EVANS SCHOOL OF PUBLIC AFFAIRS
UNIVERSITY of WASHINGTON
Evans School Policy Analysis and Research (EPAR)

Travis Reynolds, Josh Merfeld,
and C. Leigh Anderson

Local Spillovers and Broader Impacts of Health Interventions

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Professor Leigh Anderson, Principal Investigator
Associate Professor Mary Kay Gugerty, Principal Investigator

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Overview

The impacts of health interventions in low-income countries are typically assessed and reported using a set of more-or-less standard micro-level impact evaluation metrics. Such metrics most commonly include number of individuals reached and/or treated, changes in the number of days sick among the target population, or changes in disability or mortality rates.[1] At the same time there is a substantial literature on the broader macroeconomic impacts of improved health, much building upon early work by the World Heath Organization (Sachs 2001) highlighting the potential economy-wide implication of a healthier, longer-lived population and workforce. However, there are several complex pathways through which health interventions might feasibly improve household welfare or economy-wide social and economic outcomes, and rarely are available data sufficient to draw strong conclusions about the "overall impacts" of a given intervention. Indeed, largely owing to the cost and difficulty of more comprehensive impact evaluations, only rarely do development interventions explicitly measure the broader social and economic implications of their projects.

In such a data-poor environment there are at least two ways to infer the total impacts of a health intervention on a household or on a broader social and economic system. One method is using estimated coefficients from econometric models that show the change in a dependent variable (such as mortality) from a one unit change in an independent variable (such as dollars spent on vaccine delivery). Causality is empirically established within a defined population through the use of randomized control and treatment groups, leading to relative confidence in estimates, albeit at a small (most often sub-national) scale. Another method is through the use of multipliers, which is based on input-output ratios of economic activity and linkages within a broader community. For example, $1 spent on a vaccine program might be associated with three fewer sick-days away from work (from a household perspective) or for three additional jobs created in health or service sectors (from a local/regional economy perspective). Causality cannot be empirically established in such non-experimental generalizations, but multipliers are relatively broadly understood concepts for projecting the ripple effect of a dollar of investment on regional/national income and employment. In both of these methods, logical theoretical pathways are important for establishing the credibility of linkages between interventions and outcomes.

This brief draws on past and present peer-reviewed articles and published reports by institutions including the World Health Organization (WHO), the UK Department for International Development (DFID), and others to provide a scoping summary of the household-level spillovers and broader impacts of a select group of health initiatives. Rather than focusing on estimates of the direct health impacts of investments (e.g., reductions in mortality from vaccine delivery), we focus on estimates of the less-often reported spillover effects of specific health investments on household welfare or the broader economy. Obviously the credibility of any spillover impact estimate (e.g., GDP growth) also depends heavily on the credibility of the direct impact estimate (e.g., mortality reduction), so we focus on investments where direct impact is relatively well-measured. The brief is designed to give a concise overview of major theories linking health improvements to broader social and economic outcomes, followed by more in-depth summaries of available local- and country-level estimates of broader impacts, defined as project spillovers offering local, regional

[1] Often reported as Disability Adjusted Life Years (DALYs), measured as the sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability (WHO, 2014)

and national social and economic benefits not typically reported in project evaluations.

Measuring Fuller Impacts of Health Interventions

In general terms "local spillovers" of health interventions might include any number of immediate and additional health, educational, and income gains realized by individuals and households as a result of an intervention outside those benefits routinely reported in standard health intervention evaluations. Specific spillover benefits of interest here include improvements in education among treated individuals, or improvements in employment and income. Further local spillover benefits include improvements in the social or economic welfare of *untreated* household members or other groups arising from health interventions, as in the case of herd immunity from childhood vaccines, or time-savings for parents or other caregivers if family members are less frequently and less seriously ill. Finally, in aggregate, both the direct (health improvement) and spillover impacts of health interventions can also have broader macroeconomic repercussions. Such "broader impacts" may include regional/national economic value generated by a healthier overall population, including overall economic growth, employment growth, and poverty reduction, as well as any distributional effects across men and women, rural and urban, income categories, and youth and non-youth that might vary by health intervention type.

The bulk of published estimates of household-level spillover benefits of health interventions consist of post-hoc analyses of benefits realized following an intervention: studies that consider improvements in worker productivity or school attendance due to nutritional supplements fall into this category. Such impact evaluations are typically considered a lower-bound estimate of household impacts, as only measured benefits (e.g., school attendance, earnings) are accounted for as opposed to non-measured benefits (e.g., well-being, willingness to invest in the future, etc.). In contrast estimates of broader regional and economy-wide impacts more typically use estimates of the burden of a disease to derive potential benefits from a proposed intervention (i.e., looking at losses averted or potentially averted rather than benefits realized). For example, if a study determines that malaria costs an economy x dollars per year, then x dollars is also the theoretical ceiling for benefits from interventions targeting malaria (i.e., the maximum benefit obtainable from eradication of the disease). Due to such methodological differences, broader regional impact estimates are often larger than the effects calculated from a simple aggregation of microeconomic studies (Malaney et al. 2004). This "gap" in estimates may also be due to negative externalities from disease (or, likewise, positive externalities from interventions). Both ranges of estimates are reported in the following sections, noting the methods used.

Whether based on relatively narrow post-hoc evaluations of specific interventions or on relatively broad projections of potential economy-wide benefits to be gained, there are a number of caveats to economic estimates of health intervention impacts. The first caveat is that the estimates are just that: estimates. They can sometimes be crude, especially when relying on figures from developing countries where data are scarce (Jerven 2013). Relatedly, quantitative results and conclusions can be very dependent on economic assumptions about market behavior and global and regional economic trends (Crafts and Haacker 2003). The final caveat relates to ethical concerns. When attempting to monetize overall benefits or impacts of an intervention, statisticians and economists must find ways to quantify concepts like "quality of life" and the statistical value of a human life. Concepts such as disability adjusted life years (DALYs) and quality adjusted life years (QALYs) are not universally regarded as appropriate. [For but one example, see Arnesen and Nord (1999).] Moreover, if societies care about distributional issues (i.e., inequality), there is the further complication of how to value these changes (WHO 2009).

With these caveats, the structure of the following sections are as follows:

Sections 1 and 2 review the theoretical pathways by which health interventions might realize spillover benefits at the local level, as well as broader impacts at the regional and national levels. These theory-based sections draw on seminal reports and articles from the health impact evaluation field to identify the types of household spillovers and broader economy-wide impacts possible from health interventions and the degree to which such impacts have been empirically estimated across national and regional contexts. Sections 2-4 compile available empirical estimates of direct impacts, local spillovers, and broader macroeconomic impacts from econometric studies on health interventions targeting three diseases – rotavirus (Section 2), HIV/AIDS (Section 3), and malaria (Section 4) - across different regions. We focus on empirical work over the last 10 years, noting the relative robustness of research designs including:

(1) statistically robust micro-level (sub-national) impact assessments, e.g., studies with randomized treatment and control groups studying the direct and local spillover impacts of interventions;
(2) panel or time series findings for the regional or economy-wide impacts of discrete interventions in a single country or region; and
(3) macro-level cross-country findings for any broader impact estimates that appear robust (noting limitations).

A summary table at the end of each section seeks to distill the available evidence on local spillovers and broader impacts for rotavirus, HIV/AIDS and malaria to a simplified range of estimates and relatively more accessible presentation style. These short summaries build on a basic framework of theoretical pathways for spillover benefits, starting from individual and household-level impacts and expanding to broader spillover outcomes based on national-level data and/or local multipliers for income and employment effects, and also noting distributional effects and other impacts reported in the current literature on individual, household, and national/regional impacts.

I. Measuring Full Impacts of Health Interventions

"The Micro- and Macro- Impacts of Health"

Over the past 15 years a burgeoning literature has sought to demonstrate how investment in health, and particularly women's and children's health, might secure a wide variety of health, social, and economic returns not captured in traditional health impact evaluation metrics (Stenberg et al. 2014). The 2001 WHO Commission on Macroeconomics and Health report "Macroeconomics and Health" remains the core document outlining the broader impacts health interventions might have in low and middle income countries, and calling for expanded attention to health as a pathway towards broader social and economic development goals (Sachs 2001).

A recent literature has now emerged reflecting on the decade since the WHO's initial report. Bloom et al. (2005) summarize the potential contributions of health interventions to both household welfare and broader socioeconomic development as follows: "The experience of development over the past half-century shows that good health fuels economic growth, just as bad health strangles it. Healthy children perform better at school, and healthy adults are both more productive at work and better able to tend to the health and education of their children. Healthy families are also more likely to save for the future; since they tend to have fewer children, resources spent on them go further, thereby improving their life prospects. Finally, healthier societies may be a stronger magnet for foreign direct investment and tourism than those where disease poses a constant threat."

In spite of a general acceptance of the many potential benefits of health interventions, recent scholarship continues to bemoan the paucity of appropriate tools to calculate the full value of these interventions (Bärnighausen et al. 2014). From an empirical perspective, there are many ways to categorize the local and national/regional spillover effects of health interventions. Sachs (2002) first divided the economic impacts of health into three categories: direct impacts in disease reduction and improvements in health; parental investment in children (e.g., education); and effects of disease on business and infrastructure investment. More recently a series of papers by Bloom et al. (Bloom and Canning 2000; Bloom and Fink 2013) divide the impacts of health interventions into four categories: productivity, education, investment, and demography. For clarity and brevity we adopt this (necessarily broad) four-category scheme, although as outlined below, each of these impacts can be further subdivided into local (individual or household) spillovers, and broader (sector- or economy-wide) impacts.

(i) Health and Productivity

Productivity includes all improvements in labor productivity due to health interventions. Labor productivity can be further divided into (individual) worker productivity and (sector-or economy-wide) labor force productivity.

The most obvious example of individual worker productivity is a decrease in work days missed due to illness and gains in work efficiency due to better health (Bloom et al. 2003; Thomas et al. 2006). In the medium-term health interventions can also lead to improved school attendance and higher levels of education and training, which may further improve worker productivity (Baird et al. 2011; Bloom and Fink 2013). There are also longer-term impacts of health interventions on worker productivity - for example, infectious disease during childhood can lead to disabilities that affect workers later in life (Sachs 2002; Bärnighausen et al. 2011; Deogaonkar et al. 2012). As a result some of the benefits of interventions targeting these types of illnesses may not be realized until target groups reached adulthood, possibly decades later. Long-term improvements in physical health can be especially important for the rural poor, as they are more likely to be involved in manual labor such as agriculture (Sachs 2002).

The second form of productivity, labor force productivity, is associated with sectors and broader economies more than individuals: labor force productivity comprises the aggregate production potential and reliability of a local, regional or national labor force. For example, researchers have found that in some areas prone to malaria, more than half of worker absenteeism can be attributed to the illness (Rosen et al. 2004; Isah 2008). By improving the health of these workers, businesses face a lower risk of absenteeism, which in turn relieves these businesses from the need to hire excess capacity in order to compensate for higher levels of absenteeism (WHO 2009). Likewise, high rates of employee turnover—whether due to illness or death—can impede human capital accumulation and increase training costs, and thus decrease firm profitability (Sachs 2002). Finally, higher rates of disease can reduce population mobility, which may interfere with skill-matching and further decrease both aggregate employment and local and regional labor force productivity (Malaney et al. 2004).

(ii) Health and Education

The effects of health interventions on education—and educational opportunities—is another pathway through which interventions can have profound local spillovers in addition to broader macroeconomic benefits. Improvements in child health (e.g., due to vaccination or other health and nutrition interventions) can lead to increased school attendance and improved academic performance (Bärnighausen et al. 2011, Madsen 2012; Malaney et al. 2004; Sachs 2002) in addition to more general (e.g., child well-being) benefits.

Meanwhile longer term benefits of health interventions may include improvements in both employment and earnings potential (flowing from either health or educational improvements, or both). An emerging literature further emphasizes the potential for childhood health interventions to have long-term impacts on cognitive function, which can have substantial implications for academic and work performance later in life (Psacharopoulos and Patrinos 2004; Colclough et al. 2009; Barofsky et al. 2011; Purdy et al. 2013).[2] Detailed case-control studies in developed countries suggest the effects of childhood illnesses can be quite long-lasting: in Australia, one study found that differences in cognitive functioning due to meningitis are still detectable 12 years after the initial infection (Grimwood et al. 2000). Recent work by Bloom et al. (2012) reports similarly significant effects of childhood vaccinations for measles, polio, tuberculosis, diphtheria, pertussis, and tetanus on cognitive test scores in the Philippines.[3]

Broader economy-wide impacts of health-related education gains are typically expressed in terms of labor force productivity (see previous section) or, in the case of childhood vaccination programs, in terms of herd immunity benefits (whereby non-vaccinated schoolchildren experience less illness, or vaccinated and non-vaccinated students experience less frequent and less severe illness) as a result of vaccination programs. In addition, some studies have suggested several indirect pathways by which health interventions might realize broader impacts through educational channels. For example, in one of the earliest studies of spillover impacts of health interventions, Shearley (1999) argued that preventative health measures such as vaccines might also be credited for indirectly improving the educational opportunities *of mothers* as prevention liberates women's time, energy and resources from caregiving responsibilities associated with preventable illnesses. Similarly, improvements in parental health – especially women's health – can have important household educational benefits, both by releasing children from household labor duties including caring for sick family members, and by increasing the availability of household resources to invest in children's educations.

(iii) Health and Investment

A third set of theoretical linkages between health interventions and spillover/broader impacts is via local and international investment. At the household level increasing investment arises from increased annual earnings (whether among rural smallholder farmers primarily engaged in agriculture or among households participating in labor markets). Such income gains are realized both through improved work attendance and work productivity, and also through increased longevity (increasing years of earning, and providing an incentive to save for retirement).

In the aggregate the economy-wide impacts of such shifts in income and investment behavior can be substantial – an oft-cited estimate by Bloom and Canning (2000) suggests a 5-year improvement in life expectancy in a low-income country can translate into as much as a 0.3—0.5% increase in annual income per capita as a result of increased domestic investment behavior. At the regional/national level disease prevalence can also significantly affect the volume and availability of investment capital. Perhaps most conspicuously, high disease prevalence can slow growth in international tourism, in-migration, and foreign investment in local businesses (Sachs 2002). While some natural-resource-extraction companies and other investors may be willing to enter high-disease areas, many will not – as for example in the historical case of the Panama Canal, where it was not until planners were able to effectively combat yellow fever that the canal was finally completed (Jones 1990).

Given recurring evidence that disease represents a significant obstacle to international investment and resultant economic development some authors see increasing reason to consider international investment a positive spillover of health interventions (Jamison et al. 2013).

(iv) Health and Demographic Transitions

Two final consequences of health interventions for local and broader regional/national social and economic patterns function through demographic channels. In the longer term, in addition to reducing mortality there is significant evidence that suggests that health interventions – particularly those leading to improvements in the child mortality rate – can encourage mothers to decrease the number of planned child births. Reductions in child births in turn decreases the number of children per household and further increases the ratio of the working population to dependents (Barnighausen

[2] A second, more indirect, effect of health interventions on education is through demographics. Decreases in infant/child mortality can lead to lower family size, which in turn decreases the burden of education (Sachs 2002).
[3] The effects amount to approximately half of a standard deviation, even after controlling for educational attainment.

et al. 2008). Some authors have argued that smaller family size allows for a greater investment in each individual child, thus leading to improved outcomes for these children (Deogaonkar et al. 2012, pg. 2). Others note that lower levels of fertility decrease the amount of time women must spend rearing children and increases educational attainment among women (Malaney et al. 2004).

At the broader regional and national levels, health interventions can reduce mortality and increase longevity, leading to an increase in the average age of the target population (Bloom and Canning 2001). A higher average age typically leads to a larger working-age population (relative to the youth population), which in turn raises national income per capita. Increased life expectancy may also provide an incentive for households to save, which can further lead to economic growth (Jamison et al. 2013). For example Sachs (2002) argued that a key link between health interventions and economic development was that increasing longevity would increase saving rates (pg.37-38), which in turn would further increase accumulation of human capital (through education) and physical capital (via investment) (Deogaonkar et al. 2012; Malaney et al. 2004). Bloom and Canning (2004) argue that the demographic change from "high mortality and fertility to low mortality and fertility" (pg. 2) led to higher economic growth in Ireland and Taiwan. Likewise, Bloom and Williamson (1998) show that the growing ratio of the working population to dependents dramatically increased economic growth in East Asia.[4]

II. Spillover Impacts of Health Conceptual Framework

The major categories of local and regional/national-level impacts of health interventions reported in published articles and reports are summarized in Figure 1.

Note that many of these broader impacts have multiple channels: for example, decreasing illness rates increases educational attainment in the short run, but in the long run increases in longevity due to health interventions also make investments in education more worthwhile, as the longer life expectancy increases the expected returns to education (Bloom and Fink 2013).

Furthermore the existence of theoretical literature on certain spillover and broader impact pathways is no guarantee of the existence of empirical support for such claims. As noted previously the most commonly reported measures of the direct and spillover impacts of health interventions focus on relatively well-established micro- and macro-economic indicators such as individual worker productivity, labor force productivity, or (at the national level) gross domestic product

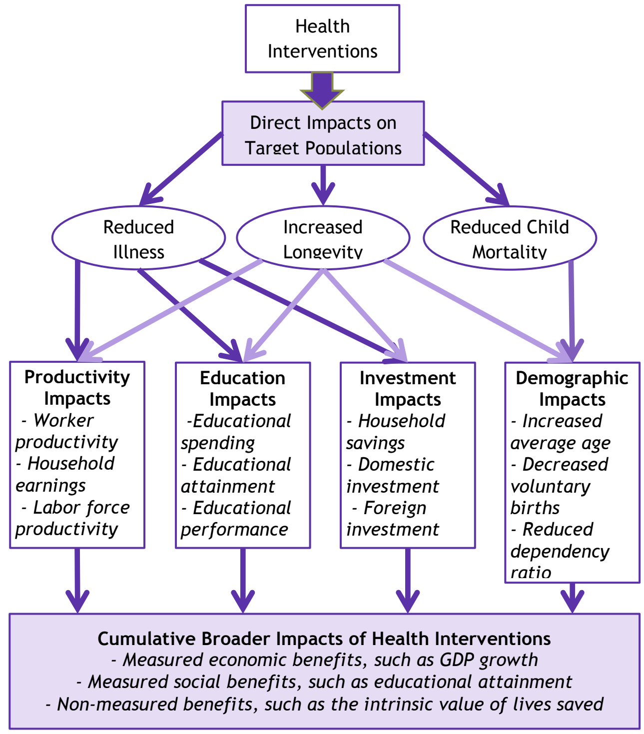


Figure 1. Conceptual Framework: Broader Impacts of Health

(GDP). For some indicators, however, economic indices do not exist or vary greatly based on social values (e.g., the value of a child life saved). In such contexts non-dollar amounts (e.g., number of lives saved) are often reported.

Some published studies emphasize individual-level spillover impacts explicitly – for example, in an ongoing study in the community of Matlab, Bangladesh, Driessen et al. (2011) find that a measles vaccination program increased the probability that a boy would enroll in school by 9.5% (they found no effect among girls). Also in Matlab, Canning et al. (2011) found that maternal tetanus vaccination reduced the probability of attaining no schooling (0 years) by 0.045, while increasing the probability of some schooling (1-7 years) by 0.015 of completing junior high school (8 or more years) by 0.03 among children whose parents had no schooling (pg. 1435). The authors then further generalized these findings across the community, estimating that as a results of education gains tetanus vaccination could translate into a wage increase of about 1.2% in the population as a whole.

Other studies focus on aggregate community-level or national-level spillover impacts. For example, in one of the most comprehensive national-level spillover impacts estimates available Stenberg et al. (2014) study six investment packages for maternal and newborn health, child health, immunization, family planning, HIV/AIDS, and malaria across 74 developing countries. They find increasing health expenditure by $5 per person per year up to 2035 could yield

[4] However, they also caution that this change is likely temporary as a large working population today will grow into a large dependent population upon retirement (Bloom and Finlay 2009).

nine times that value in economic benefits, with estimated returns including substantial GDP growth and prevention of the deaths of 147 million children, 32 million stillbirths, and 5 million women by 2035. In a comprehensive analysis of GAVI-eligible countries, Stack et al. (2011) estimate the overall economic gains from vaccinations between 2010 and 2020: USD $68 billion for pneumonia and USD $35 billion for rotavirus. (In Africa, returns to rotavirus vaccinations are actually higher than returns for pneumonia vaccinations.)

The following sections review available empirical estimates of spillover impacts associated with health interventions targeting three of the most costly – and yet in many ways very preventable – diseases in developing countries: rotavirus, HIV/AIDS and malria (MacLennan and Saul 2014). We organize each section by intervention, including those for vaccination (with a focus on rotavirus vaccines), HIV/AIDS prevention, and malaria prevention. A table at the end of each section summarizes key findings by intervention, also identifying caveats and data limitations to estimates available to date.

III. Vaccine Delivery: Local Spillovers and Broader Impacts

As Ehreth (2003) observes, "Vaccination is a collective activity in the sense that the act of immunizing one person can lead to the protection of an entire group of people and can cross boundaries between countries and continents resulting in a global impact […] High rates in one country benefit other countries; and high rates in one generation benefit the next generation." (Ehreth 2003, pg. 597).

A recent literature review by Ozawa et al. (2012) more specifically highlights how vaccines may bring multiple economic and social benefits beyond individual health gains alone. Among the pathways highlighted are reduced child illness leading to reduced household medical costs, reduced child disability leading to improved cognitive development, school attendance, and educational attainment among vaccinated children, and reduced child mortality leading to changes in household fertility decisions (i.e., smaller family sizes). Stack et al. (2011) estimated the economic benefits from the introduction and increased use of vaccination for pneumococcal diseases, rotavirus, pertussis, measles, and malaria from 2011-2020 could save 6.4 million lives, avert 426 million cases of illness, eliminate $6.2 billion in treatment costs, and recover some $145 billion in productivity losses.

Ozawa et al. among others further emphasize that unlike many health interventions, vaccines can also avert illness both directly through immunization and indirectly through herd immunity (see e.g., Atherly et al. 2009). From a productivity perspective, this implies vaccines may support both greater individual productivity and overall labor force productivity (although exact estimates are not provided).

Outside labor and productivity impacts, the vaccination of young children has also been shown to have an indirect effect on very young infants, i.e. those too young to be vaccinated. In a randomized double-blind study in Israel 262 children were followed for 2 years after receiving either the pneumococcus vaccine PCV9 or a control vaccine, and while there was an expected decrease in disease incidence among PCV9 recipients, an unexpected parallel reduction among their younger, unvaccinated siblings was also observed. Similarly, a recent study in South Africa found flu vaccines administered to pregnant mothers conferred additional resistance to influenza upon newborns (Madhi et al. 2014).

A recent special issue of the *Proceedings of the National Academy of Sciences* reviewed the many purported and potential gains of vaccination programs, considering an array of potential benefit categories as summarized in Table 1 (Bamighausen et al. 2014). However in spite of widespread anecdotal and theoretical reasons to suspect significant

Table 1. Framework of vaccination benefits (as reported in Bamighausen et al. 2014)

Perspective		Benefit categories	Definition
Broad	Narrow	Health care cost savings	Savings of medical expenditures because vaccination prevents illness episodes
		Care-related productivity gains	Savings of patient's and caretaker's productive time because vaccination avoids the need for care and convalescence
		Outcome-related productivity gains	Increased productivity because vaccination improves physical or mental health
		Behavior-related productivity gains	Vaccination improves health and survival, and may thereby change individual behavior, for example by lowering fertility or increasing investment in education
		Community health externalities	Improved outcomes in unvaccinated community members, e.g., through herd effects or reduction in the rate at which resistance to antibiotics develops
		Community economic externalities	Higher vaccination rates can affect macroeconomic performance and social and political stability
		Risk reduction gains	Gains in welfare because uncertainty in future outcomes is reduced
		Health gains	Utilitarian value of reductions in morbidity and mortality above and beyond their instrumental value for productivity and earnings

spillover benefits from vaccines, for many vaccines quantitative evidence of broader impacts – particularly in Africa and Asia - remains limited. Indeed, in their comprehensive review Ozawa et al. (2012) observed that as of 2012 less than one-quarter of all published articles on vaccine impact assessments attempted to quantify such broader effects.

Case Study: Rotavirus Vaccine Spillovers and Broader Impacts

Among specific recent vaccination programs rotavirus vaccine impacts have recently been studied in detail, and associated with particularly impressive declines in rotavirus (and resultant spillover impacts) in many countries (Tate et al. 2012; Patel et al. 2011). Rotavirus is the most frequent pathogen causing severe episodes in children under 5 years old, accounting for as much as 40% of diarrhea-related hospitalizations (Centenari et al. 2010). Diarrhea is also the third most common cause of death in children in developing countries and the second most common cause of hospitalizations. (Pneumococcus-related diseases, including pneumonia and meningitis among others, are considered as the number one vaccine-preventable cause of death in children (Pittet and Posfay-Barbe 2012).)

Rigorous experiments including randomized, double-blind and placebo-controlled trials have been undertaken in both South Asia and Sub-Saharan Africa demonstrating the effectiveness of rotavirus vaccines at preventing disease and reducing mortality (see Armah et al. 2010 for Africa, Zaman et al. 2010 for Asia). Two rotavirus vaccines are now recommended for routine immunization of all infants by the World Health Organization (WHO): a single-strain attenuated human rotavirus vaccine (Rotarix) and a multistrain bovine-human reassortant vaccine (RotaTeq). Efficacy of the vaccines ranges from 80% to 98% in industrialized countries, and 39% to 77% in developing countries in Africa and Asia (Patel et al. 2011; Armah et al. 2010; Grimwood et al. 2010).

Rotavirus vaccines and productivity. Impacts on individual and labor force productivity arising from rotavirus vaccination in low-income countries remains scarce. Evidence from developed countries, however, strongly suggests the presence of significant nonmedical costs associated with the disease, most prominently arising from productivity losses among the sick and their caregivers. For example, in a study in the U.S. Lee et al. (2005) found the average nonmedical cost per case of rotavirus disease was $448.77, including $359.04 for missed work, $56.66 for transportation, $11.90 for oral rehydration solutions, $9.59 for diapers, $6.83 for child care changes, $3.82 for special foods and $0.93 for formula changes. Moreover over half of these expenses (53%) occurred outside the hospitalization period (suggesting studies focusing on hospital costs alone may miss substantial losses attributable to the disease). Among nonmedical costs, fully80% were attributable to missed work.

In one of the few detailed empirical studies of household-level spillovers associated with rotavirus vaccination, Tate et al. (2009) use interviews with parents in Kenya to estimate costs of transportation; previous treatments for the same episode of diarrhea; expenses incurred during the current visit for food, medicine, and tests; and the estimated income lost while caring for a sick child. They conclude that for children hospitalized with diarrhea, total costs to households averaged USD $19.86, of which USD $6.60 was lost income. For children treated in clinics, total costs were USD $2.40, of which more than half ($1.50) was attributed to lost income.

More recently, Rheingans et al. (2012a) used survey data from 3 sites in Sub-Saharan Africa (Gambia, Kenya, Mali) participating in the Global Enteric Multicenter Study (GEMS) to estimate the direct medical, direct nonmedical, and indirect (productivity losses) costs borne by households due to diarrhea in young children. They found the mean cost per diarrheal episode was USD $2.63 in Gambia, $6.24 in Kenya, and $4.11 in Mali – noting that nonmedical costs accounted for more than half of household costs in many contexts (primarily time lost from income-generating employment, which amounted to USD $1.55 in Gambia, $4.99 in Kenya, $1.72 in Mali) (Rheingans et al. 2012a).

In a very similar study in South Asia, Rheingans et al. (2012b) estimated direct, indirect and productivity-related medical costs associated with diarrhea in Bangladesh, India, and Pakistan. In noteworthy contrast to results from Sub-Saharan Africa, in the case of South Asia the authors concluded that the majority of costs of diarrheal episodes for households (USD $1.82 in Bangladesh, $3.33 in India, $6.47 in Pakistan) were attributable to direct medical costs from treatment, rather than productivity losses (Rheingans et al. 2012b).

At the regional/national level, some global studies of productivity losses that might be averted through rotavirus vaccines have been undertaken in recent years. The total value of worker productivity lost due to premature mortality avertable through vaccines in selected low- and middle-income countries overall, for example, has been estimated to be as much as 1.5 times per capita GDP (Mirelman et al. 2014). Mirelman et al. (2014) conclude that by eliminating all preventable deaths via Hib, pneumococcal, and rotavirus vaccines combined, total economic benefits could include an additional USD $9.1 billion for India, USD $5.8 billion for China, USD $560 million for the Russian Federation, USD $400 million for South Africa, and USD $18 million for Brazil (Mirelman et al. 2014, pg. 455).

However such broad estimates suffer from several limitations both in terms of measures (types of productivity considered and not considered) and in terms of data available. The vast majority of economic evaluations of rotavirus vaccination in Africa and Asia to date emphasize some combination of illnesses averted, lives saved (typically measured as DALYs) and direct medical costs from outpatient/inpatient visits (see e.g., Podewils et al. (2005) for several Asian countries, Atherly et al. (2013) for all GAVI countries). In some instances transport costs are also included (e.g., Esposito et al. (2008) for India; Verguet et al. (2013) for India and Ethiopia) and even more infrequently lost wages for the sick and caregivers (e.g., Rheingans et al. (2007) for Latin America).

In other cases data limitations lead to very coarse measures of spillover productivity impacts. For example, in a recent study of the impacts of vaccines in 72 poor countries Stack et al. (2011) estimated successful implementation of rotavirus vaccination could provide some USD $34.59 billion in benefits, of which the lion's share – USD $31.99 billion – arose from avoided death-related losses in productivity (the remaining benefits stemmed from avoided treatment and caretaker costs). In this case caretakers' lost productivity from seeking care for a sick child was roughly approximated by assuming a caretaker lost half of her daily productivity for an outpatient visit and a full day's productivity for each day a child was hospitalized. Daily productivity was estimated as the projected annual per capita gross domestic product for each year in the analysis divided by the number of days in a year. [Note this procedure may greatly overestimate actual earnings a worker or caretaker might obtain given an extra day of unimpeded work following a vaccination campaign.]

Such data limitations are not unique to Africa and Asia – for example Takemoto et al. (2013) recently reviewed all rotavirus cost-of-illness studies in Latin America to date, finding only 10 that explicitly measured non-medical costs at all and, among these 10, only one that directly measured non-medical costs (Clark et al. (2009) used a survey of self-reported indirect costs). The remaining studies relied upon rough assumptions of productivity losses based upon estimated time sick/caregiving multiplied by per capita GDP.

Finally, the broader issue of herd immunity and worker productivity in communities and countries undertaking rotavirus immunization campaigns has also received some scholarly attention in recent years. Atherly et al. (2009) most prominently demonstrated that indirect rotavirus protection through herd immunity might increase the cost-effectiveness of vaccination and reduce the effects of delays or disparities in coverage, although specific estimates were not provided. More recent research has expressed cautious optimism surrounding the herd immunity potential of rotavirus vaccines (Verguet et al., 2013; Grimwood et al. 2010), noting that while herd immunity in developed countries is well-documented, in lower income countries with higher incidence rates the evidence remains hopeful, but not conclusive (Rheingans et al. 2014).

Rotavirus vaccines and education. Apart from general claims that reduced diarrheal illnesses will improve schooling attendance, there is limited empirical evidence of strong education-vaccination links specific to rotavirus. For example, in India, which accounts for 23% of global rotavirus mortality in under-five children with more than 100,000 deaths from rotavirus annually (Rheingans et al. 2014), immunization programs have been shown to significantly decrease child mortality (and thus increase the number of children undertaking schooling in the future). Grimwood et al. (2010) also observe that one benefit of rotavirus herd immunity appears to be a reduction in diarrheal incidence among non-immunized and older children. However, among empirical studies of current students rotavirus vaccination has had mixed effects on education: Kumar (2009) curiously found immunization in India *decreased* the probability of graduating primary school by almost five percentage points, while simultaneously increasing the probability of graduating secondary school by almost two percentage points. He hypothesizes the negative effect at lower levels of schooling might be due to lower average health among newly surviving children or, perhaps, a "quantity-quality tradeoff" whereby the unanticipated survival of children induces families to under-invest in the education of each of their children.

Rotavirus vaccines and investment. Estimates of the direct impact of rotavirus on investment are not available at the time of preparing this brief. That said, several more general studies have linked disease prevalence and life expectancy to investment rates. For example, Alsan et al. (2006) estimate that a one-year increase in life expectancy increases foreign direct investment by as much as 9.5 percentage points.

Rotavirus vaccines and demographics. Bloom et al. (2005) estimate that as many as 3 million people die each year from vaccine-preventable diseasesOne recent study estimates that if China and India were able to eliminate all preventable childhood deaths with Hib, pneumococcal, and rotavirus vaccines, up to 157,000 deaths would be prevented annually (Mirelman et al. 2014).

Specifically for rotavirus, a recent study across the 72 GAVI-eligible countries found vaccination of a birth cohort could prevent 55% of rotavirus deaths. Over ten years, this would prevent up to 2.8 million deaths (Kim et al. 2010). An among impact evaluations of specific interventions, Cherian et al. (2012) report that in Mexico and Brazil reductions in diarrhea-related mortality in children under 5 years olds were as much as 35% and 22%, respectively, following the introduction of a rotavirus vaccine (Cherian et al 2012). In aggregate, the demographic impacts of vaccination can be profound: Bloom et al. (2005) estimate that the GAVI program alone has the potential to increase overall life expectancy in target countries by more than one and a half years by the end of the program.

Table 2: Local Spillovers and Broader Impacts of Rotavirus Vaccination.

		Rotavirus vaccination spillover and broader impact estimates
Direct Impact Estimates *(standard metrics)*	*Reduced Illness*	- Rotavirus is the most frequent pathogen in children under 5, accounting for 40% of diarrhea-related hospitalizations (Centenari et al. 2010). - Efficacy of vaccines now recommended by the WHO ranges from 39% to 77% in developing countries in Africa and Asia (Patel et al. 2011; Armah et al. 2010; Grimwood et al. 2010).
	Increased Longevity	- Across the 72 GAVI-eligible countries vaccination of a birth cohort could prevent 55% of rotavirus deaths, saving up to 2.8 million lives over ten years (Kim et al. 2010).
	Reduced Child Mortality	- Diarrhea is the third most common cause of death in children in developing countries and the second most common cause of hospitalizations (Pittet and Posfay-Barbe 2012). - Reductions in diarrhea-related mortality in children under 5 were 35% in Mexico and 22% in Brazil following the introduction of a rotavirus vaccine (Cherian et al 2012).
Local Spillover Estimates *(additional livelihood impacts)*	*Productivity Impacts*	- Individual and household-level productivity impacts of rotavirus vaccination vary dramatically by region and income level. - In SSA, Rheigans et al. (2012a) estimate nonmedical costs accounted for more than half of household costs of rotavirus (primarily time lost from income-generating employment for caregivers), totaling USD $1.55 in Gambia, $4.99 in Kenya, and $1.72 in Mali. - In Kenya, one of the most detailed cost studies to date found a child hospitalized with diarrhea costs a household an average of USD $19.86, of which USD $6.60 represents lost income. For children treated in clinics, total costs average USD $2.40, of which more than half ($1.50) represents lost income (Tate et al. 2009).
	Education Impacts	- Individual-level impacts of rotavirus vaccination on educational outcomes are mixed, with some studies finding improvement among vaccinated children and others finding no impact or even decreasing per-child educational outcomes in households with more surviving children (and hence fewer resources available per child) (Kumar 2009). - Rotavirus herd immunity is associated with a reduction in diarrheal incidence among non-immunized and older children (Grimwood et al. 2010), although some authors caution that in lower income countries with higher incidence rates the evidence of herd immunity benefits remains hopeful, but not conclusive (Rheingans et al. 2014).
	Investment Impacts	- No rotavirus-specific specific data on domestic or international investment impacts are available at this time. - Alsan et al. (2006) estimate more generally that a one-year increase in life expectancy increases foreign direct investment by 9.5 percentage points.
	Demographic Impacts	- Bloom et al. (2005) estimate that the GAVI program alone will could increase overall life expectancy in target countries by more than one and a half years by the end of the program (Bloom et al. 2005).
Broader Impact Estimates *(economy-wide impacts)*	*Economic Growth*	- Stack et al. (2011) estimated successful worldwide implementation of rotavirus vaccination could provide some USD $34.59 billion in economic benefits, of which the largest share – USD $31.99 billion – would come from avoided death-related losses in productivity (the remaining stems from treatment and caretaker costs). - Mirelman et al. (2014) conclude that by eliminating all preventable deaths via Hib, pneumococcal, and rotavirus vaccines combined, total economic benefits could include an additional USD $9.1 billion for India, USD $5.8 billion for China, USD $560 million for the Russian Federation, USD $400 million for South Africa, and USD $18 million for Brazil (Mirelman et al. 2014, pg. 455).
	Other Quantitative Measures	- The global economic benefits from increasing vaccination against pneumococcal diseases, rotavirus, pertussis, measles, and malaria from 2011-2020 could save 6.4 million lives, avert 426 million cases of illness, eliminate $6.2 billion in treatment costs, and recover some $145 billion in productivity losses (Stack et al. 2011).
Other Impacts *(e.g., distributional effects)*	*Distributional Effects (across income and/or social groups)*	- Rheingans et al. (2012c) note that access to both treatment and vaccination for rotavirus remains higher among the wealthy as opposed to the poor in LDCs. - In Ethiopia and India Verguet et al. (2013) find rotavirus vaccines disproportionately lower deaths and health impoverishment among the poor, though also noting vaccine efficacy is the lowest among the poorest. - Rheingans et al. (2012a, 2012b) find that in both SSA and SA private household expenditures on rotavirus treatment is lowest among the poor, and often lower for girls than for boys – suggesting women and the poor might benefit disproportionately from publicly-supported rotavirus vaccination efforts.

IV. HIV/AIDS Interventions: Spillovers and Broader Impacts

In 2010, roughly two thirds of all people with HIV/AIDS and 70% of new infections were in Sub-Saharan Africa (UNAIDS 2014). As many as 2.5 million people are infected with HIV each year (Gomez et al. 2013). The majority of people infected with HIV are adults in their most productive years, with dramatic consequences for both households and regional economies.

Today, in addition to longstanding behavioral strategies including condom use and reduction of sexual partners, relatively new prevention measures have also recently been shown to be effective including treating HIV-infected individuals with antiretroviral drugs to reduce transmission, and pre-exposure prophylaxis (PrEP), where people not infected with HIV take antiretroviral drugs to reduce the probability of transmission (Gomez et al. 2013).

There is a vast literature on HIV/AIDS and economic growth spanning nearly 2 decades of research (see Canning 2006).[5] Although, as Gomez et al. (2013) observe, published cost-benefit estimates remain overwhelmingly driven by the cost of drugs or, at best, rely on averted anti-retroviral therapy cost savings as a proxy for the benefits of HIV prevention. As a result, "[c]ost-effectiveness studies that demonstrate where resources applied can have the greatest impact" remain scarce (Gomez et al. 2013), although recent efforts in South Africa have started to develop more comprehensive accounting of prevention costs and benefits alike (Pretorius et al. 2010).

This section reports only the most relevant available literature emphasizing spillover benefits at the local (household) level and the most current or accepted estimates of broader impacts at the regional or national level.

HIV/AIDS and productivity. Empirical studies consistently find decreases in worker productivity associated with HIV/AIDS, especially in the latter stages of the disease. At the household level, the consequences of the loss of the primary wage earner to sickness or death can be profound: Collins and Leibbrandt (2007) reported that in a survey of 181 poor households in South Africa, nearly half of households were dependent on a wage earner, and eighty per cent of households would lose over half of their monthly income should the highest income recipient in the household die. AIDS deaths are furthermore often preceded by a prolonged period of illness during which one or more other household members must provide care to the ill and contribute toward their medical expenses (McIntyre et al. 2005). AIDS-related death can also pose substantial medium-to-long term burdens for households owing to funeral expenses (which can be large even in rural settings) and the ongoing loss of income into future years (Ardington et al. 2014).

Much of the empirical literature on HIV/AIDS impacts on labor focuses on southern African labor markets. In one of the first nationally representative estimates of the impact of HIV status on employment outcomes for southern Africa, Levinsohn et al. (2013) find that being HIV positive is associated with an increase of 6 to 7 percentage points in the likelihood of unemployment, and an increase in 10 to 11 percentage points among the relatively less educated.

Meanwhile, among the employed HIV/AIDS can also have substantial productivity impacts, with consequences for both individual wage earners and for employers. Fox et al. (2004) document this decrease among tea pickers in Kenya, finding HIV-positive workers picked between 4.11 and 7.93 kg per day less than similar, HIV-negative workers in the year and a half prior to termination (termination which was typically due to the disease). Moreover, HIV-positve workers "used between 9.2 and 11.0 more sick leave days, between 6.4 and 8.3 more annual leave days, between 19.9 and 11.8 more [total] casual leave days, and spent between 19.2 and 21.8 more [total] days doing less strenuous tasks" in the 24 months prior to termination (pg. 318). From a household perspective, workers with HIV/AIDS earned 16% less in the second year prior to termination and almost 18% less in the year immediately prior to termination.

Also in Kenya, Larson et al. (2008) found that tea pickers with HIV worked 2.79 fewer days than HIV-negative workers in the nine months before starting antiretroviral (ARV) treatment. The difference increased to 5.09 days in the month immediately prior to starting ARV treatment.

In such contexts interventions targeting HIV/AIDS can drastically improve both worker welfare and overall productivity. In one study of African firms, antiretroviral therapy caused illness-related absences to decrease by roughly one day per month in the six months following initiation of treatment (Habyarimana 2010). Similarly, Thirumurthy et al. (2008) find within six months following the start of an ARV regime, the likelihood of a patient participating in the labor force increased by 20 percent, and simultaneously there was a 35 percent increase in weekly hours worked (pg. 512). The authors further estimate the lower bound, a 6.7-hour increase in weekly hours (11.1 percentage points), and upper bound of the effects of treatment, a 26-hours weekly increase (85.4 percentage points) (pg. 538-539).

HIV/AIDS also affects broader labor force productivity. In one recent study, 60% of business respondents in Sub-Saharan

[5] For an expanded discussion of the economic benefits of HIV/AIDS control see: http://heapol.oxfordjournals.org/content/24/4/239.short

Africa reported that HIV/AIDS had or would have a serious impact on their business (Asiedu et al. 2012). Moore (1999) estimated HIV/AIDS could add up to 15% to South African business' wage expenditures due to low productivity and hiring/training costs (in Haacker 2004). Rosen et al. (2004) found slightly smaller estimates of the impact in South Africa, between 0.4 and 5.9%, although they also find the cumulative effects can be quite large: they estimated the aggregate economic costs of an individual HIV infection to range between 0.5 and 3.6 times the annual salary of an infected worker (pg. 317).

Finally, in one of the few studies of agricultural market impacts, in a recent simulation-based study in Nigeria Abdulsalam (2010) finds HIV/AIDS reduces output in agriculture by 0.07 per cent and in manufacturing by 0.23 per cent.

HIV/AIDS and education. In Sub-Saharan Africa HIV/AIDS largely affects young adult women and middle-aged men (Canning 2006). As a result, the effect of HIV/AIDS on education often manifests itself following the death (or severe sickness) of a parent. In Kenya, one study estimated that school participation falls by 5.5 percentage points immediately following the death of a parent (Evans and Miguel 2007).[6] This decrease appears to be driven by the death of the mother: Evans and Miguel (2007) estimate the post-death decrease in school participation to be 9.3 percentage points and the pre-death decrease to be 6.5 percentage points.[7]

Other studies support these findings. In Tanzania Beegle et al. (2009) find children who lose a mother before turning 15, on average, complete one less year of schooling than other children. In Zimbabwe, female double-orphans (girls that have lost both parents) are 13 percentage points less likely to be enrolled in school than non-orphans (Birdthistle et al. 2009). In Uganda, Kasirye and Hisali (2010) estimate that orphans are not more likely to drop out of school, but are more likely to fall behind in school: on average, orphans are four years below their appropriate grade.

One final study estimates the effect of being orphaned by AIDS in ten different sub-Saharan countries (Case et al. 2004), concluding the aggregate educational impacts of HIV/AIDS differ depending on year, country, and household type ("blended household" in which there are orphans and nonorphans, or nonblended household). The estimates range from a high of an 11.7-percentage-point decrease in school enrollment for orphans in nonblended households (Ghana in 1998) to small positive educational effects for a handful of countries in some years (pp. 498-499).

More broadly, Fortson (2011) estimates that a regional HIV prevalence of 10% decreases average schooling by 0.5 years (as compared to a regional prevalence of zero). Further effects are a decrease of 6 percentage points in the probability of attending school and a decrease of 8 percentage points in the probability of completing primary school. As Fortson points out, "[b]ecause levels of completed schooling are low in these countries, these differences are in fact quite large: adults in post-1980 birth cohorts (relative to adults in pre-1980 birth cohorts) in areas with regional HIV prevalence of 10% (relative to areas without HIV) experienced a 12% reduction in completed years of schooling, a 10% reduction in the probability of attending school, and a 20% reduction in the probability of completing primary school" (pg. 7).

Other more qualitative accounts of the broader education-related impacts of HIV/AIDS focus on national-level human capital accumulation. In Uganda, 33 percent of students that graduated from college in 1980, 14% that graduated in 1988, and 3% that graduated in 1997 had died of AIDS by 2001 (Aiedu et al., 2012). In addition to the profound human cost, these deaths represent a tremendous loss of skilled workers in developing economies. Such losses have also been significant in Malawi, Tanzania, and Zimbabwe (Aiedu et al., 2012).

HIV/AIDS and investment. Increasing life expectancy can increase time horizons and increase saving (Bloom and Canning 2008). Specifically in the context of AIDS, Baranov and Kohler (2014) find that decreasing the distance from a household to an antiretroviral treatment center in Malawi by 5.8 kilometers increases the likelihood of household saving (having a savings account) by roughly 9 to 10%. The total volume of savings also increases with proximity to a treatment center: decreasing the distance by half (5.68 kilometers) increases the amount saved by approximately USD $20, or more than 40%.

Using a dataset of more than 60 countries, Bloom et al. (2003) estimate that a ten-year increase in longevity would increase the aggregate saving rate by up to 4.5%. In an even larger cross-sectional study of 163 different countries Lorentzen et al. (2008) find that a one-standard-deviation increase in the adult male mortality rate decreases domestic investment by 2.61 percentage points (pg. 106). They also point out that the mean investment rate in their sample is 15.12%, so the decrease caused by mortality amounts to over

[6] The authors also find in the two years preceding the parent's passing, school participation is on average 2 percentage points lower, although this estimate is not statistically different from zero (Evans & Miguel, 2007).
[7] One final, important point from the study is that these effects are dependent on the academic ability of the child. A child that scores one standard deviation below the mean on an academic test has more than twice the decrease in school participation than a child at the mean, while the decrease for a child that is one standard deviation above the mean is practically zero.

17% of investment. It is important to note, however, that the empirical findings on savings and growth are somewhat mixed, with other studies finding the causal link working in the opposite direction, from growth to saving (see Mohan (2006) for an example of the mixed evidence and Aghion et al. (2006) for evidence that saving may matter more for low-income countries).

HIV/AIDS can also affect a developing economy through foreign direct investment. For example, Azémar and Desbordes (2009) estimated that in Sub-Saharan Africa a one-percentage-point increase in HIV prevalence decreased net foreign direct investment (FDI) by 3.5%. For the period 2000-2004, a hypothetical SSA country with a prevalence rate of zero for both HIV and malaria would have approximately one-third higher FDI than the average country in SSA, with the effect of HIV and malaria being almost equal (pg. 698). Research in Nigeria suggests HIV/AIDS-related reductions in output are associated with up to a 1.19 per cent in investment (Abdulsalam, 2010). Similarly, in a global study Asiedu et al. (2011) find that an increase of one standard deviation in the HIV prevalence rate in the median country (their example is Honduras) results in a decrease of FDI by about 0.081 percent in the short run and 0.011 percent in the long run.

In another global study Alsan et al. (2006) estimated that an increase in life expectancy by one year was associated with an increase in gross FDI of as much as 9%.

HIV/AIDS and demographics. One clear change in demographics due to HIV/AIDS is the mortality rate and life expectancy (Tadele and Kloos 2013). Haacker (2004) argues that HIV/AIDs increased the mortality rate for those aged 15-49 in Zambia in 2004 four times, from 0.5 percent to 1.9 percent, while the mortality rate of the entire population increased from 1.0 percent to 2.1 percent (pg. 43).

In some countries with especially high HIV/AIDS rates overall life expectancy actually *decreased* in many countries in recent decades: for example life expectancy in Botswana was 55 in 1970, rose to 64 by 1990, but then dropped back to 55 by 2009 (Asiedu et al. 2012).

Other studies have also examined the incidence and implications of HIV/AIDS among youth and children. Stover et al. (2014) recently estimated that scaling up investments and services according to the UNAIDS Investment Framework for HIV could avert 2 million new adolescent HIV infections by 2020.

The overall effects of HIV/AIDS itself on fertility are indeterminate (see Young 2004 and Kalemli-Ozcan 2012 for opposing views), although there is clear evidence that the fertility rate responds to mortality. Lorentzen et al. (2008) find a very large increase: a one-standard-deviation increase in the adult mortality rate is accompanied by an increase in the fertility rate of 0.459 children per woman. Furthermore, as more adults die, more children become orphans. In addition to the effects of orphanhood on child wellbeing and educational attainment, a further impact of orphanhood is through the dependency ratio: in households with orphans, the dependency ratio is up to 20 percent higher than other households (Haacker 2004), which may substantially decrease average investment per child (Sachs 2002).

Recent work using broad population-based surveys in Sub-Saharan Africa find that among women infected with HIV on average the number of births in the previous year was 20-25% lower (Juhn et al. 2013). However the authors also note that they find no effect in their data – which spanned 13 Sub-Saharan African countries – of an impact of regional HIV/AIDS prevalence on fertility decisions.

Table 3: Local Spillovers and Broader Impacts of AIDS Prevention.

		HIV/AIDS prevention spillover and broader impact estimates
Direct Impact Estimates	*Reduced Illness*	- As many as 2.5 million people are infected with HIV each year (Gomez et al. 2013). - There are five new HIV infections every minute, of which three are among children and young people. Each day 5,500 people die from AIDS-related illnesses, and more than 12 million orphans now live in Sub-Saharan Africa. (UNAIDS 2014).
	Increased Longevity	- Today, nearly more than three million people are on antiretroviral treatment (UNAIDS 2014).
	Reduced Child Mortality	- Stover et al. (2014) estimate that scaling up investments and services according to the UNAIDS Investment Framework for HIV could avert 2 million new adolescent HIV infections by 2020.
Broader Impact Estimates	*Productivity Impacts*	- In Kenya Fox et al. (2004) found workers with HIV/AIDS earned 16% less in the second year prior to termination and almost 18% less in the year immediately prior to termination (with termination itself often due to HIV/AIDS illness or death). - Leibbrandt (2007) reported that in a survey of 181 poor households in South Africa, eighty per cent of households would lose over half of their monthly income should the highest income recipient in the household die.

		- AIDS deaths are often preceded by a prolonged period of illness during which one or more other household members must provide care to the ill (McIntyre et al. 2005).
	Education Impacts	- In Kenya Evans and Miguel (2007) find school participation falls by 5.5 percentage points immediately following the death of a parent. - In Tanzania Beegle et al. (2009) find children that lose a mother before turning 15, on average, complete one less year of schooling than other children. - Fortson (2011) estimates that a regional HIV prevalence of 10% decreases average schooling by 0.5 years.
	Investment Impacts	- Baranov and Kohler (2014) find that living near an antiretroviral treatment center in Malawi increases the likelihood of saving by 9 to 10%. - Lorentzen et al. (2008), in a large cross-section study of 163 different countries, found that a one-standard-deviation increase in the adult male mortality rate decreases domestic investment by 2.61 percentage points (or 17% of domestic investment).
	Demographic Impacts	- The impacts of HIV/AIDS on demography are well-documented and profound. As a dramatic example, in Botswana the average life expectancy was 55 in 1970, rose to 64 by 1990, but then dropped back to 55 by 2009 as a result of the AIDS epidemic (Asiedu et al. 2012).
Aggregate Impact Estimates	*Economic Growth*	- Azémar and Desbordes (2009) estimated that in Sub-Saharan Africa a one-percentage-point increase in HIV prevalence decreased net foreign direct investment (FDI) by 3.5%.
	Other Quantitative Measures	---
Other Impacts	*Distributional Effects (across income and/or social groups)*	Recent work by Burke at al. (2014) suggests that income shocks (e.g., poor harvests, drought) may explain as much as 20% of variation in HIV prevalence across African countries – the authors conclude existing approaches to HIV prevention could be bolstered by helping rural households manage income risk.

IV. Malaria Intervention Spillovers and Broader Impacts

There are upwards of 500 million cases of malaria annually and almost one million deaths in Sub-Saharan Africa. These figures represent 71% and 86% of the global totals, respectively (Barofsky et al. 2011). As with HIV/AIDS, malaria can affect the broader economy through its effects on productivity, education, investment, and demographics.

Malaria and productivity. A number of studies use 19th century America to illustrate the dramatic effects of malaria on worker productivity. In one example, Hong (2011) estimates that 19th century migrants who “moved to an area where the malaria index was one unit higher had… about 75 percent less wealth” (pg. 665-666), which the author attributes to reductions in worker productivity and local labor force productivity.

Studies focusing on contemporary impacts of malaria also emphasize reductions in worker productivity, particularly agricultural productivity in SSA. Isaac et al. (2013) find that in Ghana a one-percentage-point increase in days of illness decreases family labor for land preparation by about three percentage points, decreases labor available for farm management by ten percentage points, and decreases the total value of agricultural production by 2% (pg. 72-75).

Kioko et al. (2013) make a similar argument for wage earnings, finding that in Kenya wage earnings are reduced by 3.3% following a ten-percent increase in the number of individuals affected by malaria. This amounts to 44% lower overall wage earnings (pg. 2). Similarly, Musumba et al. (2014) estimate that the use of treated mosquito nets can decrease productivity losses by more than six percent and Oluwatayo (2014) finds that the average number of days missed due to malaria in southwest Nigeria was about 10 per farmer. He further argues that upwards of one-quarter of the farmers have the potential to improve output through health status.

In terms of costs to businesses, malaria control in Zambia was estimated to have saved mining companies upwards of six million USD in indirect costs and almost 800,000 USD in direct costs (Utzinger et al. 2002), indicating that interventions directed at malaria have significant capacity to improve economic outcomes of individuals and businesses.

Malaria and education. Barofsky et al. (2011), studying malaria eradication in one region of Uganda, find that those born following the malaria eradication campaign had an increase of 8% in educational gains, an increase of 0.81% literacy, and a large increase of 52.5% in rates of primary school completion. (However, they also find that this effect is driven almost entirely by males.)

Likewise, in Paraguay and Sri Lanka Lucas (2010) estimates that individuals born during a malaria epidemic would have 0.77 fewer years of schooling than an individual born following the epidemic. Using a back-of-the-envelope calculations, the author further argues that a 10-percentage-point reduction in the malaria illness rate in Sri Lanka could result in an average 0.114 years of additional schooling per student, while a 10-percentage-point reduction in Paraguay would result in 0.118 years of additional schooling.

Malaria during childhood can also have detrimental effects on cognitive abilities later in life (Clarke et al. 2008; Thuilliez et al. 2010). For example, Clarke et al. (2008) find anemia (a major consequence of malaria) decreases sustained attention; in a placebo study, treatment subjects scored more than one standard deviation higher than control subjects. Similarly, Thuilliez et al. (2010) report that children who had experienced a clinical attack of malaria between follow-up visits scored between one-third and one-half of a standard deviation lower on a test of cognitive ability than children that had not contracted malaria.

Malaria and investment. As Malaney et al. (2004) note, "In a rapidly globalizing economy, malaria can prove excessively burdensome in the long run" (pg. 144). Empirical evidence suggests that household, domestic and foreign investment decrease in the face of malaria. Zhang et al. (2011) find that malaria incidence decreases the likelihood of settling on a plot in the Brazilian Amazon. An increase in the malaria rate from zero to one lowered the probability that a plot would be settled by 36 percent. Given the average rates in the area, the estimated effect of a one percent increase in malaria on local settlement rates was approximately 12 percent.

Isaac et al. (2013) find that a one-percentage-point increase in the number of malarial illness days reported decreases money spent on hiring a tractor and chemicals by approximately 2.2% and decreases money spent on improved seeds by about 3.4% (pg. 73).

Malaria and demographics. Finally, malaria has dramatic consequences for demographics. Sachs and Malaney (2002) argue that malaria is responsible for approximately one-quarter of all deaths in children between birth and the age of four, which they also argue is directly linked to higher fertility rates. Likewise, Desai et al. (2007) estimate that complete prevention of malaria in sub-Saharan Africa "reduces the risk of severe maternal anemia by 38%, low birth weight by 43%, and perinatal mortality by 27% among paucigravidae (i.e., women in their first and second pregnancies). Low birthweight associated with malaria in pregnancy is estimated to result in 100 000 infant deaths in Africa each year" (pg. 93).

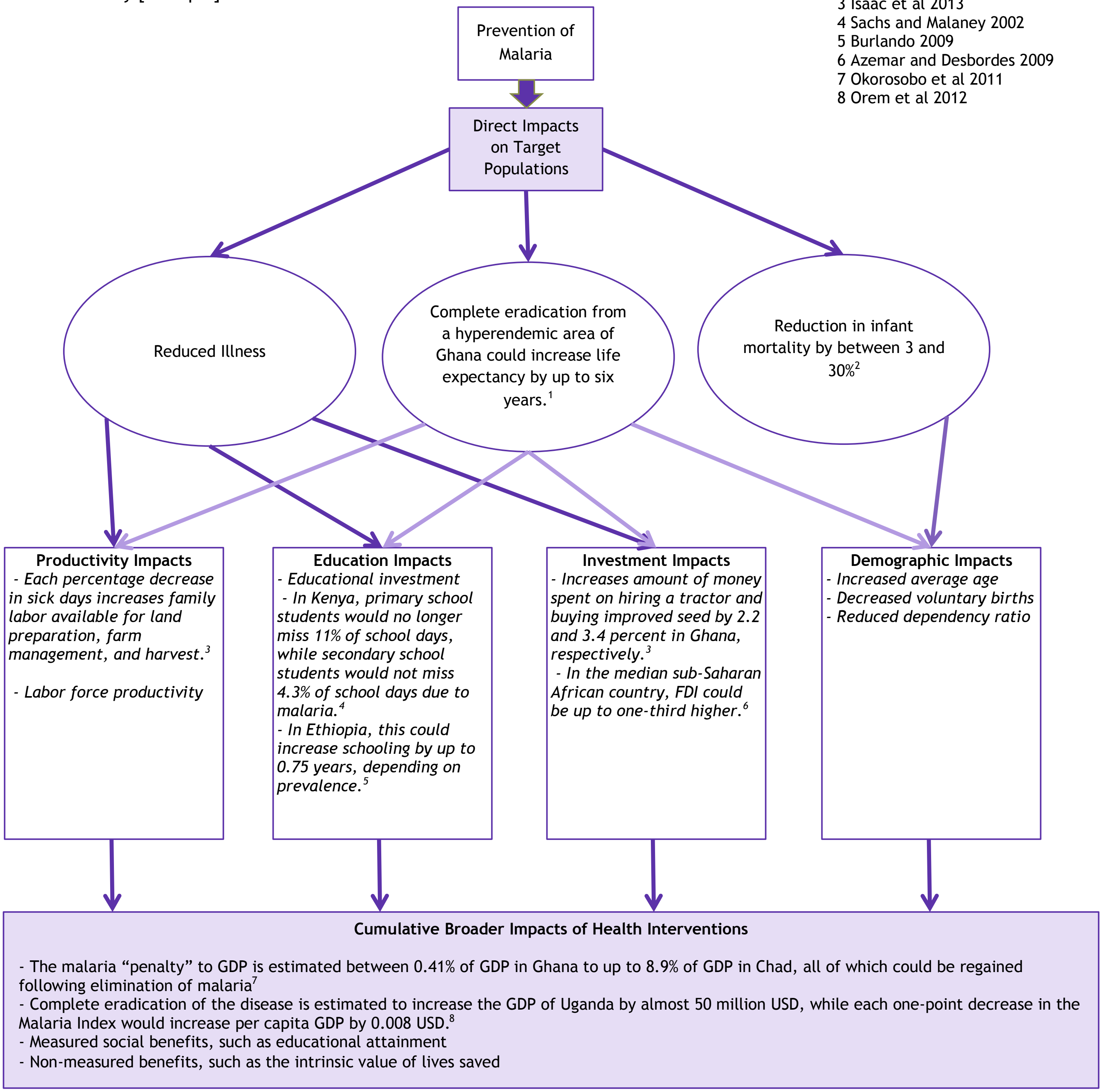
Finally, Lucas (2013) estimates that eradication of malaria from the Rain Fed Dry Zone in Sri Lanka (the zone with the highest incidence of malaria in the country) would increase the probability of a woman having a live birth in any given year by 11 percentage points (pg. 62). Eradication from the median level in the study would increase the probability of a live birth by 5.8 percentage points. The author further estimates that malaria decreased total fertility by approximately 25% prior to eradication.

Table 4: Local Spillovers and Broader Impacts of Malaria Prevention.

		Malaria prevention spillover and broader impact estimates
Direct Impact Estimates	*Reduced Illness*	- There are 500 million cases of malaria annually and almost one million deaths in Sub-Saharan Africa (86% of the global total) (Barofsky et al. 2011).
	Increased Longevity	- Complete eradication of malaria from a hyperendemic area of Ghana could increase life expectancy by six years (Bawah and Binka 2007).
	Reduced Child Mortality	- Global eradication of malaria could lead to a reduction in infant mortality by between 3 and 30% (Lucas 2013).
Broader Impact Estimates	*Productivity Impacts*	- In general, each percentage decrease in sick days from malaria increases family labor for farm land preparation, management and harvest (Isaac et al. 2013)
	Education Impacts	- In Uganda, those born following a malaria eradication campaign had an increase of 8% in overall education and 52.5% in rates of primary school completion (Barofsky et al. 2011). - In Kenya, if malaria were eradicated primary school students would miss 11% fewer school days, while secondary school students would miss 4.3% fewer (Sachs and Malaney 2002). - In Ethiopia, eradication of malaria could increase average educational attainment in some subregions by up to 0.75 years, depending on prevalence (Burlando 2009).
	Investment Impacts	- Malaria eradication leads to increases in the amount of money spent on hiring a tractor and buying improved seed by 2.2 and 3.4 percent in Ghana, respectively (Isaac et al 2013). - In the median sub-Saharan African country, FDI could be up to one-third higher as a result of malaria eradication (Azemar and Desbordes 2009).
	Demographic Impacts	- Desai et al. (2007) estimate that low birthweight associated with malaria in pregnancy results in as many as 100 000 infant deaths in Africa each year. - In Sri Lanka Lucas (2013) estimates that malaria decreased total fertility by approximately 25% prior to eradication.
Aggregate Impact Estimates	*Economic Growth*	- The malaria "penalty" to GDP is from 0.41% of GDP in Ghana to 8.9% of GDP in Chad, all of which could be regained following elimination of malaria (Okorosobo et al. 2011). - Complete eradication of the disease would increase GDP in Uganda by 50 million USD, while each one-point decrease in the Malaria Index would increase per capita GDP by 0.008 USD (Orem et al. 2012).
	Other Quantitative Measures	
Other Impacts	*Distributional Effects (across income and/or social groups)*	- Barofsky et al. (2011) find that males are more likely to increase educational attainment than females following the institution of malaria eradication efforts.

Figure 2 Possible Impacts of Malaria Prevention in an East African Country [Example].

Sources
1 Bawah and Binka 2007
2 Lucas 2013
3 Isaac et al 2013
4 Sachs and Malaney 2002
5 Burlando 2009
6 Azemar and Desbordes 2009
7 Okorosobo et al 2011
8 Orem et al 2012



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