FOR ONLINE PUBLICATION

Supplemental Appendix to Disease and Human Capital Accumulation: Evidence from the Roll Back Malaria Partnership in Africa

1 Model

1.1 Set-up

We consider a unitary household composed of one adult and the adult's surviving offspring.[1] We assume that the household cares about its own consumption c and leisure ℓ as well as about the number n and human capital h of the offspring. Though human capital in childhood is an important determinant of future earnings (Becker, 1975; Currie and Madrian, 1999; Currie, 2009; Hong, 2013), we focus only on contemporaneous effects of improved health on fertility, labor supply and education. We denote by b the number of births and by s the probability for a newborn to survive, such that $n = sb$ (with $0 < s < 1$).

The household's preferences are summarized by the following Cobb-Douglas utility function:

$$u(c, \ell, sb, h(e, H)) = (c\ell)^{1-\gamma}(sbh(e, H))^{\gamma}, \tag{1}$$

where

$$0 < \gamma < 1 \text{ and } h(e, H) = (e^{\rho} + H^{\rho})^{\frac{1}{\rho}} \text{ with } \rho < 1.$$

---

[1] The impact of children's exposure to malaria control campaigns on their adult longevity has not yet been documented (and cannot be investigated based on our data). Our analysis therefore relies on a one-period model, with no reference to adult longevity. The interplay between adult longevity and some of our outcomes is complex. For instance, increased longevity does not necessarily increase parents' incentives to invest in their offspring's education. On one hand, the longer the stream of payouts, the more valuable the investment. Increased longevity should therefore translate into more parental investment in education (Ben-Porath, 1967; Soares, 2005; Jayachandran and Lleras-Muney, 2009). On the other hand however, a higher life expectancy affects not only the returns to children's quality but also the returns to their quantity. Greater longevity might therefore result in no increase in the level of education chosen by the parents (Hazan and Zoabi, 2006) and could even reduce income per capita (Acemoglu and Johnson, 2007). Adult and child mortality shocks can also bring about opposing influences on fertility (Boucekkine, Desbordes and Latzer, 2009). As is apparent from the subsequent sections, the impact of improved children's survival rate and health on our various outcomes is not trivial either.

The human capital $h(e, H)$ of a surviving child is assumed to be a CES production function that depends on his/her education e and his/her health H, with $H > 1$. We denote by σ the elasticity of substitution between these two inputs. Therefore, $\sigma = \frac{1}{1-\rho}$. The lower (resp. the higher) ρ, the higher the complementarity (resp. the substitutability).[2] In particular, if $\rho < 0$, then the impact of one additional unit of education on human capital increases with health ($h_{eH} > 0$). If $0 < \rho < 1$ instead, the reverse is true ($h_{eH} < 0$).

For the sake of generality, we allow ρ to take positive values. We assume that each member of the household is endowed with one unit of time. The adult allocates this unit between work, leisure and time spent caring for surviving child(ren). We denote by τ the time the parent dedicates to each surviving child, with $\tau > 0$.[3] As for each surviving child, the parent allocates time between education and child labor. Put differently, we assume that education and child labor are mutually exclusive.[4] (Child labor may also extend to non-remunerative domestic tasks and other productive activities which we abstract from here.) The wage rates of the parent and of each child are denoted by W and $w(H) = wH$ respectively, with $W > 0$ and $w > 0$.[5]

Therefore, the budget constraint is

$$c \leq W(1 - \ell - \tau sb) + sbwH(1 - e). \tag{2}$$

The parameters of the model are chosen to yield an interior solution for the optimal number of births b^*, the optimal level of leisure ℓ^* and the optimal level of education e^*. More precisely, they ensure that (i) $0 < b^* < \frac{W(1-\ell^*)}{s(W\tau - wH(1-e^*))}$, that (ii) $0 < \ell^* < 1$ (iii) and that $0 < e^* < 1$. The first condition is obtained by assuming a positive consumption. This notably implies that $W\tau - wH(1 - e^*) > 0$ for all e^* between 0 and 1. Put differently, a surviving child must cost more than the labor earnings he/she generates. Otherwise, the optimal number of births is infinite.

---

[2] If ρ converges to 1, $h(e, H)$ is a linear production function; if ρ converges to 0, $h(e, H)$ is a Cobb-Douglas production function; if ρ converges to $-\infty$, $h(e, H)$ is a Leontief production function.

[3] For the sake of simplicity, but without loss of generality, τ depends on neither e nor H.

[4] Evidence confirms that, on average, child labor and education exert a negative impact on one another (Beegle, Dehejia and Gatti, 2009; Edmonds and Shrestha, 2014), although exceptions obviously exist (Basu and Van, 1998; Basu, 1999; Psacharopoulos, 1997).

[5] Just as $w(H)$ depends positively on H, W depends positively on the parent's health. However, this relationship is not made explicit since we focus on the impact of an increase in *children*'s survival rate and health.

1.2 Predictions

Solving the model yields the optimal level of education e^*, the optimal amount of time worked by the parent Λ^* and the optimal number of births b^*:

$$e^* = (\frac{W\tau - wH}{wH^{\rho+1}})^{\frac{1}{1-\rho}}, \tag{3}$$

$$\Lambda^* = 1 - \ell^* - \tau s b^* = \frac{(1-\gamma)W\tau - wH(1-e^*)}{(2-\gamma)(W\tau - wH(1-e^*))}, \tag{4}$$

and

$$b^* = \frac{\gamma W}{(2-\gamma)s(W\tau - wH(1-e^*))}. \tag{5}$$

Proof:

Using monotonic transformation, the household's preferences can be represented by

$$U(c, \ell, sb, h(e, H)) = (1-\gamma)[\log c + \log \ell] + \gamma[\log sb + \log h(e, H)],$$

which yields the following maximization problem:

$$\max_{e,b,\ell}(1-\gamma)[\log(W(1-\ell-\tau sb) + w(H)sb(1-e)) + \log \ell] + \gamma[\log sb + \log h(e, H)].$$

The first-order conditions for the optimal level of education e^*, for the optimal number of births b^* and for the optimal level of leisure ℓ^* are given by Equations (1) to (3) respectively:

$$\frac{\gamma e^{\rho-1}}{e^\rho + H^\rho} = \frac{(1-\gamma)sbwH}{W(1-\ell) - sb(W\tau - wH(1-e))}, \tag{6}$$

$$\frac{\gamma}{b} = \frac{(1-\gamma)s(W\tau - wH(1-e))}{W(1-\ell) - sb(W\tau - wH(1-e))}, \tag{7}$$

and

$$\frac{1}{\ell} = \frac{W}{W(1-\ell) - sb(W\tau - wH(1-e))}. \tag{8}$$

Dividing Equation (1) by Equation (2) and rearranging yields

$$e^* = (\frac{W\tau - wH}{wH^{\rho+1}})^{\frac{1}{1-\rho}}.$$

Solving the system of Equation (2) and Equation (3) yields

$$\ell^* = \frac{1-\gamma}{2-\gamma},$$

and

$$b^* = \frac{\gamma W}{(2-\gamma)s(W\tau - wH(1-e^*))}$$

$\square$

We observe that b^* declines in inverse proportion to the survival rate s. Indeed, since parents care about surviving children, this probability affects parents' fertility choices through the net cost of a surviving child (denoted by $W\tau - wH(1-e^*)$), which is independent of s. Consequently, parents choose the preferred number of surviving children irrespective of s, leading to a total number of births that is inversely proportional to this parameter. Therefore, since education and labor supply depend on the number of surviving children (not on the total number of births), they are not affected by s.

1.2.1 The optimal level of education

The optimal level of education e^* increases with child health if $\rho < \overline{\rho_1}$, with $\overline{\rho_1} = -\frac{W\tau}{W\tau - wH}$; e^* decreases with child health otherwise.

Proof:

Deriving e^* with respect to H yields

$$\frac{\partial e^*}{\partial H} = -(\frac{1}{1-\rho})(\frac{\rho(W\tau - wH) + W\tau}{wH^{\rho+2}})(\frac{W\tau - wH}{wH^{\rho+1}})^{\frac{\rho}{1-\rho}}.$$

We observe that $\frac{\partial e^*}{\partial H}$ is of the opposite sign of $\rho(W\tau - wH) + W\tau$. More precisely, $\frac{\partial e^*}{\partial H}$ is positive if $\rho < -\frac{W\tau}{W\tau - wH}$. It is negative otherwise. $\square$

Consistent with Bleakley (2010), an increase in child health raises the child's wage rate (wH) and, hence, the opportunity cost of education. If education and health are substitutes $(0 < \rho < 1)$, this negative effect is reinforced. If, however, education and health are complements $(\rho < 0)$, an increase in health generates an additional impact that runs in the opposite direction: better health improves the returns to education. In this setting, if the complementarity between education and health is sufficiently high $(\rho < \overline{\rho_1})$, then the latter effect wins out, and e^* increases with child health.

1.2.2 The optimal labor supply and number of births

The optimal labor supply Λ^* increases with child health while the optimal number of births b^* decreases with child health if $\rho < \overline{\rho_2}$, with $\overline{\rho_2} < \overline{\rho_1}$; Λ^* (resp. b^*) decreases (resp. increases) with child health otherwise.

Proof:

Deriving Λ^* and b^* with respect to H yields

$$\frac{\partial \Lambda^*}{\partial H} = -\frac{\gamma W \tau w (1 - e^* - \frac{\partial e^*}{\partial H} H)}{(2-\gamma)(W\tau - wH(1-e^*))^2},$$

and

$$\frac{\partial b^*}{\partial H} = \frac{\gamma W w (1 - e^* - \frac{\partial e^*}{\partial H} H)}{(2-\gamma)s(W\tau - wH(1-e^*))^2}$$

respectively.

We observe that Λ^* (resp. b^*) increases (resp. decreases) with H when $\frac{\partial e^*}{\partial H} > \frac{1-e^*}{H} > 0$. Yet, as we show below, $\frac{\partial e^*}{\partial H}$ decreases with ρ when it is positive. Consequently, there exists a unique value of ρ, that we denote by $\overline{\rho_2}$, such that (i) $\frac{\partial e^*}{\partial H} = \frac{1-e^*}{H}$; (ii) $\frac{\partial e^*}{\partial H} > \frac{1-e^*}{H}$ when $\rho < \overline{\rho_2}$; (iii) $\frac{\partial e^*}{\partial H} < \frac{1-e^*}{H}$ when $\rho > \overline{\rho_2}$. Given that $\frac{1-e^*}{H}$ is strictly positive, $\overline{\rho_2}$ is necessarily lower than $\overline{\rho_1} = -\frac{W\tau}{W\tau - wH}$.

To show that $\frac{\partial e^*}{\partial H}$ decreases with ρ when it is positive, one can rewrite $\frac{\partial e^*}{\partial H}$ as the product of two functions, denoted by $f(\rho)$ and $g(\rho)$, with

$$f(\rho) = -\frac{wH(\rho(W\tau - wH) + W\tau)}{1-\rho}$$

and

$$g(\rho) = (\frac{W\tau - wH}{wH^2})^{\frac{\rho}{1-\rho}}.$$

When $\frac{\partial e^*}{\partial H}$ is positive (i.e. $\rho < -\frac{W\tau}{W\tau - wH}$), $f(\rho)$ is a positive decreasing function of ρ. Moreover, using the fact that e^* must be comprised between 0 and 1 and, hence, that $\frac{W\tau - wH}{wH^{\rho+1}} < 1$ for $\rho < 1$, it is easy to show that $g(\rho)$ is also a positive decreasing function of ρ. Therefore, $\frac{\partial e^*}{\partial H}$ is decreasing with ρ when it is positive. □

We know that an increase in child health decreases each child's "price" by raising the child's wage rate wH. As a result, the adult's labor supply decreases, and her preferred number of births increases. If education also decreases with health, these effects are reinforced since better health increases children's working time. If, however, education increases with health, then a child's "price" increases. Provided that the complementarity between education and health is sufficiently high, this counter-effect wins out: the parent's labor supply increases while the preferred number of births decreases, following a well-documented quality-quantity trade-off (Becker and Lewis, 1973; Rosenzweig and Zhang, 2009; Bleakley and Lange, 2009).[6] The extent to which other aspects of fertility, such as age at first birth, may be influenced by this dynamic in the medium-run is unclear. Female age at first birth in Sub-Saharan Africa appears to follow a relatively stable trajectory (Field et al., 2016). Therefore, though we include this outcome in our empirical study, we do not augment our simple theoretical framework with more detailed fertility outcomes.

Note that the condition of $\overline{\rho_2} < \overline{\rho_1}$, emphasized in Proposition 3, is more binding than that of Proposition 2. For the labor supply (resp. the number of births) to increase (resp. decrease) with health, the impact of health on education does not simply need to be positive: it must be greater than a strictly positive value.

---

[6] The variation in opposite directions of Λ^* and b^* is intuitive: a lower fertility allows the parent to dedicate more time to the labor market, while a lower labor supply allows the parent to raise more children.

2 Data

2.1 Human capital

Source(s): The Demographic and Health Surveys are nationally representative studies that collect detailed information on numerous population and health characteristics. We select 27 countries which were surveyed at least once post-campaign, which received RBM disbursements, and which include geocoded clusters and all of our outcome variables. Figure 1 outlines the period of time covered for each country within the range of 1999 to 2014.

Infant mortality (infants): Because infant mortality may vary substantially within the first year of life, we follow Pathania (2014) to compute three binary indicators of mortality: neonatal (if death occurred within the first month of life); post-neonatal (if death occurred within months 1-11); infant (if death occurred within first year of life) from the Child Recode of children under five.

Total births (women): Total number of children ever born to eligible women (ages 15 to 45) in the Individual Recode.

Age at first birth (women): Age at first birth of eligible women (ages 15 to 45) in the Individual Recode.

Total years of education (all): Education in single years for all individuals in the DHS Person Recode.

Completed primary education (all): From the DHS Person Recode, we use total years of education to compute an indicator for all respondents who have completed at least the full number of years of primary education (five, six or seven) in their country's educational system.

Employed in last 12 mo. (adults): Binary variable equal to one if respondent (ages 15 to 59) was employed within last 12 months for all eligible respondents in Individual and Male Recodes.

Paid in cash for employment (adults): Binary variable equal to one if respondent (ages 15 to 59) is paid at least partly in cash while employed for all eligible respondents in Individual and Male Recodes.

2.2 RBM disbursements

Source(s): According to Pigott et al. (2012), the three largest funders of anti-malaria campaigns to date, aside from governments, are the Global Fund to Fight AIDS, Tuberculosis and Malaria (since 2003), the President's Malaria Initiative (since 2005), and the World Bank Booster Program for Malaria Control in Africa (since 2006). We focus on external aid, using fixed effects and robustness checks to address the question of malaria-specific government expenditure. We extract GFATM disbursements on malaria, tuberculosis, and HIV/AIDS by year from individual country files available at the International Aid Transparency Initiative website (`http://iatiregistry.org/`). We transcribe PMI expenditures by country and year from the PMI Ninth Annual Report to Congress (2005-2014). Finally, we rely on data kindly provided by David Pigott to compile disbursements from the World Bank Booster Program. We total RBM disbursements by country and year following studies on malaria expenditure (Snow et al., 2010; Pigott et al., 2012). Because these disbursements are at the country-year level, we merge them with each DHS recode by country-year. In a handful of cases, negative disbursements indicate corrupt or inefficient use of funds that donors requested for return.

Exposure to RBM campaigns: Exposure captures the yearly amount per capita (at the country level)[7] disbursed by the three main RBM funders during a respondent's lifetime. A respondent's lifetime is defined as the difference between the DHS survey year and this individual's year of birth, from which we subtract one year. We consider a respondent's exposure to begin in utero (though defining the beginning as the year after birth does not alter our results). To illustrate the construction of this variable, we take the example of Ethiopia. As reported in Figure 1, RBM campaigns in Ethiopia started in 2003. Moreover, three DHS surveys years are available (in 2000, 2005 and 2010). Consider an individual born in 1999. If this individual is surveyed in 2000, he experiences no exposure since the RBM disbursements were to begin only in 2003. If he is surveyed instead in 2005, he experiences three years of exposure to RBM disbursements. His exposure will therefore be equal to the sum of the RBM disbursements per capita during these three years, divided by his lifetime, hence 2005-(1999-1)=7 years. If he was exposed, for example, to \$1 per capita each year, he

---

[7] Yearly population data come from the World Development Indicators.

would therefore receive \$3/7=\$0.43 per capita per year over his lifetime. Similarly, if this individual is surveyed in 2010, he experiences eight years of exposure to RBM disbursements. His exposure will therefore be equal to the sum of RBM disbursements per capita during these eight years, divided by his lifetime, hence 2010-(1999-1)=12 years. In this case, if he received \$1 per capita for each year of exposure, he would therefore receive \$8/12=\$0.66 per capita per year over his lifetime.

2.3 Malaria risk and control programs

Source(s): We obtain data on malaria prevalence and control strategies from the Malaria Atlas Project (`http://www.map.ox.ac.uk/`). Data on insecticide treated net (ITN) use and access to artemisinin combination therapies (ACTs) from over one million households were combined with national malaria control programme data on ITN and ACT provision to develop time-series models of coverage at the country level (Bhatt et al., 2015). We use the DHS to provide complementary measures of control strategies from microdata.

Malaria risk (2000-2015): We proxy for malaria risk by relying on the *P. falciparum* parasite rate (PfPR) computed for each DHS cluster. For a given year, PfPR describes the estimated proportion of individuals in the general population aged 2 to 10 years old who are infected with *P. falciparum* at any given time. These estimates are generated by a geostatistical model that relies on parasite rate surveys as well as bioclimatic and environmental characteristics. The PfPR is a commonly reported index of malaria transmission intensity. PfPR reaches a peak after about two years and remains fairly constant in older children until age ten before declining throughout adolescence and adulthood. The 2-10 age group has been suggested as the more informative to describe malaria risk and is therefore used. Gething et al. (2011) and Bhatt et al. (2015) describe the estimation process.

Insecticide treated net coverage (MAP): Calculated at the household level as the proportion of individuals who slept under a net.

Artemisin combination therapies coverage (MAP): Percentage of fever cases in children under five treated with ACT.

Insecticide treated net usage (DHS): Proportion of households per region that had an ITN for sleeping and that always use an ITN for children under five (DHS Household

Recode).

Artemisin combination therapies usage (DHS): Proportion of children under five per region treated for fever with ACT during past 2 weeks (DHS Child Recode).

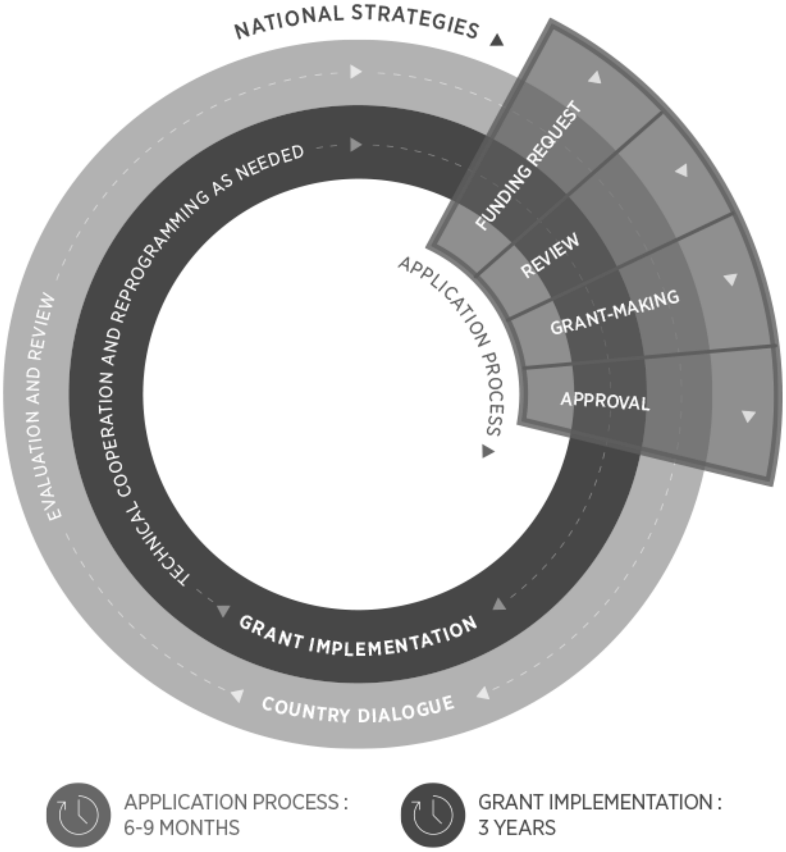
Chloroquine usage (DHS): Proportion of children under five per region treated for fever with chloroquine during past 2 weeks (DHS Child Recode).

2.4 Public expenditure

We obtain expenditure on public education as a percentage of GDP from the World Bank EdStats, Education Statistics: Core Indicators. To compute total public expenditure per capita in each of these categories, we rely on GDP in current USD and total population (both from WDI).

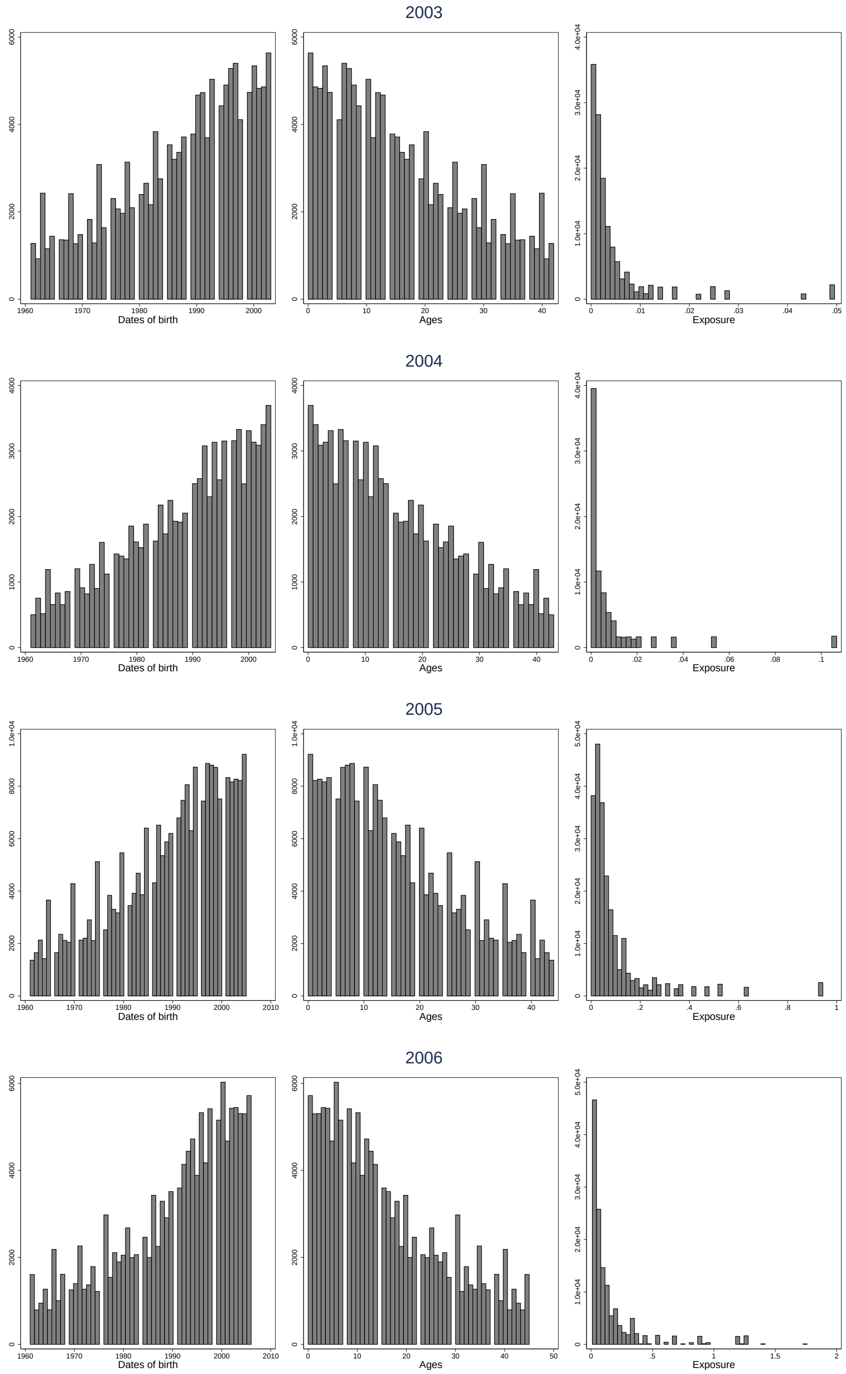
3 Figures

Figure A1: Example - The Global Fund funding process and steps

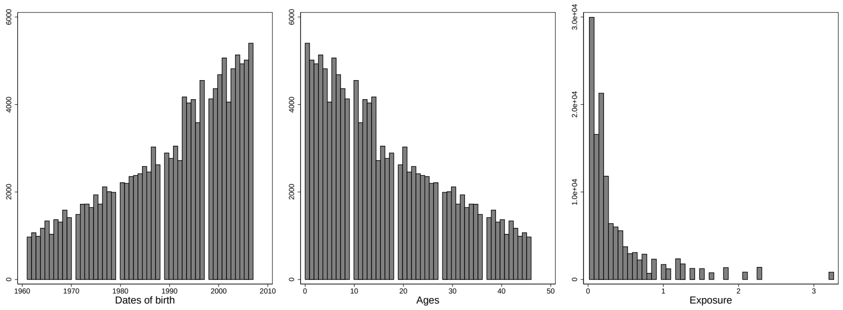


Notes: We obtained this figure from `http://www.theglobalfund.org/en/fundingmodel/process/`.

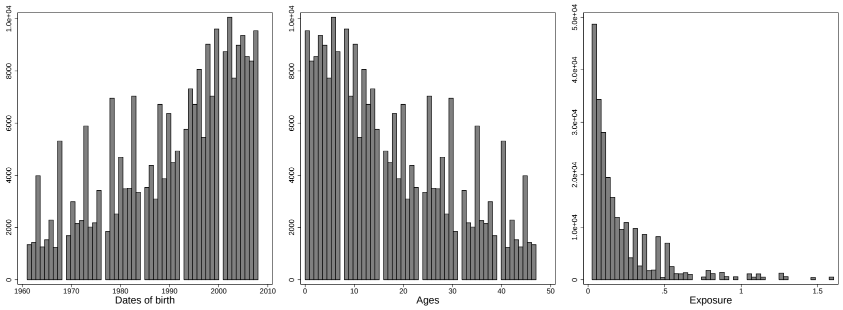
Figure A2: Frequency distributions of date of birth, age and Roll Back Malaria exposure by year of survey



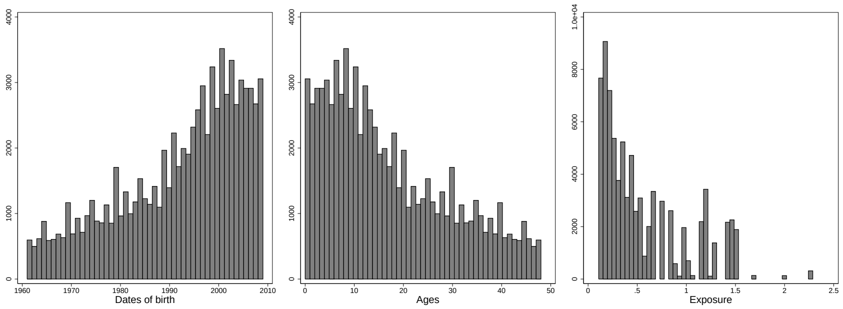
2007



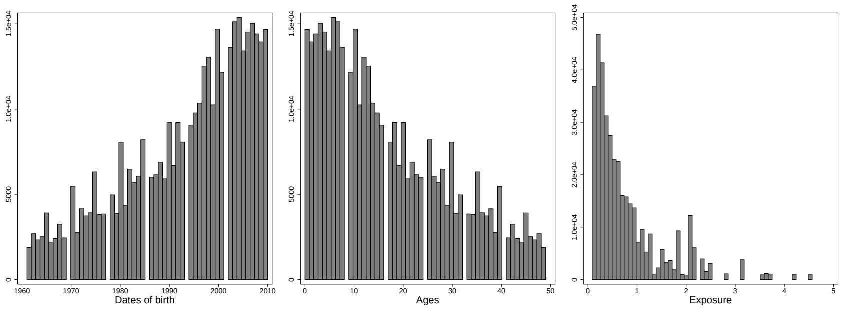
2008



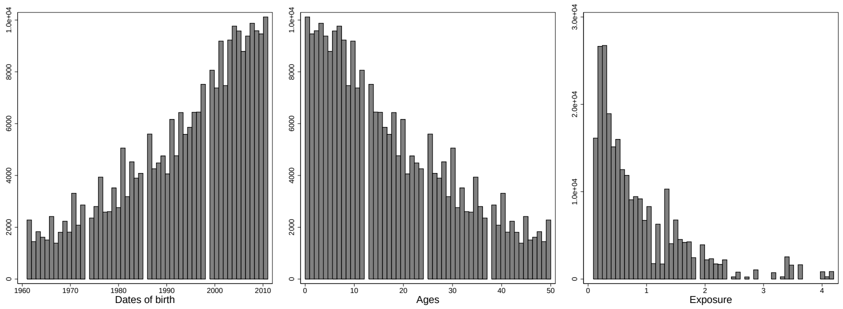
2009



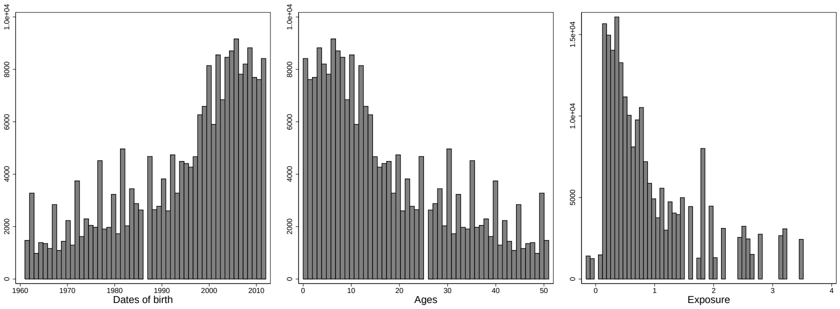
2010



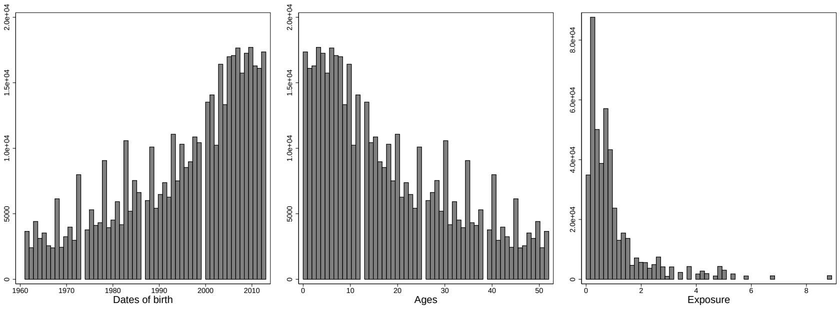
2011



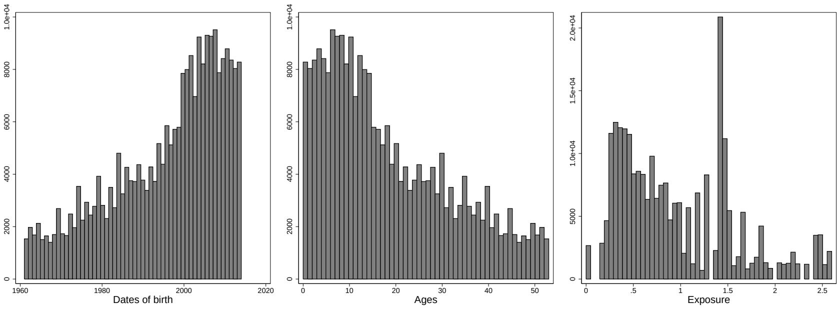
2012



2013



2014



4 Tables

Table A1: Descriptive statistics

	Mean (1)	SD (2)	Min (3)	Max (4)	N (5)
Explanatory variables					
Malaria risk (PfPR in 2000)	0.351	0.236	0.000	0.964	25,827
Exposure to Roll Back Malaria	0.570	0.787	-0.162	8.918	2,857,253
Dependent variables					
Child survival and health					
Infant mortality	0.065	0.247	0	1	353,650
Neonatal mortality	0.032	0.176	0	1	353,650
Post-neonatal mortality	0.033	0.179	0	1	353,650
Fertility					
Total number of births	2.757	2.722	0	18	646,208
Age at first birth	19.095	3.779	12	45	487,700
Adult labor supply					
Employed in last 12 months	0.684	0.465	0	1	896,887
Paid in cash if employed	0.680	0.466	0	1	607,668
Education					
Number of years of education completed	3.220	4.137	0	26	2,850,793
Primary education completed	0.262	0.440	0	1	2,850,793
Socioeconomic controls					
Male	0.489	0.500	0	1	2,866,372
Age	16.837	12.930	0	53	2,866,431
Wealth	2.969	1.427	1	5	2,866,431

Notes: The variables are measured at the individual level, with the exception of PfPR in 2000 which is computed at the DHS cluster level.

Table A2: Descriptive statistics for exposure to Roll Back Malaria disbursements

Date of birth	Mean (1)	SD (2)	Min (3)	Max (4)	N (5)	Age	Mean (6)	SD (7)	Min (8)	Max (9)	N (10)
1965	0.119	0.148	0.000	0.705	25,475	0	1.190	1.093	-0.162	4.251	112,882
1970	0.130	0.160	0.000	0.785	32,186	5	1.007	1.044	0.000	5.024	95,621
1975	0.154	0.185	0.000	0.885	39,127	10	0.604	0.655	0.000	3.139	107,579
1980	0.176	0.210	0.000	1.016	46,755	15	0.409	0.455	0.000	2.158	70,563
1985	0.211	0.250	0.000	1.191	54,222	20	0.293	0.336	0.000	1.644	70,973
1990	0.243	0.298	0.000	1.439	63,871	25	0.236	0.268	0.000	1.328	63,667
1995	0.331	0.377	0.000	1.817	77,621	30	0.202	0.225	0.000	1.114	63,188
2000	0.522	0.526	0.000	2.466	101,094	35	0.178	0.196	0.000	0.959	51,359
2005	1.108	0.768	0.000	3.793	88,740	40	0.162	0.174	0.000	0.842	43,139
2010	1.993	1.252	0.132	6.822	57,944	45	0.181	0.153	0.010	0.751	25,535
2014	1.498	0.558	0.000	1.835	8,280	50	0.246	0.152	0.091	0.677	12,095
Survey year						Survey year					
1999	0.000	0.000	0.000	0.000	22,263	2007	0.391	0.505	0.016	3.263	130,321
2000	0.000	0.000	0.000	0.000	148,225	2008	0.219	0.242	0.026	1.604	242,097
2001	0.000	0.000	0.000	0.000	94,699	2009	0.563	0.430	0.108	2.287	81,118
2002	.	.	.	.	.	2010	0.786	0.741	0.087	4.566	385,477
2003	0.005	0.008	0.000	0.050	133,568	2011	0.868	0.774	0.091	4.199	258,130
2004	0.008	0.018	0.000	0.107	83,450	2012	0.949	0.811	-0.162	3.519	219,140
2005	0.096	0.140	0.000	0.944	226,954	2013	1.026	1.171	0.000	8.918	453,016
2006	0.159	0.238	0.010	1.760	136,707	2014	0.971	0.609	0.000	2.598	251,266
Country						Country					
Benin	1.145	1.063	0.000	4.067	105,223	Mali	0.334	0.578	0.000	2.539	170,726
Burkina Faso	0.380	0.622	0.001	3.128	118,737	Mozambique	0.770	0.532	0.167	2.024	56,122
Burundi	0.517	0.371	0.116	1.676	38,501	Nambia	1.078	1.642	0.000	8.918	97,664
DRC	0.515	0.509	0.016	1.830	123,167	Nigeria	0.272	0.258	0.000	0.891	325,292
Cote d'Ivoire	0.476	0.373	0.091	1.794	44,616	Rwanda	1.058	1.227	0.028	4.566	92,345
Cameroon	0.362	0.603	0.002	3.381	107,951	Senegal	0.648	0.707	0.024	2.504	123,800
Ethiopia	0.170	0.256	0.000	1.238	178,991	Sierra Leone	0.451	0.346	0.046	1.467	103,122
Gabon	0.605	0.402	-0.162	1.387	34,729	Swaziland	0.089	0.076	0.020	0.352	18,776
Ghana	0.570	0.662	0.001	2.502	98,760	Tanzania	0.930	0.710	0.154	2.416	42,984
Guinea	0.396	0.541	0.011	2.630	70,528	Togo	0.493	0.315	0.000	1.154	42,056
Kenya	0.689	0.540	0.001	1.835	204,828	Uganda	0.432	0.490	0.000	1.740	107,516
Liberia	1.771	1.654	0.080	5.294	73,229	Zambia	1.335	0.889	0.130	3.670	108,573
Madagascar	0.540	0.419	0.096	1.604	75,111	Zimbabwe	0.184	0.298	0.000	1.588	94,030
Malawi	0.440	0.631	0.000	2.164	209,054						

Table A3: Controlling for mother fixed effects and additional controls

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Infant		Neonatal		Post-neonatal	
	Panel A: Mother FE					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-0.414***	-0.049	-0.195***	0.013	-0.219***	-0.061
	(0.041)	(0.037)	(0.024)	(0.047)	(0.023)	(0.050)
R^2	0.564	0.875	0.565	0.755	0.536	0.676
Observations	129,636	90,813	129,636	90,813	129,636	90,813
Age-by-Region	no	yes	no	yes	no	yes
Exposure-by-Region	no	yes	no	yes	no	yes
Mother FE	yes	yes	yes	yes	yes	yes
	Panel B: Same sub-sample without mother FE					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-0.450***	-0.085*	-0.213***	-0.021	-0.237***	-0.064
	(0.042)	(0.034)	(0.024)	(0.052)	(0.023)	(0.057)
R^2	0.230	0.792	0.213	0.569	0.200	0.453
Observations	129,636	90,813	129,636	90,813	129,636	90,813
Age-by-Region	no	yes	no	yes	no	yes
Exposure-by-Region	no	yes	no	yes	no	yes
Mother FE	no	no	no	no	no	no
	Panel C: Full sample with additional controls					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-0.470***	-0.065*	-0.196***	0.018	-0.274***	-0.083*
	(0.037)	(0.029)	(0.020)	(0.037)	(0.022)	(0.041)
R^2	0.137	0.739	0.112	0.468	0.117	0.404
Observations	276,898	204,936	276,898	204,936	276,898	204,936
Age-by-Region	no	yes	no	yes	no	yes
Exposure-by-Region	no	yes	no	yes	no	yes
Mother FE	no	no	no	no	no	no
	Panel D: Controlling for Age-by-Region					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-0.453***	-0.061*	-0.208***	0.005	-0.245***	-0.066ˆa
	(0.034)	(0.023)	(0.018)	(0.034)	(0.019)	(0.036)
R^2	0.116	0.742	0.094	0.467	0.096	0.381
Observations	353,379	258,809	353,379	258,809	353,379	258,809
Age-by-Region	no	yes	no	yes	no	yes
Exposure-by-Region	no	yes	no	yes	no	yes
Mother FE	no	no	no	no	no	no
	Panel E: Replacing Age-by-Region by Age-by-Malaria					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-0.414***	-0.332***	-0.195***	-0.147*	-0.219***	-0.185***
	(0.041)	(0.053)	(0.024)	(0.052)	(0.023)	(0.052)
R^2	0.564	0.799	0.565	0.707	0.536	0.645
Observations	129,636	90,813	129,636	90,813	129,636	90,813
Age-by-Region	no	yes	no	yes	no	yes
Exposure-by-Region	no	yes	no	yes	no	yes
Mother FE	no	no	no	no	no	no

Notes: Each cell reports the OLS estimate of coefficient β in Equation (4). The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year, and exposure-by-region. The additional controls in Panel C are mother's age and length of preceding birth interval. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

Table A4: Controlling for household fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Tot. births	Age at first birth	Employed	Paid in cash	Years of ed.	Completed primary ed.
	Panel A: Household FE					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-4.669***	0.507	0.544***	0.033	2.237***	0.213***
	(0.383)	(1.245)	(0.067)	(0.094)	(0.112)	(0.011)
R^2	0.847	0.588	0.614	0.675	0.743	0.653
Observations	302,473	112,936	636,443	352,967	2,773,967	2,773,967
Age-by-Region	yes	yes	yes	yes	yes	yes
Exposure-by-Region	yes	yes	yes	yes	yes	yes
Household FE	yes	yes	yes	yes	yes	yes
	Panel B: Same sub-sample without Household FE					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-4.616***	0.477	0.517***	0.110	2.358***	0.222***
	(0.037)	(1.126)	(0.062)	(0.082)	(0.113)	(0.011)
R^2	0.741	0.309	0.356	0.426	0.633	0.534
Observations	302,473	112,936	636,443	352,967	2,773,967	2,773,967
Age-by-Region	yes	yes	yes	yes	yes	yes
Exposure-by-Region	yes	yes	yes	yes	yes	yes
Household FE	no	no	no	no	no	no
	Panel C: Replacing Age-by-Region by Age-by-Malaria					
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	-1.800***	1.606*	0.245***	0.068	1.331***	0.153***
	(0.366)	(0.810)	(0.072)	(0.090)	(0.120)	(0.012)
R^2	0.664	0.228	0.333	0.412	0.628	0.532
Observations	646,169	464,336	896,857	607,572	2,850,716	2,850,716
Age-by-Malaria	yes	yes	yes	yes	yes	yes
Exposure-by-Region	yes	yes	yes	yes	yes	yes
Household FE	no	no	no	no	no	no

Notes: Each cell reports the OLS estimate of coefficient β in Equation (4). The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year, age-by-region, and exposure-by-region. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

Table A5: Probability of post-RBM birth event in mother-year panel

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Probability of birth					
	All women			All mothers		
$\text{malaria}_{2000j} \times \text{Post}_{Nt}$	-0.007*	-0.002	-0.065***	-0.013***	-0.014***	-0.019***
	(0.003)	(0.004)	(0.001)	(0.004)	(0.001)	(0.004)
R^2	0.020	0.020	0.051	0.015	0.044	0.056
Observations	9,151,265	9,151,265	9,151,242	8,193,551	8,193,529	8,193,309
Post-by-Country	yes	no	no	no	no	no
Post-by-Region	no	yes	no	yes	no	yes
Respondent Age-by-Region	no	no	yes	no	yes	no
Cluster FE	yes	yes	yes	yes	yes	no
Mother FE	no	no	no	no	no	yes

Notes: This table reports estimates using a panel of female birth events from sampled women ages 15-45. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

Table A6: Removal of potential outlying countries

	(1) No CI	(2) No CD	(3) No ET	(4) No KE	(5) No LB	(6) No NG	(7) No SL	(8) No TZ	(9) No ZM	(10) Mult. surveys
Infant	-0.148*	-0.164***	-0.149*	-0.122*	-0.165*	-0.133*	-0.149*	-0.156*	-0.149*	-0.183*
	(0.048)	(0.049)	(0.047)	(0.049)	(0.053)	(0.044)	(0.047)	(0.050)	(0.048)	(0.056)
R^2	0.281	0.277	0.280	0.285	0.283	0.310	0.286	0.274	0.268	0.244
Observations	347,929	336,529	334,539	331,016	343,760	308,887	342,072	347,697	339,754	293,595
Tot. births	-3.806***	-3.935***	-3.839***	-3.906***	-4.137***	-4.284***	-3.638***	-3.877***	-3.757***	-3.715***
	(0.291)	(0.298)	(0.291)	(0.312)	(0.316)	(0.297)	(0.291)	(0.296)	(0.309)	(0.317)
R^2	0.667	0.667	0.664	0.666	0.667	0.668	0.667	0.666	0.665	0.672
Observations	636,453	619,683	604,825	599,616	630,320	568,333	622,339	636,438	622,933	537,894
Age at first birth	0.927	1.388*	0.944	0.202	1.227	1.110ˆ a	1.076	0.936	0.947	1.394*
	(0.654)	(0.666)	(0.651)	(0.702)	(0.757)	(0.656)	(0.655)	(0.664)	(0.721)	(0.706)
R^2	0.231	0.232	0.233	0.229	0.231	0.224	0.232	0.230	0.230	0.232
Observations	457,099	444,924	438,131	430,300	451,552	410,038	446,421	457,308	446,828	385,247
Employed in last 12 mo.	0.470***	0.470***	0.488***	0.519***	0.509***	0.586***	0.430***	0.525***	0.422***	0.497***
	(0.057)	(0.059)	(0.057)	(0.062)	(0.062)	(0.060)	(0.057)	(0.059)	(0.062)	(0.062)
R^2	0.335	0.335	0.337	0.330	0.334	0.336	0.335	0.333	0.333	0.330
Observations	882,587	859,110	836,870	847,802	871,433	786,627	863,378	884,704	853,881	742,553
Years of ed.	2.347***	2.267***	2.406***	2.554***	2.331***	2.539***	2.281***	2.416***	2.310***	2.290***
	(0.114)	(0.115)	(0.112)	(0.116)	(0.117)	(0.110)	(0.111)	(0.119)	(0.118)	(0.128)
R^2	0.637	0.632	0.636	0.520	0.637	0.629	0.639	0.634	0.630	0.637
Observations	2,806,266	2,727,903	2,663,079	2,637,310	2,769,796	2,525,623	2,739,211	2,807,837	2,742,652	2,377,194

Notes: The unit of observation is the individual. For all dependent variables, each cell reports the OLS estimate of coefficient β in Equation (4). The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year and subcomponents, age-by-region (except infant mortality), and exposure-by-region. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels. Our results are not driven by any country or subset of countries. Complementary analysis to Table A5 is available upon request.

Table A7a: Infant mortality estimates when substituting alternative treatment probabilities for initial malaria risk (*Plasmodium falciparum* parasite rate)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Infant			Neonatal			Post-neonatal		
Exposure*Δ Malaria	0.330*			0.106			0.224*		
	(0.106)			(0.086)			(0.175)		
Exposure*Δ ACTs		-2.430*			-0.782			-1.647*	
		(0.854)			(0.647)			(0.617)	
Exposure*Δ Bednets			-0.737*			-0.237			-0.500*
			(0.244)			(0.195)			(0.178)
R^2	0.278	0.266	0.270	0.182	0.180	0.180	0.175	0.164	0.169
Observations	353,379	353,379	353,379	353,379	353,379	353,379	353,379	353,379	353,379
Age-by-Region	no	no	no	no	no	no	no	no	no
Exposure-by-region	yes	yes	yes	yes	yes	yes	yes	yes	yes

Notes: The unit of observation is the individual. For all dependent variables, each cell reports the OLS estimate of coefficient β in Equation (4). Malaria risk and bednets vary at the regional level, while ACTs vary primarily at the national level. The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year and subcomponents, and exposure-by-region. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

Table A7b: Fertility, employment and education estimates when substituting alternative treatment probabilities for initial malaria risk (*Plasmodium falciparum* parasite rate)

	(1)	(2)	(3)	(4)	(5)	(6)
	Tot. births			Age at first birth		
Exposure*Δ Malaria	8.056***			-2.069		
	(0.640)			(1.415)		
Exposure*Δ ACTs		-70.710***			24.560	
		(7.992)			(17.010)	
Exposure*Δ Bednets			-9.945***			3.102
			(0.826)			(2.118)
R^2	0.666	0.661	0.665	0.230	0.229	0.230
Observations	646,169	646,169	646,169	464,336	464,336	464,336
	Employed last 12 mo.			Paid in cash for emp.		
Exposure*Δ Malaria	-1.027***			-0.357*		
	(0.123)			(0.140)		
Exposure*Δ ACTs		9.326***			2.641*	
		(1.384)			(1.048)	
Exposure*Δ Bednets			1.302***			0.412*
			(0.158)			(0.161)
R^2	0.334	0.330	0.333	0.412	0.412	0.412
Observations	896,857	896,857	896,857	607,572	607,572	607,572
	Years of ed.			Completed primary ed.		
Exposure*Δ Malaria	-4.683***			-0.437***		
	(0.250)			(0.024)		
Exposure*Δ ACT		43.723***			4.076***	
		(3.926)			(0.369)	
Exposure*ΔBednets			7.288***			0.679***
			(0.404)			(0.039)
R^2	0.631	0.615	0.631	0.535	0.522	0.535
Observations	2,850,716	2,850,716	2,850,716	2,850,716	2,850,716	2,850,716
Age-by-region	yes	yes	yes	yes	yes	yes
Exposure-by-region	yes	yes	yes	yes	yes	yes

Notes: The unit of observation is the individual. For all dependent variables, each cell reports the OLS estimate of coefficient β in Equation (4). Malaria risk and bednets vary at the regional level, while ACTs vary primarily at the national level. The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year and subcomponents, age-by-region, and exposure-by-region. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

Table A8: Alternative infant health variables

	(1) Acute respiratory infection	(2) Diarrhea	(3) BCG	(4) DPT	(5) Polio	(6) Measles
$\text{malaria}_{2000j} \times \text{exposure}_{Nct}$	0.044	-0.003	-0.039ˆ	-0.023	-0.030	-0.012
	(0.063)	(0.022)	(0.021)	(0.026)	(0.028)	(0.022)
R^2	0.296	0.152	0.433	0.436	0.313	0.479
Observations	108,254	469,021	478,155	476,563	477,797	475,255
Age-by-Region	no	no	no	no	no	no
Exposure-by-Region	yes	yes	yes	yes	yes	yes

Notes: The unit of observation is the individual. For all dependent variables, each cell reports the OLS estimate of coefficient β in Equation (4). The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year and subcomponents, and exposure-by-region. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

Table A9: Estimation of artificial treatments

	(1) Tot. births	(2) Age at first birth	(3) Employed	(4) Paid in cash	(5) Years of ed.	(6) Completed primary ed.
20 years	1.851***	-5.111***	-0.306***	0.005	-3.186***	-0.223***
	(0.344)	(0.820)	(0.086)	(0.097)	(0.551)	(0.063)
R^2	0.595	0.211	0.296	0.419	0.593	0.507
Observations	521,530	441,686	717,674	531,953	1,274,398	1,274,398
30 years	1.735*	1.326	-0.235*	-0.014	0.965	0.095
	(0.695)	(1.380)	(0.108)	(0.110)	(0.837)	(0.093)
R^2	0.539	0.231	0.332	0.456	0.603	0.515
Observations	311,351	278,524	431,628	335,523	861,112	861,112
Age-by-Region	yes	yes	yes	yes	yes	yes
Exposure-by-Region	yes	yes	yes	yes	yes	yes

Notes: The unit of observation is the individual. For all dependent variables, each cell reports the OLS estimate of coefficient β in Equation (4). The regression controls for gender and wealth as well as fixed effects for DHS clusters, country-by-cohort-by-DHS year and subcomponents, age-by-region, and exposure-by-region. Standard errors (in parentheses) are clustered at the DHS cluster level. ˆ, *, ** and *** indicate significance at the 10, 5, 1 and 0.1% levels.

References

Acemoglu, Daron, and Simon Johnson. 2007. "Disease and Development: The Effect of Life Expectancy on Economic Growth." *Journal of Political Economy*, 115(6): 925–985.

Basu, Kaushik. 1999. "Child Labor: Cause, Consequence, and Cure, with Remarks on International Labor Standards." *Journal of Economic Literature*, 37(3): 1083–1119.

Basu, Kaushik, and Pham Hoang Van. 1998. "The Economics of Child Labor." *The American Economic Review*, 88(3): 412–427.

Becker, Gary S. 1975. "Investment in Human Capital: Effects on Earnings." In *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education, Second Edition*. NBER.

Becker, Gary Stanley, and Harold Gregg Lewis. 1973. "On the interaction between the quantity and quality of children." *Journal of Political Economy*, 81: S279–S288.

Beegle, Kathleen, Rajeev Dehejia, and Roberta Gatti. 2009. "Why Should We Care about Child Labor? The Education, Labor Market, and Health Consequences of Child Labor." *The Journal of Human Resources*, 44(4): 871–889.

Ben-Porath, Yoram. 1967. "The production of human capital and the life cycle of earnings." *The Journal of Political Economy*, 352–365.

Bhatt, S., D. J. Weiss, E. Cameron, D. Bisanzio, B. Mappin, U. Dalrymple, K. E. Battle, C. L. Moyes, A. Henry, P. A. Eckhoff, and others. 2015. "The effect of malaria control on Plasmodium falciparum in Africa between 2000 and 2015." *Nature*, 526(7572): 207–211.

Bleakley, Hoyt. 2010. "Malaria eradication in the Americas: A retrospective analysis of childhood exposure." *American Economic Journal: Applied Economics*, 1–45.

Bleakley, Hoyt, and Fabian Lange. 2009. "Chronic disease burden and the interaction of education, fertility, and growth." *The review of economics and statistics*, 91(1): 52–65.

Boucekkine, Raouf, Rodolphe Desbordes, and Hélène Latzer. 2009. "How do epidemics induce behavioral changes?" *Journal of Economic Growth*, 14(3): 233–264.

Currie, Janet. 2009. "Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development." *Journal of Economic Literature*, 47(1): 87–122.

Currie, Janet, and Brigitte C. Madrian. 1999. "Chapter 50 Health, health insurance and the labor market." In . Vol. 3, Part C, , ed. BT Handbook of Labor Economics, 3309–3416. Elsevier.

Edmonds, Eric V, and Maheshwor Shrestha. 2014. "You get what you pay for: Schooling incentives and child labor." *Journal of Development Economics*, 111: 196–211.

Field, Erica, Vera Molitor, Alice Schoonbroodt, and Michèle Tertilt. 2016. "Gender gaps in completed fertility." *Journal of Demographic Economics*, 82(02): 167–206.

Gething, Peter W., Anand P. Patil, David L. Smith, Carlos A. Guerra, I. R. Elyazar, Geoffrey L. Johnston, Andrew J. Tatem, and Simon I. Hay. 2011. "A new world malaria map: Plasmodium falciparum endemicity in 2010." *Malaria Journal*, 10(378): 1475–2875.

Hazan, Moshe, and Hosny Zoabi. 2006. "Does longevity cause growth? A theoretical critique." *Journal of Economic Growth*, 11(4): 363–376.

Hong, Sok Chul. 2013. "Malaria: An early indicator of later disease and work level." *Journal of Health Economics*, 32(3): 612–632.

Jayachandran, Seema, and Adriana Lleras-Muney. 2009. "Life Expectancy and Human Capital Investments: Evidence from Maternal Mortality Declines." *The Quarterly Journal of Economics*, 124(1): 349–397.

Pathania, Vikram. 2014. "The impact of malaria control on infant mortality in Kenya." *Economic Development and Cultural Change*, 62(3): 459–487.

Pigott, David M., Rifat Atun, Catherine L. Moyes, Simon I. Hay, and Peter W. Gething. 2012. "Funding for malaria control 2006–2010: a comprehensive global assessment." *Malaria Journal*, 11: 246.

Psacharopoulos, George. 1997. “Child Labor versus Educational Attainment Some Evidence from Latin America.” *Journal of Population Economics*, 10(4): 377–386.

Rosenzweig, Mark R., and Junsen Zhang. 2009. “Do population control policies induce more human capital investment? twins, birth weight and china’s “one-child” policy.” *The Review of Economic Studies*, 76(3): 1149–1174.

Snow, Robert W, Emelda A Okiro, Peter W Gething, Rifat Atun, and Simon I Hay. 2010. “Equity and adequacy of international donor assistance for global malaria control: an analysis of populations at risk and external funding commitments.” *The Lancet*, 376(9750): 1409–1416.

Soares, Rodrigo R. 2005. “Mortality reductions, educational attainment, and fertility choice.” *American Economic Review*, 580–601.