The Twenty Year Economic Impacts of Deworming in Kenya

Sarah Baird Joan Hamory Hicks Michael Kremer
Edward Miguel Michael Walker*

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Abstract

Estimating the impact of child health investments on adult living standards faces several major methodological challenges, including the paucity of experimental interventions for which it is feasible to locate participants many years later, as well as difficulties in accurately measuring economic outcomes. This study exploits a randomized school health intervention that provided deworming treatment to Kenyan children. We estimate impacts on their living standards and wellbeing 20 years later, at which point the effective respondent tracking rate was 85%. We show that deworming beneficiaries experience a 10% gain in consumption expenditure, and a 7% gain in total adult earnings. Effect sizes are similar (14% and 4%) when pooling across multiple survey rounds 10 to 20 years after the deworming treatment. This measure improves on previous work in its comprehensiveness and methodology. Treatment group individuals are also more likely to live in urban areas. Given deworming's extremely low cost, a conservative estimate of deworming's annualized social internal rate of return is 42.1%.

(JEL codes: E21, I15, I25, J24, O15)

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*Baird: George Washington University; Hicks: University of Oklahoma; Kremer: Harvard University and NBER; Miguel: University of California, Berkeley and NBER; Walker: University of California, Berkeley.
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1 Introduction

The role that child health status plays in determining later life outcomes is a major topic of inquiry across research fields. Beyond the direct utility benefits that healthy children (and their families) experience, the belief that investing in child health and nutrition can generate improvements in these individuals' quality of life when they reach adulthood has been used to justify many public policy initiatives around the world, including in low-income countries, from school feeding programs to subsidized access to health insurance and medical care for children. An area of key interest within this debate is whether such health investments must fall within a critical early period of child development for long-term gains to accrue, or whether investments made in preschool and school-aged children can also have important long-term impacts.

Despite the academic and policy interest, there remains a limited body of evidence establishing causal impacts of child health gains on adult living standards, due to the methodological challenges inherent in doing so. While there has been some recent progress in wealthy countries, often exploiting administrative data and the targeting or scale-up rules of large-scale public programs (as surveyed in Almond, Currie, and Duque (2017)), there are few studies in low-income countries that are able to exploit credibly exogenous variation in child health status, combined with long-term tracking of program participants and the detailed measures of adult living standards. This is in part due to the lack of high-quality administrative data on workers in low-income countries. Measurement of economic wellbeing is also typically more challenging in poor countries given widespread of informal sector activity and participation in subsistence agriculture. One notable exception is the remarkable 30-year follow-up of the four villages in the INCAP nutritional supplementation study in Guatemala, which studies long-term gains from a nutritional intervention targeting pregnant women and very young children (Martorell et al. 2010).

This study exploits a randomized health intervention that provided deworming treatment to Kenyan primary school children starting in 1998, the Primary School Deworming Project (PSDP). The PSDP treatment group (50 schools) received up to 3 years of additional deworming treatment, relative to the control group (25 schools). We estimate impacts on their living standards and wellbeing roughly 20 years later, during 2017-2019, using data from the Kenya Life Panel Survey (KLPS). A noteworthy aspect of KLPS is its success at maintaining contact with the original sample: at the 20 year follow-up, the effective respondent tracking rate was 85% among those still alive, with rates balanced across treatment arms. Rates were similarly high and balanced across treatment arms in the 10-year (2007-09) and 15-year (2011-14) follow-up survey rounds. This success is largely due to the project's decision to track migrants beyond the original study region, including to other parts of Kenya, East Africa, and beyond. The survey instrument, which we designed, also gathers rich information on living standards, adult earnings, labor productivity, and occupation. Taken together, these features allow this study to address many of the methodological challenges faced in the literature.

We find that deworming beneficiaries experience a 10% gain in consumption expenditure and a 4% gain in total earnings 20 years after the launch of the PSDP. Effect sizes are similar when pooling across survey rounds, with mean consumption expenditure gains of 14% 15 to 20 years post-treatment and mean earnings gains of 7% 10 to 20 years post-treatment. Treatment group individuals also are more likely to live in urban areas. Given these benefits and deworming's extremely low cost, a conservative estimate implies that deworming's annualized social internal rate of return is 42.1%, a very high return by any standard, and that deworming in Kenya is likely to generate more in future government tax revenue than it initially cost.

Intestinal helminth infections are extremely widespread, infecting one in five people worldwide (Pullan et al. 2014). Worm infections are known to have a range of adverse health and nutritional consequences for children, including stunted growth, weakness, and anemia (for certain types of worms) (Stephenson et al. 1993; Stoltzfus et al. 1997; Guyatt et al. 2001; Silva et al. 2003; Project 2008). There is also some evidence that worm infections have broader immunological effects, making individuals more prone to other infections such as malaria (Kirwan et al. 2010), and having adverse consequences for the gut microbiome (Guernier et al. 2017; Zaiss and Harris 2016); worm infections in pregnant mothers may also affect the birthweight of their children (Larocque et al. 2006). It has long been hypothesized that this constellation of health effects could translate into deficits in cognitive development as well as worse living standards and life outcomes (Schapiro 1919; Weisbrod et al. 1973).

The health impact of helminthes formed the basis for the World Health Organization's long-standing recommendation to provide mass school-based treatment in endemic regions with prevalence greater than 20% (World Health Organization 1992). Mass treatment is attractive because common deworming drugs are safe and typically cost less than US$0.60 per year per child, while diagnosing infections (typically using stool samples analyzed by lab technicians) is imprecise and much more expensive (Ahuja et al. 2015).

The appropriateness of this recommendation has been actively debated recently, following the appearance of a recent survey article that claimed no population-wide child nutritional, health, and education gains from mass treatment (Taylor-Robinson et al. 2015). However, more recent meta-analysis incorporating more studies and focusing on settings with worm infection prevalence over 20% – the relevant range for mass treatment programs – find larger, positive and statistically significant impacts of mass deworming on child weight, as well as on height and mid-upper arm circumference (Croke et al. (2016) and recent analysis). The low cost of deworming drugs mean that it is far more cost effective than other approaches to improving child nutritional status, such as school-feeding programs. There is limited evidence regarding long-run impacts, with the exception of Bleakley (2007), which finds that the expansion of mass deworming in the U.S. South in the early 20th century led to higher educational attainment and income gains when the beneficiary children reached adulthood.

Several existing studies have exploited the experimental variation induced by the PSDP. Miguel and Kremer (2004) find evidence of improvements in child school participation in the treatment schools over the first two years of the deworming program, with absenteeism falling by roughly one quarter. They also estimate sizeable deworming treatment externalities, presumably as treatment kills off worms already in the body and thus reduces transmission to others in the community. In particular, they document reductions in worm infection rates both among untreated children attending treatment schools, as well as among children attending other primary schools located within 4 km of the treatment schools. Further evidence on deworming treatment externalities is provided in Ozier (2017), who shows that young children living in the deworming treatment communities – who were not yet school aged, and thus did not receive the drugs themselves – also experienced sizeable gains in school learning outcomes up to ten years later. These gains, which are equivalent to roughly 0.5 years of schooling on average, are twice as large among children with older siblings, suggesting that reducing infection transmission within the home may be particularly important.

The current study builds on previous work examining PSDP deworming impacts in the 10 year follow-up survey (Baird et al. 2016). That study documented several long-run benefits of deworming treatment, including improvements in self-reported health, educational attainment (by roughly 0.3 years on average), test scores and higher secondary schooling attainment (concentrated among females), as well as higher incomes among wage earners (20% gains), more meals eaten, longer hours worked and more manufacturing employment (concentrated among males). However, Baird et al. (2016) was subject to several limitations: first because many respondents were still in school, estimating of some key labor market impacts were necessarily conducted on selected samples; second only very limited data was conducted on agricultural productivity, making it difficult to estimate impacts on total earnings; and third, consumption data was not available.

The current study addresses these limitations, allowing it to make several novel contributions beyond those already documented in Baird et al. (2016). First, the analysis makes use of two additional survey rounds to estimate impacts up to 20 years after the start of the deworming program, when most respondents were between 29 to 35 years old, allowing us to estimate impacts on individuals who have left adolescence and are in their prime working years. Second, the measurement of living standards, earnings, and economic productivity was improved between survey rounds. The KLPS-4 round incorporates a detailed consumption expenditure questionnaire modeled on the World Bank Living Standards Measurement Survey, which is often considered the gold standard for measuring living standards in rural low income settings (Glewwe and Grosh 2000), for all respondents. In addition, the KLPS-3 round included the consumption expenditure module for a representative subsample of respondents. Both KLPS-4 and KLPS-3 rounds contain better measures of agricultural productivity, including in subsistence agricultural production, providing a more comprehensive measure of total earnings.

Although individual indicators are subject to noise, particularly when looking at a subsample of respondents, overall we find that deworming has a persistent gains in both earnings and consumption across survey rounds, which are noticeably larger than the gains needed to justify deworming on cost-effectiveness grounds.

2 Data and Estimation Strategy

2.1 The Primary School Deworming Project and Kenya Life Panel Survey Dataset

The PSDP study area is Busia District, a largely agrarian region located in western Kenya that is fairly representative for Kenya in terms of living standards, if not slightly poorer than average. Children typically attend local primary schools, with dropout rates rising in grades 7 and 8 (the final two years of primary school). Children generally complete primary school at 15 to 18 years of age, after which just under half go on to attend some secondary school. Among adults, occupational and family roles differ markedly by gender, such that fishing, driving bicycle taxis, and manufacturing are overwhelmingly male, while small-scale market trading and domestic service are largely female. This segmentation makes it plausible that the impacts of human capital interventions could differ by gender, as hypothesized in Pitt, Rosenzweig, and Hassan (2012), who argue that child health gains in low-income, "brawn-based" economies may translate into increased human capital for females but increased labor for males.

In 1998 the non-governmental organization International Child Support (ICS) launched the PSDP in two divisions of Busia District, in 75 primary schools including a total of 32,565 pupils. Parasitological surveys indicated that baseline helminth infection rates were over 90% in these areas. Using modified WHO infection thresholds, over one third of the sample had moderate-heavy infections with at least one helminth (Miguel et al. 2014), a high rate but not atypical in African settings (Brooker et al. 2000; Pullan et al. 2011; Pullan et al. 2014).

The schools were experimentally divided into three groups (Groups 1, 2, and 3) of 25 schools each: the schools were first stratified by administrative sub-unit (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. Appendix Figure A.1 presents the project research design and describes the timing of data collection. The three treatment groups were well-balanced along baseline characteristics (see Miguel and Kremer (2004)).

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 assigned 2.41 more years of deworming than Group 3 children on average. These early beneficiaries are the treatment group in the analysis here (following Baird et al. 2016). Drug take-up rates were approximately 75% in the treatment group and under 5% in the control group (Miguel and Kremer 2004).

In 2001, the NGO required cost-sharing contributions from parents in a randomly selected half of the Group 1 and Group 2 schools, substantially reducing take-up, from approximately 75% to 18% (Appendix Figure A.1). In 2002-2003 the NGO again provided free deworming in all schools (Kremer and Miguel 2007).

In early 2009, approximately 1,500 individuals in the KLPS PSDP sample additionally took part in a vocational training voucher randomized controlled trial prior to the start of the KLPS-3, and a subset of these also took part in a randomized cash grant program prior to the KLPS-4 data collection rounds. Approximately three quarters (1,070) of these 1,500 individuals were randomly selected to receive either vocational training vouchers or cash grants (or both). In order to focus the present analysis on the impacts of the deworming treatment intervention, and not confuse findings with these other interventions, these 1,070 individuals arere dropped from the deworming analysis sample for any survey rounds after their assignment to treatment.[1] Because the voucher and grant winners and non-winners were selected randomly, in the analysis we adjust the survey weights for individuals in the non-winner comparison group in order to maintain initial (baseline PSDP) population representativeness. This sample adjustment was not made in Baird et al. (2016), which focused on data collected prior to the launch of the vocational training voucher and cash grant interventions.

1. Namely, vocational training voucher winners are dropped from both the KLPS-3 and KLPS-4 data, and vocational training control individuals that received cash grants are dropped from KLPS-4.

The Kenya Life Panel Survey Round 1 (KLPS-1) was collected during 2003-2005, and tracked a representative sample of approximately 7,500 respondents who were enrolled in grades 2-7 in the PSDP schools at baseline. At that time, sample respondents were still mainly teenagers, and few were active labor market participants. Subsequent survey rounds were collected in 2007-2009 (KLPS-2), in 2011-2014 (KLPS-3), and 2017-2019 (KLPS-4) and these are the focus of this study. Survey enumerators traveled throughout Kenya and Uganda to interview those who had moved out of local areas, and the growing ubiquity of mobile phones in East Africa during the study period greatly facilitated participant tracking.

The effective survey tracking rate has remained high across KLPS rounds (Table 1). In KLPS-4, the rate is 85% among those still alive (column 1), and tracking rates are nearly identical and not significantly different in the treatment and control groups (columns 4-6) (Panel A). In KLPS-3, the rate is 84.6% among those still alive (Panel B), and similarly balanced across treatment groups. A representative subsample of respondents were visited for a second time during KLPS-3 for a detailed module capturing consumption expenditures and subjective wellbeing measures. Effective tracking rates are somewhat lower in this subsample (75% among those still alive, Panel C), possibly in part due to survey fatigue, though tracking rates remain balanced across treatment arms even in this case.

2.2 Estimation strategy

Our analytical approach follows Baird et al. (2016). We exploit the PSDP's experimental research design, namely, that the program exogenously provided individuals in treatment schools (Groups 1 and 2) two to three additional years of deworming. We focus on intention-to-treat estimates, since compliance rates are high, and previous research shows that untreated individuals within treatment communities experienced gains (Miguel and Kremer 2004), complicating estimation of treatment effects on the treated within schools.

We build on Baird et al. (2016) in two important ways. First, the analysis utilizes the latest rounds of data (KLPS-3 and KLPS-4), which include enhanced measures of consumption, agricultural productivity, and total household earnings. Second, with these additional rounds of data, we are able to conduct panel analysis, both by pooling data across rounds, and examining the evolution of outcomes over time.

The econometric approach we will utilize takes two main forms: i) pooled regressions using data from KLPS-2, KLPS-3, and KLPS-4 and ii) cross-sectional analysis by survey round, focusing on KLPS-4 data. There is a difference in interpretation of results from the two approaches. The results of pooled approach yields the average impact of deworming on outcomes between roughly 10 to 20 years after a child treatment program began. The KLPS-

4 cross-sectional approach yields the average impact of deworming on outcomes roughly 20 years after a child treatment program began.

The dependent variable is an outcome Y_{ijt} is the outcome Y for individual i in school j in survey round t, which we can estimate both by pooling data across survey rounds and restricting data to a single survey round:

$$Y_{ijt} = \alpha + \lambda_1 T_j + \lambda_2 C_j + \lambda_3 P_j + X'_{ij,0}\beta + \varepsilon_{ijt}. \tag{1}$$

The outcome is a function of $T_j \in 0, 1$, the assigned deworming program treatment status of the individual's primary school (defined as in Baird et al. 2016). The main coefficient of interest is λ_1, which captures gains accruing to individuals in treatment schools relative to the control. Since deworming was assigned by school rather than at the individual level, some of the gains in treatment schools are likely due to within-school externalities. This is an attractive coefficient to focus on since it is a lower bound on the overall effect of deworming, as shown in Baird et al. (2016).

$C_j \in [0, 1]$ is an indicator for whether the school was designated as "cost sharing" in later years of the PSDP, $P_j \in [0, 1]$ is the treatment saturation proportion among neighboring schools within 6 km during the PSDP (explained in more detail in Baird et al. 2016), and ε_{ijt} is the error term clustered at the school level.

As in Baird et al. (2016), we also include a vector $X_{ij,0}$ of individual and school covariates. The covariates include a series of baseline school characteristics (average test score, school population size, number of primary school students within 6 km, and an indicator for the administrative zone of school,) as well as baseline individual characteristics (indicators for gender and grade at the launch of the PSDP), and indicators for the calendar month and wave of KLPS-4 survey. We will additionally include an indicator variable denoting individuals in the vocational training voucher and cash grant control group (who are included in the sample). When pooling data across survey rounds, we additionally include a survey-year fixed effect.

All regressions will be Ordinary Least Squares unless specified otherwise, and estimates will be weighted to maintain representativeness with the baseline PSDP population, taking into account the sampling for inclusion in the KLPS, the two-stage KLPS tracking methodology, and inclusion in the vocational training voucher and cash grant program.

We present results for both the entire sample, as well as broken out by gender. To estimate effects by gender, we interact an indicator equal to one for females with our treatment variables (T_j, C_j, and P_j) in Equation 1, and use these coefficients to construct gender-specific treatment effects.

3 Results

This study focuses on estimating the impacts of deworming treatment on adult living standards, earnings, labor market outcomes, and residential choice.[2] Measuring living standards and economic productivity is challenging in low income countries. Informal employment is widespread, and much informal or home production is "missed" in rural areas in official economic statistics. A key advance of KLPS-3 and 4 is the careful, detailed measurement of these topics, following World Bank Living Standards Measurement Survey best practices.

3.1 Impacts on living standards

All KLPS-4 respondents, and a representative subset of roughly one sixth of the KLPS-3 sample was administered a consumption expenditure module. The consumption questions follow the standard LSMS format of detailed consumption recall questions. In cases where a large share of household income comes from subsistence agriculture or informal sector employment, consumption may yield a more accurate measure of total household income. We report per-capita consumption expenditure values in constant 2017 USD PPP, and trim the top 1% of observations to reduce the influence of outliers.

Deworming treatment has a positive impact on total household consumption expenditures. 20 years after the deworming treatment, respondents in the treatment group report a 10% increase (USD PPP 199, s.e. 130) in per-capita consumption expenditure (Table 2, Panel A, column 4). This is a very large effect, especially compared to the small cost of deworming. When pooling across KLPS-3 and 4 for greater precision, we estimate an average effect on per-capita consumption expenditure of USD PPP 305 (s.e. 159, p-value< 0.1), a 14% increase relative to the control mean (column 1).

Columns 2 and 3 report estimates separately for female and male respondents (recall that these columns are derived from interaction terms from a single regression). Effects are larger for male respondents in both absolute and percentage terms in both the KLPS-4 and pooled specifications.

We find positive point estimates on a wide range of consumption expenditure categories, including both food consumption and non-food consumption, using both KLPS-4 and pooled data, though neither component is statistically significant.

As a re-assuring check, when looking into group means by finer-grained treatment status (comparing across groups and cost sharing statuses), we find a sensible pattern: mean con-

2. Baird et al. (2019) pre-specifies a number of additional domains that are beyond the focus of the current study.

sumption expenditure increases monotonically with increased treatment (Appendix Figure A.3).[3]

3.2 Impacts on earnings

We next turn to measures of total individual earnings, which includes the sum of earnings in wage employment (across all jobs), non-agricultural self-employment profit across all businesses, and farming profits, including in subsistence agriculture. This is our most comprehensive measure of individual labor productivity, including both formal and informal sector earnings. In order to focus on *individual* labor productivity, we only include farming profits for which the respondent reported providing all reported household labor hours. This measure thus misses agricultural profits to which the respondent contributes jointly with other household members, which is one benefit of our consumption expenditure measure. We also look separately at total per-capita household earnings.

Our main measure focuses on yearly earnings, converted to 2017 USD PPP. Those without any earnings in the last year are included in the analysis as zeros. We focus on measures that trim the top 1% of earnings observations throughout in order to limit the influence of outliers in the analysis.

Table 2, Panel B presents our main measure of yearly earnings, which, while not statistically significant, is suggestive of higher earnings gains. The pooled point estimate of USD PPP 80 corresponds to a treatment effect of 6.5%. The magnitude of the coefficient estimate remains relatively stable across survey rounds, though as a percentage goes down as the control mean increases over time (Appendix Figure A.2).

20 years after deworming treatment, hourly earnings (a key measure of productivity) are 20 percent higher (USD PPP +1.14 on a base of 5.54, p-value < 0.1), and 18 percent higher in the pooled specification. Those in the treatment group are also 2 percentage points more likely to report positive earnings in the pooled specification.

Point estimates for both wage earnings and self-employment profits are positive, with significant effects on self-employment profits in both the pooled and KLPS-4 specifications. Farming profits do not appear to have increased, but the individual measure of farming profits may be missing a substantial portion of agricultural productivity. Notably, when we look at household earnings, the effect on per-capita household earnings (which we only have for KLPS-4) of USD PPP 239 (p-value < 0.1, Table 3, Panel A, row 8) is very similar to our estimated per-capita consumption expenditure gain (USD PPP 199, Table 2, Panel A), which is reassuring.

3. However, we note that this pattern is less clear with earnings data.

There is a large shift into residence in urban areas, with an increase of 4 percentage points on base urban residence of 45% in the pooled specification (Panel B, row 1, column 1, p-value< 0.05). The move into urban areas among treatment group individuals can likely explain at least part of the deworming earnings results, particularly for hourly earnings: in related work, Hicks et al. (2017) find a moderate positive wage premium for urban employment in Kenya, on the order of 15-20 log points.

Hours worked results are suggestive of a shift out of agricultural work and into non-agricultural work, but in contrast to Baird et al. (2016), we see less of a shift among employment categories.

The total yearly earnings results suggest that, on average 10 to 20 years after the deworming treatment, the dollar value of effects are roughly twice as large for males than for females, though they are similar in percentage terms (and this difference is not statistically significant). Interestingly, this pattern appears to have reversed in KLPS-4: females experience a 10 percent increase in earnings, compared to an increase of 2 percent for males.

4 Cost-effectiveness, rate of return and fiscal impacts of deworming subsidies

The estimated impacts of deworming on labor market outcomes, combined with other data, allow us to estimate the internal financial rate of return and fiscal impacts of deworming subsidies.[4] The social net present value (NPV) of providing deworming subsidies takes into account the cost of deworming medication subsidies, the cost of additional schooling resulting from deworming (Baird et al. 2016), direct child health benefits and labor market gains, measured via earnings or consumption.

We calculate the net present value of deworming as follows (Figure 1 displays this graphically):

$$\begin{aligned} NPV = & -\sum_{t=0}^{t=2} SQ(S)\left(\frac{1}{1+r}\right)^t - K\sum_{t=0}^{t=9}\Delta\bar{E}_t(S)\left(\frac{1}{1+r}\right)^t \\ & + \sum_{t=0}^{t=2} H\left(\frac{1}{1+r}\right)^t + \sum_{t=10}^{t=50}\lambda_1\left(\frac{1}{1+r}\right)^t. \end{aligned} \tag{2}$$

The first term captures the upfront cost of providing a deworming subsidy at level $S > 0$

4. We focus on earnings rather than consumption expenditure as we have earnings data for KLPS-2. As our documented earnings gains are less than the consumption expenditure gains, to the extent this pattern holds in KLPS-2, the following exercise is a conservative estimate of potential living standard gains.

(relative to the case of no subsidies), calculated as the subsidy cost (S) times the take-up ($Q(S)$); take-up is non-decreasing in the subsidy. We focus on the free treatment case, and use PSDP project data to compute this (Miguel and Kremer 2004; Kremer and Miguel 2007), together with current estimates of per pupil mass deworming treatment costs (based on 2018 data provided by the NGO Deworm The World) of USD PPP 0.83 per year. These direct costs are illustrated in darkest gray in the first years of Figure 1.

The second term in the square brackets accounts for the fact that improved child health may lead the government to accrue additional educational expenditures, for instance, if secondary schooling rates increase, which we find for females in our sample. Let K capture the cost of an additional unit of schooling, and $\Delta\bar{E}_t(S)$ denote the average increase in schooling after the deworming subsidy is introduced. These costs are represented by the darker gray section labeled as teacher costs in Figure 1.

The third term, H, represents direct health benefits to children (in money-metric terms) that accrue during the deworming treatment. To be conservative, our main calculations below do not include direct child health benefits, and thus may underestimate the return.

The fourth term captures increased earnings gains, making use of the λ_{1t} term across survey rounds (KLPS-2,3, and 4). We assume these gains start 10 years after deworming treatment.[5] We make several alternative assumptions about the persistence of earnings gains. Our most conservative assumption, which we present in Figure 1, assumes that round-by-round gains last for 5 years (roughly the time between survey rounds) and then go to zero. Thus, this measures treatment effects out to 25 years (columns 1 and 3 of Table 4). Alternatively, we assume workers experience persistent effects for the remainder of their careers (a total of 40 years), presented in columns 2 and 4 of Table 4.

We make two additional conservative assumptions that plausibly make these estimates a lower bound: first, we ignore cross-school externality effects (Baird et al. 2016), and second, we ignore externality effects to other populations (such as younger siblings of treated children, Ozier (2017)).

In addition to calculating the social NPV, we can also calculate the NPV of additional government tax revenue. To do so, we multiply the earnings gains by τ. Kenyan taxes (mainly on consumption) absorb roughly 16.6% of GDP so we set the tax rate τ to 16.6%.[6]

5. This 10 year gap roughly corresponds to the time elapsed from the start of PSDP until the KLPS-2 survey (2007-09). By ignoring the time before KLPS-2 data was collected, it underestimates gains due to greater work hours prior to the survey. Yet it misses any reduction in work hours due to substitution of school for work. However, existing estimates of child labor productivity suggest these foregone earnings are likely to be small (Udry 1996).

6. From World Development Indicators, government expenditures are roughly 19.5% of GDP, and from `http://blogs.worldbank.org/africacan/three-myths-about-aid-to-kenya` about 15% of government expenditure is financed from donors, thus 0.195*0.85=0.166.

In Table 4, Panel A, we begin by calculating the earnings and consumption gains that would be required to generate social and fiscal internal rates of return of 5 and 10%. These correspond to the second quartile and median real interest rates in Kenya from 1998 to 2018 (calculated based on Kenyan government bond and inflation rates), and thus gains larger than these amounts would provide strong evidence for the cost effectiveness of deworming. Our most conservative assumptions for the social IRR (no earnings gains after 25 years and a desired IRR of 10%), earnings or consumption gains would need to be at least USD PPP 7.99 in order for deworming to be cost-effective. (This is illustrated by the dotted line in Figure 1.) As shown in Figure 1 and Table 2, the point estimates of our estimated gains are an order of magnitude larger than this. We can repeat this analysis for a desired fiscal IRR of 10%, and find that under these conservative assumptions, average earnings or consumption gains must be at least USD PPP 48.21, still less than we estimate for both earnings and consumption. These results provide the first indication that deworming is highly cost-effective. In Panel B, we calculate the social NPV of earnings costs and benefits applying an assumed discount rate of 10%, though we also explore using a discount rate of 5%. Again, the most conservative scenario estimates a social NPV of USD PPP 249, and a fiscal NPV of USD PPP 20.

In Panel C, we use our observed earnings and consumption gains to calculate the social and fiscal internal rate of return. Under our more conservative scenario, we calculate a social IRR of 42.1% based on the observed earnings gains, and a fiscal IRR of 16.4%.

In fact, the upfront costs of deworming subsidies are so low that an average earnings gain of USD PPP 7.99, or 0.65% of the control mean from years 10 to 25, would deliver a social IRR of 10% (per annum), which roughly corresponds to real interest rates in Kenya. In other words, even miniscule earnings gains (or other welfare benefits) could justify deworming subsidies given their small cost.

5 Conclusion

This study estimates the long-run impacts of mass school-based deworming treatment on adult living standards, earnings and labor market twenty years later. Relative to the control group, deworming beneficiaries in Kenya experience substantial gains in consumption expenditures, later earnings, and higher rates of urban residence. The findings add to a growing body of evidence that the Primary School Deworming Project had meaningful positive effects on child education (Miguel and Kremer 2004), labor market outcomes over a ten year time horizon (Baird et al. 2016), and generated positive treatment externalities both among primary school age children as well as among infants living in the study area at the time (Ozier 2017). Taken together, the social rate of return for this intervention appears to be large.

From a policy perspective, it is important to consider the external validity of the findings. Intestinal worm infections are widespread globally, with high infection rates in many parts of Africa, South Asia, and Latin America, and a possible (and unfortunate) recent resurgence in poor rural pockets of the U.S. South (McKenna et al. 2017). The ubiquity of the infections suggests that this study's findings have relevance for many other settings. At the same time, the degree to which deworming treatment generates positive long-run labor market effects is plausibly linked to the extent of infections. The study setting was one with quite high baseline infection prevalence, at over 90%, and a fairly large share of children with moderate to heavy infections (roughly one third). The PSDP intervention also began in the midst of the 1997-1998 El Niño–Southern Oscillation (ENSO) event, one of the most powerful in recorded history. The 1997-1998 ENSO brought torrential rains to many parts of Kenya, including the study area, and led to a substantial deterioration of the disease environment, with outbreaks of cholera, malaria, and rift valley fever. The deterioration in hygiene and access to sanitation almost certainly contributed to elevated infection prevalence for both the soil-transmitted helminths and schistosomiasis. Deworming treatment impacts would plausibly have been somewhat smaller if worm infection levels had not been at these unusually high levels, although this is admittedly speculative.

There are several important questions for future research in this area. First, it is unknown if the gains that we document will continue to persist in the future. To assess the durability of these gains, we plan to continue tracking these individuals over time and will periodically collect information on their economic and other life outcomes. Most individuals in the study sample have also already become parents themselves. Another direction for future research will be to assess the extent of any inter-generational impacts of deworming treatment on the children of sample respondents. The sizeable labor market and living standards gains we document suggest that these are at least plausible. The existence of any gains for the next generation would further bolster the cost-effectiveness of the deworming child health intervention. Finally, and echoing Almond et al.'s (2017) review, further research is needed to understand how institutional and contextual factors interact with child health investments to change adult outcomes, in order to better understand the cause of heterogeneous treatment impacts across settings, as well as the mechanisms driving these effects.

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Table 1: Effective Tracking Rates, Kenya Life Panel Survey (KLPS)

	Control Mean			**Treatment − Control (se)**		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	Female	Male	All	Female	Male
Panel A: KLPS-4 E Module (2017-19)						
Found	.882	.895	.871	.015	-.009	.038
				(.027)	(.027)	(.036)
Deceased	.029	.025	.032	.009*	.006	.013*
				(.005)	(.007)	(.007)
Surveyed, among non-deceased	.850	.875	.827	.005	-.042	.051
				(.028)	(.029)	(.038)
Panel B: KLPS-3 I Module (2009-11)						
Found	.861	.849	.872	-.005	-.019	.010
				(.022)	(.028)	(.023)
Deceased	.024	.023	.024	.004	-.001	.009
				(.005)	(.006)	(.007)
Surveyed, among non-deceased	.846	.831	.860	-.012	-.023	.000
				(.024)	(.030)	(.024)
Panel C: KLPS-3 E Module (2011-14)						
Found	.840	.795	.879	.032	.042	.028
				(.048)	(.072)	(.053)
Deceased	.028	.031	.025	-.002	-.020	.015
				(.011)	(.016)	(.017)
Surveyed, among non-deceased	.747	.699	.787	.005	.016	.002
				(.049)	(.069)	(.053)
Panel D: KLPS-2 (2009-11)						
Found	.867	.854	.879	-.007	-.021	.007
				(.017)	(.026)	(.022)
Deceased	.014	.012	.016	.004	.006	.003
				(.004)	(.005)	(.005)
Surveyed, among non-deceased	.839	.829	.848	.001	-.018	.018
				(.017)	(.025)	(.023)

Notes: Tracking data comes from a regression of indicators for respondent found, surveyed, or deceased on an indicator for PSDP treatment. Sample includes all PSDP individuals found in initial tracking or placed under intensive tracking, and only includes individuals in the PSDP sample not treated in a separate vocational training intervention or small grant intervention (see Hicks et al. 2018). Estimates are weighted to make the results representative of the full PSDP sample. 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: Per-Capita Consumption and Individual Earnings

	Pooled			KLPS-4		
	(1) All	(2) Female	(3) Male	(4) All	(5) Female	(6) Male
Panel A: Consumption						
Treatment (λ_1)	305*	147	464	199	102	297
	(159)	(125)	(282)	(130)	(123)	(200)
Control Mean	2156	1715	2594	2044	1655	2440
Treatment Effect (%)	14.15	8.56	17.89	9.73	6.17	12.16
Number Observations	4794	2473	2321	4076	2102	1974
Panel B: Earnings						
Treatment (λ_1)	80	53	105	85	117	53
	(76)	(64)	(119)	(171)	(145)	(281)
Control Mean	1218	674	1728	2133	1136	3138
Treatment Effect (%)	6.53	7.86	6.10	4.00	10.34	1.69
Number Observations	13624	6826	6798	4072	2099	1973

Notes: Columns (1)-(3) in Panel A use KLPS-3 and KLPS-4 data. Columns (1)-(3) in Panel B use KLPS-2, KLPS-3, and KLPS-4 data. Columns (4)-(6) in both panels use KLPS-4 cross-sectional data. Panel A is yearly per-capita total consumption, which is calculated as the sum of the monetary value of good consumed by the household through purchase, gift, barter, or home production in the last 12 months divided by the number of household members (converted to 2017 USD at PPP, top 1% dropped). Panel B is yearly total earnings, which is calculated as the sum of wage employment across all jobs, non-agricultural self-employment profit across all business, and farming profit (converted to 2017 USD at PPP, top 1% dropped). Covariates follow Baird et al. 2016, including controls for baseline 1998 primary school population, geographic zone of the school, survey wave and month of interview, a female indicator variable, baseline 1998 school grade fixed effects, the average school test score on the 1996 Busia District mock exams, total primary school pupils within 6 km, and a cost-sharing school indicator. Observations are weighted to account for KLPS population weights, SCY and VocEd control group weights, and KLPS intensive weights. Standard errors clustered at the 1998 school level. * denotes statistical significance at 10 pct., ** at 5 pct., and *** at 1 pct. level.

Table 3: Earnings, Labor Supply, Occupation, and Sectoral Choice

	Pooled		**KLPS-4**	
	(1) Treatment (λ_1)	(2) Control Mean	(3) Treatment (λ_1)	(4) Control Mean
Panel A: Earnings				
Total Yearly Earnings	80	1218	85	2133
	(76)		(171)	
Log Yearly Earnings	0.09	6.73	0.11	6.87
	(0.06)		(0.09)	
Wage Earnings	81	887	106	1488
	(68)		(138)	
Self-Employment Profit	41*	212	113**	394
	(24)		(58)	
Farming Profit	-0	9	2	21
	(2)		(5)	
Non-Zero Earnings	0.02*	0.59	-0.00	0.83
	(0.01)		(0.02)	
Hourly Earnings	0.53*	2.92	1.14*	5.54
	(0.27)		(0.60)	
Per Capita Household Earnings			239*	1296
			(129)	
Panel B: Labor Supply, Occupation, and Sectoral Choice				
Urban Residence	0.04**	0.45	0.05*	0.56
	(0.02)		(0.03)	
Total Hours Worked	1.14	39.84	-0.23	38.29
	(1.05)		(1.21)	
Hours Worked - Agriculture	-1.29	7.88	-2.08**	7.89
	(0.85)		(0.89)	
Hours Worked - Non-Agriculture	2.43**	31.97	1.84	30.40
	(0.95)		(1.22)	
Employed - Agriculture/Fishing	-0.003	0.043	-0.006	0.037
	(0.008)		(0.013)	
Employed - Services/Wholesale/Retail	0.002	0.230	0.013	0.337
	(0.014)		(0.023)	
Employed - Construction/Trade Contractor	0.004	0.033	0.009	0.044
	(0.007)		(0.013)	
Employed - Manufacturing	-0.001	0.026	-0.006	0.034
	(0.004)		(0.008)	

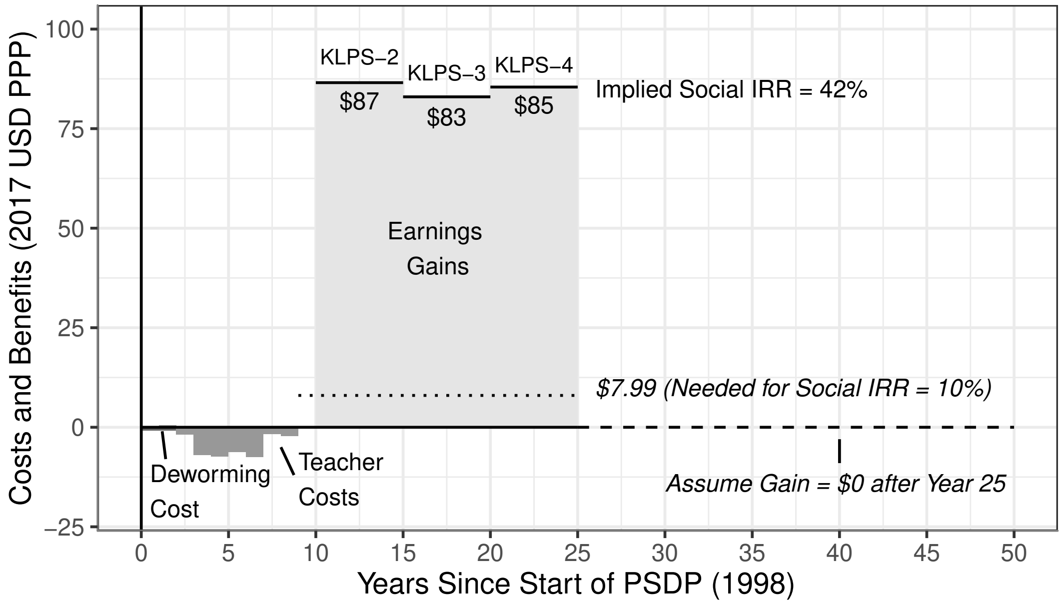
Notes: Columns (1) and (2) use KLPS-2, KLPS-3, and KLPS-4 data. Columns (3) and (4) use KLPS-4 cross-sectional data. Total yearly earnings is calculated as the sum of wage employment across all jobs, non-agricultural self-employment profit across all business, and farming profit (converted to 2017 USD at PPP, top 1% dropped). Farming profits are not available for KLPS-2. Non-zero earnings is an indicator variable for having non-zero earnings and is untrimmed. Total hours worked is equal to the total hours worked in wage employment, non-agricultural self-employment, and/or farming across all jobs within the last 7 days and is trimmed at the 1% level. Employed - agriculture/fishing is an indicator variable coded as ”1” for working as a farmer, agricultural laborer, livestock care/sheppard, fishing, or selling your own agricultural products in the market as the main wage-earning job. Employed - services/wholesale/retail is an indicator variable coded as ”1” for working in services/wholesale/retail as the main wage-earning job. Employed - construction/trade contractor is an indicator variable coded as ”1” for working in construction or as a trade contractor as the main wage-earning job. Employed - manufacturing is an indicator coded as ”1” for working in the manufacturing sector as the main wage-earning job. Covariates follow Baird et al. 2016, including controls for baseline 1998 primary school population, geographic zone of the school, survey wave and month of interview, a female indicator variable, baseline 1998 school grade fixed effects, the average school test score on the 1996 Busia District mock exams, total primary school pupils within 6km, and a cost-sharing school indicator. Observations are weighted to account for KLPS population weights, SCY and VocEd control group weights, and KLPS intensive weights. Standard errors clustered at the 1998 school level.* denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table 4: Rate of Return and Net Present Value of Child Deworming

	Earnings		Consumption	
	25 years	50 years	25 years	50 years
Panel A: Required Labor Market Gains (Calculated) for Internal Rates of Return (IRR)				
Social IRR of 10%	7.99	6.20	7.99	6.20
Social IRR of 5%	4.83	2.90	4.83	2.90
Fiscal IRR of 10%	48.21	37.42	48.21	37.42
Fiscal IRR of 5%	29.12	17.48	29.12	17.48
Panel B: Net Present Value (NPV) from Observed Labor Market Gains				
Social NPV for assumed discount rate of 10%	249	329	1108	1295
Social NPV for assumed discount rate of 5%	537	918	2523	3419
Fiscal NPV for assumed discount rate of 10%	20	33	162	193
Fiscal NPV for assumed discount rate of 5%	62	125	391	540
Panel C: Internal Rate of Return (IRR) from Observed Labor Market Gains				
Social IRR	42.1%	42.1%	48.4%	48.5%
Fiscal IRR	16.4%	17.5%	28.8%	29.0%

Notes: This table presents results related to calculations of the costs and benefits of deworming following Equation (2). The social net present value (NPV) / internal rate of return (IRR) includes the full earnings/consumption expenditure benefits, while the fiscal NPV/IRR includes only government tax revenue benefits. Panel A calculates the minimum average gains ($\bar{\lambda}_{1t}$ required to achieve a desired internal rate of return r for alternative assumptions about the treatment effect timeframe. Panel B calculates the social and fiscal NPV of observed labor market and living standard gains under varying assumptions of the treatment effect timeframe and discount rates. Panel C calculates the social and fiscal IRR under using observed earnings and consumption gains under each assumption of treatment effect timeframes. Deworming costs include the direct cost of deworming medicine and the cost of additional schooling. The cost of additional schooling is given by the product of the annual cost of schooling each child and number of additional years children attend school a a result of deworming. The cost of schooling each child for an additional year (USD PPP 267.88) is calculated by dividing an estimate of annual teacher salary (USD PPP 12055) by the number of average number of students per teacher (45). The estimates of annual teacher salaries are based on the upper tier of monthly teacher salaries reported by two Kenyan news sources: Nyanchama (2018) and Oduor. The estimated average number of students per teacher and increased educational gains are based on Baird et al. (2016). On average, from 1999 to 2007, students attended school for an additional 0.15 years. The benefits of deworming are measured via earnings and consumption. Earnings are measured 10, 15 and 20 years after the start of deworming. We assume no gains in the first 10 years after receiving deworming medication, and consider two cases for earnings gains after 20 years: gains disappear after the last observed five-year period (25 years after receiving treatment, columns 1 and 3), or persist through the end of one's working life (50 years after receiving treatment, columns 2 and 4).

Figure 1: Cost-Benefit of Deworming for Estimated Earnings Gains



Notes: This figure presents the timeline of costs and benefits for deworming that illustrates Table 4, Panel C, column 1. See Table 4 for full details on construction.

A Appendix

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

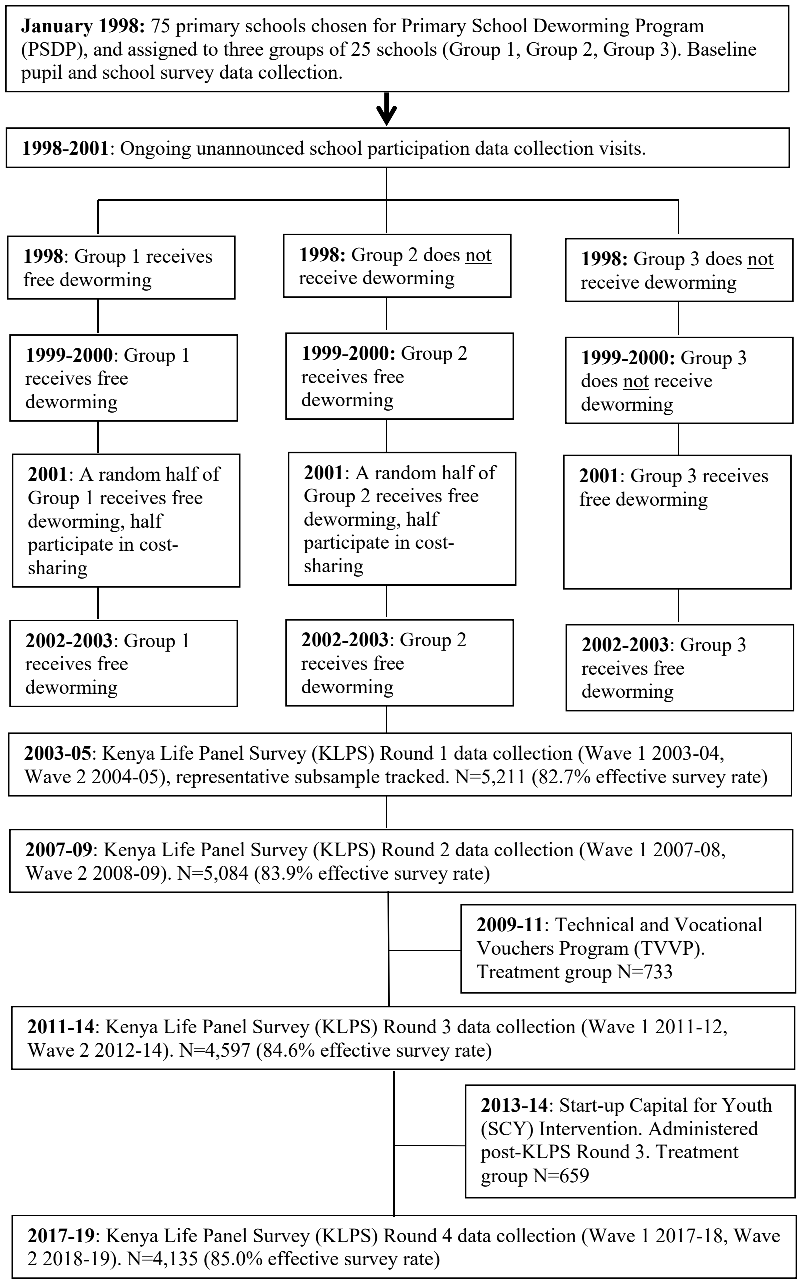
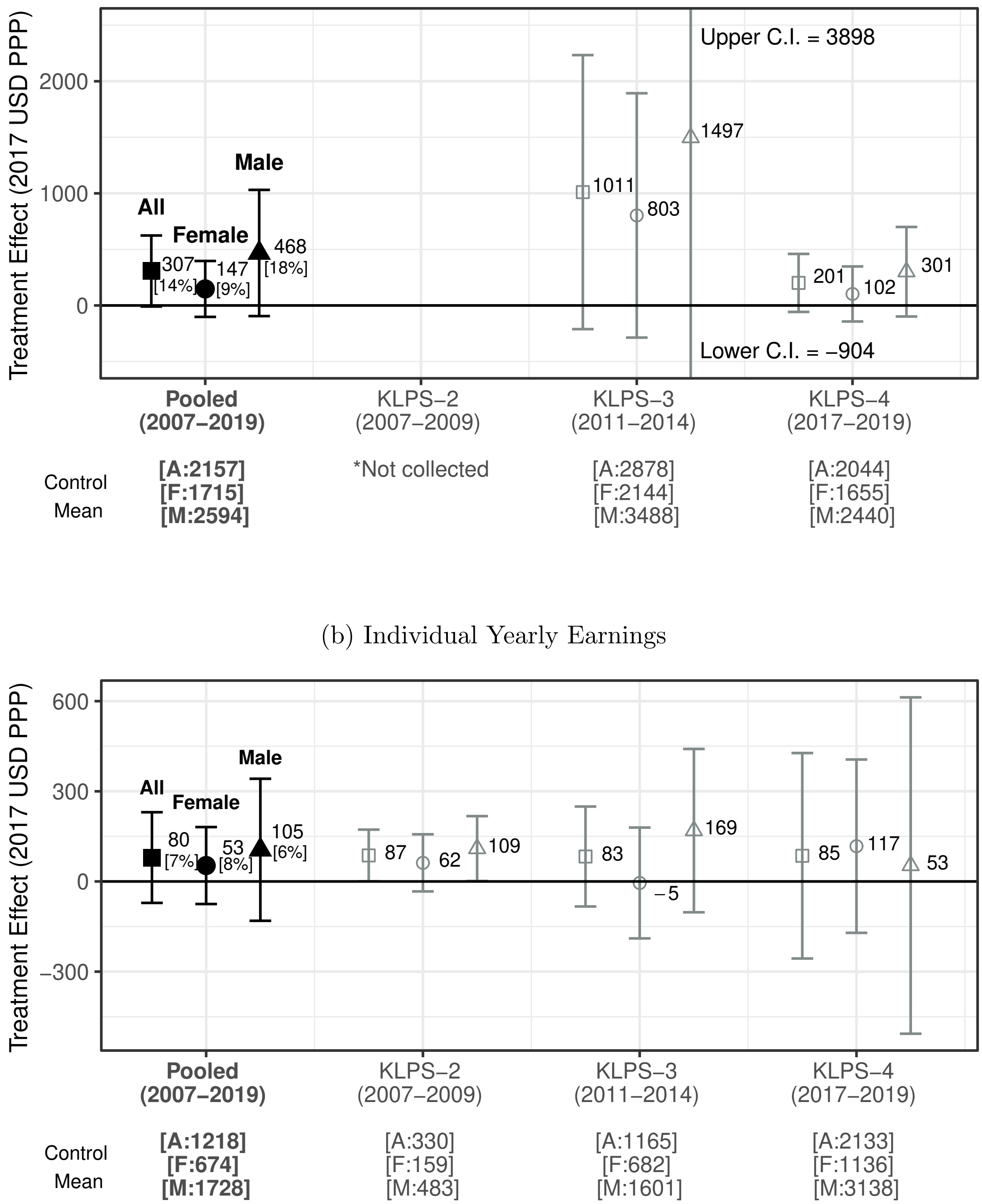


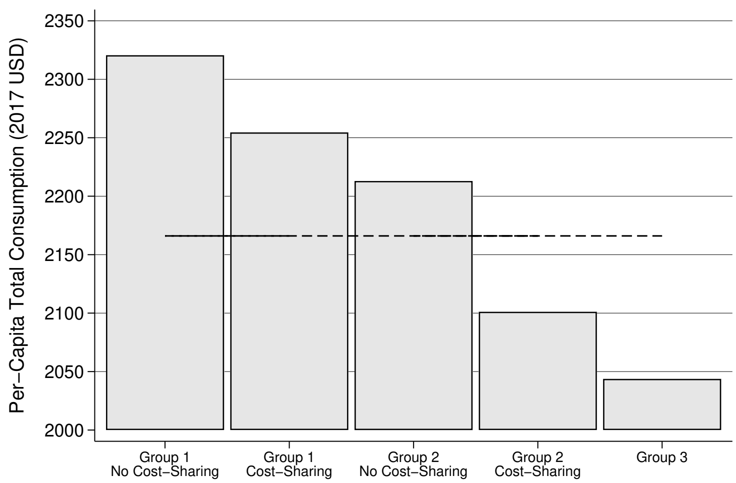
Figure A.2: Treatment Effects by Survey Round

(a) Consumption Expenditure



(b) Individual Yearly Earnings

Figure A.3: KLPS-4 Mean Consumption Expenditure by Treatment Group



Notes: This figure plots mean consumption expenditure by treatment group, going from those with the greatest deworming exposure (Group 1, No Cost Sharing) to those with the least (Group 3). The dotted horizontal line plots the overall mean.