Series Name: WPS
Paper No.: 130
Issue Date: 6 Aug 2020

Twenty Year Economic Impacts of Deworming

Joan Hamory, Edward Miguel, Michael W. Walker, Michael Kremer, and Sarah J. Baird

CEGA
Center for Effective Global Action

Working Paper Series

Center for Effective Global Action
University of California

eScholarship
University of California

Twenty Year Economic Impacts of Deworming

Joan Hamory ⓡ, Edward Miguel ⓡ, Michael W. Walker ⓡ, Michael Kremer ⓡ, and Sarah J. Baird

July 2020
JEL No. I15,J24,O15

ABSTRACT

This study exploits a randomized school health intervention that provided deworming treatment to Kenyan children and utilizes longitudinal data to estimate impacts on economic outcomes up to 20 years later. The effective respondent tracking rate was 84%. Individuals who received 2 to 3 additional years of childhood deworming experience an increase of 14% in consumption expenditure, 13% in hourly earnings, 9% in non-agricultural work hours, and are 9% more likely to live in urban areas. Most effects are concentrated among males and older individuals. Given deworming's low cost, a conservative annualized social internal rate of return estimate is 37%.

Joan Hamory
Department of Economics
University of Oklahoma
308 Cate Center Drive
Norman, OK 73072
jhamoryhicks@ou.edu

Edward Miguel
Department of Economics
University of California, Berkeley
530 Evans Hall #3880
Berkeley, CA 94720
and NBER
emiguel@econ.berkeley.edu

Michael W. Walker
University of California, Berkeley
Center for Effective Global Action
714B Giannini Hall
Berkeley, CA 94720
mwwalker@berkeley.edu

Michael Kremer
Harvard University
Department of Economics
Littauer Center M20
Cambridge, MA 02138
and NBER
mkremer@fas.harvard.edu

Sarah J. Baird
Department of Global Health
Milken Institute School of Public Health
George Washington University
950 New Hampshire Ave NW 4th Floor
Washington, DC 20052
sbaird@gwu.edu

A randomized controlled trials registry entry is available at
https://www.socialscienceregistry.org/trials/1191
An OSF Project Page, containing additional results is available at
https://osf.io/gx96j/

The belief that investing in child health and nutrition can generate improvements in individuals' future quality of life is the rationale for many policy initiatives around the world. Yet there remains limited evidence on the causal impacts of child health gains on adult living standards, especially in low- and middle-income countries (LMICs). While there has been some recent progress in wealthy countries (Almond, Currie, and Duque 2018, Hendren and Sprung-Keyser 2020), few studies in LMICs are able to exploit credibly exogenous variation in child health status, combined with long-term participant tracking and detailed adult outcome measures. This is in part due to the lack of high-quality administrative data on workers, as well as widespread participation in the informal sector and subsistence agriculture.[1]

This study contributes new evidence that addresses leading methodological concerns. First, we exploit exogenous variation in child health via a randomized health intervention (the Primary School Deworming Project, PSDP) that provided deworming treatment to Kenyan children. Starting in 1998, 50 schools that we term the treatment group received 2 to 3 years of additional deworming relative to the 25 control group schools. Second, we estimate impacts on individual living standards up to 20 years later, using data from the Kenya Life Panel Survey (KLPS), which we designed to follow a representative sample of PSDP participants. Specifically, we utilize a detailed consumption questionnaire, considered the gold-standard of living standards measurement in LMICs, and gather rich information on adult labor and earnings, including in the informal sector and subsistence agriculture. Third, we successfully survey respondents over time: at the 20 year follow-up (round 4, 2017-19), the effective respondent survey rate was 84% among those still alive, with rates balanced across treatment arms; rates were similarly high in the 10-year (round 2, 2007-09) and 15-year (round 3, 2011-14) rounds. This is in part due to the decision to track migrants beyond the original study region, to other parts of Kenya, East Africa, and beyond.

In our main analysis, we find those in the deworming treatment group experience a 14% gain in consumption expenditures (p-value < 0.10), 7% increase in total earnings, and an 13% gain in hourly earnings (p-value < 0.10) during the period 10 to 20 years after the start of treatment. There are also shifts in sectors of residence and employment: treatment group individuals are 9% more likely to live in urban areas (p-value < 0.05), and experience an 9% increase in non-agricultural work hours (p-value < 0.05). Effects are concentrated among males (though we typically cannot reject equal effects across genders), and impacts are also typically larger for individuals who are older (those above age 12 at baseline); below we return to interpretation of these patterns. The observed consumption and earnings benefits,

1. A notable exception is the 35-year follow-up (Martorell et al. 2010) of the four villages in the Guatemala INCAP nutritional intervention for pregnant women and young children (63% respondent tracking rate). Bouguen et al. (2019) finds few studies of development interventions with more than a 7 year follow-up.

together with deworming's low cost when distributed at scale, imply that a conservative estimate of its annualized social internal rate of return is 37%, a high return by any standard.

As background, intestinal helminth infections are widespread, infecting one in five people worldwide (Pullan et al. 2014), and have adverse health and nutritional consequences for children, including stunted growth, weakness, and anemia (Stephenson et al. 1993; Stoltzfus et al. 1997; Guyatt et al. 2001; Silva et al. 2004; Disease Control Priorities Project 2008). The infections also may have broader immunological effects, for instance, by making individuals more prone to other infections such as malaria (Kirwan et al. 2010; Wammes et al. 2016) and altering the gut microbiome (Guernier et al. 2017; Zaiss and Harris 2016); worm infections in pregnant mothers may also reduce child birthweight (Larocque et al. 2006). These adverse health effects form the basis for the World Health Organization's (WHO) long-standing recommendation to provide mass school-based treatment in regions with infection prevalence above 20% (WHO 1992; 2017). Mass treatment is attractive because common deworming drugs are safe and cost less than US$1 per year per child, while diagnosing infections (through stool sample analysis) is imprecise and far more expensive (Ahuja et al. 2015). The appropriateness of this recommendation has been actively debated following a survey article that claimed few population-wide child gains from mass treatment (Taylor-Robinson et al. 2012). However, a recent meta-analysis incorporating more studies finds larger positive and significant impacts on child weight, height and mid-upper arm circumference (Croke et al. 2016). There is little evidence regarding long-run economic impacts, with the exception of Bleakley (2007), which finds that deworming in the U.S. South in the early 20th century led to higher adult educational attainment and income.

Several studies analyze the PSDP experiment. Miguel and Kremer (2004) find improvements in child school participation in treatment schools over the first two years of the program, with absenteeism falling by one quarter. They also estimate sizeable treatment externalities, presumably as treatment kills off worms already in the body, reducing transmission to others in the community; in particular, they document reductions in worm infection rates among both untreated children attending treatment schools, and children attending other schools located within 4 km of the treatment schools.[2] Ozier (2018) provides further evidence on externalities, showing that young children living in the treatment communities – who were not yet school aged and thus did not themselves receive deworming – experienced gains in learning outcomes up to ten years later, equivalent to 0.5 years of schooling on average. The current study most directly builds on Baird et al. (2016), which documented deworming

2. For discussions of the original school participation cross-school externalities estimates, see Aiken et al. (2015), Davey et al. (2015), Miguel and Kremer (2014), Clemens and Sandefur (2015), and Miguel, Kremer, and Hicks (2015); the current analysis employs a new dataset.

impacts 10 years later, including improved self-reported health, educational attainment (by 0.3 years on average), test scores and secondary schooling attainment (concentrated among females), as well as higher incomes among wage earners (20% gains), more meals eaten, hours worked and manufacturing employment (concentrated among males).

Baird et al. (2016) was subject to several limitations that the current study was designed to address. First, because many respondents were still in school at the 10 year follow-up, estimation of some labor market effects was necessarily conducted on selected samples. Second, only partial information was collected on subsistence agricultural production. Third, consumption data was not available for that round, leading to a reliance on a proxy (meals eaten). The current paper makes several novel contributions. The analysis utilizes two additional survey rounds to estimate impacts at 15 and 20 years after deworming treatment – an unusually long timeframe for experimental studies (Bouguen et al. 2019) – when most respondents were between 29 to 35 years old, allowing us to estimate impacts during individuals' prime working years. The measurement of economic outcomes was also improved: KLPS round 4 incorporates a detailed consumption expenditure questionnaire (modeled on the World Bank Living Standards Measurement Survey, LSMS, see Grosh and Glewwe 2000) for all respondents, and round 3 collected this for a representative subsample. Both KLPS rounds 3 and 4 also contain improved measures of agricultural productivity, including in subsistence agriculture, which, combined with other measures, provides a measure of total household earnings. Finally, while earlier PSDP deworming cost-benefit analyses were necessarily speculative, our use of long-run follow-up data means the calculations here are based almost entirely on observed outcomes.

1 Data and Estimation Strategy

1.1 Program Background and Data Collection

The PSDP study area is Busia District (since renamed Busia County), a largely agrarian region in western Kenya that is fairly representative of rural Kenya in terms of living standards. At the start of the program in 1998, the vast majority of children attended primary school, but dropout rates were high in grades 6, 7 and 8 (the final three years) and fewer than half went on to secondary school. Secondary schooling rates increased dramatically in the region over the next decade. Among adults, occupational and family roles continue to differ markedly by gender. This segmentation makes it plausible that the impacts of a health intervention could differ by gender, for instance, as hypothesized in Pitt, Rosenzweig, and Hassan (2012), who argue that child health gains in low-income, "brawn-based" economies may translate into greater labor market gains for males.

In 1998 a non-governmental organization (NGO) launched the PSDP in two geographic divisions of Busia, 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).[3] 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 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. The three treatment groups were well-balanced along baseline characteristics (see Miguel and Kremer 2004, Baird et al. 2016 and Appendix Figure A.1 for project details).

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 Baird et al. (2016). Drug take-up rates were high, at approximately 75% in the treatment group, and under 5% in the control group (Miguel and Kremer 2004).

The Kenya Life Panel Survey was launched in 2003 to track a representative sample of approximately 7,500 respondents enrolled in grades 2-7 in the PSDP schools at baseline. During round 1 (2003-2005), sample respondents were still mainly teenagers and few were active in the labor market; 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 (Appendix Figure A.2). 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 (Appendix Table A.1).[4] In KLPS-4, 87% were found and 83.9% surveyed among those still alive (Panel A, column 1). Rates are similar and not statistically significantly different across the treatment and control groups, and the same holds by gender (columns 4-6) and among those above and below median age (specifically, baseline age 12, Table A.2). Notably, rates are similarly high and balanced in earlier rounds.[5] In all, 86% of the KLPS sample was surveyed at least once

3. Rates this high are also found in some other African settings (Pullan et al. 2014).

4. The effective tracking rate is calculated as a fraction of those found, or not found but searched for during intensive tracking, with weights adjusted appropriately, in a manner analogous to the approach in the U.S. Moving To Opportunity study (Orr et al. 2003; Kling, Liebman, and Katz 2007), and Baird et al. (2016).

5. A representative subsample of respondents were visited again in KLPS-3 for the consumption expenditures module; the effective tracking rate is lower in this subsample (74.7%, Panel C), though rates are balanced across treatment arms. The survey rate among those still alive in KLPS-2 is 83.9% (Panel D).

during the 10, 15 or 20 year rounds.

Two 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% (Appendix Figure A.1); Group 3 schools received free deworming treatment in 2001. In 2002-2003, the NGO again provided free deworming in all 75 schools (Kremer and Miguel 2007). We estimate 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 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.[6] The randomly assigned voucher and cash control group (non-recipient) individuals are retained throughout, and given greater weight in the econometric analysis to maintain the representativeness of the original PSDP sample.

1.2 Estimation strategy

The analytical approach builds on Baird et al. (2016) and follows our pre-analysis plan (PAP) (Baird et al. 2017). 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 (ITT) estimates for two main reasons: first, since treatment compliance was relatively high, and second, because previous research shows that untreated individuals within treatment communities experienced gains (Miguel and Kremer 2004), complicating estimation of treatment effects on the treated (TOT) within schools.

The analysis focuses on two main approaches, namely: i) pooled regressions that use data from KLPS rounds 2, 3 and 4 to estimate the overall long-run deworming effects 10 to 20 years after treatment, and ii) regressions using only KLPS-4, the longest-term follow-up. These two approaches, as well as the main outcome measures, were pre-specified in Baird et al. (2017) prior to conducting any analyses on the KLPS-4 data. The first approach has the advantage of utilizing all possible data, including information on the vocational training and cash grant recipients (who are dropped from the later rounds, as noted above), and is

6. Specifically, vocational training voucher winners are dropped from both the KLPS rounds 3 and 4 analysis, and cash grant winners dropped from round 4; those interventions are studied in separate work. The results below are robust to including these voucher and grant winners in the analysis, see Appendix A.

our focus here, with the KLPS-4 only results presented in the Appendix.

The dependent variable Y_{ijt} is an outcome for individual i in original PSDP school j as measured in survey round t:

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

The outcome is a function of $T_j \in \{0, 1\}$, the assigned deworming program treatment status of the individual's school. The pre-specified main coefficient of interest is λ_1, which captures gains accruing to individuals in the 50 treatment schools relative to the 25 control schools. 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 in the presence of cross-school treatment externalities, as shown in Baird et al. (2016).[7]

The vector $X_{ij,0}$ of individual and school covariates includes baseline school characteristics (average test score, population, number of students within 6 km, and administrative zone indicators), baseline individual characteristics (gender and grade), indicators for the KLPS survey calendar month, wave and round, and an indicator for the vocational training and cash grant control group. Estimates are weighted to maintain representativeness with the baseline PSDP population, taking into account the sampling for KLPS, the two-stage tracking methodology, and inclusion in the vocational training and cash grant program. Finally, ε_{ijt} is the error term clustered at the school level, allowing for correlation in outcomes both across individuals in those schools and across survey rounds.

We consider two secondary sources of exogenous variation in exposure to deworming, namely, the 2001 cost-sharing school indicator, $C_j \in \{0, 1\}$, and the proportion of students in neighboring schools within 6 km that received deworming, $P_j \in [0, 1]$, which we call local deworming saturation. While not the main focus, Appendix B presents evidence on their effects on outcomes. Conceptually, we expect (and find) λ_2 to generally have a sign opposite to that estimated for λ_1 (since cost-sharing reduced treatment). While we expect λ_3 to have the same sign as λ_1, in practice few estimates are significant, and we cannot reject that there is no relationship between the sign of the local saturation effect and the direct deworming effect. Baird et al. (2016) analyzed interactions between treatment and local saturation, and non-linearities in saturation, but cannot reject that T_j and P_j are additively separable and enter linearly; we thus use a similarly parsimonious specification here.[8]

7. In the presence of within-school epidemiological externalities, we cannot separately identify the effects of individual treatment versus schoolmates' deworming status. We can, however, identify the aggregate school-level effect, and thus classify all individuals in treatment schools as "treated" in the analysis.

8. Note that the bound proven in Baird et al. (2016) is still valid, albeit looser, if the geographic spread

We present results for the entire sample and broken out by gender and respondent age (namely, baseline age greater than 12), as mentioned in the pre-analysis plan.[9] We interact an indicator for females (baseline age > 12) with the main explanatory variables in equation 1, and use the resulting estimates to construct gender-specific (cohort-specific) effects.

2 Main Results

Here we present treatment effect estimates on adult living standards, earnings, labor market outcomes, and residential choice.[10]

2.1 Impacts on living standards

All KLPS round 4 (20 year follow-up) respondents and a representative subset of one sixth of round 3 (15 year) respondents were administered a detailed consumption expenditure module featuring questions on over 150 distinct items. It is often argued that the resulting measure of consumption may more accurately capture total household income (and living standards) than direct income measures in settings like rural Kenya. In the PAP, we specified that per capita household consumption expenditures would be one of two main outcomes; the other is total respondent earnings (presented in the next subsection). We present results for both in constant 2017 USD PPP, and trim the top 1% of observations (as pre-specified) to reduce the influence of outliers. We present real values below that account for urban-rural price differences, based on regular price surveys we collected in multiple Kenyan regions and cities (including Nairobi and Mombasa).

Deworming treatment has a positive impact on total household per capita consumption expenditures between 15 to 20 years after treatment: pooling KLPS rounds 3 and 4, the estimated effect is USD PPP 305 (s.e. 159, p-value < 0.10), a 14% increase relative to

of epidemiological externalities over time means that even "pure control" (i.e., T_j 0, P_j 0) schools are subject to some spillovers. In particular, those whose infection intensity falls due to cross-school externalities could themselves generate positive spillovers for other nearby schools, and so on. While such effects may fade over time, no school in the study area of roughly 15 by 40 km can definitively be considered a "pure control", making meaningful long-run cross-school spillover effects less likely.

9. Baird et al. (2016) show that those older than 12 at baseline experienced larger gains in terms of hours worked, meals eaten, and non-agricultural earnings, a finding they attribute to the fact that these individuals – who were at least 22 by KLPS-2 – had largely completed their schooling while younger individuals had not. The hypothesis that differential age effects were driven by school enrollment patterns led us to postulate in the PAP that there would be only minimal age differences in impacts by KLPS-4, as only 3% of the sample was still enrolled in school then. We show that there remain meaningful cohort differences in treatment effects in rounds 3 and 4, and discuss explanations below.

10. Baird et al. (2019) pre-specifies other outcome domains that are the subject of ongoing data collection, e.g., health, marriage, fertility, etc., and will be the focus of future research.

the control mean of USD PPP 2156 (Table 1, Panel A, column 1). A shift to the right in the distribution of consumption is visually apparent (Appendix Figure A.3, Panel A). Estimated effects by round are presented in Appendix Figure A.4 (Panel A). In the 20 year data, treatment group individuals report a 10% increase in consumption (USD PPP 199, s.e. 130, Table A.3, column 1). We find positive point estimates on sub-categories, including both food and non-food consumption (see Layvant, Miguel, and Walker (2020)).

Effects on consumption are larger in magnitude for male (USD PPP 513, p-value < 0.10) than female respondents (USD PPP 89) in both absolute and percentage terms (Panel A, cols. 2 and 3), although the gender difference is not significant at traditional levels. Women also have far lower average consumption, a pattern mirrored for all living standards and labor market measures, and likely indicative of the limited economic opportunities open to many women in Kenya.[11] Consumption effects are also far larger for older individuals (those older than 12 at baseline, who were typically 32 to 36 years old by KLPS-4), at USD PPP 886 (col. 4, p-value< 0.01), an effect that remains significant at traditional levels accounting for the false discovery rate (FDR) adjustment (Anderson 2008). Note that average living standards (in the control group) are considerably higher for younger than older individuals (col. 5), which likely at least partially reflects rapidly rising schooling levels in western Kenya in the years following the launch of the PSDP (Appendix Table A.10, Panel C).

2.2 Impacts on earnings and other labor outcomes

The second pre-specified main outcome measure, total individual earnings, includes the sum of earnings in the past year in wage employment (across all jobs), non-agricultural self-employment profits (for all businesses), and farming profits, including in subsistence agriculture. Note that those without any reported earnings in the last year are included in the analysis as zeros. To be sure we are focusing on *individual* labor productivity, we first only include farming profits in activities (e.g., growing a particular crop) for which the respondent reported providing all household labor hours. This measure thus misses agricultural profits derived from activities to which the respondent contributed jointly with other household members. The data indicate that 70% of agricultural activities are in fact conducted jointly with others, making it challenging to confidently assess individual agricultural productivity; this is a well-known concern in development economics. We later present a measure of total household income per capita that includes all household agricultural profits as well as earnings generated by the respondent and other adult household members.

Across the 10 to 20 year follow-up rounds, individual earnings are USD PPP 80 (s.e.

11. Gender differences in reporting or household structure could also potentially contribute to these gaps.

76) higher in the deworming treatment group (Table 1, Panel B, column 1). This estimate corresponds to a 6.5% increase in earnings. The estimated treatment effect is quite stable across across survey round 2 (USD PPP 87), round 3 (USD PPP 83) and round 4 (USD PPP 85, see Appendix Figure A.4), although none are statistically significant. The effect falls as a percentage of the control mean across rounds, as average earnings rise over time. The increase in the confidence interval surrounding estimates from rounds 2 through 4 also appear likely to be driven by the growth in both the mean and variability of earnings as individuals move into their prime working years.

As with consumption, estimated effects are larger for males (USD PPP 118) than females (USD PPP 41, cols. 2 and 3), though this difference is also not significant. Average individual earnings are nearly three times larger for males than females, again highlighting women's labor market disadvantages. Earnings gains are far larger for older (USD PPP 258, p-value< 0.05) than younger (USD PPP -75) individuals, and once again the effect for the older group remains significant when the FDR multiple testing adjustment is applied.

Effects on the narrow measure of individual reported farming profits are close to zero, but as noted above, these exclude most household agricultural activity. In contrast, there is a sizeable deworming effect on total household earnings per capita (only collected in KLPS-4), at USD PPP 239 (p-value < 0.10, Panel C, col. 1), and this effect is reassuringly similar in magnitude to the estimated impact on total household consumption per capita in round 4 (USD PPP 199, Appendix Table A.3). Total household earnings gains are again concentrated among males (USD PPP 439, p-value < 0.10, col. 3) and older individuals (USD PPP 565, p-value < 0.05, col. 4).[12]

There are meaningful changes in other labor market outcomes. Log annual earnings increase by 9 log points among those with non-zero earnings, and the likelihood that individuals have non-zero earnings rises by 2 percentage points (p-value < 0.10, Table 2, Panel A, col. 1). Gains in both wage earnings and self-employed profits appear to be contributing to the overall effect, and individual earnings per hour also increases, by USD PPP 0.14 (p-value < 0.10), or 13%. Patterns are similar in the KLPS round 4 data (Appendix Table A.4). Treatment individuals live in households with roughly 13% greater wealth per capita (collected in KLPS-4), although this effect is not significant at traditional levels. For most measures, gains are meaningfully larger among males and older individuals (cols. 2-3).

There are also shifts in the nature and sector of employment. While total labor supply (hours worked) increases only slightly, if at all, in the treatment group (1.04 hours, s.e. 0.66,

12. The FDR adjustment is not presented in Panel C since the total household earnings measure was not one of the two pre-specified primary outcomes. If the FDR adjustment is carried out across the six λ_1 coefficient estimates in columns 4-5 across the three panels, all three estimates for the older subgroup are significant with q-value < 0.05.

Table 2, Panel B, col. 1), there is a significant increase in hours worked in non-agricultural employment (1.99 hours, p-value < 0.01), concentrated among males (2.77 hours, p-value < 0.01, col. 2) and older individuals (2.24 hours, p-value < 0.05, col. 3). Some of this shift is likely related to the substantial increase in urban residence, which rises by 4 percentage points on a base of 45 percent (p-value < 0.05), or 9%; note that roughly one third of urban migrants live in Nairobi, and many others live in Mombasa or other large cities.[13] In contrast to Baird et al. (2016), there is no significant change in employment in manufacturing or other broad job categories (among wage workers) overall or for males or older individuals when pooling rounds 2, 3 and 4 (Panel B) or round 4 alone (Appendix Table A.4).

2.3 Heterogeneous effects and mechanisms

The concentration of deworming effects among males and those older than 12 at baseline is notable. Here we briefly discuss potential explanations for this heterogeneity, and what it suggests about the mechanisms underlying long-run impacts.

It is puzzling that females show fewer economic benefits than males since they experience larger gains in schooling attainment, test scores, and self-reported health than males (Baird et al. 2016 and Appendix Table A.11, Panel B). A possible explanation is that these human capital gains alone may be insufficient in a context where many women face important constraints and fewer economic opportunities than men (USAID 2020). For instance, KLPS sample women spend roughly three times more hours than men doing household chores and more than twice as much time providing childcare, and their participation in the non-agricultural labor force is far lower (Appendix Table A.10, Panel C).

The larger estimated gains among older participants may also be surprising at first given an intuitive sense that younger children might gain more from human capital investments, but note that all sample individuals are already outside of hypothesized "critical" windows of early childhood development (Appendix Table A.10, Panel A). One piece of evidence that could help explain the age pattern is the finding that deworming led to larger human capital gains among older individuals. Older individuals in the control group have lower levels of schooling than younger individuals (Appendix Table A.10, Panel C),[14] but the deworming effect for the older group is +0.45 years of schooling (s.e. 0.18, p-value < 0.05, Appendix Table A.11, Panel B), while for younger individuals it is closer to zero (+0.04 years). While schooling gains alone are not sufficient to guarantee later labor market benefits – as demonstrated by the experience of females – they are plausibly driving some of the long-

13. Urban residence was included as an outcome in the later Baird et al. (2019) PAP, as we collect more a more detailed migration history as part of ongoing survey modules relative to the data utilized in this paper.

14. This reflects the rapid increase in schooling over the decade following the start of PSDP.

run gains in the older group.

Since deworming was assigned at the school level, changes in social networks could also be a channel. We find that older individuals in the treatment group are indeed more likely to learn of a job through a primary school classmate (+6 percentage points on a base of 13%, p-value < 0.05, Appendix Table A.11), suggesting this could also be a partial explanation.

A more speculative explanation is that the *level* of deworming treatment is playing a role. While the average *difference* in assigned years of deworming between treatment and control schools is the same for younger and older cohorts (Appendix Table A.10), the distributions are different, and in particular the average years of assigned treatment in the control group is far higher among younger individuals (Appendix Table A.11), as many older control group students graduate from (or leave) primary school before receiving any deworming (Appendix Figure A.5, Panels B and C). If the marginal benefit of deworming is declining with each additional year of treatment (leading to a concave functional form), this could lead treatment effects to be larger among the older subgroup. For the primary consumption per-capita outcome, treatment effects are (reassuringly) monotonically increasing with additional years of deworming treatment assignment, and there is some evidence of concavity, especially at greater than 4 years (Panel A). While promising, this explanation remains tentative given limited epidemiological evidence on the deworming dose response function.

We are also able to rule out several alternative explanations for differential treatment effects, see Appendix C. The most obvious explanation for heterogeneous effects would be differential baseline worm infection levels across subgroups, or varying degrees of infection reduction, but we do not find meaningful differences along these lines by gender or age (Appendix Tables A.10, A.11). Nor did Baird et al. (2016) estimate significant differences in impacts as a function of baseline local area infection levels, although this latter analysis is somewhat statistically under-powered. The differential gains by age do not appear to be due to life cycle or age-at-survey explanations, but instead are driven by cohort effects (Appendix Table A.9). There are differences in average levels of parental education across older and younger cohorts, but little evidence of heterogeneous treatment effects by level of parental education (Appendix Table A.8).

3 Rate of return and fiscal impacts of deworming

Here we present deworming cost-effectiveness estimates (see Appendix D for details).

The social net present value (NPV) of providing free deworming treatment takes into account the cost of deworming medication, the cost of additional schooling resulting from deworming (Baird et al. 2016), and economic gains measured via consumption or earnings.

Figure 1 displays these components graphically, where the direct costs are illustrated in the darkest gray in the first years. We use 2018 deworming drug costs, while schooling costs come from multiplying secondary schooling rate increases (Baird et al. 2016) by recent Kenyan teacher salary figures (Nyanchama 2018; Oduor 2017). On the benefit side, we use λ_{1t} estimates for consumption and earnings generated from our pooled specification across KLPS rounds 2, 3, and 4. For earnings, we assume these gains start 10 years after deworming treatment, roughly coinciding with entry into adulthood and KLPS round 2. Since we do not have consumption data until KLPS-3, we conservatively assume that the average estimated effect from KLPS 3 and 4 only pertains during the period from 15 to 25 years after treatment. We also make the conservative assumption, presented graphically in Figure 1, that effects last for five years, roughly the time between survey rounds, and fall to zero five years after round 4 (at t 25).[15] The main estimates use an annual discount rate of 10%, the median real interest rate in Kenya during 1998-2018, which is conservative if other potential funders (e.g., international donors) face lower rates. We also compute the internal rate of return (IRR). The dotted horizontal line in Figure 1 shows the magnitude of average annual treatment effects needed to attain an annualized IRR of 10% is USD PPP 7.99. We also calculate the NPV and IRR of additional government tax revenue generated by deworming by multiplying earnings or consumption gains by the average Kenyan tax rate.

The estimated deworming consumption and earnings gains are both an order of magnitude larger than the USD PPP 7.99 needed to attain the social IRR of 10% noted above (Figure 1, Appendix Table A.12), and are also far larger than the gains needed to attain a fiscal IRR of 10% (USD PPP 29.12 and 48.21, respectively, Appendix Table A.12). The social and fiscal NPV estimates are positive for both the consumption and earnings effects, and for annual discount rates of 10%. In the most conservative scenario, focusing on earnings gains and the 10% discount over 25 years, the social NPV is USD PPP 230.71 and the fiscal NPV is USD PPP 16.74 (Panel B). The implied social and fiscal IRR estimates in this case are 40.7% and 15.5%, with values higher if we allow gains to persist beyond year 25 (Panel C). If we focus on consumption and consider gains out to 25 years, the social and fiscal IRR estimates are 36.7% and 19.6%, respectively.

15. This calculation is also conservative by not including direct child health benefits or any persistent health gains, and ignoring cross-school externalities among sample individuals and other community members (Ozier 2018).

4 Discussion

This study provides novel causal evidence on the long-run effects of child health investments on adult living standards and labor market outcomes. Individuals who received deworming as children experience substantial increases in adult consumption, hourly earnings, non-agricultural employment, and urban residence. These findings add to growing evidence that the Primary School Deworming Project had meaningful positive effects on recipients (Miguel and Kremer 2004; Baird et al. 2016). Even ignoring spillovers and making other conservative assumptions, the social rate of return appears to be very high.

From a policy perspective, it is important to consider external validity. Intestinal worm infections are widespread globally, with high infection rates in many parts of Africa, South Asia, and Latin America, and even a possible (and unfortunate) resurgence in the rural 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 school-based mass deworming generates positive long-run benefits is plausibly linked to the extent of infection. The study setting featured high baseline infection prevalence, at over 90%, and a large share of children with intense infections. The PSDP intervention also began during the strong 1997-1998 El Niño–Southern Oscillation event, which brought torrential rains to the region, and the related deterioration in hygiene and sanitation likely contributed to elevated worm infection levels. Deworming treatment impacts would presumably have been smaller had worm infection levels been lower.

The analysis does not resolve the issue of exactly why and through what channels deworming affected adult outcomes. Since changes to health, education, social activity among schoolmates, marital choices, and income levels may all affect each other in various directions, the impacts should not be interpreted strictly as all reflecting deworming's direct health effects, but rather are likely to be the result of a cumulative process of interaction among these factors.[16] Our examination of heterogeneous treatment effects by gender and age sheds some light on the importance of certain factors, but cannot definitively adjudicate between channels. Further research is needed to understand how institutional and contextual factors interact with child health investments, to better understand mechanisms (Almond, Currie, and Duque 2018). Another area of ongoing debate is whether child health and nutrition investments must fall within a "critical" early period of development for long-term gains to accrue (Bundy et al. 2018). Our findings indicate that even health programs focused on school-age children can yield substantial benefits, consistent with recent US findings

16. To be clear, we do not expect that child deworming treatment would have a direct impact on respondents' adult worm loads decades later, given worms' relatively short average lifespan in the human body.

(Hendren and Sprung-Keyser 2020).

As most study participants have already also become parents themselves, another interesting future direction will be to investigate possible deworming effects on the next generation. The economic impacts we document suggest that such effects are plausible; it is also possible that the education gains experienced by women could improve life outcomes for their children. The existence of any inter-generational benefits would further bolster deworming's cost-effectiveness.

References

Ahuja, Amrita, Sarah Baird, Joan Hamory Hicks, Michael Kremer, Edward Miguel, and Shawn Powers. 2015. "When should governments subsidize health? The case of mass deworming." *World Bank Economic Review* 29 (supplement) (June): S9–S24.

Aiken, Alexander M., Davey Calum, James R. Hargreaves, and Richard J. Hayes. 2015. "Re-analysis of health and educational impacts of a school-based deworming programme in western Kenya: a pure replication." *International Journal of Epidemilogy* 44 (5): 1572–1580.

Almond, Douglas, Janet Currie, and Valentina Duque. 2018. "Child Circumstances and Adult Outcomes: Act II." *Journal of Economic Literature* 56, no. 4 (December): 1360–1446.

Anderson, Michael L. 2008. "Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects." *Journal of the American Statistical Association* 103 (484): 1481–1495.

Baird, Sarah, Joan Hamory Hicks, Michael Kremer, and Edward Miguel. 2016. "Worms at Work: Long-run Impacts of a Child Health Investment." *The Quarterly Journal of Economics* 131, no. 4 (July): 1637–1680.

———. 2017. "Pre-Analysis Plan for "The 20-year Impacts of Child Deworming in Kenya"." RCT ID: AEARCTR-0001191.

Baird, Sarah, Joan Hamory Hicks, Michael Kremer, Edward Miguel, and Michael Walker. 2019. "Pre-Analysis Plan for "The 20-year Impacts of Child Deworming in Kenya: Additional Domains"." RCT ID: AEARCTR-0001191.

Bleakley, Hoyt. 2007. "Disease and Development: Evidence from Hookworm Eradication in the American South." *Quarterly Journal of Economics* 122 (1): 73–117.

Bouguen, Adrien, Yue Huang, Michael Kremer, and Edward Miguel. 2019. "Using Randomized Controlled Trials to Estimate Long-Run Impacts in Development Economics." *Annual Review of Economics* 11 (1): 523–561.

Bundy, Donald A.P., Nilanthi de Silva, Susan Horton, George C. Patton, Linda Schultz, Dean T. Jamison, the Disease Control Priorities-3 Child, Adolescent Health, and Development Authors Group. 2018. "Investment in child and adolescent health and development: key messages from Disease Control Priorities, 3rd Edition." *The Lancet* 391 (10121): 687–699.

Clemens, Michael, and Justin Sandefur. 2015. "Mapping the Worm Wars: What the Public Should Take Away from the Scientific Debate about Mass Deworming." Center for Global Development Blog.

Croke, Kevin, Joan Hamory Hicks, Eric Hsu, Michael Kremer, and Edward Miguel. 2016. "Does mass deworming affect child nutrition? Meta-analysis, cost-effectiveness, and statistical power." NBER Working Paper No. 22382.

Davey, Calum, Alexander M. Aiken, Richard J. Hayes, and James R. Hargreaves. 2015. "Re-analysis of health and educational impacts of a school-based deworming programme in western Kenya: a statistical replication of a cluster quasi-randomized stepped-wedge trial." *International Journal of Epidemiology* 44:1581–1592.

Disease Control Priorities Project. 2008. *Deworming Children Brings Huge Health and Development Gains in Low-Income Countries.* Technical report.

Grosh, Margaret, and Paul Glewwe, eds. 2000. *Designing Households Survey Questionnaires for Developing Countries: Lessons from 15 Years of the Living Standards Measurement Study.* Vol. 3. Washington, DC: World Bank.

Guernier, Vanina, Bradley Brennan, Laith Yakob, Gabriel J. Milinovich, Archie C. A. Clements, and Ricardo J. Soares Magalhaes. 2017. "Gut microbiota disturbance during helminth infection: can it affect cognition and behaviour of children?" *BMC Infectious Diseases* 17 (58): 58.

Guyatt, Helen L., Simon Brooker, Charles M. Kihamia, Andrew Hall, and Donald A.P. Bundy. 2001. "Evaluation of efficacy of school-based anthelmintic treatments against anaemia in children in the United Republic of Tanzania." *Bulletin of the World Health Organization* 79 (8): 695–703.

Hendren, Nathaniel, and Ben Sprung-Keyser. 2020. "A Unified Welfare Analysis of Government Policies." *The Quarterly Journal of Economics* 135, no. 3 (March): 1209–1318.

Kirwan, Patrick, Andrew Jackson, Samuel Asaolu, Síle Molloy, Titilayo Abiona, Marian Bruce, Lisa Ranford-Cartwright, Sandra O'Neill, and Celia Holland. 2010. "Impact of repeated four-monthly anthelmintic treatment on Plasmodium infection in preschool children: A double-blind placebo-controlled randomized trial." *BMC Infectious Diseases* 10 (September): 277.

Kling, Jeffrey R., Jeffrey B. Liebman, and Lawrence F. Katz. 2007. "Experimental Analysis of Neighborhood Effects." *Econometrica* 75 (1): 83–119.

Kremer, Michael, and Edward Miguel. 2007. "The Illusion of Sustainability." *The Quarterly Journal of Economics* 122, no. 3 (August): 1007–1065.

Larocque, R., M. Casapia, E. Gotuzzo, J.D. MacLean, J.C. Soto, Rahme E., and T.W. Gyorkos. 2006. "A double-blind randomized controlled trial of antenatal mebendazole to reduce low birthweight in a hookworm-endemic area of Peru." *Tropical Medicine & International Health* 11 (10): 1485–1495.

Layvant, Michelle, Edward Miguel, and Michael Walker. 2020. "Pre-Analysis Plan Report for Twenty Year Economic Impacts of Deworming." Available at `https://osf.io/gx96j`.

Martorell, Reynaldo, Paul Melgar, John Maluccio, Aryeh Stein, and Juan Rivera. 2010. "The Nutrition Intervention Improved Adult Human Capital and Economic Productivity." *The Journal of Nutrition* 140 (February): 411–4.

McKenna, Megan, Shannon McAtee, Peter Hotez, Patricia Bryan, Rebecca Jeun, Maria Bottazzi, Catherine Flowers, Tabitha Ward, Jacob Kraus, and Rojelio Mejia. 2017. "Human Intestinal Parasite Burden and Poor Sanitation in Rural Alabama." *The American Journal of Tropical Medicine and Hygiene* 97 (5).

Miguel, Edward, and Michael Kremer. 2004. "Worms: identifying impacts on education and health in the presence of treatment externalities." *Econometrica* 72 (1): 159–217.

———. 2014. "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities, Guide to Replication of Miguel and Kremer (2004)." Center for Effective Global Action Working Paper Series #39.

Miguel, Edward, Michael Kremer, and Joan Hamory Hicks. 2015. "Comment on Macartan Humphreys' and Other Recent Discussions of the Miguel and Kremer (2004) Study." CEGA Working Paper #54.

Nyanchama, Venic. 2018. "New TSC salaries and grading system for teachers 2020." `https://www.tuko.co.ke/281149-new-tsc-salaries-grading-system-teachers-2020.html`.

Oduor, Augustine. 2017. "Windfall for teachers as TSC releseases new salaries." `https://standardmedia.co.ke/article/2001249581/windfall-for-teachers-as-tsc-releases-new-salaries`.

Orr, Larry, Judith Feins, Robin Jacob, Eric Beecroft, Lisa Sanbonmatsu, Lawrence F. Katz, Jeffrey B. Liebman, and Jeffrey R. Kling. 2003. *Moving to Opportunity: Interim Impacts Evaluation.* Technical report. Washington, D.C.

Ozier, Owen. 2018. "Exploiting Externalities to Estimate the Long-term Effects of Early Childhood Deworming." *American Economic Journal: Applied Economics* 10, no. 3 (July): 235–62.

Pitt, Mark M., Mark R. Rosenzweig, and Mohammed Nazmul Hassan. 2012. "Human Capital Investment and the Gender Division of Labor in a Brawn-Based Economy." *American Economic Review* 102, no. 7 (December): 3531–60.

Pullan, Rachel, Jennifer Smith, Rashmi Jasrasaria, and Simon Brooker. 2014. "Global numbers of infection and disease burden of soil transmitted helminth infections in 2010." *Parasites & Vectors* 7 (January): 37.

Silva, Nilanthi, Simon Brooker, Peter Hotez, Antonio Montresor, Dirk Engels, and Lorenzo Savioli. 2004. "Soil-Transmitted Helminth Infections: Updating the Global Picture." *Trends in parasitology* 19 (January): 547–51.

Stephenson, Lani S., Michael C. Latham, Erin J. Adams, Stephen N. Kinoti, and Anne Pertet. 1993. "Physical fitness, growth and appetite of Kenyan school boys with hookworm, Trichuris trichiura and Ascaris lumbricoides infections are improved four months after a single dose of albendazole." *The Journal of Nutrition* 123 (June): 1036–46.

Stoltzfus, R.J., H.M. Chwaya, Tielsch J.M., Schulze K.J., Albonico M., and Savioli L. 1997. "Epidemiology of iron deficiency anemia in Zanzibari schoolchildren: the importance of hookworms" [in English (US)]. *American Journal of Clinical Nutrition* 65, no. 1 (January): 153–159.

Taylor-Robinson, David, Nicola Maayan, Karla Soares-Weiser, Sarah Donegan, and Paul Garner. 2012. "Deworming drugs for soil-transmitted intestinal worms in children: Effects on nutritional indicators, haemoglobin, and school performance." *Cochrane Database of Systematic Reviews (Online)* 7 (November): CD000371.

Udry, Christopher. 1996. "Gender, agricultural production, and the theory of the household." *Journal of Political Economy* 104 (5): 1010–1046.

USAID. 2020. "USAID 2020 Kenya Gender Fact Sheet." USAID 2020 Kenya Gender Fact Sheet.

Wammes, Linda J., Firdaus Hamid, Aprilianto Eddy Wiria, Linda May, Maria M. M. Kaisar, Margaretta A. Prasetyani-Gieseler, Yenny Djuardi, et al. 2016. "Deworming improves immune responsiveness." *Proceedings of the National Academy of Sciences* 113 (44): 12526–12531.

World Health Organization. 1992. *Model Describing Information. Drugs used in Parasitic Diseases.* Geneva.

———. 2017. *Guideline: Preventive Chemotherapy to Control Soil-Transmitted Helminth Infections in At-Risk Population Groups.* Geneva.

Zaiss, Mario M., and Nicola L. Harris. 2016. "Interactions between the intestinal microbiome and helminth parasites." *Parasite Immunology* 38 (1): 5–11.

Table 1: 10 to 20 Year Deworming Treatment Effects on Consumption and Earnings, KLPS Rounds 2, 3 and 4

	(1) Full Sample	(2) Female	(3) Male	(4) Older	(5) Younger
Panel A: Annual Per-Capita Consumption (KLPS-3 and 4)					
Treatment (λ_1)	305*	89	513*	886***	-179
	(159)	(134)	(304)	(223)	(185)
Control Mean	2156	1715	2594	1908	2381
Treatment Effect (%)	14.15	5.21	19.76	46.44	-7.52
Treatment p-value	.058	.505	.096	.000	.337
FDR q-value	.132	.630	.623	.001	.290
Number Observations	4794	2473	2321	2402	2341
Panel B: Annual Individual Earnings (KLPS-2, 3, and 4)					
Treatment (λ_1)	80	41	118	258**	-75
	(76)	(62)	(133)	(108)	(100)
Control Mean	1218	674	1728	1177	1242
Treatment Effect (%)	6.53	6.02	6.84	21.93	-6.07
Treatment p-value	.297	.515	.376	.019	.451
FDR q-value	.175	.630	.630	.030	.292
Number Observations	13624	6826	6798	6791	6780
Panel C: Annual Per-Capita Household Earnings (KLPS-4)					
Treatment (λ_1)	239*	36	439*	565**	-22
	(129)	(107)	(252)	(232)	(171)
Control Mean	1296	973	1623	1082	1501
Treatment Effect (%)	18.44	3.68	27.06	52.17	-1.48
Treatment p-value	.069	.738	.086	.017	.897
Number Observations	4074	2099	1975	2039	1982

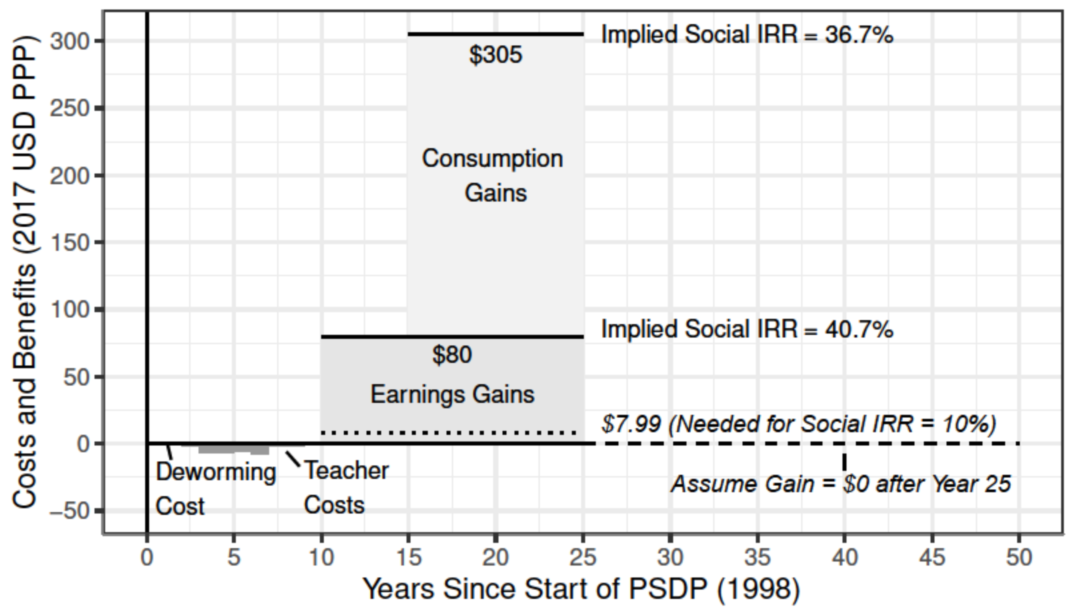
Notes: Panel A reports annual per-capita total consumption, calculated as the sum of the monetary value of goods consumed by the household through purchase, gift, barter, or home production in the last 12 months, divided by the number of household members. The consumption/expenditure module was administered to a subset of the sample during round 3 and the full sample during round 4. Consumption is adjusted for urban-rural price differences for respondents living in Nairobi and Mombasa. Panel B reports annual individual earnings, calculated as the sum of wage employment across all jobs; non-agricultural self-employment profit across all business; 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 months. Wage earnings and self-employment profits were collected in KLPS rounds 2, 3 and 4; agricultural profits were collected in KLPS 3 and 4. Panel C reports annual per-capita household earnings, calculated as the sum of wage employment earnings, self-employment profits, and agricultural profits across all household members, divided by the number of household members. Household earnings are only available in KLPS-4. All outcomes are converted to constant 2017 USD at PPP rates, and the top 1% of observations are trimmed. Treatment is an indicator variable equal to 1 for PSDP Worm Groups 1 and 2, which received an additional 2.4 years of deworming on average compared to Group 3. Columns (2) through (5) report estimates separately by gender and age at baseline (older than 12, 12 or younger). Columns (2) and (3) report estimates for Female and Male are constructed from a single regression including treatment-female, cost-sharing-female, and saturation-female interaction terms. Columns (4) and (5) also report results from a single regression, using an indicator for those older than 12 at baseline and analagous interaction terms to Columns (2) and (3). The pre-analysis plan (PAP) specified annual per-capita consumption and annual individual earnings as primary outcomes. Following the PAP, the FDR adjustment in column (1) is carried out across the two λ_1 coefficient estimates from Panels A and B of column (1). The FDR adjustment in columns (2) and (3) are carried out across the four λ_1 coefficient estimates from Panels A and B of columns (2) and (3). Similarly, the FDR adjustment in columns (4) and (5) are carried out across the four λ_1 coefficient estimates from Panels A and B of columns (4) and (5). Covariates follow Baird et al. (2016) and include 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. Those treated in a separate vocational training intervention (VocEd) which occurred prior to KLPS-3 are dropped from the KLPS-3 and KLPS-4 sample. Those treated in a separate small grant intervention (SCY) which occurred after KLPS-3 are dropped from the KLPS-4 sample. Observations are weighted to be representative of the original PSDP 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 significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table 2: 10 to 20 Year Deworming Treatment Effects on Earnings, Labor Supply, Occupation, and Sectoral Choice, KLPS Rounds 2, 3 and 4

	Treatment (λ_1)			Full Sample	
	(1) Full Sample	(2) Male	(3) Older	(4) Control Mean	(5) Number Obs.
Panel A: Earnings and Wealth					
Log Annual Individual Earnings	0.09	0.06	0.19**	6.73	7698
	(0.06)	(0.07)	(0.08)		
Wage Earnings (annual)	81	138	162*	887	13628
	(68)	(110)	(89)		
Self-Employment Profit (annual)	41*	51	70*	212	13638
	(24)	(48)	(39)		
Individiual Farming Profit (annual)	-0	1	-3	9	13707
	(2)	(3)	(3)		
Non-Zero Earnings	0.02*	0.04**	0.02	0.59	13794
	(0.01)	(0.02)	(0.02)		
Hourly Earnings	0.14*	0.22	0.32*	1.07	6096
	(0.08)	(0.15)	(0.16)		
Per-Capita Household Wealth (KLPS-4)	69	102	253***	522	4085
	(50)	(97)	(89)		
Panel B: Labor Supply, Occupation, and Sectoral Choice					
Urban Residence	0.04**	0.06**	0.03	0.45	13793
	(0.02)	(0.03)	(0.03)		
Total Hours Worked (last 7 days)	1.04	2.20**	1.79**	24.19	13807
	(0.66)	(0.92)	(0.91)		
Hours Worked - Agriculture (last 7 days)	-0.87**	-0.57	-0.46	3.99	13807
	(0.43)	(0.62)	(0.56)		
Hours Worked - Non-Agriculture (last 7 days)	1.91***	2.77***	2.24**	20.20	13807
	(0.65)	(0.94)	(1.08)		
Employed - Agriculture/Fishing	-0.003	-0.001	0.004	0.043	13768
	(0.008)	(0.013)	(0.012)		
Employed - Services/Wholesale/Retail	0.002	0.012	-0.002	0.230	13761
	(0.014)	(0.020)	(0.019)		
Employed - Construction/Trade Contractor	0.004	0.011	-0.007	0.033	13760
	(0.007)	(0.014)	(0.009)		
Employed - Manufacturing	-0.001	0.002	0.002	0.026	13760
	(0.004)	(0.007)	(0.006)		

Notes: This table reports treatment effects for numerous outcomes, using data pooled across KLPS-2, KLPS-3, and KLPS-4 unless otherwise indicated. Column (1) reports the overall treatment effect (λ_1 from Equation (1)) for the full sample, while columns (2) and (3) report estimated treatment effects for males and those older than 12 at baseline, respectively. Columns (4) and (5) report the full sample control mean and number of observations for each outcome, respectively. Variables in Panel A are converted to 2017 USD at PPP and trimmed at the top 1%. Log annual individual earnings is based on annual individual earnings from Table 1. Wage earnings, self-employment profits and farming profits are annual amounts. Hourly earnings is calculated by dividing annual individual earnings by 52, divided by the total hours worked across all activities during the last week, among those with at least 10 work hours across all activities. Per-capita household wealth is calculated as the sum of total household durable asset ownership and livestock ownership, divided by the number of household members. Urban residence is an indicator variable coded as "1" for living in a non-rural area, which includes both towns and cities. Hours worked variables are based on the total hours worked within the last 7 days; hours worked in each job, within job categories (i.e., wage-earning, self-employment, and farming), and across all jobs are top-coded at 100 hours per week. Employed variables are indicator variables coded as "1" for those with wage employment in a given sector. See the PAP report (Layvant, Miguel, and Walker 2020) for additional details on variable construction, results for female and younger respondents, and statistical significance levels. Weights and control variables included in the regression are defined in the notes for Table 1. Standard errors are clustered at the 1998 school level. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Figure 1: Deworming Costs, Benefits and Rate of Return



Notes: This figure presents the costs and benefits of deworming over time, and calculated social internal rate of return (IRR). Costs and benefits in the figure are reported in 2017 USD PPP terms. For additional details and alternative assumptions, see Table A.12 and Appendix D.
Costs: Total costs include the direct cost of providing mass school-based deworming from the NGO Deworm the World plus the costs of additional teachers, based on documented educational gains and the approach of Baird et al. (2016). We calculate teacher costs as average educational gains per student per year as a result of deworming (from Baird et al. (2016)) times annual teacher salary costs per pupil (USD PPP 267.88, based on an estimate of annual teacher salary (USD PPP $12,055) from the upper tier of monthly teacher salaries from (Nyanchama 2018) and (Oduor 2017) of and a pupil-teacher ratio of 45, as in Baird et al. (2016)). On average, from 1999 to 2007, students attended school for an additional 0.15 years.
Benefits: We assume no earnings gains in the first 10 years after receiving deworming medication. We use the estimate of treatment effects for annual individual earnings measured 10, 15 and 20 years after the start of deworming and pooled across rounds (λ_{1t} from Table 1, Panel B). We assume no per-capita consumption gains in the first 15 years after receiving deworming medication. As for earnings, we use the estimate of annual per-capita consumption expenditures measured 15 and 20 years after the start of deworming and pooled across rounds from Table 1, Panel A. For both earnings and per-capita consumption, we assume zero gains after the last observed five-year period (25 years after receiving treatment).
Calculations: The dotted line at USD PPP 7.99 shows the average treatment effect (λ_{1t}) needed from year 10 to year 25 in order to generate a Social IRR of 10%. A return of 10% represents the median real interest rate from 1998 to 2018 (based on Kenyan government bond rates and inflation rates). The annualized Social IRR for earnings gains is 40.7% and for consumption gains is 36.7%. Assuming a discount rate of 10%, the net present value (NPV) from observed earnings gains is USD PPP 230.71, and for consumption gains is USD PPP 467.90.

Appendix

Table of Contents

Additional Supplemental Information

The AEA Trial Registry for this project contains the pre-analysis plan, and is available at the following link:
`https://www.socialscienceregistry.org/trials/1191`

This pre-analysis plan denoted two primary outcomes: per-capita consumption and individual annual earnings, which are the main focus of this paper. For brevity, we do not present all outcomes included in the PAP. We show 21 out of 54 outcomes, including all primary outcomes and at least one summary measure from each broad family of items. Some disaggregated outcomes are only presented in the PAP report. The PAP report containing all pre-specified analyses is available at the following link, as are the pre-analysis plan and the main paper:
`https://osf.io/gx96j`

A Additional figures and tables

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

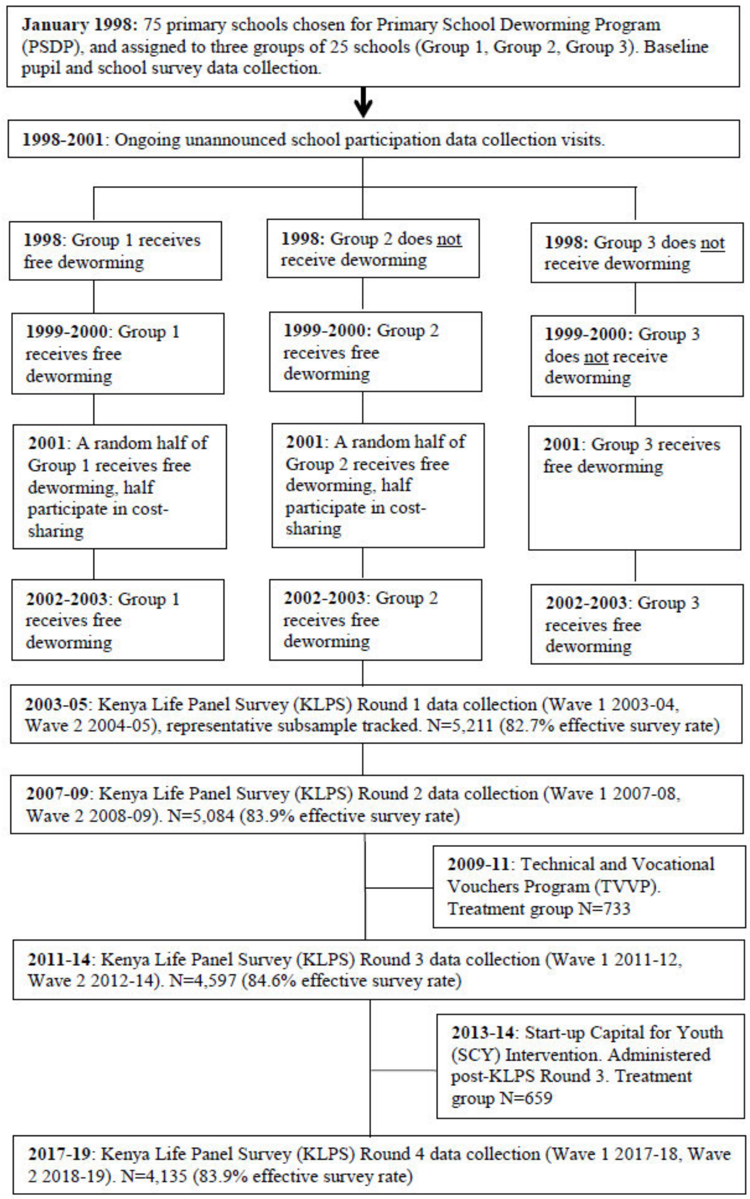
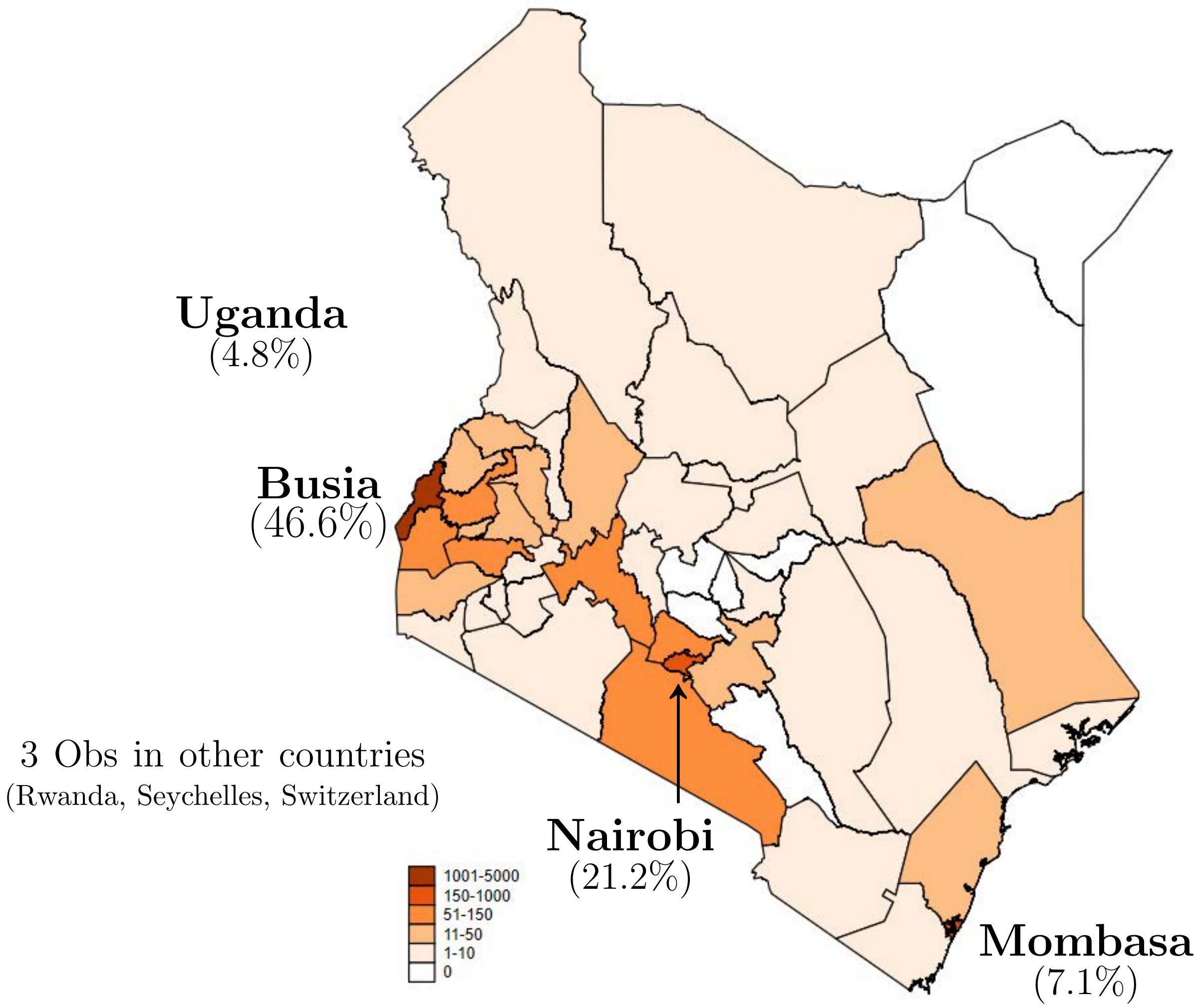


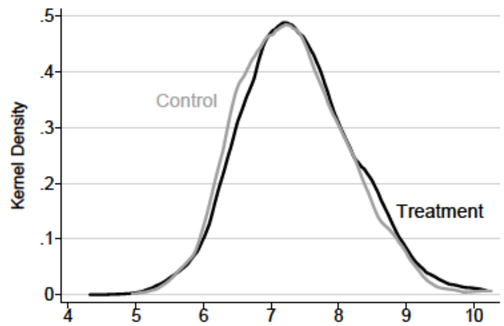
Figure A.2: Residential location at the time of KLPS-4 E+ Module (2017-2019)



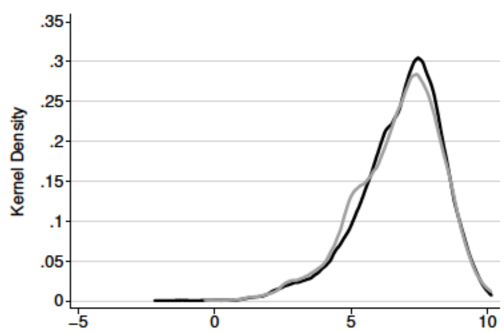
Notes: This figure plots the residential location at the time of the KLPS-4 E+ Module survey, conducted in 2017-19. All respondents attended primary school in Busia County in western Kenya. The figure presents the number of observations by Kenyan county that were surveyed in the KLPS-4 E+ Module Observations are weighted to be representative of the original PSDP population, and account for KLPS population weights, SCY and VocEd control group weights, and KLPS-4 intensive tracking weights.

Figure A.3: Kernel Densities of (Log) Consumption and Earnings, KLPS Rounds 2, 3 and 4

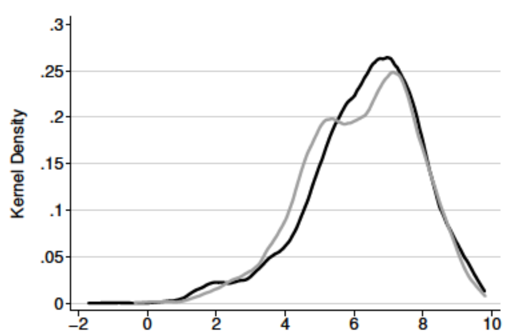
A: Annual Per-Capita Consumption (KLPS 3 & 4)



B: Annual Individual Earnings (KLPS 2, 3 & 4)



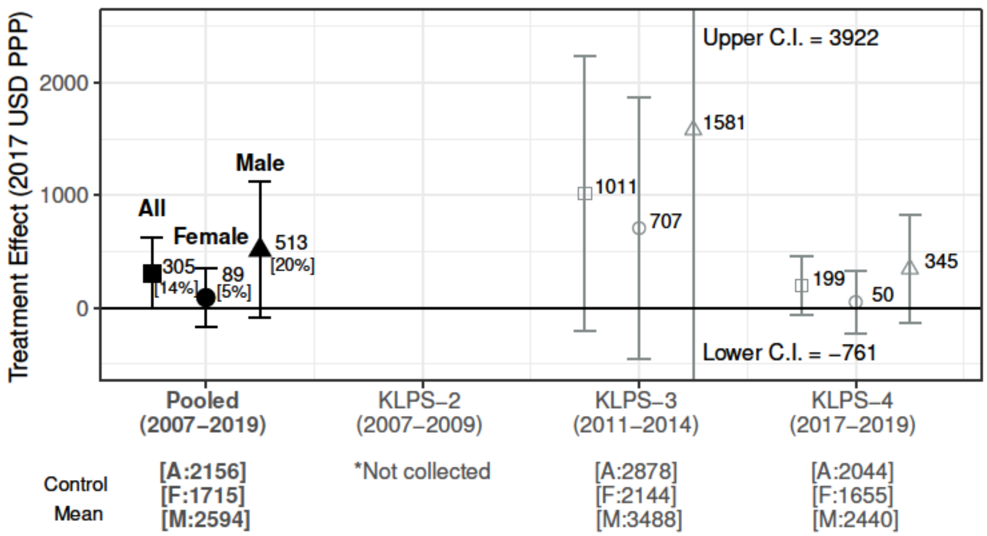
C: Annual Per-Capita Household Earnings (KLPS-4)



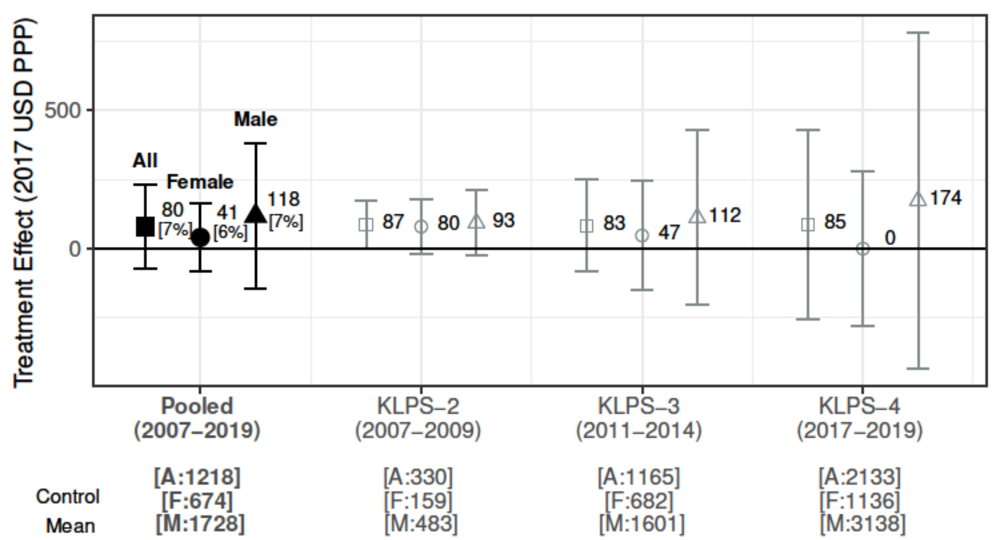
Notes: This figure plots the smoothed (Epanechnikov) kernel densities of log per-capita annual per-capita consumption, log annual individual earnings, and log annual per-capita household earnings of the full sample (2017 USD PPP, top 1% trimmed). See Table 1 for additional details on outcome construction. Household earnings are only available in KLPS-4. The grey line represents the control group and the black line represents the treatment group. Observations are weighted to be representative of the original PSDP sample, and account for KLPS population weights, SCY and VocEd control group weights, and KLPS intensive tracking weights.

Figure A.4: Deworming Treatment Effects by Survey Round

A: Annual Per-Capita Consumption

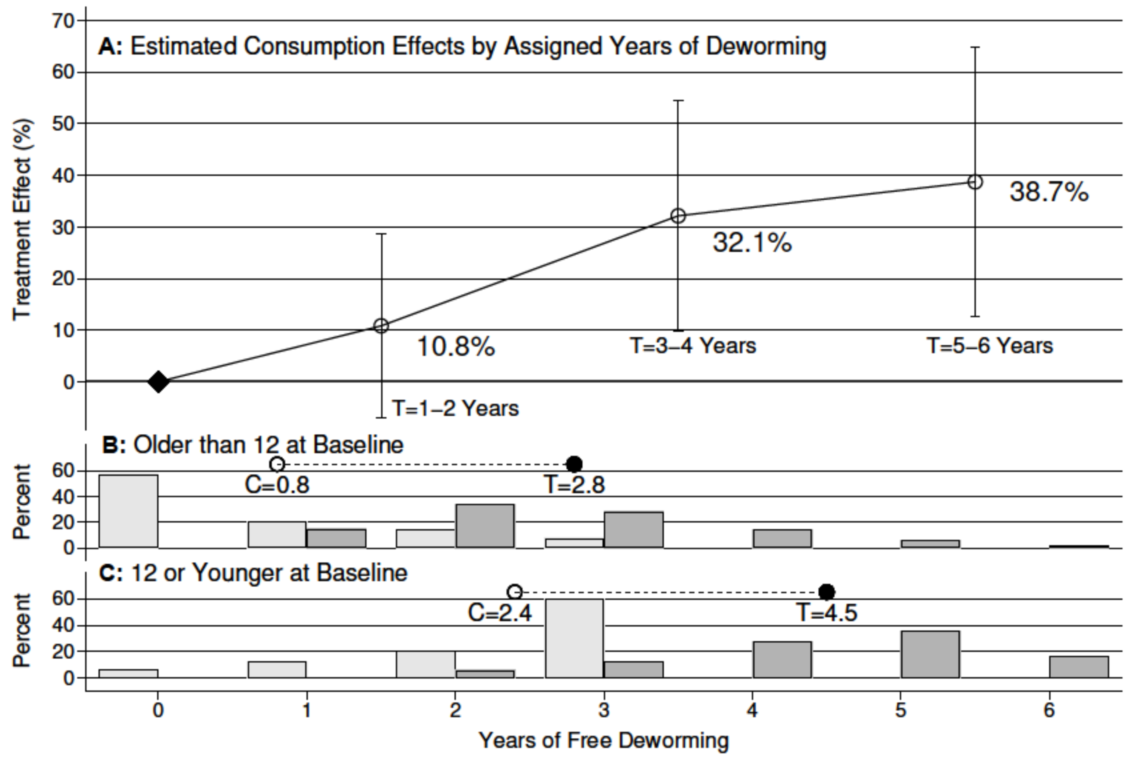


B: Annual Individual Earnings



Notes: This figure plots treatment effects by survey round for annual per-capita consumption and annual individual earnings. Consumption expenditures were not collected in KLPS-2, and are only collected for a representative subset of the KLPS-3 sample. See Table 1 for full details on construction of consumption and earnings. Observations are weighted to be representative of the original PSDP population, and account for KLPS population weights, SCY and VocEd control group weights, and KLPS intensive weights.

Figure A.5: Annual Per-Capita Consumption Treatment Effects by Years of Deworming



Notes: Panel A plots the estimated treatment effects for annual per-capita consumption by years of assigned deworming. 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). See Table 1 for full details on construction of annual per-capita consumption. Panels B and C plot the years of free deworming by treatment and control groups for those who are older than 12 at baseline and those 12 or younger at baseline, respectively. The light grey are those in the treatment group and the dark grey are those in the control group.

Table A.1: Effective Tracking and Survey Rates, Kenya Life Panel Survey (KLPS) Rounds 2, 3 and 4

	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	.872	.886	.858	.013	-.009	.034
				(.026)	(.027)	(.035)
Deceased	.035	.034	.036	.009	.004	.015*
				(.006)	(.009)	(.008)
Surveyed, among non-deceased	.839	.866	.814	.003	-.042	.046
				(.027)	(.028)	(.038)
Number Surveyed	4135	2112	2023			
Panel B.1: KLPS-3 I Module (2011-14)						
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)
Number Surveyed	4597	2256	2341			
Panel B.2: 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)
Number Surveyed	727	371	356			
Panel C: KLPS-2 (2007-09)						
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)
Number Surveyed	5084	2486	2598			

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. The sample includes all PSDP individuals found in initial tracking or placed under intensive tracking (known as the attrition sample), and only includes individuals in the PSDP sample. 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 pct., ** at 5 pct., and *** at 1 pct level.

Table A.2: Effective Tracking and Survey Rates by Age at Baseline (Older/Younger than 12), Kenya Life Panel Survey (KLPS) Rounds 2, 3 and 4

	Control Mean			**Treatment − Control (se)**		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	Older	Younger	All	Older	Younger
Panel A: KLPS-4 E+ Module (2017-19)						
Found	.908	.913	.904	.005	.005	.005
				(.018)	(.022)	(.028)
Deceased	.030	.033	.028	.008	.013	.003
				(.006)	(.009)	(.007)
Surveyed, among non-deceased	.875	.874	.876	-.002	-.002	-.003
				(.021)	(.023)	(.029)
Number Surveyed	4082	2071	2011			
Panel B.1: KLPS-3 I Module (2011-14)						
Found	.906	.878	.932	-.003	.019	-.025
				(.019)	(.025)	(.022)
Deceased	.017	.016	.018	.003	.011*	-.004
				(.004)	(.006)	(.005)
Surveyed, among non-deceased	.892	.861	.922	-.009	.014	-.031
				(.020)	(.027)	(.023)
Number Surveyed	4597	2292	2305			
Panel B.2: KLPS-3 E Module (2011-14)						
Found	.892	.829	.945	.006	.046	-.028
				(.037)	(.056)	(.041)
Deceased	.029	.021	.036	-.009	.011	-.025
				(.011)	(.014)	(.018)
Surveyed, among non-deceased	.796	.706	.872	-.015	.067	-.085*
				(.042)	(.066)	(.047)
Number Surveyed	727	356	371			
Panel C: KLPS-2 (2007-09)						
Found	.902	.878	.923	-.003	-.008	.000
				(.013)	(.022)	(.020)
Deceased	.010	.013	.009	.002	.003	.001
				(.003)	(.005)	(.004)
Surveyed, among non-deceased	.877	.861	.893	.003	-.009	.013
				(.014)	(.024)	(.020)
Number Surveyed	5084	2540	2544			

Notes: Columns (1) to (3) present control means for indicator variables for respondent found, deceased, or surveyed, respectively restricted to those with available data on the individual's age at baseline. Column (4) presents regression results of these indicator variables regressed on an indicator for PSDP treatment. Columns (5) and (6) present regression results for older and younger subsamples, respectively. Older includes those that are older than 12 years at baseline and younger includes those that are 12 or younger years at baseline. Age at baseline is missing for 173 individuals in the KLPS-4 attrition sample, 114 individuals in the KLPS-3 I Module attrition sample, 14 individuals in the KLPS-3 E Module attrition sample, and 119 individuals in the KLPS-2 attrition sample. The sample includes all PSDP individuals found in initial tracking or placed under intensive tracking (known as the attrition sample), and only includes individuals in the PSDP sample. 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 significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.3: 20 Year Deworming Treatment Effects on Consumption and Earnings, KLPS Round 4

	(1) Full Sample	(2) Female	(3) Male	(4) Older	(5) Younger
Panel A: Annual Per-Capita Consumption					
Treatment (λ_1)	199	50	345	575***	-96
	(130)	(141)	(242)	(199)	(132)
Control Mean	2044	1655	2440	1873	2204
Treatment Effect (%)	9.73	3.02	14.15	30.70	-4.35
Treatment p-value	.129	.723	.158	.005	.471
FDR q-value	.349	1.000	1.000	.022	.309
Number Observations	4076	2102	1974	2051	1974
Panel B: Annual Individual Earnings					
Treatment (λ_1)	85	-0	174	479**	-252
	(171)	(141)	(306)	(223)	(278)
Control Mean	2133	1136	3138	1800	2433
Treatment Effect (%)	4.00	-.03	5.54	26.60	-10.34
Treatment p-value	.620	.998	.572	.035	.368
FDR q-value	.450	1.000	1.000	.056	.309
Number Observations	4072	2099	1973	2040	1979
Panel C: Annual Per-Capita Household Earnings					
Treatment (λ_1)	239*	36	439*	565**	-22
	(129)	(107)	(252)	(232)	(171)
Control Mean	1296	973	1623	1082	1501
Treatment Effect (%)	18.44	3.68	27.06	52.17	-1.48
Treatment p-value	.069	.738	.086	.017	.897
Number Observations	4074	2099	1975	2039	1982

Notes: This table shows the treatment effect on annual per-capita consumption, annual individual earnings, and annual per-capita household earnings using KLPS-4 cross-sectional data. See Table 1 and the PAP report (Layvant, Miguel, and Walker 2020) for full details on the construction of these variables and the regression specification. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.4: 20 Year Deworming Treatment Effects on Earnings, Labor Supply, Occupation, and Sectoral Choice, KLPS Round 4

	Treatment (λ_1)			Full Sample	
	(1) Full Sample	(2) Male	(3) Older	(4) Control Mean	(5) Number Obs.
Panel A: Earnings and Wealth					
Log Annual Individual Earnings	0.11	0.09	0.32**	6.87	3330
	(0.09)	(0.10)	(0.14)		
Wage Earnings (annual)	106	194	296*	1488	4074
	(138)	(235)	(172)		
Self-Employment Profit (annual)	113**	176	201**	394	4077
	(58)	(120)	(102)		
Individual Farming Profit (annual)	2	6	-1	21	4078
	(5)	(10)	(8)		
Non-Zero Earnings	-0.00	0.02	-0.00	0.83	4122
	(0.02)	(0.02)	(0.02)		
Hourly Earnings	0.26*	0.45*	0.51	1.28	2718
	(0.14)	(0.26)	(0.31)		
Per-Capita Household Wealth	69	102	253***	522	4085
	(50)	(97)	(89)		
Panel B: Labor Supply, Occupation, and Sectoral Choice					
Urban Residence	0.05*	0.10**	-0.01	0.56	4121
	(0.03)	(0.05)	(0.05)		
Total Hours Worked (last 7 days)	-0.23	1.81	1.56	38.29	4135
	(1.21)	(1.66)	(1.86)		
Hours Worked - Agriculture (last 7 days)	-2.08**	-2.36	-0.74	7.89	4135
	(0.89)	(1.60)	(1.15)		
Hours Worked - Non-Agriculture (last 7 days)	1.84	4.17**	2.31	30.40	4135
	(1.22)	(1.68)	(2.04)		
Employed - Agriculture/Fishing	-0.006	-0.004	-0.007	0.037	4109
	(0.013)	(0.022)	(0.016)		
Employed - Services/Wholesale/Retail	0.013	0.017	0.012	0.337	4109
	(0.023)	(0.038)	(0.029)		
Employed - Construction/Trade Contractor	0.009	0.016	-0.010	0.044	4109
	(0.013)	(0.024)	(0.013)		
Employed - Manufacturing	-0.006	-0.012	-0.000	0.034	4109
	(0.008)	(0.014)	(0.010)		

Notes: This table reports treatment effects for numerous outcomes using KLPS-4 cross-sectional data. Column (1) reports the overall treatment effect (λ_1 from Equation (1)) for the full sample, while columns (2) and (3) report estimated treatment effects for males and those older than 12 at baseline, respectively. Column (4) reports the full sample control mean for each outcome. Column (5) reports the number of observations in the full sample for each outcome. See Table 2 and the PAP report (Layvant, Miguel, and Walker 2020) for additional details on variable construction and the regression specification. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.5: 10 to 20 year Deworming Treatment Effects on Consumption and Earnings including Individuals in the Vocational Training (VocEd) and Cash Grant (SCY) Programs, KLPS Rounds 2, 3 and 4

	(1) Full Sample	(2) Female	(3) Male	(4) Older	(5) Younger
Panel A: Annual Per-Capita Consumption (KLPS-3 and 4)					
Treatment (λ_1)	172	47	299	667***	-224
	(132)	(134)	(248)	(189)	(177)
Control Mean	2172	1727	2638	1926	2401
Treatment Effect (%)	7.94	2.70	11.32	34.62	-9.35
Treatment p-value	.195	.729	.232	.001	.208
FDR q-value	.196	.582	.582	.003	.162
Number Observations	5654	2886	2768	2857	2746
Panel B: Annual Individual Earnings (KLPS-2, 3, and 4)					
Treatment (λ_1)	136*	81	191	353***	-52
	(77)	(74)	(130)	(109)	(107)
Control Mean	1219	674	1751	1167	1253
Treatment Effect (%)	11.15	12.06	10.92	30.25	-4.17
Treatment p-value	.082	.276	.147	.002	.626
FDR q-value	.196	.582	.582	.003	.385
Number Observations	15145	7540	7605	7580	7512
Panel C: Annual Per-Capita Household Earnings (KLPS-4)					
Treatment (λ_1)	257**	25	489**	608***	-35
	(115)	(102)	(212)	(198)	(182)
Control Mean	1295	969	1649	1057	1527
Treatment Effect (%)	19.85	2.60	29.64	57.50	-2.27
Treatment p-value	.029	.806	.024	.003	.850
Number Observations	4936	2511	2425	2493	2390

Notes: This table shows the treatment effect on annual per-capita consumption, annual individual earnings, and annual per-capita household earnings. Analysis includes observations for the full KLPS sample, including respondents who participated in SCY or VocEd, with indicators for receiving a SCY grant or a vocational training voucher. See Table 1 and the PAP report (Layvant, Miguel, and Walker 2020) for full details on the construction of these variables and the regression specification. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.6: 10 to 20 Year Deworming Treatment Effects on Earnings, Labor Supply, Occupation, and Sectoral Choice including Individuals in the Vocational Training (VocEd) and Cash Grant (SCY) Programs, KLPS Rounds 2, 3 and 4

	Treatment (λ_1)			Full Sample	
	(1) Full Sample	(2) Male	(3) Older	(4) Control Mean	(5) Number Obs.
Panel A: Earnings and Wealth					
Log Annual Individual Earnings	0.10*	0.07	0.22***	6.74	8817
	(0.06)	(0.06)	(0.08)		
Wage Earnings (annual)	116*	175	256***	887	15151
	(67)	(106)	(89)		
Self-Employment Profit (annual)	42*	46	59	212	15152
	(24)	(45)	(38)		
Individual Farming Profit (annual)	-1	1	-3	11	15220
	(2)	(3)	(3)		
Non-Zero Earnings	0.02*	0.04***	0.03*	0.59	15320
	(0.01)	(0.01)	(0.02)		
Hourly Earnings	0.12**	0.17*	0.27***	1.07	7002
	(0.06)	(0.10)	(0.09)		
Per-Capita Household Wealth (KLPS-4)	21	31	162**	531	4949
	(39)	(62)	(65)		
Panel B: Labor Supply, Occupation, and Sectoral Choice					
Urban Residence	0.03	0.05**	0.02	0.46	15320
	(0.02)	(0.03)	(0.03)		
Total Hours Worked (last 7 days)	1.38**	2.11***	2.44**	23.94	15334
	(0.57)	(0.71)	(0.96)		
Hours Worked - Agriculture (last 7 days)	-0.50	-0.17	-0.25	3.75	15334
	(0.34)	(0.37)	(0.48)		
Hours Worked - Non-Agriculture (last 7 days)	1.88***	2.28***	2.70**	20.20	15334
	(0.55)	(0.74)	(1.11)		
Employed - Agriculture/Fishing	-0.004	-0.001	0.006	0.041	15291
	(0.007)	(0.012)	(0.010)		
Employed - Services/Wholesale/Retail	0.000	0.009	0.001	0.227	15284
	(0.013)	(0.017)	(0.018)		
Employed - Construction/Trade Contractor	0.004	0.009	-0.001	0.032	15283
	(0.006)	(0.012)	(0.008)		
Employed - Manufacturing	-0.000	0.003	0.005	0.025	15283
	(0.004)	(0.007)	(0.006)		

Notes: This table shows the treatment effect for numerous outcomes. Analysis includes observations for the full KLPS sample, including respondents who participated in SCY or VocEd, with indicators for receiving a SCY grant or a vocational training voucher. Column (1) reports the overall treatment effect (λ_1 from Equation (1)) for the full sample, while columns (2) and (3) report estimated treatment effects for males and those older than 12 at baseline, respectively. Column (4) reports the full sample control mean for each outcome. Column (5) reports the number of observations in the full sample for each outcome. See Table 2 and the PAP report (Layvant, Miguel, and Walker 2020) for additional details on variable construction and the regression specification. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.7: 10 to 20 Year Deworming Treatment Effects on Consumption, Earnings, Labor Supply, Occupational Choice, and Sector, KLPS Rounds 2, 3 and 4

	(1) Per Capita Consumption	(2) Total Earnings	(3) Per Capita Household Earnings
Treatment (λ_1)	305*	80	239*
	(159)	(76)	(129)
Cost Sharing (λ_2)	-136	-32	-157
	(144)	(76)	(120)
Saturation (λ_3)	957	-366	-1011*
	(1408)	(463)	(604)
Control Mean	2156	1218	1296
Treatment Effect (%)	14.2	6.5	18.4
Joint F-Test (p-value)	.259	.427	.018
Number Observations	4794	13624	4074

	(1) Log Yearly Earnings	(2) Wage Earnings	(3) Self-Employment Earnings	(4) Farming Profit	(5) Non-Zero Earnings	(6) Hourly Earnings	(7) Per Capita Household Wealth
Treatment (λ_1)	.09	81	41*	-0	.02*	.14*	68
	(.06)	(68)	(24)	(2)	(.01)	(.08)	(50)
Cost Sharing (λ_2)	-.04	-63	-7	2	-.00	-.22***	-60
	(.06)	(67)	(25)	(2)	(.01)	(.07)	(39)
Saturation (λ_3)	-.14	-280	255	-23*	.03	.06	-394*
	(.28)	(506)	(195)	(12)	(.06)	(.36)	(213)
Control Mean	6.73	887	212	9	.59	1.07	522
Treatment Effect (%)	8.8	9.2	19.3	-3.8	3.6	12.7	13.1
Joint F-Test (p-value)	.297	.316	.314	.308	.323	.021	.043
Number Observations	7698	13628	13638	13707	13794	6096	4085

	(1) Urban Residence	(2) Total Hours Worked	(3) Hours Worked - Agriculture	(4) Hours Worked - Non-Agriculture	(5) Employed - Agriculture/ Fishing	(6) Employed - Services/ Wholesale/ Retail	(7) Employed - Construction/ Trade Contractor	(8) Employed - Manufacturing
Treatment (λ_1)	.04**	1.04	-.87**	1.91***	-.003	.002	.004	-.001
	(.02)	(.66)	(.43)	(.65)	(.008)	(.014)	(.007)	(.004)
Cost Sharing (λ_2)	-.02	-.38	.22	-.59	.005	-.018	.003	.005
	(.02)	(.67)	(.30)	(.71)	(.011)	(.014)	(.007)	(.004)
Saturation (λ_3)	.21*	1.84	-2.62	4.46	-.102*	-.029	.015	-.002
	(.11)	(4.30)	(1.94)	(3.75)	(.056)	(.071)	(.060)	(.027)
Control Mean	.45	24.19	3.99	20.2	.043	.23	.033	.026
Treatment Effect (%)	9.3	4.3	-21.8	9.5	-7.9	1.1	12.3	-5.6
Joint F-Test (p-value)	.086	.471	.243	.036	.282	.497	.826	.693
Number Observations	13793	13807	13807	13807	13768	13761	13760	13760

Notes: This table shows the treatment, cost sharing, and saturation effect from Equation 1 on a variety of outcomes. See Tables 1 and 2 and the PAP report (Layvant, Miguel, and Walker 2020) for full details on the construction of these variables and the regression specification. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.8: Interaction Effects between Deworming Treatment and Parents' Average Education, KLPS Rounds 2, 3 and 4

	Annual Per-Capita Consumption			Annual Individual Earnings			Annual Per-Capita Household Earnings		
	(1) Full Sample	(2) Male Subsample	(3) Older Subsample	(4) Full Sample	(5) Male Subsample	(6) Older Subsample	(7) Full Sample	(8) Male Subsample	(9) Older Subsample
Treatment (λ_1)	252	376	688***	40	44	234**	179	357	461**
	(152)	(277)	(211)	(73)	(135)	(110)	(127)	(216)	(187)
Cost Sharing (λ_2)	-101	-36	-352	-2	-49	-84	-141	-451**	-494***
	(147)	(250)	(225)	(74)	(128)	(105)	(121)	(214)	(173)
Saturation (λ_3)	1014	2450	2943*	-493	-717	507	-1351**	-1555	670
	(1433)	(2211)	(1754)	(468)	(894)	(644)	(648)	(1147)	(711)
Treatment x Parents' Average Education	-41	-69	-24	-33	-27	-14	-17	-22	10
	(36)	(66)	(49)	(21)	(40)	(32)	(32)	(50)	(49)
Cost Sharing x Parents' Average Education	19	71	28	27	26	5	44	71	5
	(41)	(60)	(59)	(18)	(36)	(25)	(38)	(53)	(48)
Saturation x Parents' Average Education	307	487	444	-54	-91	117	-201	-374	202
	(297)	(509)	(385)	(111)	(198)	(133)	(184)	(278)	(288)
Parents' Average Education	111***	139***	91***	76***	93***	63**	95***	120***	45*
	(22)	(44)	(23)	(16)	(25)	(25)	(17)	(29)	(26)
Control Mean	2168	2626	1947	1205	1715	1169	1311	1652	1103
Treatment Effect (%)	11.6	14.3	35.4	3.3	2.6	20.0	13.7	21.6	41.8
Joint F-Test (p-value)	.209	.187	.531	.392	.888	.693	.504	.280	.914
Number Observations	4650	2252	2329	13386	6688	6670	3941	1910	1972

Notes: This table shows the treatment, cost sharing, and saturation effect from Equation 1 when including a continuous variable on the parents' average education and interaction terms with parents' average education on annual per-capita consumption, annual individual earnings, and annual per-capita household earnings (separately for the full sample, subsample of males, and subsample of those older than 12 at baseline). Parents' average education is the average of the highest years of schooling attained by the parents of the KLPS respondent. Parents' highest educational attainment is first taken from KLPS-1 and then supplemented with KLPS-2, KLPS-3, and finally KLPS-4 I-Module Wave 1 data when unavailable from a previous round. Parents' average education is demeaned across the full sample. See Table 1 and the PAP report (Layvant, Miguel, and Walker 2020) for notes on covariates. The Joint F-Test (p-value) gives the p-value associated with an F-test on the joint significance of the treatment, cost-sharing, and saturation interaction coefficients against the null hypothesis that all three coefficients are jointly equal to zero. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.9: Interaction between Deworming Treatment, Age at Baseline (Cohort Effects), and Age at Time of Survey, KLPS Rounds 2, 3 and 4

	Annual Per-Capita Consumption		Annual Individual Earnings		Annual Per-Capita Household Earnings	
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment x Older than 12 (at baseline)		1237***		300*		601
		(338)		(154)		(367)
Treatment x Survey Age 15-19			-28	-32		
			(88)	(89)		
Treatment x Survey Age 20-24	-1889	-1945	105*	21		
	(1653)	(1658)	(61)	(64)		
Treatment x Survey Age 25-29	691	404	62	-98		
	(444)	(359)	(101)	(130)		
Treatment x Survey Age 30-34	248	-320	-48	-216	222	-35
	(192)	(235)	(189)	(250)	(203)	(218)
Treatment x Survey Age 35-39	606	-624	879	577	625	15
	(386)	(510)	(537)	(543)	(409)	(575)
Cost Sharing x Older than 12 (at baseline)		-196		38		-537
		(326)		(141)		(397)
Cost Sharing x Survey Age 15-19			-70	-71		
			(90)	(91)		
Cost Sharing x Survey Age 20-24	782	777	38	26		
	(695)	(689)	(60)	(71)		
Cost Sharing x Survey Age 25-29	-194	-190	-144	-165		
	(374)	(321)	(97)	(135)		
Cost Sharing x Survey Age 30-34	-84	10	227	209	128	354
	(186)	(219)	(180)	(225)	(317)	(324)
Cost Sharing x Survey Age 35-39	-451	-264	-716	-754	-135	417
	(344)	(428)	(441)	(457)	(434)	(560)
Saturation x Older than 12 (at baseline)		8080**		873		3960*
		(3088)		(900)		(1991)
Saturation x Survey Age 15-19			468	461		
			(484)	(498)		
Saturation x Survey Age 20-24	-3779	-3853	-505	-763		
	(3540)	(3526)	(391)	(460)		
Saturation x Survey Age 25-29	5427	3248	53	-420		
	(5575)	(4263)	(552)	(890)		
Saturation x Survey Age 30-34	266	-3527*	-1313	-1831	873	-821
	(1179)	(2016)	(1077)	(1368)	(1534)	(1637)
Saturation x Survey Age 35-39	-1029	-9100***	2224	1315	3287*	-649
	(1868)	(2580)	(2309)	(1938)	(1888)	(2193)
Indicator for Older than 12 (at baseline)		-640***		-546***		-639***
		(202)		(134)		(233)
Indicator for Survey Age 15-19			1866***	1257***		
			(326)	(339)		
Indicator for Survey Age 20-24	2661*	2049	1580***	1091***		
	(1518)	(1523)	(322)	(336)		
Indicator for Survey Age 25-29	631	112	1626***	1309***		
	(394)	(471)	(308)	(309)		
Indicator for Survey Age 30-34	447*	74	1251***	1033***	-563***	-395
	(252)	(262)	(307)	(293)	(207)	(248)
Control Mean	2161	2161	1211	1211	1306	1306
Num. Obs. Survey Age 15-19	0	0	594	594	0	0
Num. Obs. Survey Age 20-24	115	115	3970	3970	0	0
Num. Obs. Survey Age 25-29	993	993	4686	4686	525	525
Num. Obs. Survey Age 30-34	2775	2775	3464	3464	2641	2641
Num. Obs. Survey Age 35-39	863	863	852	852	850	850

Notes: This table shows the treatment, cost sharing, and saturation effect from Equation 1 when interacting with the age of the KLPS respondent at the time of the survey. Columns (2), (4), and (6) include interaction terms with an indicator for being older than 12 years at baseline. See Table 1 and the PAP report (Layvant, Miguel, and Walker 2020) for notes on covariates. 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. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.10: Summary Statistics on Heterogeneity by Gender and Baseline Age

	(1) Female	(2) Male	(3) Difference	(4) Older	(5) Younger	(6) Difference
Panel A: Baseline Summary Statistics (Full Sample Mean)						
Age at Baseline (1998)	12.08	12.49	-0.44***	14.39	10.46	3.93***
			(0.07)			(0.04)
Any Moderate-Heavy Infection 1998 (WHO)	0.305	0.350	-0.037	0.306	0.359	-0.053*
			(0.028)			(0.030)
Z-Score of Mean Intensity 1998 (WHO)	-0.008	0.077	-0.069	0.052	0.008	0.044
			(0.056)			(0.056)
Average Years of Parents' Education	7.36	7.09	0.28***	6.70	7.68	-0.98***
			(0.10)			(0.10)
Years of Assigned Deworming - Control Mean	1.68	1.77	-0.09	0.91	2.42	-1.50***
			(0.09)			(0.07)
Panel B: Health Outcomes Summary Statistics (Control Mean)						
Any Moderate-Heavy Infection 1999 (WHO)	0.508	0.470	0.039	0.505	0.470	0.035
			(0.042)			(0.042)
Any Moderate-Heavy Infection 2001 (WHO)	0.245	0.243	0.002	0.202	0.261	-0.059
			(0.042)			(0.041)
Indicator for Self-Perceived Health Very Good	0.56	0.66	-0.10***	0.60	0.63	-0.04
			(0.02)			(0.02)
Panel C: Education and Labor Market Outcomes Summary Statistics (Control Mean)						
Years of Education by 2011	8.69	9.85	-1.16***	8.67	9.88	-1.22***
			(0.19)			(0.20)
Indicator for Any Secondary School by 2011	0.33	0.54	-0.21***	0.31	0.56	-0.25***
			(0.03)			(0.03)
Learned of Any Job Through Primary Classmate	0.09	0.22	-0.14***	0.13	0.17	-0.04
			(0.04)			(0.03)
Indicator for Urban Residence	0.53	0.60	-0.07*	0.57	0.57	0.00
			(0.04)			(0.04)
Chore Hours	27.4	9.9	17.5***	17.8	18.7	-0.8
			(0.7)			(0.8)
Childcare Hours	16.4	7.2	9.2***	12.3	11.7	0.6
			(0.9)			(1.0)
Hours Worked - Non-Agriculture	15.5	24.5	-9.0***	22.4	18.1	4.3***
			(1.1)			(1.1)

Notes: Panel A shows the full KLPS sample mean (unless otherwise stated) of baseline summary statistics and Panels B and C show the control mean for health outcomes and education and labor market outcomes, respectively. Columns (3) and (6) show the difference between females and males, and older than 12 and 12 or younger at baseline, respectively. We define moderate-heavy infection according to the World Health Organization (WHO) cutoffs for moderate to heavy worm infections, which are 100 eggs per gram (epg) for *S. mansoni*, 5000 epg for Roundworm, 2000 epg for Hookworm and 1000 epg for Whipworm. We denote mean intensity of infection for individual j as $Inf_j = \sum_{k=1}^{4} \omega_k eggs_{jk}$ in which ω_k is the inverse of the threshold for moderate to heavy infections for worm k, and EPG in the Kato-Katz test. The Z-intensity measure for individual j is then computed by normalizing intensity of infection by the 1998 mean and standard deviation, that is $Z_j = \frac{Inf_j - \mu_{Inf\ 1998}}{\sigma_{Inf,1998}}$. Average Years of Parents' Education is the average of the highest years of schooling attained by the parents of the KLPS respondent. Parents' highest educational attainment is first taken from KLPS-1 and then supplemented with KLPS-2, KLPS-3, and finally KLPS-4 I-Module Wave 1 data when unavailable from a previous round. 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 for KLPS-4 respondents. 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). Indicator for Self-Perceived Health Very Good uses KLPS-2 and KLPS-3 data. Years of Education by 2011 and Indicator for Any Secondary School by 2011 uses KLPS-3 data. Learned of Any Job Through Primary Classmate, Indicator for Urban Residence, and Childcare Hours uses KLPS-4 cross-sectional data. Learned of Any Job Through Primary Classmate is an indicator variable for whether a primary schoolmate ever informed the respondent of a job opening, helped the respondent search for a job, or helped the respondent find a job and only includes data from KLPS-4 E+ Wave 2. Childcare hours includes total hours spent doing childcare in the last 7 days even if overlapped with other tasks. Chore Hours uses data from KLPS-3 and KLPS-4 and includes total hours spent doing household chores in the last 7 days excluding time spent on childcare. Hours Worked - Non-Agriculture uses data from KLPS-2-4 and includes total hours worked in wage and self-employment in the last 7 days. 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 (where applicable). * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.11: Heterogeneous Treatment Effects by Gender and Age for Health, Education and Labor Market Outcomes, KLPS Rounds 2, 3 and 4

	(1) Female	(2) Male	(3) Difference	(4) Older	(5) Younger	(6) Difference
Panel A: Health Outcomes						
Years of Assigned Deworming	2.07***	2.12***	-0.05	2.09***	2.11***	-0.01
	(0.10)	(0.10)	(0.04)	(0.09)	(0.11)	(0.06)
Any Moderate-Heavy Infection 1999 (WHO)	-0.264***	-0.265***	0.001	-0.262***	-0.264***	0.002
	(0.069)	(0.062)	(0.053)	(0.059)	(0.073)	(0.060)
Z-Score of Mean Intensity 1999 (WHO)	-0.698***	-0.463**	-0.235	-0.493**	-0.647***	0.154
	(0.196)	(0.195)	(0.210)	(0.207)	(0.192)	(0.222)
Any Moderate-Heavy Infection 2001 (WHO)	-0.117***	-0.139***	0.023	-0.072	-0.156***	0.084*
	(0.044)	(0.036)	(0.051)	(0.044)	(0.035)	(0.046)
Z-Score of Mean Intensity 2001 (WHO)	-0.271***	-0.149**	-0.122	-0.145**	-0.241***	0.096
	(0.087)	(0.068)	(0.106)	(0.073)	(0.080)	(0.111)
Indicator for Self-Perceived Health Very Good	0.05*	0.02	0.03	0.02	0.03	-0.01
	(0.02)	(0.02)	(0.04)	(0.03)	(0.02)	(0.04)
Panel B: Education and Labor Market Outcomes						
Years of Education by 2011	0.39	0.06	0.33	0.45**	0.04	0.40
	(0.27)	(0.21)	(0.30)	(0.18)	(0.26)	(0.29)
Indicator for Any Secondary School by 2011	0.07*	-0.03	0.10**	0.06	-0.01	0.07
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
Learned of Any Job Through Primary Classmate	0.05**	-0.02	0.07	0.06**	-0.03	0.09**
	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)	(0.05)
Indicator for Urban Residence	0.01	0.10**	-0.09	-0.01	0.11***	-0.11*
	(0.03)	(0.05)	(0.06)	(0.05)	(0.04)	(0.06)
Chore Hours	-0.8	0.6	-1.4	1.0	-0.9	1.9*
	(0.9)	(0.6)	(1.1)	(0.8)	(0.7)	(1.1)
Childcare Hours	0.8	-0.4	1.1	-0.5	0.8	-1.4
	(1.0)	(0.7)	(1.3)	(0.8)	(0.7)	(1.0)
Hours Worked - Non-Agriculture	1.0	2.8***	-1.7	2.2**	1.9	0.4
	(1.0)	(0.9)	(1.4)	(1.1)	(1.1)	(1.8)

Notes: Panel A reports heterogeneous treatment effects for various health outcomes, and Panel B reports heterogeneous treatment effects for various education and labor market outcomes. See Table A.10 for full details on the construction of these outcomes. Treatment is an indicator variable which equals 1 for PSDP Groups 1 and 2. Reported estimates for Female and Male are constructed from a single regression including treatment-female, cost-sharing-female, and saturation-female interaction terms for all education and labor market outcomes, Years of Assigned Deworming, and Indicator for Self-Perceived Health Very Good. Similarly, reported estimates for Older and Younger are calculated from a single regression including an indicator for those older than 12 at baseline and interaction terms for treatment-older, cost-sharing-older, and saturation-older for all education and labor market outcomes, Years of Assigned Deworming, and Indicator for Self-Perceived Health Very Good. Any Moderate-Heavy Infections and Z-Score of Mean Intensity outcomes include treatment-female and treatment-older interaction terms for the gender and age columns, respectively. See Table 1 and the PAP report (Layvant, Miguel, and Walker 2020) for notes on covariates. Covariates for Any Moderate-Heavy Infections and Z-Score Mean Intensity outcomes exclude survey wave and month variables, as well the cost-sharing school indicator. 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 clustered at the 1998 school level. * denotes significance at 10 pct., ** at 5 pct., and *** at 1 pct.

Table A.12: Rate of Return and Net Present Value of Child Deworming

	Consumption		Earnings	
	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%	467.90	751.68	230.71	304.67
Social NPV for assumed discount rate of 5%	1157.62	2517.58	499.72	854.14
Fiscal NPV for assumed discount rate of 10%	56.05	103.08	16.74	28.99
Fiscal NPV for assumed discount rate of 5%	164.93	390.34	55.88	114.63
Panel C: Internal Rate of Return (IRR) from Observed Labor Market Gains				
Social IRR	36.7%	37.1%	40.7%	40.8%
Fiscal IRR	19.6%	21.0%	15.5%	16.7%

Notes: This table presents results related to calculations of the costs and benefits of deworming following Equation (2) in 2017 USD PPP. 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 (λ_{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. See Figure 1 for additional details on the construction of the additional schooling costs. The benefits of deworming are measured via annual per-capita consumption and annual individual earnings. Consumption expenditures are measured 15 years (KLPS-3) and 20 years (KLPS-4) after the start of deworming and the effects are pooled across rounds. For consumption, we assume no gains in the first 15 years after receiving the deworming medication. Earnings are measured 10, 15 and 20 years after the start of deworming and effects are pooled across rounds. We assume no gains in the first 10 years after receiving deworming medication. We consider two cases for earnings and consumption 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).

B Secondary sources of variation in deworming

We present results for the effect of the two secondary sources of variation, cost-sharing and local treatment saturation, on the same outcomes reported in this paper (Appendix Table A.7). There is ample evidence that cost-sharing had a negative effect on later outcomes: the estimated λ_{2t} effect has the opposite sign of the direct λ_{1t} effect for 19 of the 21 outcomes in this paper (and 43 of the 54 pre-specified outcomes), as predicted; this is extremely unlikely to occur by chance (p-value < 0.001). To illustrate, for the primary consumption per capita measure, the coefficient estimate on the cost-sharing indicator is sizeable although not significant, at USD PPP -136 (s.e., 144), or -6.3%. We further explore the extent of the cost-sharing effect, as well as the additional variation induced across Groups 1 and 2, in Appendix Figure A.5. There is a large and visually apparent marginal effect of each additional year of subsidized deworming treatment assignment for the per-capita consumption measure (Panel A).

In terms of the effect of local spillovers, few estimates are statistically significant, and we cannot reject that there is no relationship between the sign of the local deworming saturation effect (λ_{3t}) and the direct deworming effect: the two coefficient estimates have the same sign (as predicted) for roughly half of all outcomes, providing little evidence that local treatment spillovers generated long-run economic impacts. When estimating saturation effects of the proportion of treatment schools within 4 km (as opposed to 6 km), saturation terms largely remain insignificant, while treatment effects remain robust.

C Discussion of heterogeneous effects and mechanisms

This section expands on the discussion of heterogeneity in deworming treatment effects in Section 2.3, namely that effects are concentrated among males and those older than 12 at baseline. Constraints on women's labor market participation may play an important role in the lack of labor market effects for females, despite larger schooling attainment and test score gains than males. In addition to the childcare and chore work hours patterns highlighted in our data, the 2020 USAID Kenya Gender Fact Sheet writes: "Limited control over benefits from land and other resources constrains women's successful participation in the economy, particularly as producers and market actors. Women's unpaid childcare and domestic work limits women's contribution in and benefit from productive activities, constrain their mobility, and limit their access to market resources and information while participating in the economy." These challenges may be particularly stark for young women in a relatively poor agrarian region like Busia given expectations around household work and childcare. While these are prime labor market years, they are also a period in which young women may have high rates of childcare responsibilities; labor market participation could occur later, once all children have reached primary school age. Ongoing research will further study marriage and fertility patterns, parenting strategies and intergenerational effects.

In terms of larger estimated gains among older participants (those older than 12 at baseline), we are able to rule out that this is simply a life cycle or timing issue: as noted above, by KLPS rounds 3 and 4, fewer than 3% of sample individuals are still enrolled in school, and by that time even the younger sample individuals are prime-age workers in their 20's or early 30's. In addition, the data suggest differences are driven by cohort, rather than age-at-survey, effects. In Appendix Table A.9, we use the data pooled across survey rounds, and generate indicators for 5-year age bins corresponding to the respondent's age at the time of the survey round. We interact these with the treatment, cost-sharing and saturation variables, and estimate two specifications: one including only the age at time of survey variables (cols 1, 3 and 5), and the second bringing in interaction terms with being older than 12 at baseline (a cohort effect, cols 2, 4 and 6). None of the treatment-survey age interactions are significant for per-capita consumption, individual earnings and per-capita household earnings when bringing in the cohort terms, while effects for per-capita consumption and individual earnings are statistically significant. Only one treatment-survey age coefficient is significant in the absence of the cohort terms.

As noted in the main text, treatment group older individuals appear to have experienced larger human capital gains. As background, by the time of the KLPS round 3 (15 year) follow-up, when nearly all individuals had completed their schooling, older individuals had attained substantially less schooling on average (8.7 years) than younger individuals (9.9 years). This reflects the rapid increase in schooling over the decade following the start of PSDP, and especially in terms of increase secondary school enrollment: 31% of older individuals had attained at least some secondary schooling, compared to a much higher 56% among the younger group, again with pronounced gender gaps (see Appendix Table A.10, Panel C). While schooling gains alone are not sufficient to drive later labor market benefits, as demonstrated by the experience of sample females, they are plausibly playing some role in driving long-run gains, at least for males in the older group. Another way of stating this is that the pattern for younger individuals indicates that the deworming health investment did not translate into additional human capital gains for the younger cohorts that were already experiencing rapidly improving educational outcomes, highlighting the importance of context in determining program treatment effects.

Another dimension of heterogeneity that appears to be a promising explanation, at least at first glance, is the difference in parental education between older individuals (whose parents received 6.7 years of school on average) and younger individuals (whose parents received 7.7). Yet there appears to be little evidence of heterogeneous treatment effects across children with different levels of parental education across our main outcome measures, and this holds overall and for age and gender subgroups (see Appendix Table A.8).

D Rate of return and fiscal impacts of deworming details

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. The social net present value (NPV) of providing deworming subsidies takes into account the cost of deworming medication, the cost of additional schooling resulting from deworming (Baird et al. 2016), and economic gains measured via consumption or earnings. We calculate the social NPV as follows:

$$NPV \qquad \sum_{t=0}^{t=2} SQ(S)\left(\frac{1}{1+r}\right)^t \qquad K\sum_{t=0}^{t=9} \Delta\bar{E}_t(S)\left(\frac{1}{1+r}\right)^t + \sum_{t=10}^{t=50} \lambda_{1t}\left(\frac{1}{1+r}\right)^t. \tag{2}$$

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 (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 Deworm The World) of USD PPP 0.83 per year. Costs and benefits are discounted at rate r per year. Figure 1 displays components of this equation graphically, where the direct costs are illustrated in the darkest gray in the first years.

The second term 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 Baird et al. (2016) find up to nine years after the start of treatment. Let K capture the cost of an additional unit of schooling, and $\Delta\bar{E}_t(S)$ denote the average increase in schooling due to deworming. These costs are represented by the dark gray section labeled as teacher costs in Figure 1. We use recent figures on Kenyan secondary school teacher salaries as estimates of K (Nyanchama 2018; Oduor 2017).

The third term captures adult consumption or earnings gains, making use of the λ_{1t} estimates generated from the pooled specification using data for KLPS rounds 2, 3, and 4. For earnings, We assume these gains start 10 years after deworming treatment, roughly coinciding with entry into adulthood and the KLPS round 2 data. For the consumption measure, where we lack data for KLPS round 2, we conservatively assume that the average estimated effect from KLPS 3 and 4 (pooled) only pertains during the period from 15 to 25 years after treatment. By ignoring the time before KLPS-2 (or KLPS-3 for consumption) was collected, it underestimates gains due to any increased earnings 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), nor are there significant effects on measured earnings in KLPS round 1.

While we observe effects at 10, 15 and 20 years after deworming, we must make assumptions about the persistence of any earnings effects during the rest of individuals' working lives (to year t 50, which is roughly retirement age), as well as between rounds. A conservative assumption, presented graphically in Figure 1, assumes that effects pertain during the roughly five years between rounds, so that KLPS round 4 effects persist for another five years through t 25, before falling to zero for all remaining working years (see columns 1 and 3 of Table A.12). An alternative assumption allows for deworming treatment effects on earnings to persist throughout individuals' careers (t 50, columns 2 and 4). We focus on the more conservative case, although it turns out that conclusions are similar under reasonable time discount rates r in the range of 5 to 10% per year.

This calculation is conservative in several ways: one could also include the direct health benefits to children (in money-metric terms) that accrue during the deworming treatment period. To be conservative, the main calculations below do not include these direct short-run child health benefits, nor any persistent health gains, and thus are likely to underestimate program returns. The analysis makes other conservative assumptions by ignoring benefits from cross-school externalities for both sample individuals and other community members (Ozier 2018).

We also calculate the fiscal NPV, the NPV of additional government tax revenue. To do so, we multiply the earnings gains by the the tax rate, τ. Kenyan taxes (mainly on consumption) absorb roughly 16.6% of GDP so we set τ to 16.6%. Following Baird et al. (2016), government expenditures are roughly 19.5% of GDP, and about 15% of government expenditure is financed from donors, thus 0.195*0.85=0.166.

The estimated λ_{1t} effects, combined with these assumptions, below 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. The equation above also implies the magnitude of deworming treatment effects needed to attain a given rate of return. As illustrated by the dotted line in Figure 1, an average adult deworming treatment effect on yearly earnings of USD PPP $7.99 is needed to attain an annualized internal rate of return of 10% (Table A.12, Panel A). Ten 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 gains would indicate that deworming is likely to be cost effective in Kenya; see http://www.centralbank.go.ke/securities/bonds/manualresults.aspx and World Bank Development Indicators for sources. This is a conservative assumption if other potential funders of deworming subsidies (e.g., international organizations or private donors) face lower interest rates; to attain an IRR of 5%, the annual earnings or consumption gain would need to be just USD PPP 4.83 (Panel A).

We next present cost-effectiveness results for the main outcome measures of consumption and earnings, in Figure 1. As shown in Table 1 and Figure 1, the estimated deworming consumption and earnings gains are both an order of magnitude larger than the USD PPP 7.99 needed to attain the social internal rate of return of 10% noted above. The estimated consumption and earnings effects are both also far larger than the gains needed to attain a fiscal IRR of 5 or 10% (USD PPP 29.12 and 48.21, respectively, Table A.12, Panel A). The social and fiscal NPV estimates are positive for both the consumption and earnings effect estimates, and for annual discount rates of both 5 and 10%. In the most conservative scenario, focusing on earnings gains and the 10% discount over 25 years, the social NPV is USD PPP 230.71 and the fiscal NPV is USD PPP 16.74 (Panel B). The implied social and fiscal IRR estimates in this case are 40.7% and 15.5%, with values higher if we allow deworming gains to persist beyond year 25 (Panel C). If we focus on consumption and consider gains out to 25 years, the social and fiscal IRR estimates are 36.7% and 19.6%, respectively.

The results imply that even miniscule earnings or consumption gains far smaller than those observed in KLPS could justify subsidies for mass deworming given its very low cost.