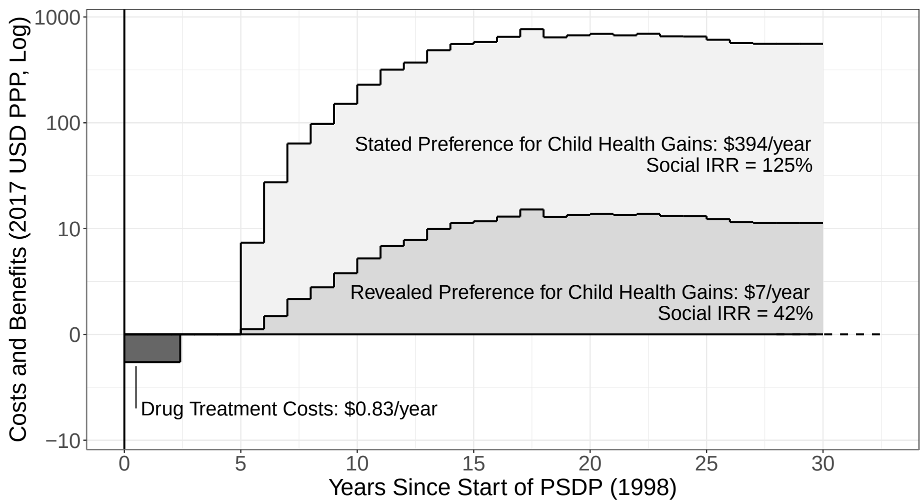
Notes: Figure 1 shows mortality rates by year. The orange line shows the mortality rates for respondents from treatment schools, and the blue line shows the mortality rates for respondents from control schools. The grey line shows the Kenyan national average by year. Panel A shows under-5 mortality which for a given year is calculated as the share of children born in that year who die before the age of 5, scaled to be deaths per 1000 births. The data is trimmed at 2016, shown by a vertical line, so that all children are observed for at least 5 years. Panel B shows under-1 mortality. The Under-1 mortality rate is calculated as the share of children born in that year who die before the age of 1, scaled to be deaths per 1000 births. The data is trimmed at 2020 so that all children are observed for at least 1 year. The grey shaded area denotes the PSDP project years from 1998-2003. The sample is weighted using the average round-specific PSDP analytical weights.

Figure 2: Deworming Impacts by Years of Assigned Deworming Treatment



Notes: This figure plots deworming treatment effects by years of assigned free deworming treatment. Years of assigned deworming is constructed as the total number of years the respondent would be expected to attend a school with free deworming medication, based on the PSDP group (Group 1, Group 2, or Group 3), the standard at baseline (1998), and assuming normal grade progression. Years in which schools were assigned to cost-sharing for deworming medicine are not counted due to the limited take-up (see Kremer and Miguel (2007) for additional details on take-up in cost-sharing schools). Panel A reports under-5 mortality coefficient estimates (with percentage effects in parentheses) from child-level regressions. Panel B is reproduced from Hamory et al. (2021) and plots coefficient estimates for annual consumption expenditure for KLPS respondents. Panel C reports total fertility effects (number of births per person) for KLPS respondent. Panel D shows the total number of births for KLPS respondents for each year of assigned deworming treatment.

Figure 3: Valuing the Benefits of Intergenerational Deworming Impacts on Child Mortality



Notes: This figure presents the deworming drug treatment costs and intergenerational mortality benefits of deworming over time, and calculated social IRR. For compatibility purposes, the costs and benefits in the figure are reported in 2017 USD PPP terms as used in Hamory et al. (2021). The y-axis uses a common logarithmic scale to show the intergenerational mortality benefits and the costs clearly. For the sake of readability, costs and benefits are presented in terms of log(1+Value), which costs then multiplied by -1 and presented as negative values in the figure. For additional details and alternative assumptions, see Appendix Table A.9 and Section D.1. The drug treatment costs include the drug cost of providing mass school-based deworming from the NGO Deworm the World Hamory et al. (2021). We calculate intergenerational mortality benefits as a monetary value of saved under-5 children's lives per deworming recipient, taking into account U5MR treatment effects, fertility rates, value of saved children's lives, and monetary value of child health gains. We use the U5MR treatment effects of children born from deworming recipients measured from 1998 to 2016 (from 0 to 18 years after the start of deworming) and pooled across rounds (from Table 1, Panel A, Column 1, Child (Under-5) Mortality: Full sample). We use the fertility rate for each year measured from 0 to 22 years after the start of deworming and pooled across rounds (See Appendix, Figure A.4). We assume a fertility remains constant at the 22-year level from years 22 to 25 post-treatment, and then to be conservative, we assume zero mortality benefits starting at 25 years post-treatment. Given the focus on U5MR, we assign health benefits at five years after a child's birth. For the monetary value of child health benefits, we estimate the costs per DALY based on two approaches: stated preference and revealed preference. For stated preference, we surveyed 753 respondents' willingness to pay for their child's health in Busia, Kenya. We estimate the willingness to pay per DALY averted at USD PPP 3611.20 (See Appendix Table A.9 and D.2). For revealed preference, we estimate the willingness to pay per DALY at USD PPP 66.82 Kremer et al. (2011). The average estimated intergenerational mortality benefits are USD PPP 394 per year for stated preference, and USD PPP 7 per year for revealed preference. A return of 5% represents the real interest rate from 1998 to 2018 (based on Kenyan government bond rates and inflation rates). Assuming a discount rate of 5%, the NPV from intergenerational mortality benefits of stated preference is USD PPP 4657.91. The NPV from revealed preference is USD PPP 84.77. The annualized social IRR for intergenerational mortality benefits of stated preference is 124.6%, while the annualized social IRR for intergenerational mortality benefits of revealed preference is 41.5%. This figure only includes intergenerational mortality benefits and deworming drug treatment costs and does not incorporate positive consumption gains, earnings gains, or teacher costs considered in Hamory et al. (2021).

Table 1: Intergenerational Deworming Impacts on Child and Infant Mortality

	(1) Child (Under-5) Mortality	(2) Infant (Under-1) Mortality
Panel A: Full Sample		
Treatment	-.017**	-.006
	(.008)	(.005)
Control Mean	.076	.040
Treatment Effect (%)	-21.83	-15.20
Number Observations	10063	13613
Panel B: Female Parents		
Treatment	-.016*	-.007
	(.009)	(.006)
Control Mean	.074	.041
Treatment Effect (%)	-21.22	-15.87
Number Observations	5838	7503
Panel C: Male Parents		
Treatment	-.017	-.005
	(.017)	(.008)
Control Mean	.078	.039
Treatment Effect (%)	-21.79	-13.63
Number of Observations	4225	6110

Notes: Column (1) shows the PSDP treatment effect on child mortality, and column (2) shows the PSDP treatment effect on infant mortality. The *Child Mortality* outcome is an indicator which is 1 if the child died before the age of 5. The data is trimmed to include only children that we observe for at least five years since birth. Similarly, the *Infant Mortality* outcome is an indicator which takes a value of 1 if the child is died before the age of 1 or over. The data is trimmed to include only children we observe for at least one year since birth. Panel A shows results using the full sample of children, whereas Panel B (Panel C) shows the results from children of female parents (male parents). The sample excludes individuals who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. The sample weights are adjusted for intensive tracking and inclusion in the vocational training and/or cash grant control group. The weights used in the regressions are the average of these round-specific adjusted sample weights. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table 2: Deworming Impacts on Potential Mechanisms for Intergenerational Effects

	Parental Health		Education Outcomes		Living Standards and Residential Choice			Fertility Patterns		Access to Healthcare	
	(1) Self-Reported Health Good	(2) Miscarriage	(3) Attended Sec. Ed.	(4) School Attainment	(5) Annual Per-Cap. Consumption	(6) Annual Ind. Earnings	(7) Lives in Urban Area	(8) Age at First Birth	(9) Num. of Children	(10) Received ANC	(11) Inst. Delivery
Correlation with Under-5 Mortality (ρ)	-0.016	0.081	-0.079	-0.081	-0.023	-0.032	-0.054	-0.071	0.164	0.000	-0.048
Panel A: Full Sample											
Treatment	.015	-.147*	.023	.25	305.1*	79.5	.042**	.436*	-.11	.013**	.021
	(.010)	(.083)	(.029)	(.18)	(158.6)	(75.7)	(.019)	(.226)	(.10)	(.005)	(.019)
Control Mean	.812	.054	.478	9.33	2156.5	1218.2	.455	22.64	2.59	.955	.731
Treatment Effect (%)	1.90	-27.17	4.83	2.67	14.15	6.53	9.33	1.93	-4.25	1.34	2.87
Number Observations	12263	8751	5506	5506	4794	13624	13793	4630	5499	11856	11796
Panel B: Female Parents											
Treatment	.030**	-.147*	.076*	.43*	89.4	40.6	.023	.366	-.10	.017**	.043*
	(.014)	(.083)	(.038)	(.24)	(133.6)	(62.0)	(.020)	(.286)	(.12)	(.007)	(.023)
Control Mean	.783	.054	.378	8.74	1715.2	673.6	.431	21.12	2.82	.947	.666
Treatment Effect (%)	3.80	-27.17	20.00	4.97	5.21	6.02	5.23	1.74	-3.69	1.80	6.38
Number Observations	6151	8751	2779	2779	2473	6826	6853	2455	2781	6688	6651
Panel C: Male Parents											
Treatment	.001		.065	512.63*	118.2	.1**	.507*	-.111	.01*	-.007	
	(.016)		(.212)	(303.86)	(132.7)	(.0)	(.258)	(.123)	(.00)	(.027)	
Control Mean	.837		9.87	2593.7	1727.8	.476	24.22	2.38	.966	.811	
Treatment Effect (%)	.14		.66	19.76	6.84	12.97	2.09	-4.68	.75	-.88	
Number Observations	6112		2727	2321	6798	6940	2175	2718	5168	5145	

Notes: The table presents regression results of five main groups of outcomes on the PSDP treatment variable and their correlation with under-5 mortality. See C for details on the variable construction. Columns (1) and (2) are outcomes on parental health, including an indicator for self-reported health good or very good, and an indicator for miscarriage (at the pregnancy-level). Column (2) is calculated as a probit regression. Columns (3) and (4) are outcomes on education outcomes and include respondents from the last survey they were observed across KLPS-2, KLPS-3, and KLPS-4. Columns (5) to (7) are outcomes on living standards and residential choice. Columns (8) and (9) are outcomes on fertility patterns and includes respondents from the last round they were observed across KLPS-2, KLPS-3, and KLPS-4. In Columns (10) and (11) are outcomes on healthcare access for all live births in the KLPS sample from the last round the parents were observed. Correlations with under-5 mortality are calculated as the average of each outcome at the PSDP respondent level. Panel A shows the full sample of the respective outcomes, Panel B (Panel C) includes female (male) respondents. All regression specifications are weighted according to their inclusion in the KLPS sample, and re-weighted for intensive tracking The sample includes individuals in the PSDP sample and excludes individuals who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. Sample weights are adjusted for intensive tracking and inclusion in the vocational training and/or cash grant control group. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level. Correlation with Under-5 Mortality (ρ) is calculated as the pairwise correlation between under-5 mortality and the stated outcome. Columns (1) - (9) show correlations between the average under-5 mortality and the average value of that outcome across survey rounds at the respondent-level. Columns (10) and (11) show correlations calculated at the child-level.

A Additional exhibits

Figure A.1: Primary School Deworming Project (PSDP) and Kenya Life Panel Survey (KLPS) Timeline

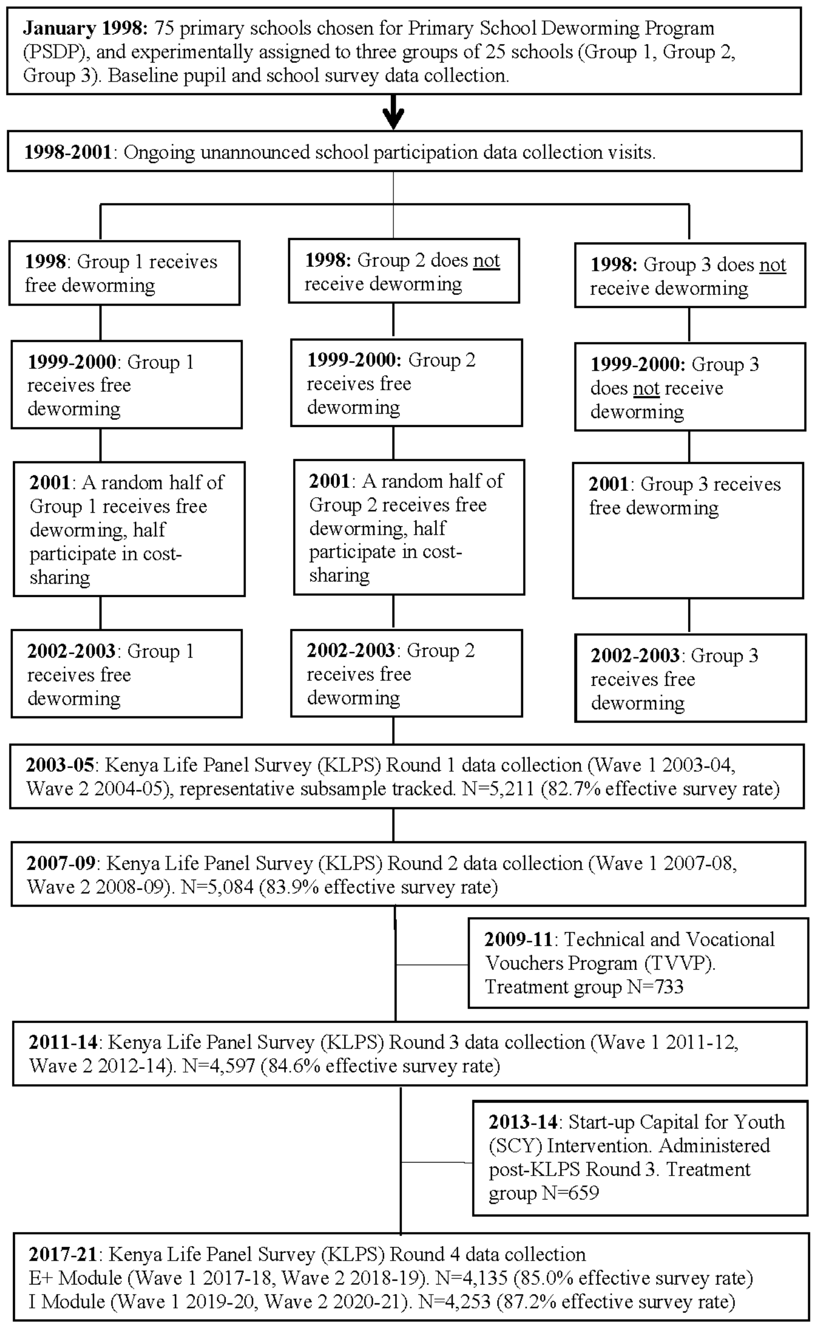
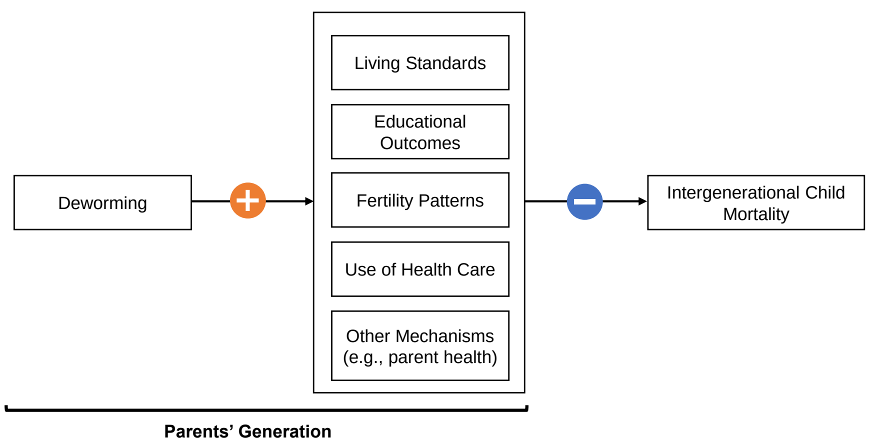
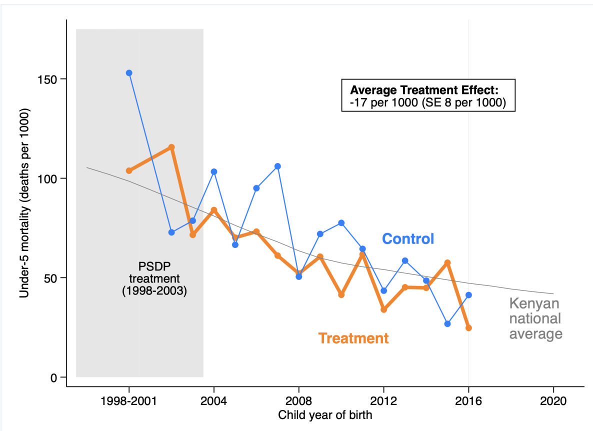


Figure A.2: Hypothesized Mechanisms for Intergenerational Child Mortality Effects from Deworming

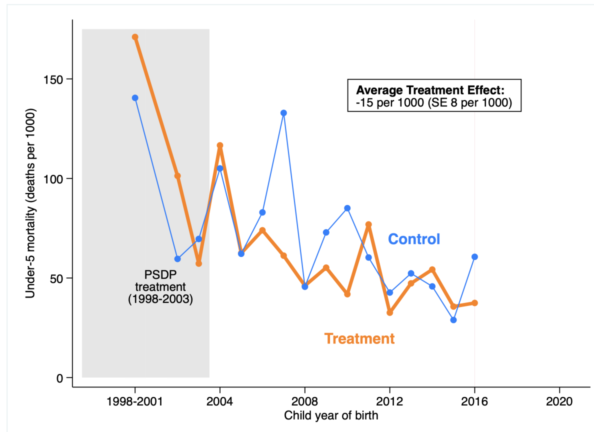


Notes: This figure presents potential causal mechanisms from deworming intervention to intergenerational child mortality. The mechanisms analysis focuses on the upper four main channels: recipients' adult living standards and residential choice, education outcomes, fertility patterns, and use of health care. See the first row of Table 2 for the results of the correlation analysis. The analysis hypothesizes that the deworming treatment positively influences these four mechanism channels; in turn, these channels are negatively related to intergenerational child mortality (i.e., lead to reduced intergenerational child mortality). Other mechanisms beyond those measured in this study may also contribute to the causal impact of deworming on intergenerational child mortality.

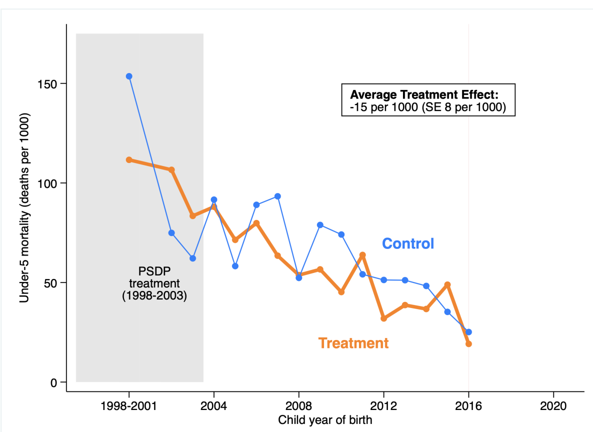
Figure A.3: Deworming Impacts on Under-5 Mortality Under Alternative Weighting Schemes



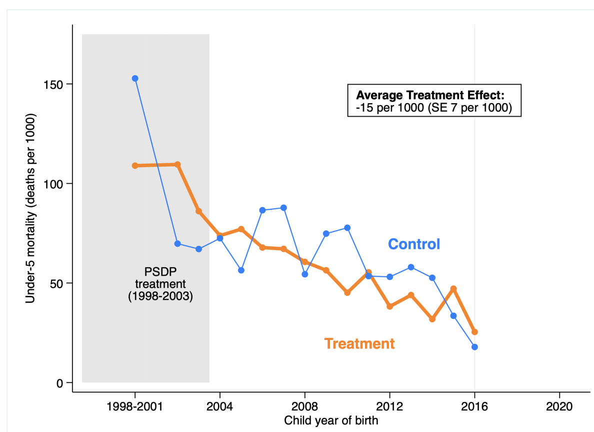
(a) Panel A: Average PSDP weights across KLPS rounds (main)



(b) Panel B: KLPS round specific weights



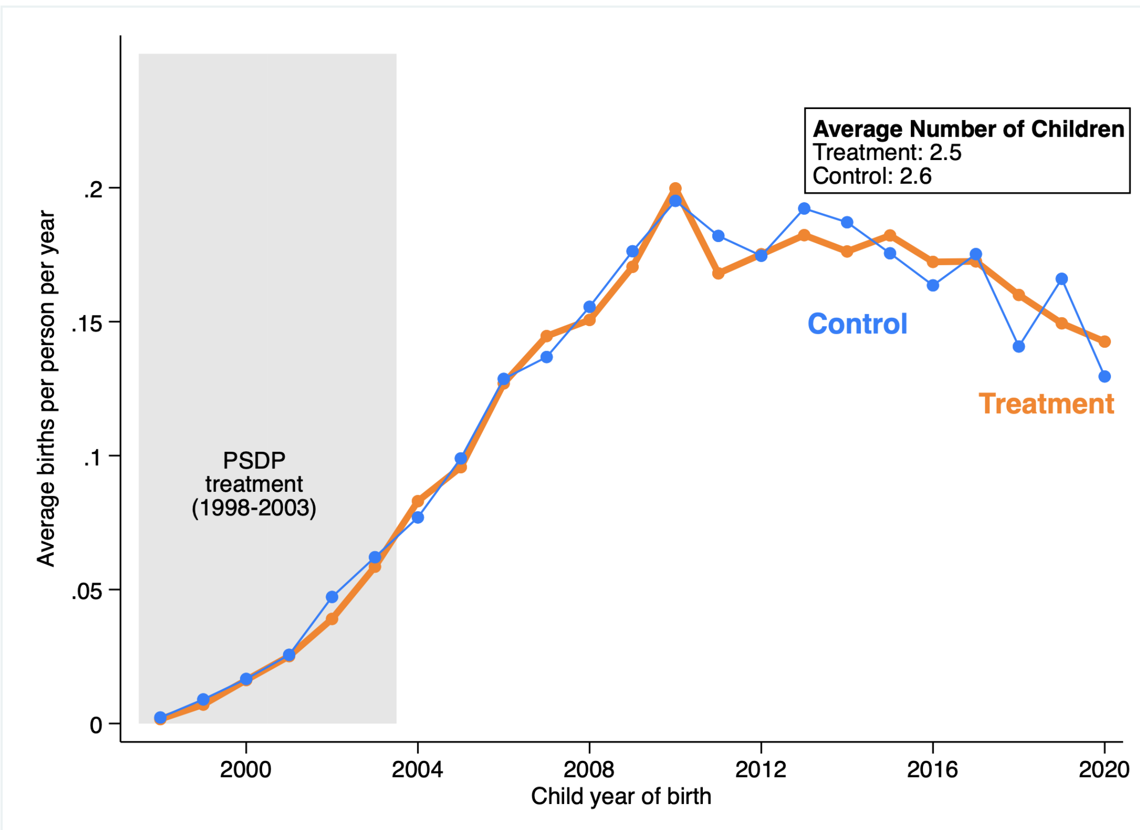
(c) Panel C: Population weights not adjusted for intensive tracking



(d) Panel D: Unweighted

Notes: This figure shows the difference in the under-5 mortality rates by year between treatment and control using alternative weighting methods. Panel A shows the trends using weights that are the average of all round-specific PSDP weights (as in Figure 1). This is the same specification used in Column 1 of Table 1. The grey line denotes the Kenyan national average during this same time period. Panel B uses weights of the first KLPS round that happens after the child turns (or would have turned) 5 years old. Panel C uses the population weights that are unadjusted for intensive tracking and are constant across rounds. Panel D are unweighted. The grey shaded area denotes the PSDP project years from 1998-2003. The Under-5 mortality rate for a given year is calculated as the share of children born in that year who die before the age of 5, scaled to be deaths per 1000 births. The data is trimmed at 2016, shown by a vertical line, so that all children are observed for at least 5 years. Table C.2 presents these results in table format.

Figure A.4: Average Number of Children Born Per Respondent Per Year



Note: This figure shows the average number of live births per respondent per year for those with available fertility data, separately by treatment and control. Those treated in a separate randomized vocational training intervention (VocEd) and small grant intervention (SCY) are dropped from this sample. The grey shaded area denotes the PSDP project years from 1998-2003.

Table A.1: Kenya Life Panel Survey (KLPS) Respondent Survey Tracking and Attrition Rates

	Control Mean			Treatment − Control (se)		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	Female	Male	All	Female	Male
Panel A: Overall (2007-2021)						
Found	.900	.902	.898	.002	-.015	.020
				(.012)	(.013)	(.014)
Deceased	.044	.034	.053	.003	.011*	-.005
				(.005)	(.006)	(.008)
Surveyed, including later deceased	.865	.872	.858	.002	-.021	.025
				(.013)	(.015)	(.015)
Number Surveyed	6523	3269	3254			
Panel B: KLPS-4 I Module (2019-2021)						
Found	.902	.913	.891	.007	-.026	.039
				(.024)	(.029)	(.029)
Deceased	.052	.049	.054	.004	.004	.004
				(.009)	(.014)	(.011)
Surveyed, among non-deceased	.872	.892	.853	-.005	-.049	.038
				(.028)	(.031)	(.035)
Number Surveyed	4253	2195	2058			
Panel C: KLPS-3 I Module (2011-14)						
Found	.875	.863	.886	-.005	-.018	.009
				(.021)	(.027)	(.021)
Deceased	.022	.022	.022	.005	.001	.008
				(.004)	(.006)	(.006)
Surveyed, among non-deceased	.861	.846	.875	-.013	-.023	-.002
				(.022)	(.028)	(.022)
Number Surveyed	4596	2260	2336			
Panel D: KLPS-2 (2007-09)						
Found	.867	.854	.878	-.007	-.021	.007
				(.017)	(.025)	(.022)
Deceased	.014	.012	.016	.004	.006	.003
				(.004)	(.005)	(.005)
Surveyed, among non-deceased	.839	.830	.847	.001	-.018	.019
				(.017)	(.025)	(.023)
Number Surveyed	5084	2489	2595			

Notes: Columns (1) to (3) present control means for indicator variables for respondent found, deceased, or surveyed, respectively. Column (4) presents regression results of these indicator variables regressed on an indicator for PSDP treatment. Columns (5) and (6) present regression results for female and male subsamples, respectively. Panel A shows the overall tracking rate across all KLPS rounds. As such, the surveyed indicator is equal to 1 if the respondent was surveyed in any of the KLPS rounds. For Panels B, C, and D the sample includes all PSDP individuals found in initial tracking or placed under intensive tracking, and only includes individuals in the PSDP sample. These tracking rates are weighted to account for the two-stage tracking approach. Those treated in a separate vocational training intervention (VocEd) which occurred prior to KLPS-3 are dropped from the KLPS-3 and KLPS-4 attrition samples. Those treated in a separate small grant intervention (SCY) which occurred during KLPS-3 are dropped from the KLPS-4 attrition sample. Observations are weighted to be representative of the original KLPS population, and include KLPS population weights, SCY and VocEd control group weights, and KLPS intensive tracking weights. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 %, ** at 5%, and *** at 1% level.

Table A.2: Intergenerational Deworming Impacts on Child and Infant Mortality, by Older vs Younger Parent Recipients

	(1) Child (Under-5) mortality	(2) Infant (Under-1) mortality
Panel A: Full Sample		
Treatment	-.017**	-.006
	(.008)	(.005)
Control Mean	.076	.040
Treatment Effect (%)	-21.83	-15.20
Number Observations	10063	13613
Panel B: Parent Older at PSDP Baseline		
Treatment	-.023**	-.011
	(.009)	(.006)
Control Mean	.079	.041
Treatment Effect (%)	-29.02	-25.38
Number Observations	6339	8116
Panel C: Parent Younger at PSDP Baseline		
Treatment	-.007	-.001
	(.015)	(.010)
Control Mean	.071	.039
Treatment Effect (%)	-10.29	-1.77
Number of Observations	3724	5497

Notes: Column (1) shows the PSDP treatment effect on child mortality, and column (2) shows the PSDP treatment effect on infant mortality. The *Child Mortality* outcome is an indicator which is 1 if the child died before the age of 5. The data is trimmed to include only children that we observe for at least five years since birth. Similarly, the *Infant Mortality* outcome is an indicator which takes a value of 1 if the child is died before the age of 1 or over. The data is trimmed to include only children we observe for at least one year since birth. Panel A shows results using the full sample of children, whereas Panel B (Panel C) shows the results from children of parents who were older (younger) at baseline, The sample excludes children of parents who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. Sample weights are adjusted for intensive tracking and inclusion in the vocational training and/or cash grant control group. The weights used in the regressions are the average of these round-specific adjusted sample weights. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.3: Intergenerational Deworming Impacts on Child and Infant Mortality, by Female and Male Children

	(1) Child (Under-5) Mortality	(2) Infant (Under-1) Mortality
Panel A: Full Sample		
Treatment	-.017**	-.006
	(.008)	(.005)
Control Mean	.076	.040
Treatment Effect (%)	-21.83	-15.20
Number Observations	10063	13613
Panel B: Female Child		
Treatment	-.010	.001
	(.010)	(.007)
Control Mean	.071	.035
Treatment Effect (%)	-13.81	3.07
Number Observations	4970	6722
Panel C: Male Child		
Treatment	-.017	-.009
	(.012)	(.006)
Control Mean	.072	.039
Treatment Effect (%)	-23.30	-23.36
Number of Observations	5058	6852

Notes: Column (1) shows the PSDP treatment effect on child mortality, and column (2) shows the PSDP treatment effect on infant mortality The *Child Mortality* outcome is an indicator which is 1 if the child died before the age of 5. The data is trimmed to include only children that we observe for at least five years since birth. Similarly, the *Infant Mortality* outcome is an indicator which takes a value of 1 if the child is died before the age of 1 or over. The data is trimmed to include only children we observe for at least one year since birth. Panel A shows results using the full sample of children, whereas Panel B (Panel C) shows the results from a subsample of female (male) children. The sample excludes children of parents who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. Sample weights are adjusted for intensive tracking and inclusion in the vocational training and/or cash grant control group. The weights used in the regressions are the average of these round-specific adjusted sample weights. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.4: Intergenerational Deworming Impacts on Child and Infant Mortality, Logit and Probit

	Logit		**Probit**	
	(1) Child (Under-5) Mortality	(2) Infant (Under-1) Mortality	(3) Child (Under-5) Mortality	(4) Infant (Under-1) Mortality
Panel A: Full Sample				
Treatment	-.295**	-.173	-.139**	-.082
	(.142)	(.150)	(.065)	(.064)
Control Mean	.076	.040	.076	.040
Probability Reduction (%)	24.19	15.41	23.94	16.64
Number Observations	10053	13550	10053	13550
Panel B: Female Parents				
Treatment	-.286*	-.188	-.131*	-.082
	(.156)	(.179)	(.072)	(.076)
Control Mean	.074	.041	.074	.041
Probability Reduction (%)	23.56	16.65	22.83	16.69
Number Observations	5829	7471	5829	7471
Panel C: Male Parents				
Treatment	-.302	-.150	-.148	-.081
	(.288)	(.253)	(.133)	(.106)
Control Mean	.078	.039	.078	.039
Probability Reduction (%)	24.68	13.47	25.30	16.57
Number of Observations	4224	6079	4224	6079

Notes: Columns (1) and (3) show the PSDP treatment effect on child mortality, and columns (2) and (4) show the PSDP treatment effect on infant mortality using logit and probit models, respectively. The *Child Mortality* outcome is an indicator which is 1 if the child died before the age of 5. The data is trimmed to include only children that we observe for at least five years since birth. Similarly, the *Infant Mortality* outcome is an indicator which takes a value of 1 if the child is died before the age of 1 or over. The data is trimmed to include only children we observe for at least one year since birth. Panel A shows results using the full sample of children, whereas Panel B (Panel C) shows the results from children of female parents (male parents). The sample excludes individuals who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. The sample weights are adjusted for intensive tracking and inclusion in the vocational training and/or cash grant control group. The weights used in the regressions are the average of these round-specific adjusted sample weights. Standard errors are clustered at the 1998 school level. Probability reduction (%) is calculated as the predicted probability in child mortality for the PSDP treatment group minus the predicted probability in child mortality for the PSDP control group divided by predicted probability in child mortality for the PSDP control group, evaluated at the regression covariate means. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.5: Deworming Impacts on Potential Mechanisms for Intergenerational Effects, by Older vs Younger Parent Recipients

	Parental Health	Education Outcomes		Living Standards and Residential Choice			Fertility Patterns		Access to Healthcare	
	(1) Self-Reported Health Good	(2) Attended Sec. Ed.	(3) School Attainment	(4) Annual Per-Cap. Consumption	(5) Annual Ind. Earnings	(6) Lives in Urban Area	(7) Age at First Birth	(8) (-1)*Num. of Children	(9) Received ANC	(10) Inst. Delivery
Panel A: Full Sample										
Treatment	.015	.023	.25	305.1*	79.5	.042**	.44*	-.11	.013**	.021
	(.010)	(.029)	(.18)	(158.6)	(75.7)	(.019)	(.23)	(.10)	(.005)	(.019)
Control Mean	.812	.478	9.33	2156.5	1218.2	.455	22.64	2.59	.955	.731
Treatment Effect (%)	1.90	4.83	2.67	14.15	6.53	9.33	1.93	-4.25	1.34	2.87
Number Observations	12263	5506	5506	4794	13624	13793	4630	5499	11856	11796
Panel B: Parent Older at Baseline										
Treatment	.003	.027	.18	886.0***	258.2**	.030	.27	-.10	.012*	.035
	(.018)	(.029)	(.18)	(223.0)	(107.5)	(.029)	(.22)	(.12)	(.007)	(.025)
Control Mean	.801	.384	8.84	1908	1177.3	.46	22.96	3.02	.962	.685
Treatment Effect (%)	.41	7.00	2.06	46.44	21.93	6.50	1.19	-3.18	1.28	5.11
Number Observations	6148	2789	2789	2402	6791	6894	2451	2752	6865	6814
Panel C: Parent Younger at Baseline										
Treatment	.025*	.020	.31	-179.2	-75.4	.053**	.57*	-.10	.014***	.018
	(.014)	(.044)	(.29)	(185.4)	(99.5)	(.022)	(.31)	(.11)	(.005)	(.025)
Control Mean	.821	.563	9.78	2381.3	1242	.451	22.35	2.21	.947	.788
Treatment Effect (%)	3.01	3.63	3.20	-7.52	-6.07	11.67	2.57	-4.48	1.43	2.23
Number Observations	6115	2717	2717	2341	6780	6852	2146	2684	4924	4916

Notes: The table presents regression results of five main groups of outcomes on the PSDP treatment variable. See C for details on the variable construction. Column (1) is the parent's self-reported health status. Columns (2) and (3) are outcomes on education outcomes and include respondents from the last survey they were observed across KLPS-2, KLPS-3, and KLPS-4. Columns (4) to (6) are outcomes on living standards and residential choice. Columns (7) and (8) are outcomes on fertility patterns and includes respondents from the last round they were observed across KLPS-2, KLPS-3, and KLPS-4. In Column (8) the number of children outcome variable is multiplied by -1 to interpret positive coefficients as reductions in fertility and vice-versa. Columns (9) and (10) are outcomes on healthcare access for all live births in the KLPS sample from the last round the parents were observed. Panel A shows the full sample of the respective outcomes, Panel B (Panel C) shows the results for a subsample of respondents who were older (younger) at baseline. All regression specifications are weighted according to their inclusion in the KLPS sample, and re-weighted for intensive tracking The sample includes individuals in the PSDP sample and excludes individuals who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. Sample weights are adjusted for intensive tracking and inclusion in the vocational training and/or cash grant control group. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.6: Deworming Impacts on Fertility Outcomes

	(1) Has Any Children	(2) Num. of Children	(3) Num. of Children (cond.)
Panel A: Full Sample			
Treatment	.003	-.110	-.102
	(.015)	(.103)	(.099)
Control Mean	.83	2.59	3.10
Treatment Effect (%)	.37	-4.25	-3.29
Number Observations	5499	5499	4631
Panel B: Female Parents			
Treatment	-.003	-.104	-.074
	(.019)	(.118)	(.108)
Control Mean	.88	2.82	3.20
Treatment Effect (%)	-.40	-3.69	-2.32
Number Observations	2781	2781	2455
Panel C: Male Parents			
Treatment	.012	-.111	-.132
	(.021)	(.123)	(.131)
Control Mean	.79	2.38	3.00
Treatment Effect (%)	1.46	-4.68	-4.41
Number of Observations	2718	2718	2176

Notes: The table present the results of regression analysis of the three fertility outcomes on the PSDP treatment variable. Column (1) shows the PSDP treatment effect on an indicator variable that is one if the respondent has ever had a child. Column (2) shows the PSDP treatment effect on the number of children the respondent has unconditional on ever having children. Column (3) shows the PSDP treatment effect on the number of children the respondent has conditional on ever having children. All are unconditional on the child being alive or not. The sample consists of children of PSDP parents from the latest KLPS round that the parent is observed and excludes individuals who were treated in a separate vocational training intervention which occurred prior to KLPS-3 and those treated in a separate small grant intervention which occurred during KLPS-3. Sample weights are re-weighted for intensive tracking and inclusion in the vocational training and/or cash grant control group. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.7: Correlations between under-5 mortality and potential mechanisms

	Dependent Variable: U5MR												
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Self-Reported Health Good	-.0087											.0004	-.0008
	(.0089)											(.0133)	(.0099)
Miscarriage		.1285***										.1200***	
		(.0342)										(.0402)	
Attended Secondary Education			-.0251***									-.0077	-.0032
			(.0051)									(.0160)	(.0116)
School Attainment				-.0044***								-.0023	-.0009
				(.0009)								(.0029)	(.0021)
Per-Capita Consumption ('000s)					-.0018							.0029	.0021
					(.0014)							(.0027)	(.0016)
Individual Earnings ('000s)						-.0024*						.0055	-.0012
						(.0012)						(.0034)	(.0015)
Lives in Urban Area							-.0211***					-.0025	-.0026
							(.0064)					(.0104)	(.0075)
Age at First Birth								-.0031***				.0051***	.0014
								(.0007)				(.0014)	(.0009)
Number of Children									.0162***			.0280***	.0188***
									(.0016)			(.0031)	(.0020)
Received ANC										.0003		-.0394	-.0494*
										(.0182)		(.0387)	(.0264)
Institutional Delivery											-.0215***	-.0021	-.0145*
											(.0041)	(.0116)	(.0085)
R^2	.0002	.0065	.0063	.0066	.0005	.0010	.0029	.0051	.0270	.0000	.0023	.0643	.0409
Number Observations	3830	2150	3870	3870	3178	3731	3734	3878	3878	11871	11811	1718	3022
Deworming Treatment	.0154	-.1469	.0231	.249	305.1	79.51	.0424	.4359	-.1101	.0128	.021		
Implied Effect on U5MR	-.0001	-.0189	-.0006	-.0011	-.0006	-.0002	-.0009	-.0013	-.0018	.0000	-.0005	-.0186	-.0023
Percent of Total U5MR Effect	.82	115.94	3.56	6.76	3.41	1.18	5.51	8.21	10.93	-.02	2.77	114.05	13.96

Notes: This table presents regression results of potential mechanisms on under-5 mortality. Columns (1)-(9) regress the average value of that outcome across survey rounds on the average under-5 mortality rate by respondent; whereas, Columns (10) and (11) regress the outcome on under-5 mortality at the child-level. Columns (12) and (13) regress all outcomes on the average under-5 mortality rate by respondent. Pregnancy-level and child-level outcomes (miscarriage, ANC, and institutional delivery) are converted to respondent-level averages in columns (12) and (13). Deworming Treatment is the effect of deworming on under-5 mortality as calculated in Table 2. Implied Effect on U5MR is calculated as Deworming Treatment multiplied by the regression coefficient of that outcome on under-5 mortality. The Implied Effect on U5MR for Per-Capita Consumption and Individual Earnings is presented as the effect of an additional unit of consumption or earnings (as opposed to '000s). Percent of Total U5MR Effect is calculated as the Implied Effect on U5MR divided by the total deworming treatment effect on under-5 mortality as presented in Panel A of Table 1. See Table 1 and Appendix C for details on the variable construction. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.8: Correlations between potential mechanisms

	Parental Health	Education Outcomes		Living Standards and Residential Choice			Fertility Patterns		Access to Healthcare	
	(1) Self-Reported Health Good	(2) Attended Sec. Ed.	(3) School Attainment	(4) Annual Per-Cap. Consumption	(5) Annual Ind. Earnings	(6) Lives in Urban Area	(7) Age at First Birth	(8) (-1)*Num. of Children	(9) Received ANC	(10) Inst. Delivery
Self-Reported Health Good	1.000									
Attended Sec. Ed.	0.092***	1.000								
School Attainment	0.127***	0.884***	1.000							
Annual Per-Cap. Consumption	0.087***	0.256***	0.289***	1.000						
Annual Ind. Earnings	0.112***	0.199***	0.240***	0.368***	1.000					
Lives in Urban Area	0.115***	0.145***	0.186***	0.227***	0.271***	1.000				
Age at First Birth	0.074***	0.330***	0.376***	0.205***	0.225***	0.177***	1.000			
(-1)*Num. of Children	0.057***	0.369***	0.378***	0.276***	0.091***	0.197***	0.494***	1.000		
Received ANC	0.022	-0.026	-0.023	-0.057***	-0.007	-0.033*	0.010	-0.124***	1.000	
Inst. Delivery	0.092***	0.279***	0.309***	0.144***	0.176***	0.140***	0.322***	0.238***	0.071***	1.000

Notes: This table presents pairwise correlations between all the potential mechanisms. See Appendix C for details on the variable construction. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

Table A.9: Valuing the Benefits of Intergenerational Deworming Impacts on Child Mortality: Benefits, Costs, and Rate of Return

		Methods for Valuing Child Health Gains	
	(1) Required Benefits	(2) Revealed Preference	(3) Stated Preference
Panel A: Required Intergenerational Mortality Benefits (Calculated) for Internal Rates of Return (IRR)			
Social IRR of 5%	\$0.09	-	-
Social IRR of 10%	\$0.13	-	-
Panel B: Net Present Value (NPV) from Observed Intergenerational Mortality Benefits			
Social NPV for assumed discount rate of 5%	-	\$84.77	\$4657.91
Social NPV for assumed discount rate of 10%	-	\$36.66	\$2055.26
Panel C: Internal Rate of Return (IRR) from Observed Intergenerational Mortality Benefits			
Social IRR	-	41.5%	124.6%

Notes: This table presents the calculations of the costs and benefits of deworming following the equation (2) in D.1 in 2017 USD PPP terms. The social net present value (NPV) and internal rate of return (IRR) consider only the drug treatment costs in Column (1) and the intergenerational child mortality benefits in Column 2 (revealed preference) and Column 3 (stated preference). Panel A calculates the minimum average benefits required to achieve an IRR of either 5% or 10% to compensate for the drug treatment costs. Panel B calculates the social NPV from two observed intergenerational mortality benefits under varying assumptions on the discount rates. Panel C calculates the social IRR using revealed preference and stated preference approaches to compute the intergenerational mortality benefit in monetary terms. Deworming costs include the direct cost of deworming medicine under school-based mass treatment. Revealed preference for child health gains uses the willingness to pay to avert a DALY of USD PPP 66.82. Stated preference for child health gains uses the willingness to pay to avert a DALY of USD PPP 3611.20. See Figure 3, and D for additional details on the assumptions.

B Additional study background details

In 1998, a nongovernmental organization (NGO) launched the PSDP in two geographic divisions of Busia District (since renamed Busia County), in 75 schools enrolling over 32,000 pupils. Baseline parasitological surveys indicated that helminth infection rates were over 90%, and over a third had a moderate–heavy infection according to a modified WHO infection criteria Miguel and Kremer (2004). The 75 schools were experimentally divided into three groups (groups 1, 2, and 3) of 25 schools each. The schools were first stratified by administrative subunit (zone), zones were listed alphabetically within each geographic division, and schools were then listed in order of pupil enrollment within each zone, with every third school assigned to a given program group. The three treatment groups were well balanced along baseline characteristics.

Due to the NGO's administrative and financial constraints, the schools were phased into deworming treatment during 1998–2001: group 1 schools began receiving free deworming and health education in 1998, group 2 schools in 1999, and group 3 in 2001. Children in group 1 and 2 schools were thus, on average, assigned 2.41 more years of deworming than group 3 children; these two early beneficiary groups are denoted the treatment group here, following Hamory et al. (2021). Drug take-up rates were high, at approximately 75% in the treatment group, and under 5% in the control group.

The KLPS was launched in 2003 to track a representative sample of approximately 7,500 respondents enrolled in grades 2 to 7 in the PSDP schools at baseline, where the KLPS subsample was selected using a computer random number generator. During round 1 (2003–2005), sample respondents were still mainly teenagers, and few were active in the labor market or had children of their own; the subsequent survey rounds collected between 2007 and 2019 are the focus of this study. From the start, KLPS enumerators have traveled throughout Kenya and beyond to interview respondents. The spread of mobile phones in Kenya during the study period has greatly facilitated tracking, and, as a result, the effective tracking rate has remained high across KLPS rounds.

Three other cross-cutting experiments are relevant for the analysis. First, in 2001, the NGO required cost-sharing contributions from parents in a randomly selected half of the group 1 and group 2 schools, reducing deworming drug take-up from 75% to 18%; group 3 schools received free deworming treatment in 2001. In 2002–2003, the NGO again provided free deworming in all 75 schools. We account for the effect of this temporary reduction in deworming on later outcomes. Second, in early 2009, approximately 1,500 individuals in the KLPS sample additionally took part in a vocational training voucher randomized control trial (RCT) prior to the start of the KLPS-3, and a subset of these also took part in a randomized cash grant program prior to KLPS-4; 1,070 of these individuals were randomly selected to receive a training voucher and/or cash grant. To focus the present analysis on deworming impacts, and avoid possible interactions with other programs, these individuals are dropped from the analysis for survey rounds after their assignment to the other treatments. The randomly assigned voucher and cash control group (nonrecipient) individuals are retained throughout, and given greater weight in the econometric analysis, to maintain the representativeness of the original PSDP sample.

With regards to external validity, the KLPS sample appears to be typical of other SSA settings. Busia is close to the Kenyan national median along several leading socio-economic measures and is not an outlier on any. The 2009 Kenya Population and Housing Census indicates that Busia falls slightly below the national median in terms of the percentage of population with secondary education (10% in Busia vs. 11% in the median county). Given that Kenyan income levels are slightly higher than the SSA average, the fact that Busia is slightly poorer than the Kenyan average arguably makes the KLPS population more representative of other African settings as a whole.

C Variable construction

C.1 Construction of child health and mortality outcomes in Table 1

The *Child Mortality* outcome is an indicator which is 0 if the child is currently alive or if the child is dead and the age at which the child died is 5 or over. The indicator is 1 if the child is dead and the age at which the child died is under 5. The data is trimmed to include only children of PSDP respondents that we observe for at least five years since birth. Similarly, the *Infant Mortality* outcome is an indicator which takes a value of 0 if the child is currently alive or if the child is dead and the age at which the child died is 1 or over. The data is trimmed to include only children of PSDP respondents we observe for at least one year since birth.

The mortality indicators are constructed for KLPS-4, SCYF2, KLPS-3, and KLPS-2. (The SCYF2 survey round was collected among participants in the vocational training and cash grant program, including the control group of those programs, who are included in the present analysis.) KLPS-4 has the parent's full roster of children, including each child's mortality status. If the parent was not observed in KLPS-4, then the children from the latest survey where they were observed is used. For KLPS-4, 78.9% of all children were observed and their mortality status was captured. For those not observed in KLPS-4, 14.6% were observed last in KLPS-3, 5.2% in SCYF2, and 1.3% in KLPS-2.

C.2 Construction of Living Standards and Residential Choice Outcomes in Table 2

All KLPS-4 (20-y follow-up) respondents and a representative subset of one-sixth of KLPS-3 (15-y) respondents were administered a detailed consumption expenditure module featuring questions on over 150 distinct items. The *Annual Per-Capital Consumption* outcome is calculated as the sum of the monetary value of goods consumed by the household through purchase, gift, barter, or home production in the last 12 mo, divided by the number of household members. Consumption is adjusted for urban-rural price differences for respondents living in Nairobi and Mombasa.

The *Annual Individual Earnings* outcome is calculated as the sum of wage employment across all jobs; nonagricultural self-employment profit across all businesses; and individual farming profit, defined as net profit generated from non-crop and crop farming activities for which the respondent provided all reported household labor hours and was the main decision maker within the last 12 mo. Wage earnings and self-employment profits were collected in KLPS-2, KLPS-3, and KLPS-4; agricultural profits were collected in KLPS-3 and KLPS-4.

Lives in Urban Area is an indicator for whether the respondent lives in an urban area at the time of survey. This outcome was measured as part of a migration history module asked in each round. The outcome used in this analysis is simply if they live in an urban area irrespective of where they lived before. The sample is a panel of KLPS-2, KLPS-3, and KLPS-4 respondents.

C.3 Construction of Education Outcomes in Table 2

The KLPS surveys each collect detailed education history for the respondents that allow us to measure, and update, the respondent's education attainment at the time of survey. The sample includes the latest survey round that the respondent was surveyed.

The *Attended Secondary Education* outcome is an indicator variable equal to 1 if the respondent attended Secondary School by the time of the latest survey, and 0 if they did not ever attend Secondary School by the time of the latest survey. On average, 48% of the sample attended secondary school.

The *School Attainment* outcome is a continuous variable that is the highest year of schooling that the respondent has completed by the time of the latest survey. On average, the highest year of schooling is 9.4 years.

C.4 Construction of Fertility Outcomes in Table 2

From the child roster that is collected in each round, we are able to construct variables on individual fertility patterns. Here, *Age at First Birth* is measured as the age in which the respondent has their first live birth. On average, the age at first birth is 22.8 years old. This analysis uses the latest KLPS round in which the respondent was surveyed.

The second fertility outcome we measure is the *Number of Children*- defined as a continuous variable of all living children that the respondent has had by the time of the latest survey. This does not include children who are deceased, miscarriages, or current pregnancies at the time of the survey. Again, this analysis uses the latest KLPS round in which the respondent was surveyed. On average, respondents have 2.6 children. In the analysis in Table 2, the number of children variable is multiplied by -1 so that positive coefficients are interpreted as lower fertility rates (a hypothesized mechanism driving reductions in under-5 mortality), and vice-versa.

C.5 Construction of Access to Healthcare Outcomes in Table 2

The child roster in each round contains questions on healthcare access for each child. *Received ANC* is an indicator variable that takes a value of 1 if the respondent or the respondent's spouse sought ANC care for their child during pregnancy, and 0 if the respondent or the respondent's spouse did not seek ANC care. Although this was collected for all pregnancies, we only include live births throughout. Overall, at the child level, ANC care is high with 96% of children receiving at least some ANC.

Institutional delivery is an indicator variable that takes a value of 1 if the child was delivered at a hospital or clinic, and 0 if the child was delivered at home. Similar to ANC, we only look at live births and exclude stillbirths and current pregnancies. Overall, 73% of children were delivered at a hospital or clinic.

Data on ANC and institutional delivery were collected for all children in KLPS-3 and KLPS-2. For KLPS-4, this data was only collected for children born between the previous round the respondent was surveyed and KLPS-4. We use the birth year of the child in the KLPS-4 roster to match these "older" children with previous rounds and merge in the healthcare access outcomes. The dataset used in the analysis is the same as the childhood health and mortality outcomes where we use the latest round the child's parents are observed.

Summary statistics for each outcome variable, including the number of observations used in the respective analytical samples can be found in Table C.1

C.6 Construction of Sample Weights

The sample weights used in the analysis are constructed according to the following steps. First, the individuals are assigned weights based on their probability of inclusion into the KLPS sample, which we call *Population Weights*. Second, the population weights are adjusted for intensive tracking. For each round, a subset of individuals who cannot be found during the regular tracking are randomly selected into an intensive tracking sample. These individuals are up-weighted to be representative of the hard-to-reach individuals that were not found. This method is analogous to the approach in the Moving to Opportunities Study (Orr et al. 2003; Kling, Liebman, and Katz 2007; and Baird et al 2016). In each KLPS round, the sample is re-weighted to account for round-specific intensive tracking status. There was no intensive tracking in the SCYF2 round so *Population Weights* are used for that round. Finally, since we exclude the treatment groups of the cash grant and vocational training interventions, the weights are re-adjusted for the inclusion into the control group. These adjustments result in the final *PSDP Analytical Weights*.

The sample used in the child mortality analysis come from the latest survey the child is observed with 78.9% of the children from KLPS-4. However, unlike the analysis of contemporaneous outcomes, like household expenditure or consumption, child health and mortality status is collected retrospectively. There are thus concerns about giving a child a KLPS-4 weight, even if the child was born years before. This is particularly of concern for children of parents who were in the intensive tracking phase in KLPS-4 as that means each of their children would be assigned a higher weight even if they were born before a previous KLPS round when a parent was found and surveyed during the regular tracking period. Therefore, in order to address this issue, we take the average of all round-specific PSDP Analytical Weights. This allows for higher weights for respondents who are harder-to-reach parents across rounds, and lower for respondents who are consistently in regular tracking.

An alternative weighting specification that we use as a robustness check is a round and child-age specific weight. That is, instead of using the PSDP Analytical Weights of the latest round the parent was observed, we use the weights of the first KLPS round that happens after the child turns (or would have turned) 5 years old for child mortality, and 1 year old for infant mortality. By using child-age to determine the round-specific weight to assign, we utilize weights that are most closely timed to the child's mortality status.

Table C.2 and Figure A.3a shows that the main results from Column 1 of Table 1 remain robust when using these alternative weighting specifications: Average Weights, Round and Age Specific, Population, and Unweighted.

Table C.1: Summary Statistics of Key Outcome Variables

	(1)	(2)	(3)	(4)	(5)	(6)	Latest Survey			
							(7)	(8)	(9)	(10)
	Mean	Standard Dev.	Median	Minimum	Maximum	Number of Obs. Total	Number of Obs. KLPS-4	Number of Obs. SCY-F2	Number of Obs. KLPS-3	Number of Obs. KLPS-2
Panel A: Mortality and Health Outcomes										
Child (Under-5) Mortality (U5MR)	0.06	0.25	0	0	1	10039	9383	65	523	68
Infant (Under-1) Mortality (IMR)	0.04	0.19	0	0	1	13560	12243	98	993	228
Panel B: Living Conditions and Residential Choice										
Annual Per-Cap. Consumption	2300.2	2566.7	1511	75	28691	4794	4076	N/A	718	0
Annual Ind. Earnings	1261.2	2469.6	195	-312	25351	13624	4072	N/A	4525	5027
Lives in Urban Area	0.47	0.50	0	0	1	13793	4121	N/A	4595	5077
Panel C: Education Outcomes										
Attended Sec. Ed.	0.48	0.50	0	0	1	5507	4254	N/A	918	335
Years of Schooling Attained	9.4	3.1	8	2	16	5507	4254	N/A	918	335
Panel D: Fertility Outcomes										
Age at First Birth	22.8	4.3	22	9	37	4598	3929	32	488	149
Number of Children	2.6	1.9	2	0	14	5437	4250	58	808	321
Panel E: Access to Healthcare										
Received Antenatal Care	0.96	0.20	1	0	1	12936	11306	181	1170	279
Institutional Delivery	0.73	0.44	1	0	1	11940	10356	255	1069	260

Notes: The table presents summary statistics for the key outcome variables for the child mortality and health analysis shown in Table 1, as well as the potential mechanisms shown in Table 2. Columns (1)-(5) presents the overall mean, standard deviation, median, minimum, and maximum, respectively, of the samples used in the regression analyses. Columns (6) is the total number of observations in that sample. Columns (7) through (10) show the number of observations in the latest KLPS round used in the respective sample. The samples used in Panels A, C, D, and E are the latest round the outcome variable was collected.

Table C.2: Intergenerational Deworming Impacts on Under-5 Mortality With Alternative Weighting

	(1) Average Weights Across KLPS Rounds	(2) Round and Child Age Specific Weights	(3) Population Weights Not Reweighted for Intensive	(4) Unweighted
Panel A: Full Sample				
Treatment (λ_1)	-.018**	-.017**	-.016**	-.017**
	(.008)	(.008)	(.007)	(.007)
Control Mean	.076	.073	.073	.072
Treatment Effect (%)	-24.11	-22.89	-21.74	-23.23
Number Observations	10030	10030	10030	10030
Panel B: Female Parents				
Treatment (λ_1)	-.020**	-.017*	-.015*	-.018**
	(.009)	(.010)	(.009)	(.008)
Control Mean	.075	.07	.073	.076
Treatment Effect (%)	-26.11	-23.54	-21.18	-23.88
Number Observations	5756	5756	5756	5756
Panel C: Male Parents				
Treatment (λ_1)	-.015	-.016	-.016	-.015
	(.017)	(.016)	(.014)	(.011)
Control Mean	.077	.075	.073	.066
Treatment Effect (%)	-19.82	-21.34	-21.51	-22.23
Number Observations	4222	4222	4222	4222

Notes: Columns (1) to (4) present the results of regression analysis of the Under-5 Mortality outcome on the PSDP treatment variable for the full sample and for the male and female subsamples using 4 weighting specifications (described in detail in Appendix C. Column (1) uses weights are the average of all round-specific PSDP weights. This is the same specification used in Column 1 of Table 1. Column (2) uses weights that are the weights of the first KLPS round that happens after the child turns (or would have turned) 5 years old for child mortality. Column (3) use the population weights that are unadjusted for intensive tracking and are constant across rounds. Column (4) are unweighted. Standard errors are clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct level.

D Details of cost-benefit calculation

D.1 Rate of return and intergenerational deworming impacts on child mortality

The estimated impacts of deworming on intergenerational child mortality outcomes, combined with other data, allow us to estimate the social rate of return and social impacts of deworming subsidies. The social net present value (NPV) of providing deworming subsidies takes into account the costs of deworming medication Baird et al. (2016) and the monetary value of intergenerational health benefits benefits of under-5 mortality reductions among children born to deworming recipients. For compatibility purposes, monetary values related to costs and benefits are reported in 2017 USD PPP terms as used in Hamory et al. (2021). We calculate the social NPV as follows:

$$
\begin{aligned}
NPV = & -\text{Discounted Deworming Costs} \\
& + [\text{Discounted, Number of Additional Surviving Children} \\
& \times \text{Number of Healthy Life Years per Child} \\
& \times \text{Monetary Value of a Healthy Life Year}] \\
& = -\sum_{t=0}^{t=2}\left(\frac{1}{1+r}\right)^{t} SQ\left(S\right) + \sum_{t=0}^{t=25}\left(\frac{1}{1+r}\right)^{t} \gamma F_t H M_p
\end{aligned} \tag{2}
$$

where

$$
\begin{aligned}
H = & \left(5 - (\text{Avg Age of Death}|\text{Dying before Age 5})\right)\left(1 - \frac{\sum_{a=0}^{a<5} YLD_a}{\sum_{a=0}^{a<5} Pop_a}\right) \\
& + (65-5)\left(1 - \frac{\sum_{a=5}^{a<65} YLL_a}{\sum_{a=5}^{a<65} Pop_a}\right)\left(1 - \frac{\sum_{a=5}^{a<65} YLD_a}{\sum_{a=5}^{a<65} Pop_a}\right) \\
& \text{for } a = \{0-4, 5-9, \cdots, 60-64\}
\end{aligned} \tag{3}
$$

The first term captures the upfront cost of providing a deworming subsidy at level $S > 0$ (relative to the case of no subsidies), calculated as the subsidy cost (S) times the take-up at that subsidy level, $Q(S)$. We focus on the free treatment case, and use PSDP project data to compute this take-up level Kremer and Miguel (2007); Miguel and Kremer (2004), together with current estimates of per pupil mass deworming treatment costs (based on 2018 data provided by Deworm The World) of USD PPP 0.83 per year. Costs and benefits are discounted at rate r per year. Figure 3 displays components of this equation graphically, where the deworming drug costs are illustrated in the darkest gray in the first 2.4 years.

The second term captures benefits due to U5MR reductions among children of deworming recipients. γ estimates the average treatment effect identified in Table 1 (Panel A, Column 1: -0.018). F_t denotes children born per deworming respondent t years after deworming (See Appendix, Figure A.4). H denotes the number of healthy life years gained by survivors. M_p denotes the monetary value of health benefits per Disability Adjusted Life Year (DALY) averted. For F_t, we use the average childbirth data from 1998 to 2020. We assume fertility remains constant at the 22-year level from years 22 to 25 post-treatment, and then to be conservative, we assume zero mortality benefits starting at 25 years post-treatment. For M_p, we set the monetary value per DALY averted based on two approaches: revealed preference and stated preference. We estimate USD PPP 66.82 for the revealed preference value Kremer et al. (2011) and USD PPP 3611.20 for the stated preference value (See Appendix, Table D.1), respectively.

We separate H into two terms: the first term captures the additional healthy life years for those who died before age 5 and the second term captures the additional healthy life years for those who survived past age 5 (up to age 65). For each term, in order to compute the number of additional healthy life years, we consider both the average per-capita years of life lost due to premature mortality (YLL) and the average per-capita years of life lived with disability (YLD), incurred by the population aged 0-64 in Kenya across 5-year age groups. Our average per-capita YLL (YLD) estimate is computed by summing across all causes of mortality (disability) occurring within the Kenyan population aged 0-64 as of 2019, then dividing by the Kenyan population aged 0-64 Global Burden of Disease Collaborative Network (2020b). We use data from the Global Burden of Disease (GBD) 2019 study Global Burden of Disease Collaborative Network (2020b) and the 2019 Kenyan Population and Housing Census Kenya National Bureau of Statistics (2019). To be conservative, we assume that children who survive to age 5 live up to 64.

For the first term in H, we compute the additional healthy life years as five minus the average age of death, conditional on dying before age five, multiplied by (one minus the YLD of the population aged 0-5). The latter term allows us to account for the additional years lived with disability, which we remove to get the number of additional healthy life years. We implement a similar procedure for the second term. For those surviving to age 5, we assume (in the absence of mortality or morbidity) that individuals can obtain a maximum of 60 additional healthy life years. However, in order to account for the mortality and morbidity conditions in Kenya for the population aged 5-64, we reduce the 60 maximum potential healthy life years by (one minus the YLL of the population aged 5-64) and (one minus the YLD of the population aged 5-64) to obtain the number of additional healthy life years for children surviving past age 5.

Through this calculation, the estimated intergenerational mortality benefits are, on average, USD PPP 7 per year for revealed preference and USD PPP 394 per year for stated preference. This calculation does not include the direct health benefits to the recipients that accrue during the deworming treatment period, the benefits pertaining to consumption gains and earnings gains of deworming recipients, or the teacher costs as estimated in Hamory et al. (2021). The calculations also exclude any reduced morbidity among children, as noted above. This analysis also makes other conservative assumptions by assuming that intergenerational child survival benefits occur at age five and ignoring benefits from cross-school externalities for both sample individuals and other community members Ozier (2018).

These assumptions allow us to compute the social internal rate of return (IRR), namely, the value of r that equates discounted costs and benefits such that social NPV = 0 (Appendix Table A.9, Panel C). The equation above also implies the magnitude of deworming treatment effects needed to attain a given rate of return. At current drug treatment costs, USD PPP 0.09 is needed as the monetary benefit of reduced U5MR due to deworming to attain an annualized internal rate of return of 5% (Appendix Table A.9, Panel A). Five percent corresponds to the median real interest rate in Kenya during the 1998 to 2018 period (calculated based on Kenyan government bond and inflation rates), and thus larger benefits would indicate that deworming is likely to be cost-effective in Kenya; see https://www.centralbank.go.ke/statistics/interest-rates/ and World Bank Development Indicators for sources.

The cost-effectiveness results are presented in Table A.9. As shown in Table A.9, the estimated deworming intergenerational health benefits far larger than the benefits needed to attain the social IRR of 5 or 10% (USD PPP 0.09 and 0.13, respectively, Panel A). Thus, the social NPV estimates are positive for both revealed preference and stated preference approaches, and for annual discount rates of both 5 and 10% (Panel B). The implied social IRR estimates for revealed preference and stated preference are 41.5% and 124.6%, respectively (Panel C).

The results imply that even the intergenerational mortality reduction alone could justify subsidies for mass deworming treatment.

D.2 Survey setting and method of stated preference valuation

This section presents the survey setting conducted to measure the stated preference willingness to pay for child health in Appendix Table D.1, and the methods of calculating the monetary value per DALY averted used for the stated preference approach in Figure 3, Appendix Table A.9.

Health Valuation Survey Data Collection

The data was collected in Busia, Kenya, by a team of 13 field officers from November 23, 2016, to December 9, 2016. Data collection locations are differentiated by "Town" (Busia town) and "Rural" (rural villages in Busia county), where rural areas comprise the administrative locations of Busibwabo, Bukhayo West, and Lwanya. Data collection alternated between town and rural daily. The team used convenience sampling in both town and rural areas, with different methods adapted to the two settings.

Busia town consists of one main road running the length of the town, with many side streets extending perpendicularly. Nearly all structures along the main road are commercial, and most structures on the side streets are residential, with some small businesses interspersed. Pairs of field officers were dropped at the beginning of side streets and then worked their way down the side street, each field officer taking one side of the street. Field officers aimed to interview one in every three homes or businesses. Businesses were excluded on the first day of piloting, but included starting on the second day and thereafter. A home was defined as an apartment or house. A single compound could have multiple homes. Only businesses in structures (cement, tin, etc.) were included. In instances where the street forked or reached a T intersection, the field manager, who was familiar with the back streets, directed the officers. The field manager's directions were based on the method of taking first a left, then a right, then a left, while the field manager also ensured that different pairs of field officers did not end up on the same streets.

Rural areas comprise individual villages, each with roughly 100-200 compounds Compounds usually have multiple structures and house a group of people who are usually related but can be part of one or more formally defined households (eating and sleeping together at least four nights per week). The team sampled businesses and compounds, as these can be identified more easily and quickly than households. At a village, the field team identified a central landmark, such as a school or health dispensary, with the help of a village guide. The village guide then helped the field manager identify the boundaries of the village. Pairs of field officers are dropped equidistantly along the outer edges of the village and then work their way inward toward the established landmark, surveying one person at every compound on their route. In some instances, a village runs parallel to a road and is shaped like a long rectangle, making the above sampling method difficult. In this case, landmarks are established equidistantly along one long side of the village. Pairs of field officers begin on opposite sides of the village and work across to their landmarks.

Within a sampling unit (business, apartment/house, or compound), field officers try to select respondents from different gender and age groups. We consider "older" respondents roughly over 35 years and "young" respondents approximately under 35 years, with a lower eligibility cutoff of 18 years. In the first two days of surveying, field officers were instructed to allow the first respondent to volunteer him/herself and then select a respondent with different demographic characteristics along both gender and age relative to the last survey conducted (with the assumption that some variation would be introduced by availability). However, due to the limited availability of male and older respondents, this approach was not sufficient to correct the imbalance. From the third day of surveying, field officers were instructed to try to survey a respondent of whichever demographic they have fewer of at that point in the day. This approach resulted in better demographic balance.

The survey collected information on the respondent's demographics: age, gender, occupation, parental status, household size. The summary statistics are in Appendix Table D.1 (Panel A). The survey instrument includes questions on household consumption in a typical month for food, fuel, health, and schooling, as shown in Panel B. The survey also asked the willingness to pay for the respondent's own health improvements and their child's health improvements. In particular, they were asked how much they were willing to pay to avoid adverse health states (e.g., diarrhea) for one month. The questions regarding these health states, the prices to be paid, and the ordering of own health versus child health questions, were all randomized across respondents (Panel C). Respondents without a child were asked to imagine if they had a child. The willingness to pay questions were asked in a single-bounded dichotomous choice format, where a respondent was asked whether or not s/he would pay a presented price for avoiding a specific health state. The asked price categories range from KES 50 to KES 8000 (specifically, 50, 100, 300, 500, 750, 1000, 2000, 5000, and 8000). (The exchange rate during the data collection period was roughly 100 KSH to 1 USD.) The 15 health states asked about comprised of conditions and severity levels are associated with intestinal helminths: Abdominopelvic problem, mild; Abdominopelvic problem, moderate; Abdominopelvic problem, severe; Anemia, mild; Anemia, moderate; Anemia, severe; Decompensated cirrhosis of the liver; Diarrhea, mild; Diarrhea, moderate; Diarrhea, severe; Infectious disease, acute episode, mild; Infectious disease, acute episode, moderate; Infectious disease, acute episode, severe; Infectious disease, post-acute consequences (fatigue, emotional lability, insomnia); Intestinal nematode (worm) infections, symptomatic. The health states and descriptions of the corresponding symptoms were cited from the Global Burden of Disease Study and asked in Swahili. We note that some health conditions are more familiar and translated more easily than others in the rural Kenyan context. Specifically, respondents understood anemia, diarrhea, and intestinal nematode infections very well. Cirrhosis of the liver was also familiar to a number of respondents. Respondents often had difficulty understanding the abdominopelvic problem, and were generally confused by infectious disease, seemingly due to its broad definition. The survey further asked for the willingness to pay for one more meal per week for the respondents and their child for one month, rental of a solar lantern for one month, and 10 jerrycans (20 liters each) of clean water delivered to their house every day for one month as economic status information.

Data Analysis

The data of 753 respondents are analyzed after eliminating irregular or missing values in willingness to pay questions. We add 1 to the answers on household size so that the data of household size includes the respondent. We trim the top 1% of observations of monthly consumption in Panel B to reduce the influence of outliers.

The mean and median values of willingness to pay in Panel C are calculated using the following method. We assume that the percentage of positive responses between adjacent categories is uniformly distributed, no respondent would have a positive response to a price higher than 8000 KES, and every respondent would have a positive response to price 0 KES. We calculate the percentage of positive responses at each price category and the relative frequency as the difference in the percentages of positive responses between the price category and one category lower. By multiplying the relative frequency and the midpoint between each price category and adding the results, we estimate the mean willingness to pay. We set the minimum price category where the percentage of the respondents who have positive answers exceeds 50 percent as the median willingness to pay. For Across All Health States in Panel C, we conduct the calculation regardless of the health states asked about. The monetary values are converted in 2017 USD PPP.

The results in Panel C show that there is a higher stated willingness to pay to avoid anemia and decompensated cirrhosis of the liver than for other conditions. The results also imply weak correlations between the willingness to pay and the disability weights because respondents might understand the health states conceptually but might have no immediate experience in some health states.

Calculation of the Monetary Value per DALY Averted

We next present the method of calculating the stated willingness to pay to avert a DALY based on the mean and median willingness to pay and the disability weights. We calculate the mean and median annual willingness to pay for averting 1 DALY by dividing the mean or median values of willingness to pay by the disability weights of each health state.

By definition, 1 DALY is equivalent to 1 year×1.000 disability weight (disability weight is a measure of health loss where zero signifies a state of total health and 1 signifies a state of death.) Grosse et al. (2009); World Health Organization (2001); Mont (2007). Because the survey prompt asked the respondents about avoiding the health states for one month, we calculate the monetary values per DALY given the period and the disability weights. For simplicity, we do not consider discount rate or age-weighting for the DALY calculation

World Health Organization, Department of Data and Analytics, Division of Data, Analytics and Delivery for Impact (2020).

Taking the average of the monetary value per DALY averted based on the mean willingness to pay (Column (1)) or taking the median of the values per DALY averted based on the median willingness to pay (Column (3)) for the health states, we estimate a mean willingness to pay to avert a DALY of USD PPP 38350.09 and a median willingness to pay of USD PPP 3611.20, respectively. To be conservative, in Figure 3 and Appendix Table A.9, we use USD PPP 3611.20 as the monetary value per DALY averted for stated preference.

Table D.1: Stated Preference Valuations of Child Health in Kenya

	(1) Mean	(2) SD	(3) Median	(4) Min	(5) Max	(6) Disability Weights
Panel A: Respondents' Demographics						
Lives in Town (vs. Rural areas)	0.54	-	-	-	-	-
Age	36.99	15.76	32	18	95	-
Female	0.62	-	-	-	-	-
Has Any Children	0.83	-	-	-	-	-
Household Size	5.07	2.37	5	1	14	-
Panel B: Monthly Consumption (2017 USD PPP)						
Food	116	90	89	0	445	-
Fuel	21	22	13	0	115	-
Health	33	56	11	0	334	-
Schooling	64	105	27	0	645	-
Panel C: Monthly Willingness to Pay (2017 USD PPP)						
Across All Health States	78	-	22	1	178	-
Abdominopelvic problem						
mild	70	-	17	1	178	0.011
moderate	82	-	22	1	178	0.114
severe	85	-	45	1	178	0.324
Anemia						
mild	82	-	45	1	178	0.004
moderate	79	-	22	1	178	0.052
severe	96	-	45	1	178	0.149
Decompensated cirrhosis of the liver	98	-	111	1	178	0.178
Diarrhea						
mild	66	-	22	1	178	0.074
moderate	72	-	17	1	178	0.188
severe	82	-	22	1	178	0.247
Infectious disease						
acute episode, mild	66	-	22	1	178	0.006
acute episode, moderate	70	-	22	1	178	0.051
acute episode, severe	69	-	22	1	178	0.133
post-acute consequences	72	-	22	1	178	0.219
Intestinal nematode infections: symptomatic	72	-	22	1	178	0.027

Notes: Num. Observation = 753. This table presents the results of a survey conducted in Busia, Kenya, in 2016 to calculate the monetary value per DALY averted for stated preference in Figure 3 and Appendix, Table A.9. Panel A shows summary statistics on the respondents' demographics. Panel B shows monthly consumption in each item category in 2017 USD PPP terms. Panel C shows the monthly willingness to pay for respondents' child health to avoid the 15 different health states in 2017 USD PPP terms. Across All Health States in Panel C denotes the average willingness to pay across all the health states. Column (6) shows the disability weights, which are measures of the disabilities corresponding to the health states associated with intestinal helminths, cited from Global Burden of Disease Study 2019 Global Burden of Disease Collaborative Network (2020a). See D.2 for details on the survey setting and the calculation methods.