Infectious Disease, Injury, and Reproductive Health

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This chapter identifies key priorities for the control of infectious disease, injury, and reproductive health problems for the 2012 Copenhagen Consensus. It draws directly upon the disease control paper (Jamison *et al.*, 2008) from the 2008 Copenhagen Consensus 2008 and the AIDS vaccine paper for the 2011 Copenhagen Consensus RethinkHIV project (Hecht and Jamison, 2012). This chapter updates the evidence and adjusts the conclusions of the previous work in light of subsequent research and experience. For the 2012 Copenhagen Consensus NCDs are being treated in a separate paper (Jha *et al.*, 2012, Chapter 3 in this volume) that complements this one. This chapter's conclusions emphasize investments in control of infection. That said, one of the six investment areas advanced – essential surgery – addresses both the complications of childbirth and injury, and points to the potential for substantial disease burden reduction in these domains.

All this work builds on the results of the Disease Control Priorities Project (DCPP).[1] The DCPP engaged over 350 authors and estimated the cost-effectiveness of 315 interventions. These estimates vary a good deal in their thoroughness and in the extent to which they provide regionally-specific estimates of both cost and effectiveness. Taken as a whole, however, they represent a comprehensive canvas of disease control opportunities.[2] We will combine this body of knowledge with the results from research and operational experience in the subsequent four years.

The DCPP concluded that some interventions are clearly low priority. Others are worth doing, but either address only a relatively small proportion of disease burden or simply prove less attractive than a few key interventions. This chapter identifies six key interventions in terms of their cost-effectiveness, the size of the disease burden they address, the amount of financial protection they provide, their feasibility of implementation, and their relevance for development assistance budgets. The resulting "dashboard" of indicators underpins overall judgments of priority. Separate but related papers for the 2012 Copenhagen Consensus deal with malnutrition (Hoddinott *et al.*, 2012, Chapter 6 in this volume), with water and sanitation (Rijsberman and Zwane, 2012, Chapter 10 in this volume), with population growth (Kohler, 2012, Chapter 9 in this volume), and with education (Orazem, 2012, Chapter 5 in this volume).

Before turning to the substance of the chapter it is worth briefly stating our perspectives on the roles of the state and of international development assistance in financing health interventions. There are major positive externalities associated with control of many infections and there are important public goods aspects to health education and R&D. On one view, the rationale for state finance is to address these market failures and the needs of vulnerable groups. Our view is rather different.

Among the high-income OECD countries, only the United States focuses public finance on vulnerable groups – the poor and the elderly. Other OECD countries provide universal public finance for the

(generally comprehensive) set of health interventions that the public sector finances at all. Private finance is explicitly crowded out by public action, even for purely private clinical services (such as setting fractures) which most individuals would be willing and able to pay for themselves (perhaps with privately financed insurance). Arrow's classic paper (Arrow, 1963) points to potential theoretical justifications for choosing universal public finance. The poor outcomes of the US system with respect to health indicators, financial protection, and total costs (and even with respect to public sector expenditures as a percentage of GDP) provide empirical evidence suggestive of the merits of universal public finance.[3]

The perspective of this chapter is that of universal public finance adopted by the non-US OECD countries.[4] From this perspective, one is seeking to maximize health gains (or a broader objective function) subject to a public sector budget constraint without regard for the presence of public goods or externalities (except insofar as they affect aggregate health) and by addressing the needs of the poor through selecting interventions for universal finance that are of particular importance to them. No costs then accrue to targeting and no disincentives to work effort result from the potential loss of income-related health benefits. We further view the political economy of universalism as enhancing sustainability. Reasonable people may disagree, however, on the merits of universal public finance but even in that case private purchasers of health or health insurance may find cost–benefit information relevant to choice.

Our view of the role of international development assistance in health does, in contrast, centrally involve externalities and international public goods. Cross-border transmission of infection or drug resistance involves important negative externalities and R&D constitutes a public good that has been enormously important in health. Two of our six priorities reflect those concerns. Likewise, facilitating diffusion of best practice through development assistance or price incentives can be viewed as correction of temporary price distortions and hence a reasonable purpose of aid. (Foreign direct investment (FDI) in the private sector provides an analogy, whereby international investors bring best practices along with their financial investments.)

When we discuss the "best buys" in health we do so principally from the perspective of national authorities, but for interventions that may be of importance to development assistance beyond their importance from a national perspective we point to the role of development assistance.

The chapter begins by documenting the enormous success in much of the world in the past forty years in improving health in LMICs. Its conclusion is that future investments can build on past successes – increasing confidence in the practical feasibility of major additional gains in disease control. The next section summarizes evidence that health gains have had major economic and welfare impact, and the next section uses this economic context to describe the methods used for the CBAs reported. The next three sections discuss problems and opportunities in reproductive and child health, HIV/AIDS, and TB, respectively. The final section concludes by identifying the six most attractive solutions and presenting (very approximate) CBAs for them. Our BCR estimates are placed on a "dashboard" including other information relevant for priority-setting. This chapter emphasizes, although not exclusively, opportunities relevant to low-income countries.

Progress and challenges

Health conditions improved markedly throughout the world during most of the second half of the twentieth century and this section begins by highlighting those achievements. Nonetheless major problems remain in the early twenty-first century. Parts of the world have failed to keep up with the remarkable progress in others; declines in mortality and fertility had led to an increasing importance of NCDs; and the now maturing problem of HIV/AIDS rapidly became prominent in many countries. Addressing these problems within highly constrained budgets will require hard choices, even in the current era of

[3] See Barr (2001) and Lindert (2004) for more extended discussions.
[4] If implemented, the 2012 Obama health care reform will align the US system much more closely with those of other high-income countries.

Table 7.1 Levels and rates of change in life expectancy, 1960–2010, by UN region

	Life expectancy (years)			Rate of change (years per decade)	
	1960	2000	2010	1960–1999	2000–2009
World	52	66	69	3.5	2.4
China	50	72	74	5.4	2.3
India	44	62	65	4.4	3.2
SSA	42	50	53	2.3	2.7
More-developed regions	70	76	78	1.6	2.0
Less-developed regions	48	64	67	4.2	2.6

Source: United Nations (2009).

expanding domestic health spending and overseas development assistance (ODA) on health. This section concludes by reviewing these challenges.

Progress

Table 7.1 shows progress in life expectancy, by UN region, between 1960 and 2010. For the first three decades of this period, progress was remarkably fast – a gain of 4.2 years in life expectancy per decade on average, in the LDCs, albeit with substantial regional variation. Progress continued between 2000 and 2010, but at a slower pace. In addition to overall progress, since 1950 life expectancy in the median country has steadily converged toward the (steadily growing) maximum across all countries and cross-country differences have decreased markedly (Oeppen and Vaupel, 2002; Vallin and Mesle, 2010). This reduction in inequality in health contrasts with long-term *increases* in income inequality between and within countries. Yet despite the magnitude of global improvements, many countries and populations have failed to share in the overall gains, or have even fallen behind. Some countries – for example, Sierra Leone – remain far behind. China's interior provinces lag behind the more advantaged coastal regions. Indigenous people everywhere lead far less healthy lives than do others in their respective countries, although confirmatory data are scant.

Much of the variation in country outcomes appears to result from the very substantial cross-country variation in the rate of diffusion of appropriate health technologies (or "technical progress"). Countries range from having essentially no decline in the infant mortality rate (IMR) caused by technical progress to reductions of up to 5 percent per year (Jamison *et al.*, forthcoming). Measham *et al.* (2003) reached a similar conclusion concerning the variation in IMR decline across the states of India. Cutler *et al.* (2006) provide a complementary and extended discussion of the importance of technological diffusion for improvements in health. Consider, for example, the 8 million child deaths that occur currently each year. If child death rates were those seen in OECD countries, fewer than 1 million child deaths would occur each year. Conversely, if child death rates were those in OECD countries just 100 years ago, there would be 30 million child deaths a year. The key difference between now and then is not income but technical knowledge – on disease causation, interventions, and their application.

Consider the remarkable declines in infectious disease, excepting HIV/AIDS, world-wide. It is difficult to overstate how much infectious disease control improved the human condition in the twentieth century. For comparison, the average annual death rate from all acts of war, genocide and murder in the twentieth century (including non-combatants) was approximately 2 million deaths p.a. Yet reasonable estimates suggest that improved immunization saves more lives p.a. than would be saved by world peace. The same can be said for each of three other areas: smallpox eradication, diarrhea treatment, and malaria treatment. The development of improved environmental living conditions combined with vaccination, anti-microbial chemotherapy, and the

ability to identify new microbes has been central to the more than 90 percent reduction in communicable disease mortality in Canada and the United States (US Centers for Disease Control and Prevention, 1999). Today more than thirty common infectious diseases are controllable with vaccines. In 1970, only 5 percent of the world's children under 5 were immunized against measles, tetanus, pertussis, diphtheria, and polio. The Expanded Program on Immunization has raised this to about 75 percent of children by 1990, saving perhaps 3 million lives a year (England *et al*., 2001). The clearest success in immunization is the WHO-led eradication of smallpox, which culminated in the eradication of smallpox in human populations by 1979. WHO is engaged in an ongoing effort to eradicate poliomyelitis, which is more difficult technically than smallpox eradication. Nonetheless, the effort has reduced polio cases by more than 99 percent to fewer than 1,000 per year.

Prior to 1950, the only major antibiotics were sulphonamides and penicillin. Subsequently, there has been remarkable growth in discovery and use of anti-microbial agents effective against bacteria, fungi, viruses, protozoa, and helminths. Delivery of a combination of anti-TB drugs with direct observation (or DOTS, described on p. 415) has lowered case-fatality rates from well over 60 percent to 5 percent, and also decreased transmission. The percentage of the world's TB cases treated with DOTS has risen from 11 percent to about 53 percent (Dye and Floyd, 2006), which points to the practical possibility of still further gains. Research into HIV/AIDS and related diseases is providing a better understanding of the internal structure of retroviruses, and is accelerating the number of anti-viral agents. Sustained investment in HIV/AIDS vaccine development is, very recently, beginning to bear fruit (Maurice, 2011). This chapter argues that investments to advance the time to availability of a vaccine would be highly attractive. Similarly, there is increasing knowledge of the modes of action of anti-fungal and anti-parasitic agents (Weatherall *et al*., 2006). Large-scale studies have been able to identify smoking as a major cause of tuberculosis mortality world-wide (Bates *et al*., 2007) but especially in India (Gajalakshmi *et al*., 2003). Finally, large-scale randomized trials have been increasingly used to establish widely practicable

therapies, especially when modest, but important treatment benefits are sought (Peto and Baigent, 2003). Advances in computing and statistics have led to more robust mathematical models of understanding infectious disease spread (Nagelkerke *et al*., 2002), and a new chapter is the development of molecular biology and recombinant DNA technology since the second half of the twentieth century. The benefits of DNA science to global health are as yet limited but could be extraordinary (see Weatherall *et al*., 2006, in DCP2).

Factors from outside the health sector also affect the pace of health improvement: education levels of populations appear quite important although the level and growth rate of income appear much less so. Of course, the importance of technical progress and diffusion should be viewed in a larger context. Expanded education improves the coverage and efficiency of disease control, as in the case of maternal education improving child health. Indeed, rapid economic growth in many parts of the world, especially in China and India, might well mean that some can buy their way into better health, but this chapter argues there will be far more benefit if expanded public coffers are used on a relatively limited set of highly effective public health and clinical interventions. This point bears reiterating in a slightly different way: income growth is neither necessary nor sufficient for sustained improvements in health. Today's tools for improving health are so powerful and inexpensive that health conditions can be reasonably good even in countries with low incomes.

Reasons for remaining health inequalities thus lie only partially in poverty or income inequality: the experiences of China, Costa Rica, Cuba, Sri Lanka, and Kerala state in India, among others, conclusively show that dramatic improvements in health can occur without high or rapidly growing incomes. The experiences of countries in Europe in the late nineteenth and early twentieth centuries similarly show that health conditions can improve without prior or concomitant increases in income (Easterlin, 1996). One review has identified many specific examples of low-cost interventions leading to large and carefully documented health improvements (Levine and the What Works Working Group, 2007). The public sector initiated and financed virtually all of these interventions.

The goal of this chapter is to assist decision-makers – particularly those in the public sector – to identify the highest-priority low-cost interventions to rapidly improve population health and welfare where the needs are greatest.

Remaining challenges

Three central challenges for health policy ensue from the pace and unevenness of the progress just summarized and from the evolving nature of microbial threats to human health.

Unequal progress

The initial challenge results from continued high levels of inequality in health conditions across and within countries. Bourguignon and Morrisson (2002) have stressed that global inequalities are declining if one properly accounts for convergence across countries in health conditions, which more than compensates for income divergence. However, in far too many countries health conditions remain unacceptably – and unnecessarily – poor. This reality remains a source of grief and misery, and it is a brake on economic growth and poverty reduction. From 1990 to 2001, for example, the under-5 mortality rate remained stagnant or increased in twenty-three countries. In another fifty-three countries (including China), the rate of decline in under-5 mortality in this period was less than half of the 4.3 percent per year required to reach MDG-4. Meeting the MDG for under-5 mortality reduction by 2015 is not remotely possible for these countries.[5]

Yet the examples of many other countries, often quite poor, show that with the right policies dramatic reductions in mortality are possible. A major goal of this chapter is to identify strategies for implementing interventions that are known to be highly cost-effective for dealing with the health problems of countries remaining behind – for example, treatment for diarrhea, pneumonia, TB, and malaria; immunization; and other preventive measures to reduce stillbirths and neonatal deaths. About 7.2 million of the 49 million deaths in LMICs occur in children between birth and age 5.[6] Table 7.2 summarizes what is known about the causes of deaths under the age of 5, and under the age of 28 days, in 2010; these proportions are unlikely to have changed substantially. Table 7.2 also includes an estimate on the number of stillbirths. About half of all deaths under the age of 5 (including stillbirths) occur in the first 28 days, indicating the importance of addressing conditions related to this period. Table 7.3 shows also that there are marked gender disparities in child mortality, for example in India, where death rates from pneumonia and diarrhea are fourfold to fivefold higher in girls in one region than in boys in other regions.

Epidemiological transition

A second challenge lies in NCDs. The next two decades will see the continuation of rising trends resulting from dramatic fertility declines (and consequent population aging) in recent decades, as well as change in patterns of risk factors. The companion 2012 Copenhagen Consensus paper (Jha *et al.*, 2012, Chapter 3 in this volume) discusses these matters further.

The combination of an aging population with increases in smoking and other lifestyle changes mean that the major NCDs – circulatory system diseases, cancers, respiratory disease, and major psychiatric disorders – are fast replacing (or adding to) the traditional scourges – particularly infectious diseases and undernutrition in children. Additionally, injuries resulting from road traffic are replacing more traditional forms of injury. Responding to this epidemiological transition within sharply constrained resources is a key challenge since NCD disease already accounts for two-thirds of all deaths over age 5 in these countries, although nearly 22 percent of deaths continue to be from infection, undernutrition, and maternal conditions, creating a "dual burden" that Julio Frenk and his colleagues have noted (Bobadilla *et al.*, 1993).

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[5] See Lopez *et al.* (2006a), for country-specific estimates of child and adult mortality rates in 1990 and 2001 that were generated in a consistent way over time and across countries, and Liu *et al.* (2012) for estimates of these rates of decline between 2000 and 2010.

[6] See Lozano *et al.* (2011).

Table 7.2 Causes of under-5 mortality, world-wide, 2010,[a] estimates from Child Health Epidemiology Reference Group (000)

Cause Days 0–27 (Neonatal)	No. (000)
Pneumonia	325
Pre-term birth complications	1,078
Intrapartum-related events	717
Sepsis/meningitis/tetanus	451
Other conditions	181
Congenital abnormalities	270
Diarrhea	54
All causes	3,072
1–59 months	
Diarrhea	751
Measles	114
Injury	354
Malaria	564
HIV/AIDS	159
Meningitis	180
Other conditions	1,356
Pneumonia	1,071
All causes	4,550
All Children 0–59 months	7,622
Stillbirths (2001 estimate)[b]	3,274

Source: Liu *et al.* (2012).
Notes:
[a] Of the estimated 7.6 million under-5 deaths in 2010 less than 0.5% occurred in high-income countries. Thus the cause distribution of deaths in this table is essentially that of LMICs countries.
[b] "Stillbirths" are defined as fetal loss in the third trimester of pregnancy. About 33 percent of stillbirths occur after labor has begun – so-called intrapartum stillbirths. No good estimates exist for stillbirths by cause, but some of the cause categories (e.g. birth asphyxia, birth trauma, congenital anomalies) are the same as for age 0–4, so part of what is categorized as "other conditions" in the total row will be distributed among the other existing rows when estimates are available. Note that these estimates use 2001 data from the *Global Burden of Disease* study (Jamison *et al.*, 2006; Mathers *et al.*, 2006) and have not yet been updated for 2010. The proportion of neonatal to total child deaths was 36 percent in 2001, but rose to 40% by 2010 (even though overall child deaths fell from about 13.8 to 7.6 million over the decade). Thus as stillbirths approximately track neonatal mortality, the absolute number in 2010 should be somewhat lower than the 2001 stillbirth totals.

Table 7.3 Gender variation in child mortality at ages 1–59 months, by cause in parts of India, 2005

Cause	Mortality rate per 1,000 live births
Pneumonia	
Girls in Central India	21
Boys in South India	4
Diarrhea	
Girls in Central India	18
Boys in West India	4

Source: Million Death Study Collaborators (2010).

HIV/AIDS epidemic

A third key challenge is the HIV/AIDS epidemic. Control efforts and successes have been very real in high- and middle-income countries but are not yet widespread in low-income countries. As we outline below, the HIV/AIDS epidemic is best viewed as a set of diverse epidemics in regions or sub-regions, but with the dominant focus in Africa. Each scenario demands understanding the reasons for HIV/AIDS growth, appropriate interventions to decrease transmission to uninfected populations, and clinical care with life-prolonging drugs for those already infected. Recent data suggest that growth of HIV/AIDS is slowing in large parts of Asia, Latin America, and elsewhere, and that such reductions might be due to a (very uneven) increase in prevention programs. The 2011 Copenhagen Consensus's RethinkHIV effort reviews priorities for addressing AIDS in Africa and placed accelerated work on development of a vaccine as the top priority.

The economic benefits of better health

On the global scale, the dramatic health improvements during the twentieth century arguably contributed as much or more to improvements in overall well-being as did the equally dramatic improvements in the availability of material goods and services. Through their substantial effects on reducing morbidity and mortality, the economic welfare returns to health investments are likely to be exceptional and positive – with only partially

recognized implications for public sector resource allocation. The purpose of this section is to motivate the high values this chapter (and other 2012 Copenhagen Consensus papers) place on mortality reduction in its CBAs. Returns to better health go far beyond the contribution better health makes to per person income, which itself appears substantial (see Bloom *et al.*, 2004; Lopez-Casasnovas *et al.*, 2005). This section first summarizes the evidence concerning the effect of health on per person income and then turns to more recent literature concerning the effect of health changes on a broader measure of economic well-being than per person income.

Health and income

How does health influence income per person? One obvious linkage is that healthy workers are more productive than workers who are similar but not healthy. Supporting evidence for this comes from studies that link investments in health and nutrition of the young to adult wages (Strauss and Thomas, 1998). Better health also raises *per capita* income through a number of other channels. One involves altering decisions about expenditures and savings over the lifecycle. The idea of planning for retirement occurs only when mortality rates become low enough for retirement to be a realistic prospect. Rising longevity in developing countries has opened a new incentive for the current generation to invest in physical capital and in education – an incentive that can dramatically affect national saving rates. Although this saving boom lasts for only one generation and is offset by the needs of the elderly after population aging occurs, it can substantially boost investment and economic growth rates while it lasts.

Encouraging FDI is another channel: investors shun environments in which the labor force suffers a heavy disease burden and where they may themselves be at risk. Endemic diseases can also deny humans access to land or other natural resources, as occurred in much of West Africa before the successful control of river blindness. Boosting education is yet another channel. Healthier children attend school, and learn more while they are there.

Demographic channels also play an important role. Lower infant mortality initially creates a "baby-boom" cohort and leads to a subsequent reduction in the birth rates as families choose to have fewer children in the new low-mortality regime. A baby-boom cohort thereby affects the economy profoundly as its members enter the educational system, find employment, save for retirement, and finally leave the labor market. The cohorts before and after a baby boom are much smaller; hence, for a substantial transition period, this cohort creates a large labor force relative to overall population size and the potential for accelerated economic growth (Bloom and Canning, 2006).

If better health improves the productive potential of individuals, good health should accompany higher levels of national income in the long run, although as Acemoglu and Johnson (2007) suggest, effects or per person income may also be adversely affected by health-related population increases. Bloom *et al.* (forthcoming) argue that a failure to consider lags between health improvements and economic gains led Acemoglu and Johnson to underestimate the net effect of health improvements on *per capita* income. Countries that have high levels of health but low levels of income tend to experience relatively faster economic growth as their income adjusts. How big an overall contribution does better health make to economic growth? Evidence from cross-country growth regressions suggests the contribution is consistently substantial. Indeed, the initial health of a population has been identified as one of the most robust drivers of economic growth – among such well-established influences as the initial level of income *per capita*, geographic location, and institutional and economic policy environment. Bloom *et al.* (2004) found that one extra year of life expectancy raises GDP per person by about 4 percent in the long run. Jamison *et al.* (2005) estimated that reductions in adult mortality explain 10–15 percent of the economic growth that occurred from 1960 to 1990. Although attribution of causality remains equivocal in analyses like these, household-level evidence also points consistently to a likely causal effect of health on income.

Health declines can precipitate downward spirals, setting off impoverishment and further ill

health. For example, the effect of HIV/AIDS on *per capita* GDP could prove devastating in the long run. The IMF has published a collection of important studies of the multiple mechanisms through which a major HIV/AIDS epidemic can be expected to affect national economies (Haacker, 2004).

Health and economic welfare

Judging countries' economic performance by GDP per person fails to take sufficient account of health: a country whose citizens enjoy long and healthy lives clearly outperforms another with the same GDP per person but whose citizens suffer much illness and die sooner. Schelling (1968) initiated efforts to assign economic value to changes in mortality probability and Johannson (1995) and Viscusi and Aldy (2003) provide more recent explications of the theory. Individual willingness to forgo income to work in safer environments and social WTP for health-enhancing safety and environmental regulations provide measures, albeit approximate, of the value of differences in mortality rates. Many such WTP studies have been undertaken in recent decades, and their results are typically summarized as the *value of a statistical life* (VSL).

Although the national income and product accounts include the value of inputs into health care (such as drugs and physician time), standard procedures do not incorporate information on the value of changes in longevity. In a seminal paper, Usher (1973) first brought estimates of VSL into national income accounting. He did this by generating estimates of the growth in what Becker *et al.* (2003) later called *full income* – a concept that captures the value of changes in life expectancy by including them in an assessment of economic welfare. Estimates of changes in full income are typically generated by adding the value of changes in annual mortality rates (calculated using VSL figures) to changes in annual GDP per person. These estimates of change in full income are conservative in that they incorporate only the value of mortality changes and do not account for the total value of changes in health status.

This chapter will later use a DALY measure, that includes disability as well as premature mortality

in a way that calibrates disability weight in terms of mortality changes. Valuation of changes in mortality, it should be noted, is only one element – albeit a quantitatively important one – of potentially feasible additions to national accounts to deal with non-market outcomes. The US National Academy of Sciences has proposed broad changes for the United States that would include but go beyond valuation of mortality change (Abraham and Mackie, 2005). The Sarkozy Commission in France (Stiglitz *et al.*, 2009) reached similar conclusions. Of specific relevance to recent economic evaluations of health interventions is the economic welfare value of reductions in financial risk potentially associated either with a health intervention – typically prevention or early treatment – or with a risk-pooled way of financing it.

For many years, little further work was done on the effects of mortality change on full income although, as Viscusi and Aldy (2003) document, the number of carefully constructed estimates of VSLs increased enormously. Bourguignon and Morrisson (2002) address the long-term evolution of inequality among world citizens, starting from the premise that a "comprehensive definition of economic well-being would consider individuals over their lifetime." Their conclusion is that rapid increases in life expectancy in poorer countries have resulted in declines in inequality (broadly defined to reflect the distributions of both mortality and income) beginning some time after 1950, even though income inequality continued to rise.

In another important paper, Nordhaus (2003) assessed the growth of full income *per capita* in the United States in the twentieth century. He concluded that more than half of the growth in full income in the first half of the century – and somewhat less than half in the second half of the century – had resulted from mortality decline. In this period, real income in the United States increased sixfold and life expectancy increased by more than twenty-five years.

Three lines of work extend those methods to the interpretation of the economic performance of developing countries. All reach conclusions that differ substantially from analyses based on GDP alone. Two of those studies – one undertaken for the Commission on Macroeconomics and Health

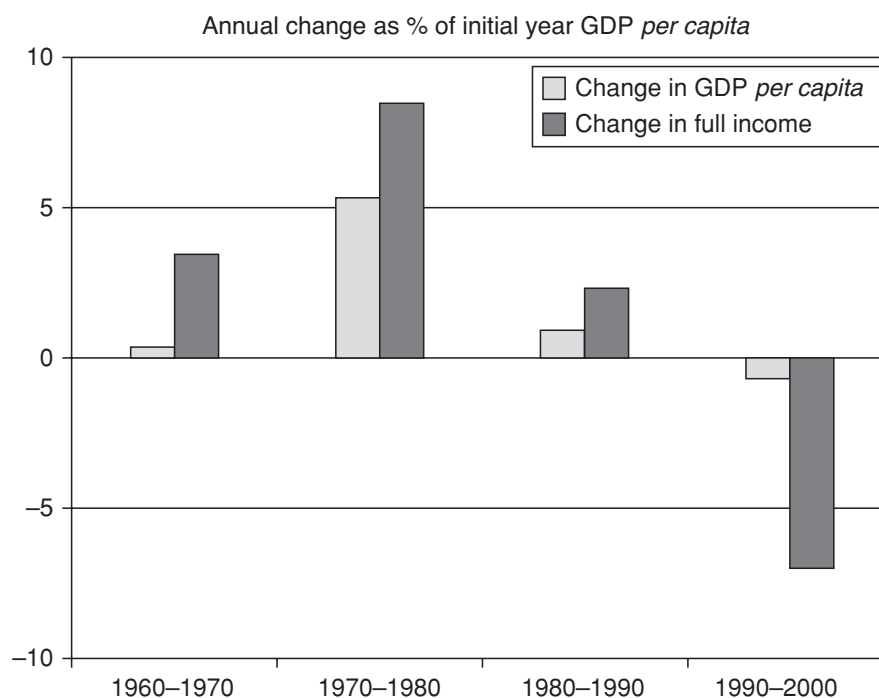Annual change as % of initial year GDP *per capita*

Figure 7.1 *Changes in GDP and full income, Kenya, 1960–2000*

(CMH) of WHO (Jamison *et al.*, 2001) and the other at the IMF (Crafts and Haacker, 2004) – assessed the impact of the HIV/AIDS epidemic on full income. Both studies conclude that the HIV/AIDS epidemic in the 1990s had far more adverse economic consequences than previous estimates of effects on per person GDP growth would suggest. The benefit estimates used in this chapter for successful interventions against HIV/AIDS are consistent with these findings from the CMH and IMF.

Accounting for mortality decline in Africa before the 1990s, on the other hand, leads to estimates of much more favorable overall economic performance than does the trend in GDP per person. Figure 7.1 shows that in Kenya, for example, full income grew more rapidly than did GDP per person before 1990 (and far more rapidly in the 1960s). After 1990 the mounting death toll from HIV/AIDS appears to have only a modest effect on GDP per person but a dramatically adverse impact on changes in full income. Becker *et al.* (2003) confirmed and extended the earlier work of Bourguignon and Morrisson (2002) in finding strong absolute convergence in full income across

countries over time, in contrast to the standard finding of continued divergence (increased inequality) of GDP per person. Finally, Jamison *et al.* (2003) have adapted standard cross-country growth regressions to model determinants of full income (rather than GDP per person). Like Bourguignon and Morrisson (2002), they concluded that inequalities have been decreasing.

The dramatic mortality declines of the past 150 years – and their reversal in parts of Africa by HIV/AIDS subsequent to 1990 – have had major economic consequences. The effect of health on GDP is substantial. The intrinsic value of mortality changes – measured in terms of VSL – is even more so. What are the implications of these findings for development strategy and for CBAs of public sector investment options? Using full income in CBAs of investments in health (and in health-related sectors such as education, water supply and sanitation, and targeted food transfers) would markedly increase estimates of net benefits or rates of return. A major purpose of the Copenhagen Consensus process is to undertake intersectoral comparisons of investment priorities by utilizing this "full benefit" approach.

Cost-benefit methodology

The basic approach to CBA used for most of the solutions is to start with the cost-effectiveness results from the extensive comparative analyses reported in DCP2 (Jamison *et al.*, 2006a; Laxminarayan *et al.*, 2006a). These results are expressed as the cost of buying a DALY, a summary measure involving mortality change and a valuation of disability change that can be considered to have been generated by calibration against mortality change.

The next subsection describes an idealized version of our approach to cost-effectiveness – idealized in the sense that it seeks to explicitly call attention to the value of financial protection and non-financial costs (e.g. use of limited system capacity). The point is to serve as a reminder in drawing conclusions of some specific important considerations that go beyond the cost-effectiveness ratios reported, considerations that appear in our "dashboard" reporting of results. The next subsection discusses DALYs and explicitly argues for a change in the way DALYs associated with deaths under the age of 5 are calculated. This change, which is adopted in our CBAs, reduces the DALY cost of a typical death under the age of 5 by about 50 percent while leaving the construction of DALYs for older ages unchanged. The next subsection draws on the earlier discussion to assign, very conservatively, dollar values to DALYs for the subsequent CBA. The final subsection summarizes this chapter's approach to costing.

Canning (2009) provides a valuable critique of aspects of this approach to valuing DALYs for a CBA. He points to a potentially lower dollar valuation of mortality reduction both in poorer countries and among the poor in a given country. This issue cuts across the 2012 Copenhagen Consensus analyses. Our view is that $1,000/DALY is a reasonable lower bound independent of the process of getting to the number.

Cost-effectiveness analysis broadly and narrowly construed

A starting point for cost-effectiveness analysis broadly construed is to observe that health systems have two objectives: (a) to improve the level and distribution of health outcomes in the population and (b) to protect individuals from financial risks that are often very substantial and that are frequent causes of poverty (WHO, 1999, 2000). Financial risk results from illness-related loss of income as well as expenditures on care; the loss can be ameliorated by preventing illness or its progression, by using an appropriate financial architecture for the system, and by improving access to capital markets or social insurance.

We can also consider two classes of resources to be available: financial resources and health system capacity. To implement an intervention in a population, the system uses some of each resource. Just as some interventions have higher dollar costs than others, some interventions are more demanding of system capacity than others. In countries with limited health system capacity, it is clearly important to select interventions that require relatively little of such capacity. Human resource capacity constitutes a particularly important aspect of system capacity, discussed in a report of the Joint Learning Initiative (2004). Figure 7.2 illustrates this broadly construed vision of cost-effectiveness and, in its shaded region, the more narrow (standard) approach for which quantitative estimates are available. Jamison (2008) provides a more extended discussion.

Although in the very short run little trade-off may exist between dollars and human resources or system capacity more generally, investing in the development of such capacity can help make more of that resource available in the future. Mills *et al.* (2006) discuss different types of health system capacity and intervention complexity and point to the potential for responding to low capacity by selecting interventions that are less demanding of capacity and by simplifying interventions. Mills *et al.* (2006) also explore the extent to which financial resources can substitute for different aspects of system capacity (see also Gericke *et al.*, 2003). An important mechanism for strengthening capacity, inherent in highly outcome-oriented programs, may simply be to use it successfully – learning by doing.

The literature on the economic evaluation of health projects typically reports the cost per unit of achieving some measure of health outcome – QALYs, or DALYs, or deaths averted – and
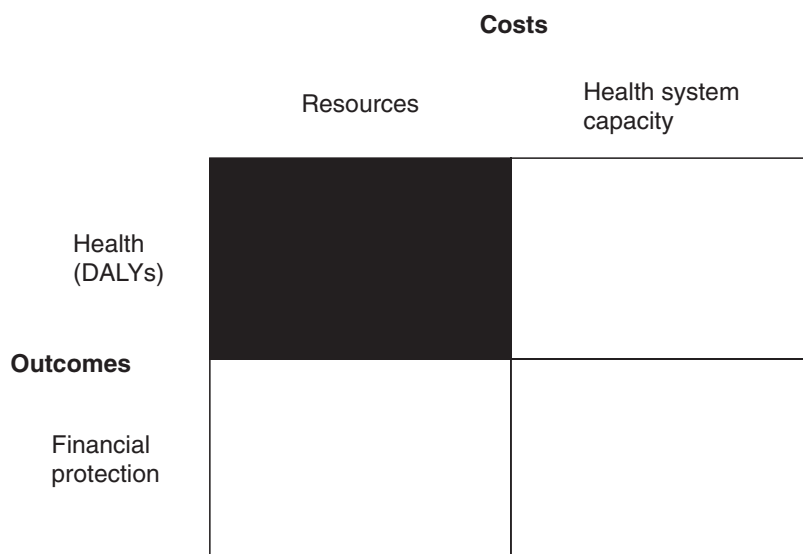
Costs

Resources   Health system
                         capacity

Health
(DALYs)

Outcomes

Financial
protection

Figure 7.2 *Intervention costs and effects: a more general view*

Note: The black box represents the domain of traditional cost-effectiveness analysis.

at times addresses how that cost varies with the level of intervention and other factors. Pritchard (2004) provides a valuable introduction to this literature. DCP1 reported such cost-effectiveness findings for about seventy interventions; DCP2 does so as well, in the end providing evidence on about 315 interventions. DCP2 authors were asked to use the methods described in Jamison (2003). Cost-effectiveness calculations provide important insights into the economic attractiveness of an intervention, but other considerations – such as the consequences for financial protection and the demands on health system capacity – need to be borne in mind. Even if factors such as system capacity remain difficult to quantify it may be useful to include a subjective judgment, for each intervention, of the extent of its demand on system capacity. We complement our quantitative (if imprecise) benefit-cost estimates with subjective judgments of this type in a "dashboard" comparison of interventions.

Defining and redefining DALYs

The DALY family of indicators measures the disease burden from the age of onset of a condition by combining an indicator of years of life lost (YLL) due to the condition with an indicator of years of

life lost due to disability (YLD) resulting from the condition. DALYs due to a condition are the sum of the relevant YLLs and YLDs.

DALYs generate a measure of the disease burden resulting from premature mortality by integrating a potentially discounted, potentially age-weighted, disability-adjusted stream of life years from the age of incidence of the condition to infinity using a survival curve based on the otherwise expected age of death. The formulation within the family of DALYs previously used to empirically assess the global burden of disease specifies a constant discount rate of 3 percent per year and an age-weighting function that gives low weight to a year lived in early childhood and older ages and greater weight to middle ages. The current comprehensive volume on burden of disease reports global burden of disease (GBD) estimates generated with the 3 percent discount rate but uniform age weights (Lopez *et al*., 2006b). Mathers *et al*. (2006) provide an extensive exploration of the uncertainty and sensitivity inherent in disease burden assessment, including the results of differing assumptions about age-weighting and discount rates. (A major revision and update of the *Global Burden of Disease* (GBD) is now nearing completion for publication later in 2012. Its headline reporting of results uses uniform age-weighting and a zero discount rate. The practical effect is to

increase markedly (and, in our view, implausibly) the relative importance of deaths in childhood relative to earlier publications.)

To be clear about the particular form of DALY being used, the terminology from Mathers *et al.* (2006) is employed. DALYs(r,K) are DALYs constructed using a discount rate of r percent per year and an amount of age-weighting indexed by a parameter K. DALYs(3,1) are DALYs generated with a discount rate of 3 percent per year and with full age-weighting, that is, $K = 1$. DALYs(3,0) are DALYs generated with a discount rate of 3 percent per year and with no age-weighting, that is, $K = 0$. Mathers *et al.* (2006) present results concerning the burden of disease based on DALYs(3,0); Ezzati *et al.* (2006) present estimates of the burden of major risk factors. This chapter is based on DALYs (3,0), but slightly generalized.

A serious problem for the standard conception of DALYs concerns death near the time of birth. The DALY measure suffers from a discontinuity at this time, with a death seconds before birth counting for 0 DALYs and a death seconds after counting for more than 30 (at 3 percent discounting). However, while there is serious disagreement about the ethics of the beginning of life, there are very few advocates of such a discontinuous jump in moral status at the exact moment of birth.

The DALY framework can be extended to smooth out this discontinuity. This can be done using a method from Jamison *et al.* (2006a), which introduces a concept called the "acquisition of life potential" (ALP). The idea is that instead of instantaneously gaining full moral weight, the fetus begins acquiring it at some stage before birth, and gradually acquires full status by some stage after birth. To calculate the DALYs due to death of a fetus or infant, one multiplies the DALYs as calculated by the standard approach by a number between 0 and 1 which represents the current level of "life potential."

Operationalizing this concept involves introducing a parameter, A, that indicates the speed of ALP (see Jamison *et al.*, 2006a for precise definitions and assessments of the burden of disease that result). A is constructed so that for the fastest possible speed of ALP, namely, instantaneous ALP, $A = 1$. A is bounded below by 0. This chapter extends the notation DALYs(r,K) in two ways. First, it explicitly indicates the level of A by extending the DALY nomenclature to DALYs(r,K,A). Thus using this nomenclature, DALYs(3,0) become DALYs(3,0,1), because the standard DALY is the special case with instantaneous ALP. Second, when stillbirths are included in the range of events to be measured in the GBD, this is explicitly noted in the DALY nomenclature as DALYsSB(r,K,A). Notation around YLL is similarly extended.

Explicit modeling of ALP permits three instrumentally useful improvements to the previous DALYs formulation:

- The ALP formulation allows, but does not require, the discontinuity in DALY loss at the time of birth to be avoided.
- The ALP formulation allows, but does not require, a positive DALY loss associated with stillbirths.
- The ratio of the DALY loss from a death at age 20, say, to that at birth is close to 1 for any reasonable set of parameter values in the previous DALY formulation. However, many people's ethical judgments would give this ratio a value substantially greater than 1. The ALP formulation allows, but does not require, these judgments.

Only a limited number of empirical studies have attempted to assess directly the views of individuals concerning deaths at different ages. In an important early study, Crawford *et al.* (1989) relate grief from a death to the concept of reproductive potential in population biology. They conclude that for several diverse human groups the relationship shows grief to be closely related to prehistoric reproductive value. An Institute of Medicine review of vaccine development priorities (IOM, 1985) uses infant mortality equivalence in cost-effectiveness calculations. The committee members preparing the report collectively judged that the loss from a death at age 20 should be about twice that from an infant death. However, some preliminary trade-off studies suggest a value closer to three or four times. All three lines of evidence point to gradual rather than instantaneous ALP. What is clear, however, is that no completely defensible estimate (or even range) is currently available, and hence the numbers used in Jamison *et al.* (2006b) should be viewed as only

Table 7.4 Discounted YLL at different ages of death for several DALY formulations

Age group	Representative age of death (years)	YLL(3,1)	YLL(3,0)	YLL$_{SB}$(3,0, 0.54)
Antepartum	−0.080	0	0	4.95
Intrapartum	−0.001	0	0	9.13
Neonatal	0.020	33.09	30.42	9.40
Infant	0.300	33.36	30.40	12.95
Postneonatal infant	0.500	33.56	30.39	15.42
Child	2.000	34.81	30.28	26.40

Note: YLL(3,1), YLL(3,0), and YLL$_{SB}$(3,0,1) assume instantaneous acquisition of life potential, ALP ($A = 1$). YLL(3,1) assumes full age-weighting ($K = 1$); the other three formulations assume uniform age weights ($K = 0$). YLL$_{SB}$(3,0,0.54) assumes gradual acquisition of life potential ($A = 0.54$). The subscript SB refers to formulations that do not give stillbirths zero weight.
Source: Jamison *et al.* (2006b: Table 6.6).

suggestive. Table 7.4 shows the YLLs associated with deaths at different young ages for alternative formulations of the DALY, including one with their preferred value of $A = 0.54$. This final column reports several estimates. (It is important to note the DALYs and YLLs for deaths above age 5 are unaffected by introduction of ALP.) *Weighting the YLLs at different ages by the relative frequency of deaths at those ages gives a DALY$_{SB}$ (3,0, 0.54) loss of 16.4 DALYs for a typical under-5 death, about half what is typically used.* Our analyses use this figure.

The value of a DALY

The VSL estimates discussed on p. 397 yield a range of values for a statistical life – from around 100 to almost 200 times *per capita* income. Very approximately, this can be translated to a value for a statistical life *year* in the range of 2–4 times *per capita* income. Tolley *et al.* (1994) provide a valuable overview of relevant estimates, including estimates of the value of preventing disability.

However, this does not answer the question of which income level we should use to set the value of a DALY. The answer to this question is highly dependent upon what the cost-benefit calculation is being used for. For example, if Uganda is deciding whether to publicly finance a disease control program, the money raised for this would come from the Ugandan people. Their nominal GNI *per capita* is about $500, so the above method would suggest

that the Ugandans would value a DALY as much as a sum of money between $1,000 and $2,000. Thus it would be counter-productive for their government to spend more than $2,000 to provide a DALY. In this usage case, where a country is spending its own money to help its own citizens, we need to use each country's GNI to determine their dollar value of a DALY and hence their BCRs. It is irrelevant to the Ugandans that the Nigerians have a GNI *per capita* of approximately $1,180 and would thus value a DALY at more than twice as many dollars.

In contrast, if we are trying to produce a global prioritization, there are strong ethical reasons for using a single dollar value for DALYs (or VSLs), no matter which country they occur in. Otherwise we would be failing to value all people equally and would end up grossly neglecting death and disability in poorer countries. Since the interventions in this chapter affect people in relatively poor countries, this effect is limited but could still be as much as a factor of 10 or 20. However, if we wanted to compare these interventions with interventions that affected people in high-income countries, then the effect could rise to a factor of 100, with a DALY being valued at $100,000–$200,000 in the United States. While there are no health interventions for US citizens discussed here, the problem could come up for any type of benefit for members of high- or middle-income countries calculated from their WTP.

For the reasons above, there cannot be a single dollar value that we can place on a DALY or a

VSL to take account of the different ways in which people might wish to use it. The best compromise that we have been able to find is to use a single figure based on the average income in our target countries. The emphasis in this chapter is on low-income countries, defined by the World Bank for 2001 as countries with *per capita* incomes of less than $1,005 (exchange rate). The World Bank's estimate of the average income of people living in low-income countries is $509 per year (World Bank, 2011: Table 1.1). Choosing a value for a statistical life year near the low end of the range (a little above 2) would give a convenient value of $1,000, which is what this chapter uses in its main calculations as the value of a DALY. (Note that, for the reasons discussed on p. 419, the DALY loss from a death under age 5 – and hence the benefit from preventing it – is about half that used in standard DALYs.)

Note that health programs in poor countries should adjust this number according to their own national incomes, as mentioned in the sensitivity analysis in the Appendix (p. 419). Furthermore, comparisons between this chapter and any CBA where WTP has been calculated based on the preferences of people in a richer country will need to scale up these ratios accordingly. For example, while our recommended TB program has an indicative BCR of 20:1, the BCR of the program should be thought of as 2000:1 if it were being compared to interventions that benefited people in the United States and used American willingness to pay estimates.

We explore the sensitivity of our results to these effects in the Appendix, as well as considering a DALY value of $5,000 for low-income countries and the standard DALYs (DALYs (3,0)) for child deaths.

The cost of a DALY

The cost of buying a DALY with different interventions was calculated, in DCP2, by combining "typical" prices for a geographical region (Mulligan *et al*., 2003) with input quantities estimated from clinical and public health experience and case studies in the literature. Because the solutions being considered usually involve substantial increments

from the status quo, long-term average costs were used. For internationally traded inputs, prices were the same for all regions.[7] For local costs regional estimates were used. Intervention costs, therefore, are *not* expressed in PPP$. The reason for this is that local costs present decision-makers with the appropriate numbers for budgeting and for comparing interventions in the context where they are working. Regional costs are taken to be a better approximation of these local costs than global costs would be. On this point the methods of this chapter differ from those of the 2004 Copenhagen Consensus (Mills and Shilcutt, 2004).

Child health

A small number of conditions account for most of the large differences in health between the poor and the not so poor. For example, less than 1 percent of all deaths from AIDS, TB, and malaria occur in the high-income countries. Available technical options – exemplified by but going well beyond immunization – can address most of the conditions that affect children, and can do so with great efficacy and at modest cost. That short list of conditions, including undernutrition, relates directly to achieving the MDGs for health. The section begins by discussing intervention to address under-5 mortality. It then turns to the problem of the world's most prevalent infections, intestinal worm infections, and the relatively straightforward approach to dealing with those in schoolchildren. The final subsection discusses delivery and includes two of our solutions for the 2012 Copenhagen Consensus pricing mechanisms to facilitate uptake of appropriate anti-malarials and the essential surgical platform.

Under-5 health problems and intervention priorities

The MDG for under-5 mortality (MDG-4) (reducing its level in 2015 by two-thirds relative to what

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[7] Because of tiered pricing, on-patent drugs were *not* considered to be internationally traded.
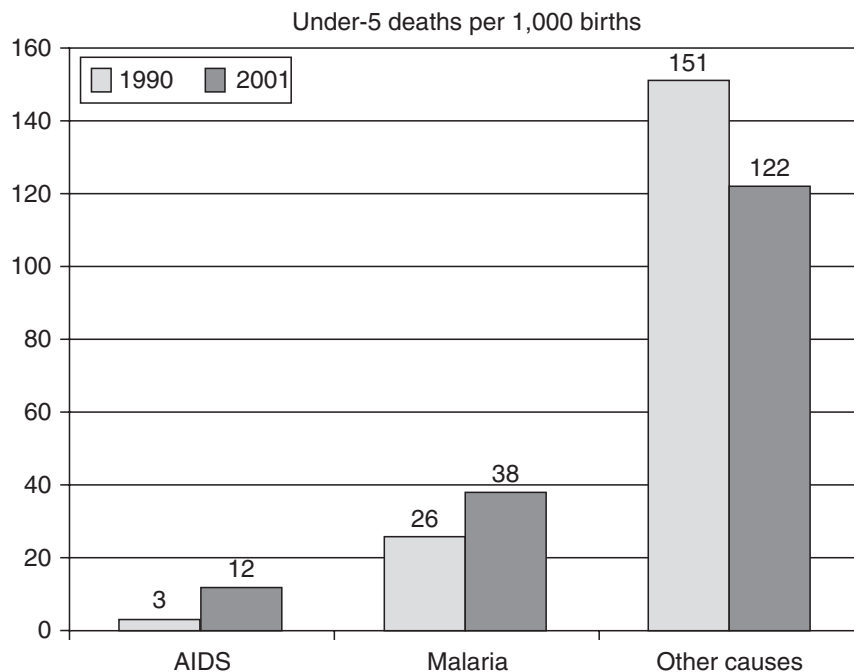
Under-5 deaths per 1,000 births

Figure 7.3 *Under-5 deaths from AIDS, malaria, and other causes, per 000 births, SSA, 1990 and 2001*

it was in 1990) is highly ambitious. Yet its implication of an average 4.3 percent per year decline is well within recent experience. In the first half of the MDG period (1990–2002), forty-six countries achieved rates of decline in under-5 mortality greater than 4.3 percent per year (Lopez *et al.*, 2006a).

Basic knowledge about the power and the cost-effectiveness of interventions to address maternal and child health has been available for many decades. DCP2's work makes four important and relatively new points. First, major declines in childhood mortality could well be accelerated with expanded case management of acutely ill children and with the addition of several new antigens to routine vaccination. These include *Haemophilus influenza* type b (Hib) and *Streptococcus pneumonia* which are common causes of childhood pneumonia; hepatitis B which protects against liver cancer; and newer rotavirus and shigella vaccines against diarrhea (England *et al.*, 2001). The Global Alliance for Vaccines and Immunization (GAVI) estimates that the addition of Hib and pneumococcal vaccines to vaccination programs could save 800,000 lives a year by 2010. Further GAVI estimates suggest that rotavirus and shigella vaccines might save 600,000 lives a year by 2010.

Second, about 40 percent of under-5 deaths (excluding stillbirths) occur at ages less than 28 days (Liu *et al.*, 2012), when the substantial but usually neglected problem of stillbirth is considered. DCP2 identifies some highly cost-effective approaches to intervention against stillbirth and neonatal death (Lawn *et al.*, 2006). These include increased reliance on delivery in facilities with surgical capacity to deal with complex obstetric emergencies, which are life-threatening for both mother and for child.

Third, there is a rapid spread of resistance of the malaria parasite to chloroquine and to sulfadoxine-pyrimethamine (SP). These inexpensive, highly effective, widely available drugs provided an important partial check on the high levels of malaria deaths in Africa, which are concentrated particularly in children. Their loss is leading to a rise in malaria mortality and morbidity that could be substantial. Figure 7.3 illustrates increases in malaria death rates and decreases in death rates from other causes except HIV/AIDS in under-5 children in SSA in the period from 1990 to 2001. This death rate increase results in hundreds of thousands of deaths more than would otherwise have occurred. (With malaria, however, there is increasing evidence that widespread use of bednets and

better treatment is partially reversing the adverse trend prior to 2011, see WHO, 2011.) The design of instruments for financing a rapid transition to effective new treatments – artemisinin combination therapies (ACTs) – is a high priority. Kenneth Arrow chaired a committee of the US IOM to design appropriate financial instruments (IOM, 2004; Arrow *et al.*, 2005). This resulted in creation of the Affordable Medicines Facility-malaria (AMFm), which would reduce the relative prices which public or private sector providers face for ACTs rather than increasing their budgets for purchasing them. This effort is now under way and early results indicate that the mechanism has been successful in lowering the price of ACTs in eight pilot countries. Fourth, although education interventions are considered in a separate paper for CC12 (Orazem, 2012), it is worth noting here that improvements in the quality of basic education can plausibly have BCRs as high as for many health interventions – even if no benefits of education other than mortality reduction are included. In a recent paper, Jamison *et al.* (2007) estimate that the effect of a 1 standard deviation improvement in quality[8] would increase the annual rate of decline of infant mortality by about 0.6 percent leading, after twenty years, to something over a 10 percent reduction in IMR relative to what it would otherwise have been. They estimate that this effect could be achieved for on the order of 10 percent of the cost of a year of schooling, which is likely to be less than $100 per student per year in a low-income country.

If the total fertility rate is 3 and the base level of IMR is 70 per 1,000 then education quality improvement is likely to result in a cost per (undiscounted) child death averted of around $1,000. Assuming (as this chapter does) a low DALY loss per child death of about 16 and the value of a DALY in low-income countries of $1,000, then the BCR will be about 13. Discounting the benefits at 5 percent would give a BCR of 4, again ignoring any other benefits from education. Increasing the value of a DALY from $1,000 to $5,000 would increase the BCR to 20 even with 5 percent discounting. In our next subsection we turn to a mechanism through which health intervention – deworming – can contribute to increasing both the quantity and quality

of education, with benefits through the mechanism reviewed here, on the next generation.

In addition to the above, other intervention priorities for addressing under-5 mortality are for the most part familiar:

- Exclusive early breast-feeding, which has increased widely in all parts of the world over the last few years.
- Expanding immunization coverage of the current set of antigens in the Expanded Program on Immunization (EPI), as well as addition HiB, hepatitis B, rotavirus, and streptococcus.
- Expanding the use of the simple and low-cost but highly effective treatments for diarrhea and child pneumonia through integrated management of childhood illness or other mechanisms.
- Preventing transmission of malaria by expanding coverage of insecticide-treated bednets; by expanding use of intermittent preventive treatment for pregnant women; and by use of indoor residual spraying with DDT.
- Enabling the use of effective anti-malarial medication, and preventing the development of resistance to it by subsidizing its price to make it affordable and to crowd out counterfeits and monotherapies that will speed resistance. The AMFm has been successful in doing this in its initial year. Its continuation and expansion is one of the five priorities this chapter recommends, in part because it addresses the externality associated with monotherapy-induced antibiotic resistance.
- Ensuring the widespread distribution of key micronutrients, most notably Vitamin A, zinc, and iron. (See Hoddinott *et al.*, 2012, Chapter 6 in this volume)
- Expanding the use of anti-retrovirals and breast-feeding substitutes to prevent mother-to-child transmission of HIV/AIDS.

Worm infections in school-age children

In addition to interventions to reduce under-5 mortality, one other priority is increasingly

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[8] As measured by scores on internationally standardized achievement tests (SATS), particularly those in mathematics.

clear. The world's most prevalent infections are intestinal helminth (worm) infections, and children of all ages are among the most heavily affected. Hotez *et al.* (2006) discuss these infections, which a low-cost drug (albendazole), taken every six months to a year, can control effectively. The Bundy *et al.* (2006) discussion of school health services points to both the importance to children's school progress of taking albendazole where needed and the potential efficacy of school health programs as a vehicle for delivery. Canning (2009) emphasized that standard health-related cost-effectiveness assessments (CEAs) fail to capture the importance (and feasibility) of deworming and the 2008 Copenhagen Consensus overall ranking for deworming was number 6 out of 30 (Bhagwati *et al.*, 2009). In the long run, improved sanitation and water supplies will prevent transmission of worm infections. Use of albendazole is only an interim solution until development-driven sanitation improvements take over, but it is one that may be required for decades if the experience of the currently high-income countries is relevant.

Worms remain a neglected infection despite the high prevalence and the low cost of treatment (Bundy *et al.*, 2006). Regions such as SSA, Southeast Asia and parts of Latin America are disproportionally affected by worms due to poor and unsanitary living conditions and personal hygiene (Hall and Horton, 2009). Human behavior, climate, and overcrowding can all contribute to the survival and transmission of worms. From complications with digestion to difficulty absorbing nutrients, worms can be detrimental to a person's overall well-being, including productivity, appetite, fitness, and growth (Stephenson, 1987; Bundy *et al.*, 2004). Children are at greater risk of infection than adults and will suffer more severe, lifelong complications if worms are left untreated. Children who do experience worm infection often live in poor communities and need a sustainable treatment plan to remedy any loss in education, nutrition, and intellectual development they may experience. The behavioral patterns of children put them at greater risk of serious infection than other age groups.

Currently there is much literature suggesting that deworming programs are extremely cost-effective. According to Deworm the World, a joint initiative launched in 2007 by the WEF, deworming programs are one of the most cost-effective health interventions in the world (Deworm the World, 2009). It is helpful in analyzing the educational consequences of deworming programs to consider more explicitly than is typical for education administrators the relation between system capacity and system utilization. The number of student places needed to serve a catchment area is simply the population size in the relevant age cohort, here ages 5–14, times the percentage of that cohort that would ideally be in school (for this age group, it would be 100 percent). Each student place requires (given local policies on class size) a certain amount of physical plant, teacher availability, and so forth; the level of those resources actually available determines the number of student places installed. Enrolment will typically be less, perhaps substantially less, than the number of places installed due to dropouts and repetitions leaving upper-grade classrooms only partially filled; similarly, student absences on any given day will leave classrooms only partially utilized. The ratio of utilization to capacity provides, we suggest, the appropriate measure of the quantitative efficiency of a school system. (The concept of qualitative efficiency, which relates the rate of learning to the expenditure per student-year of actual attendance, is more frequently discussed in the literature.) Miguel and Kremer (2004) find the major effect of deworming in Kenya to be on quantitative efficiency: treated children ended up acquiring 0.15 additional years of school, at only the cost of deworming because capacity limits had not been met. Orazem *et al.* (2009) stress the importance of explicit attention to these limits, which suggest corresponding limits on extent of potential impact of deworming absent complementary investments in educational infrastructure.

The preceding discussion has provided a structure for deworming in the context of interventions to affect educational outcomes. The examples developed by Jamison and Leslie (1990), and Horton and Hall (2009) and the Kenya work of Miguel and Kremer (2004) all point to the potential for *highly* attractive cost-effectiveness or BCRs from deworming's effect through school. In the 2008 Copenhagen Consensus assessment of educational

priorities deworming ranked high (Orazem *et al.*, 2009) as it also did in the context of assessing nutritional priorities (Horton *et al.*, 2008). And, as previously noted, the 2008 Copenhagen Consensus Expert Panel of distinguished economists (Bhagwati *et al.*, 2009) ranked school-based deworming number 6 in its assessment of 30 development priorities.

When turning to the health dimension of outcomes and cost-effectiveness there has been substantial recent controversy. The non-profit charity evaluator GiveWell, in its review of DCP2's estimates of cost per DALY found (in collaboration with the DCP2 authors) important errors that suggest (from a health perspective) that deworming may be far less cost-effective than thought. A major problem was an error in WHO's published disability weights for helminthic infection.[9]

Two related issues arise in trying to express health loss from worm infections in an aggregate measure like the DALY. The first is that the DALY loss from these infections is very little in mortality (YLLs) and very substantial in disability (YLDs). The effective disability weights are small but multiplied by an enormous number of infections. Whether the product is large or small depends entirely on the disability weights and we would assert that *estimating these small disability weights with any accuracy is far beyond the state of the art*. A second related problem is that the distribution of intensity of worm infections is highly "overdispersed," i.e. only a few people harbor most worms (Bundy *et al.*, 2004; Hall and Horton, 2009). Defining who is sick, and how sick, becomes rather arbitrary even though the definitions may be quite clear. We suggest that any discussion of the health-related cost-effectiveness for deworming not use DALYs and focus instead on costs per "real" outcome: person treated; infected person treated; "diseased" person treated (at greater than or equal to 10 worms, etc.). Hall and Horton (2009) provides an excellent example.

Delivering reproductive and child health interventions

The list of potential interventions is far from exhaustive and different regions, countries, and communities will face different mixes of the problems that these interventions address. However, there can be little dispute that any short list of intervention priorities for under-5 mortality in LMICs would include many on the list in the preceding sections. Why not, then, simply put money into scaling up these known interventions to a satisfactory level? In this section we first discuss constraints to scaling up and approaches to overcoming them. We next discuss a specific financial mechanism – the AMFm – in detail and conclude that its continuation and expansion is a high priority. Finally we discuss the neglected priority often accorded to the platform of essential surgery. Much of what surgical intervention addresses deals with complicated delivery, contraception (vasectomy, tubal ligation and subdermal hormones), and injury.

Overcoming implementation constraints

To greatly oversimplify – and these issues are discussed more substantially in Mills *et al.* (2006) – two schools of thought exist. One line of thinking – often ascribed to the macroeconomist Jeffrey Sachs and his work as chair of the WHO CMH – concludes that more money and focused effort *are* the solutions. Although acknowledging dual constraints – of money and of health system capacity – Sachs and his colleagues (WHO CMH, 2001; Sachs, 2005) contend that money can buy (or develop, or both) relevant system capacity even over a period as short as five years. Major gains are affordable and health system capacity constraints can be overcome. Immunization provides an example of where, even in the short term, money can substitute for system capacity. Adding newer antigens to the immunization schedule is costly (although still cost-effective). In some environments, however, it proves less demanding of system capacity than expanding coverage does. Money can be effectively spent by adding antigens at the same time as investing in the capacity to extend coverage.

A second school of thought acknowledges the need for more money but asserts that health system capacity is often a binding short- to medium-term

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[9] See http://blog.givewell.org/2011/09/29/errors-in-dcp2-cost-effectiveness-estimate-for-deworming/.

constraint on substantial scaling up of interventions. Van der Gaag (2004) emphasized this point in his critique of an earlier Copenhagen Consensus paper on health. Critical priorities are, therefore, system reform and strengthening while ensuring that such reforms focus clearly on achieving improved health outcomes and financial protection.

This chapter's perspective is closer to that of Sachs than of Van der Gaag while emphasizing the need (on p. 400) to be explicit about intervention costs that are non-financial. This points both to the need for considering how to relax these constraints and to selecting interventions in part on the extent to which they are less demanding of non-financial inputs. Frenk *et al.* (2006) and Sepúlveda *et al.* (2006) have described a "diagonal" approach being used in Mexico where systems are strengthened while focusing on specific disease outcomes. Experience suggests that while such an approach demands considerable management, it is highly effective.

Against a backdrop of low immunization coverage in Africa, Malawi, one of the poorest countries in the world, has succeeded in boosting immunization coverage against measles from only 50 percent in 1980 to almost 90 percent today. Malawi undertook a program to raise routine measles immunizations, including campaigns to catch children missed out by routine efforts. As a result, the number of reported cases and deaths has fallen dramatically. During 1999, only two laboratory-confirmed cases were reported and, for the first time ever, no measles deaths. Yet only two years earlier, almost 7,000 measles cases were reported and 267 deaths (both of which are likely to be undercounts). This was achieved despite one in five of the population not having access to health services, fever than 50 percent having access to safe water, and only 3 percent having access to adequate sanitation (Jha and Mills, 2002).

Mills *et al.* (2006), as indicated, discussed these issues further in the context of all the problems facing a health system. From an individual country's perspective, however, if financial resources are available, the question is very much an empirical one: to what extent can those resources be effectively deployed in buying in interventions, in buying out of prevailing system constraints, and in investing in relevant system capacity for the future? Accumulating experience suggests that, to be successful, these choices will involve sustained funding to achieve specific outcomes (Jha *et al.*, 2002; Crogan *et al.*, 2006).

The AMFm

Innovations in financing and delivery have been a key feature of global health investments during the past decade. The number of privately initiated, publicly funded innovative financing mechanisms includes GAVI (for vaccines), the Global Fund for AIDS, TB, and malaria (for anti-retrovirals, TB drugs and diagnostics, bednets and drugs for malaria), Advance Market Commitments (for pneumococcal and other vaccines), and, more recently, the AMFm. The AMFm was created in 2010 as a separate arm of the Global Fund to implement the pilot phase of a high-level subsidy for ACTs in eight countries in SSA. The original idea of AMFm was mooted by the IOM committee as a response to the problem of growing artemisinin monotherapy use in the retail shops where treatment for malaria is most frequently obtained. And artemisinin monotherapy could increase the likelihood of parasite resistance to artemisinins, the last major class of compounds that are still effective against malaria parasites. ACTs were available in some public sector facilities through donor financing and in the private sector at a cost of between \$8 and \$12, which is out of the reach of all but the wealthiest section of the population in malaria-endemic countries. Artemisinin monotherapies, and monotherapies of the drugs used to protect artemisinin in ACTs, were typically available at far lower prices, with the obvious behavioral consequences.

A high-level subsidy for quality ACTs, it was argued, would crowd out monotherapies from the informal private sector, increase access to these drugs in both public and private sectors, lower ACT prices by ensuring stable and high demand, and lower incentives for sales of counterfeit and expired artemisinin drugs. Since the cost of delivering the drugs would be borne largely by private sector supply chains, the donor cost of the subsidy would be restricted to the difference between the unsubsidized wholesaler price and the subsidized price.
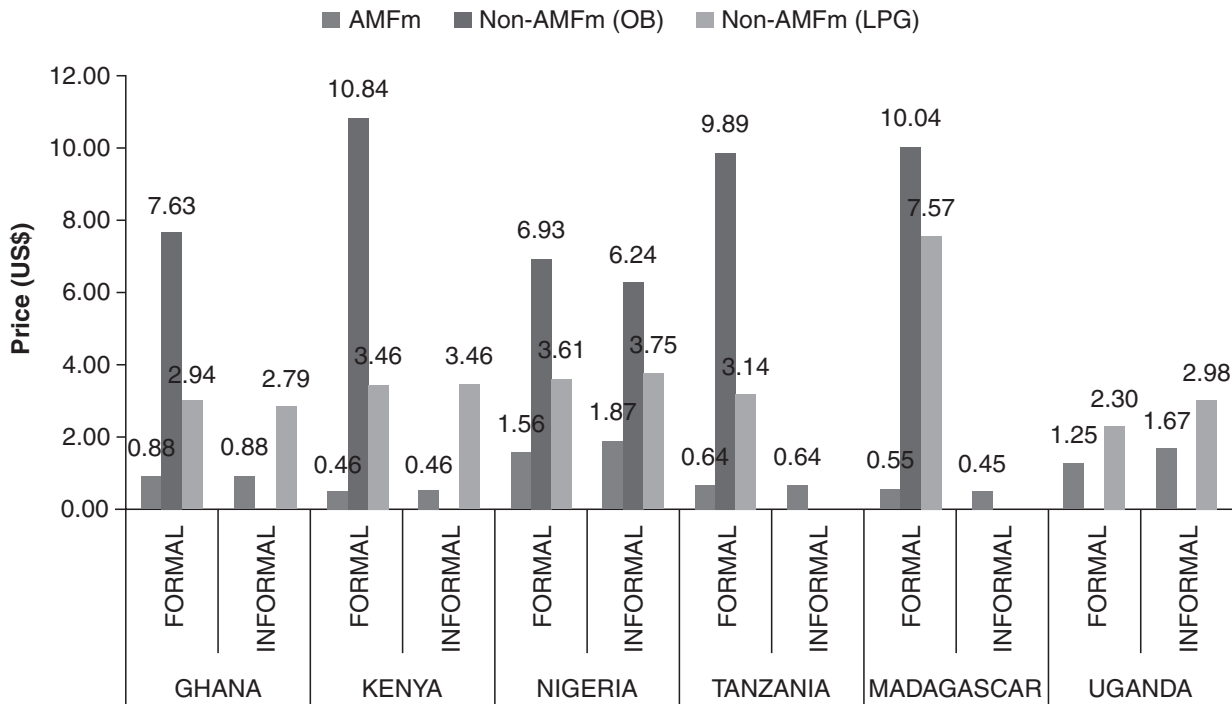
Figure 7.4 *Median prices of AL 20/120 mg (pack size 6 × 4), by country: AMFm versus non AMFm*

Note: OB: Other brands; LPG: Lowest-priced generic

Early cost-effectiveness estimates based on sophisticated mathematical models of malaria transmission and resistance indicated that a child death could be averted at roughly $1,000 (Laxminarayan *et al.*, 2006c). Similar estimates are obtained through back-of-the-envelope calculations. US$1 million spent on a subsidy would expand access to 300,000 more children with malaria (based on 67 percent of AMFm ACTs being pediatric formulations), treat 20,000 severe malaria cases, and avert roughly 1,000 child deaths. This calculation does not include the benefits associated with averted resistance because of crowding out artemisinin monotherapy, the benefits of lower counterfeit drugs use, or of price reductions because of stabilized demand for ACTs. According to one model-based study, the discounted externality benefits of resistance reduction including (a) the reduction in malaria transmission from infected to susceptible individuals due to increased overall drug treatment and (b) the increase in average drug effectiveness, which benefits treated patients themselves as well as reducing infection transmission from them to other individuals; and less the discounted gross distortionary cost of the subsidy, is about 6:1 (Laxminarayan *et al.*, 2010).

Early evidence from the AMFm pilot indicates that the goal of lowering ACT prices relative to other drugs in the retail sector has been achieved in nearly all AMFm countries (see Figure 7.4). The ratio of the price of a full course of AMFm-subsidized ACTs to the price of a full course of the lowest-priced generic ranges from 1:2 in Nigeria and Uganda to 1:14 in Madagascar. The ratios are even more stark when the price of AMFm drugs is compared to the price of non-AMFm branded drugs, and range from 1:3 in Nigeria to 1:23 in the Kenyan formal sector. A full independent evaluation of the AMFm pilot has been commissioned by the Global Fund board and is expected in September 2012. This should shed more light on the utility of this novel market-based mechanism in drug delivery, and inform a future course of action once the large-scale pilot funding runs out in December 2012. One of our 2012 Copenhagen Consensus solutions is that continued funding for AMFm should claim high priority.

Essential surgery

Almost one in ten pregnancies in developing countries result in deliveries with major complications – heavy bleeding, torn tissues, or obstruction to the child's passage, that leads to days of extreme pain and often death for the mother and child. Dealing with these problems usually requires surgical intervention (although not necessarily by a board-certified surgeon or obstetrician.) A range of correctable problems of the very young also require surgical intervention and the global community has advanced "safe motherhood" initiatives to strengthen the national capacity to deal with these problems. The same skill sets – surgery, anesthesia, nursing – that can respond to complications of pregnancy can also respond to a range of other problems, most prominently trauma including burns but also a range of abdominal problems and suppurative infections common in developing countries (see Mock *et al.* (2009) for a discussion of priority areas for essential surgery).

Debas *et al.* (2006) in DCP2 decided to undertake a CEA of a modest district hospital (100-bed) with some degree of surgical capacity rather than to look at the cost-effectiveness just of obstetric or other specific surgical interventions. The reasoning is that investment in expanding capacity or improving quality are, at this *platform* level, a platform that responds to multiple and diverse problems. For undertaking a CEA they assessed all the costs of operating the district hospital surgical platform for a year. For effectiveness they looked, in different epidemiological environments, at the annual mix of admissions and at the consequences (using best judgment to apportion part of the consequence to surgical intervention). An early example of this platform analysis comes from Bangladesh, where low costs and substantial numbers of (probably) obstetric deaths averted led to highly favorable cost-effectiveness estimates. (McCord and Chowdhury, 2003). The best estimates of cost per DALY for what we might call "essential surgery" range across geographical regions from $40–$100, with their high estimates at about twice their best estimates (Debas *et al.*, 2006).

Why might such surgery appear so cost-effective? Like the drugs for malaria, TB, HIV/AIDS pneumonia, and other infectious killers, a one- or two-hour surgical procedure can change outcomes decisively: from death to a four-week recovery or from being seriously crippled for life to having a mild limp. Very basic surgery can achieve these outcome changes at modest cost.

HIV/AIDS

For dozens of countries around the world – including several of the most populous – the HIV/AIDS epidemic threatens every aspect of development. No other threat comes close, with the possible exceptions of use of nuclear weapons in densely populated areas or a devastating global pandemic similar to the 1917–1918 influenza episode. Most governments of affected LMICs and most providers of development assistance have only recently begun to respond more than minimally at the beginning of the twenty-first century. The creation of the Global Fund to Fight AIDS, Tuberculosis, and Malaria can be viewed as an attempt of the world's top political leaders to improve on the records of existing institutions. The Global Fund's initial years have seen substantial success, but as this volume goes to press that success is being undermined by sharp constraints on resource availability, as was foreseen by Bezanson (2005).

Thirty years have passed since the recognition of the infectious disease now named acquired immune deficiency syndrome (AIDS). In that relatively short time HIV/AIDS has killed over 30 million individuals, and an additional 33.3 million people are now living with the infection. Africa shoulders the burden of the epidemic: UNAIDS estimates that in 2009 1.3 million people died from AIDS in Africa, 22.5 million were living with the infection, and a further 1.5 million acquired the infection during the year. Even though prevention and treatment programs are expanding, the epidemic is holding its ground. Only two out of every five people requiring anti-retroviral therapy currently have access to treatment – and this number is threatened by financial pressures. Though universal access to treatment is a morally compelling goal, the high costs associated with treatment argue for a

strategy that emphasizes prevention (See Hecht *et al.*, 2010; UNAIDS *et al.*, 2010).

In contrast to the initially slow programmatic movement of most national leaders and international institutions, the R&D community – public and private – has made rapid progress in developing tools to control the HIV/AIDS epidemic. Sensitive, specific, and inexpensive diagnostics are available; means of prevention have been developed and tested; modes of transmission are well understood; and increasingly powerful drugs for controlling the viral load allow radical slowing of disease progression. Tools for dealing with HIV/AIDS are thus available: Bertozzi *et al.* (2006) emphasized that a number of countries have shown by example that those tools can be put to effective use. Most of the high-income countries have done so, and Brazil, Mexico, and Thailand provide examples of upper-middle-income countries that have forestalled potentially serious epidemics (del Rio and Sepúlveda, 2002).

This section first discusses behavioral prevention and medical then vaccine development. It closes with a discussion of anti-retroviral therapy. It draws importantly on papers prepared for the 2011 Copenhagen Consensus RethinkAIDS exercise.

Prevention of HIV transmission

The reasons for the variations in prevalence between countries are not entirely clear despite substantial research. It is now established that high levels of male circumcision protect against HIV/AIDS transmission at the population and individual level (Abdool Karim, 2007). High levels of genital ulcer disease and low levels of male circumcision may help to explain the high levels of HIV/AIDS infection seen in southern and eastern Africa. These conditions also include high levels of paid sex and partner change, common sexually transmitted infections (STIs), low condom use rates, male mobility and migration, and low rates of male circumcision. These points suggest the opportunities for preventive intervention.

The key challenge for HIV/AIDS policy is to prevent HIV transmission. In the absence of a vaccine, several interventions are of key importance. For the Copenhagen Consensus effort Rethink HIV,

Bollinger (2012) reviews the benefits and costs of options for presenting non-sexual transmission, and Behrman and Kohler (2010) assess sexual transmission. The most clearly effective preventive interventions against HIV/AIDS are those targeting groups that – because of high rates of partner change, increased susceptibility to infection, or both – are highly vulnerable. Peer interventions among sex workers teach them high levels of condom use, control of STIs, and client negotiation skills that appear highly effective. Sex workers and their clients represent an important vulnerable group who are central to the spread of HIV/AIDS in most populations, including in Africa, and vulnerable groups might even be important in early as well as late stages of the epidemic (Chen *et al.*, 2007). In some contexts fewer than one sex worker would need to be covered in a program for one year to prevent one infection (Jha *et al.*, 2001).

A few countries in Asia with conditions for rapid growth in HIV/AIDS infections acted early by scaling up vulnerable group interventions. Their common principles were to work with the commercial sex industry, map where it occurs, aim for high coverage, and base action on solid epidemiological information. The results are impressive. Thailand is the most famous example, where HIV/AIDS peaked in the early 1990s and has stayed at below 2 percent seroprevalence since. Less known are Mexico (del Rio and Sepúlveda, 2002) and Cambodia, which copied the Thai "100 percent condom" program in commercial sex in 1997 in one state, and has shown impressive declines in HIV/AIDS. More recent evidence from the four southern states of India suggest that new HIV/AIDS infections might have dropped by 30 percent, probably due to change in sex workers (either the proportion using condoms or men going less often to sex workers, Kumar *et al.*, 2006).

Other measures that complement vulnerable group interventions are effective. Despite controversy about the evidence, the best judgment is that STIs remain important as risk markers and risk factors for HIV/AIDS spread. STI treatment for vulnerable and general populations is probably effective for HIV/AIDS control. Voluntary counseling and testing has led to some reduction in unsafe behavior in some studies, though the duration of

the change is not clear. However, such testing is not necessarily a cost-effective form of prevention in all or even most settings, especially where prevalence is low. Voluntary testing is, however, a necessary prerequisite to some forms of treatment.

Although the transmission of HIV/AIDS from mother to child is not of great epidemiological importance, since the infected children are very unlikely to transmit the disease, it is a mode of transmission that can be blocked. Short courses of single anti-retrovirals can halve the transmission risk from about 40 percent to 20 percent. To be fully effective, replacement feeding is also required, given that breast milk is a source of transmission. Finally, needle exchange and blood safety programs can reduce these less common modes of transmission.

More broadly, prevention efforts appear to work best when there is national leadership and simultaneous, sustained investment in multiple approaches to prevention, including efforts to reduce the stigmatization of vulnerable groups. Increasing the availability of condoms for the wider population can be enabling of more focused action. For example, the proportion of Senegalese women easily able to procure condoms rose from below 30 percent to 80 percent between 1992 and 1997. Focused information campaigns aimed at building public support and awareness are also seen to be important, although these are not likely to change behavior by themselves, but reinforce the message of simultaneous use of multiple interventions.

In those SSA countries with generalized epidemics that have spread far beyond vulnerable groups, a national approach is a necessity. The reasons for the sharp decline in HIV/AIDS prevalence in Uganda, from about 20 percent in 1990 to 10 percent in 1999, are widely debated. It may be due, at least in part, to a broad-based prevention strategy addressed at the population as a whole, or due simply to the fact that high death rates among the most susceptible helped the epidemic to decline (James, 2005). The replicability of the Ugandan experience to lower-prevalence settings has not been established.

Bertozzi *et al.* (2006) point out that even by 2003 fewer than one in five people at high risk of infection had access to the most basic preventive services. In much of the world, little has been spent on prevention, and little has been achieved. In addition, fundamentalist factions in both national governments and the development assistance community may be partially responsible for discouraging condom use in some countries and in stigmatizing and alienating commercial sex workers who are particular priorities for prevention programs. Despite those problems, the potential for prevention is very real, and a number of successful countries have shown the possibility of using that potential well. While evaluations of single interventions have often failed to find an impact, the countries that have mounted major programs of "combination prevention" have often achieved substantial success. The ingredients in the combination cocktail will vary by location, but Peter Piot has argued that there is now reasonable evidence for its general success (Piot *et al.*, 2008). Combination prevention was on the solution list for the 2008 Copenhagen Consensus.

AIDS vaccine development

An AIDS vaccine[10] is the ultimate preventative tool – vaccination would provide a manageable and affordable way to confer protection against HIV infection. When fully developed and licensed, an AIDS vaccine could have a powerful and immediate impact; the International AIDS Vaccine Initiative (IAVI) estimates that an AIDS vaccine of 50 percent efficacy given to just 30 percent of the population could reduce the number of new infections in the developing world by 24 percent in 15 years (IAVI, 2009). Yet AIDS vaccine development is proving to be enormously expensive. Is the perhaps $15–20 billion of additional resources that it may cost the world to develop an AIDS vaccine worth it?

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[10] We use the term "AIDS vaccine" to denote the probable set of vaccines that could emerge from ongoing development efforts. Hypothetical values of vaccine cost and efficacy in this chapter are for the best (mix) to emerge over time, and in a more extended assessment the sensitivity of the CBA results to these parameters would be evaluated. We limit our discussion in this chapter to vaccines that prevent infection, but it is important to note that efforts are also under way to develop vaccines that strengthen the immune system's response to established disease. Animal trials have generated hope for the prospects of this type of vaccine (Maurice, 2011).

One of the papers in the 2011 RethinkHIV project addressed the potential returns to expanding the technological base through development, manufacture, and utilization of a vaccine to prevent HIV infection (Hecht and Jamison, 2012). That paper did not argue for investment in vaccine development at the expense of ongoing HIV prevention or treatment interventions. Rather, it examined the proposition that accelerated investment in AIDS vaccine development would have high benefit relative to cost – and hence justify diversion of resources from less productive development assistance investments.

The current and likely future sources of funding for vaccine development come from parts of the public sector that differ from those that fund AIDS control. Private sector product development funds likewise do not come at the cost of control money. Only in foundations is there likely to be genuine fungibility between product development resources and control sources. In this environment the role of the 2012 Copenhagen Consensus is perhaps not that of trading-off vaccine development resources with resources for attractive control options. Rather, a conclusion that the economic attractiveness of a continued vaccine development effort is high relative to other development assistance options would be *signaled* by perhaps modest allocation of control resources to vaccine development by the Expert Panel. That new products such as potential AIDS vaccines constitute international public goods – unlikely to be domestically financed by developing countries – is an additional factor. The RethinkHIV paper compared continued vaccine development efforts to a base scenario of discontinued funding and it also estimated what the benefits would be if additional funding were to reduce the time until a vaccine becomes available. The RethinkHIV Panel placed accelerated vaccine development at the top of its list of priorities, and this Challenge Paper places it on the short list of six solutions, replacing the expansion of combinations of existing means of prevention.

Hecht and Jamison (2012) assessed the consequences of scaling up funding to reduce the amount of time it takes to develop an AIDS vaccine. They assumed modest but real time savings from an additional $100 million dollar expenditure p.a. (over the approximately $900 million p.a. current rate of expenditure). The $100 million figure was based on interviews with vaccine experts, who argued that the award of five–ten packages of $10–20 million a year over a decade to carefully selected research consortia would substantially accelerate progress. They assumed that an 11 percent increase in vaccine R&D ($100 million more each year) would correspond to a shortened time to product launch of 0.4–1.0 years (with much uncertainty). Assuming first a 1.0-year gain, the time to vaccine approval would be eighteen years as opposed to nineteen years in the base scenario. This implies that an additional $100 million dollar expenditure p.a. would increase the total discounted funding requirement from $13.9 billion to $15.4 billion. However, shortening the time to approval would also decrease proportionally the number of years in which one would have to pay development costs. Because of this shortened period of expenditure, the (discounted) funding requirement would result in a net increase to $14.6 billion. The calculation of discounted R&D financing for accelerating vaccine development by 0.42 of a year follows the same steps as those outlined above.

What would be the benefits of such accelerated vaccine development? To calculate this, Heent and Jamison used the estimated benefits from receiving the vaccine in 2030 (or in 2040, under alternative assumptions about product launch), then calculated the incremental benefit associated with accelerating the time to vaccine development by 1.0 or 0.4 years. They found that for a $5,000 VSLY and a 5 percent discount rate, the benefits of advancing the approval time by 1.0 years is $73.5 billion (or $29.3 billion when the time gain is 0.4 years). From there, we estimate the BCR with sensitivity analyses around the VSLY and the discount rate. Even in the most conservative case of a $1,000 VSLY, a 3 percent discount rate, and a 0.4 year advance, the BCR exceeds 6:1. Table 7.5 shows the BCR of accelerating vaccine development under alternative assumptions. These findings make a strong case for increased funding to AIDS vaccine R&D, even though there is great sensitivity in benefit-cost to the underlying assumptions. For the 2012 Copenhagen Consensus we assume a $1,000 VSLY, a 5 percent discount rate, and an intermediate

Table 7.5 Hypothetical BCRs from advancing time of vaccine availability

Value of statistical life year (VSLY) ($)	Discount rate p.a. (%)	Years sooner that vaccine is available	
		1.0	0.4
1,000	3	26:1	6:1
1,000	5	18:1	4:1
5,000	3	106:1	22:1
5,000	5	71:1	16:1

Note: Entries in the table are BCRs.
Source: Hecht and Jamison (2012).

reduction in time to vaccine availability implying a BCR of 11:1.

Anti-retroviral treatment of AIDS

A primary focus on prevention strategies in the global response to HIV/AIDS reflects the fact that the future of the pandemic lies with those not yet infected. However, this cannot be taken as a reason to neglect the 33 million people currently living with the infection, two-thirds of them in Africa. Prophylaxis or treatments for some of the opportunistic infections that contribute to HIV/AIDS mortality are cost-effective (most notably antibiotics effective against TB). Since 1996, highly active anti-retroviral therapy has increased the life expectancy of people on treatment considerably. In developed countries, anti-retroviral therapy has dramatically reduced but not eliminated AIDS mortality. Reduction in the viral load slows or halts the progression of AIDS and can return individuals from serious illness to reasonable health. Available drugs leave a residual population of HIV in the body, however, and this population grows if the drugs stop. At present, the drugs must be taken for life. Widespread use of these drugs in high-income (and some middle-income) countries has transformed the life prospects of HIV-infected individuals and the RethinkHIV paper on treatment (Over and Garnett, 2011) found an attractive BCR for expanded treatment.

Early-generation anti-retroviral drugs suffered notable shortcomings: they were enormously costly; regimens for their use were complicated, making adherence difficult; their use generated unpleasant side effects; and rapid evolution of HIV led to resistant mutants that undermined the efficacy of therapy. In a remarkably short time scientific advances have substantially attenuated those problems, making feasible, at least in principle, anti-retroviral therapy in low-income settings. WHO's "3 by 5" program had as its objective, for example, to reach 3 million people in LMICs with anti-retroviral therapy by 2005. That goal was met (by 2007) and the global effort to make treatment widely available is well under way. An important contributor has been the Clinton Foundation's effort to negotiate reductions in the prices of first-line and, more recently, second-line drugs.

Despite the indicated progress against the problems with anti-retroviral drugs, challenges to their effective use in low-income environments remain formidable. The complexity of patient management is very real. Management requires high levels of human resources and other capacities in many of the countries where those capacities need to be most carefully rationed. Perhaps in consequence, achieving effective implementation has been difficult on even a limited scale. Bertozzi *et al.* (2006) review those problems and how they might be addressed.

Three points concerning widespread anti-retroviral drug use are particularly noteworthy:

- Poor implementation (low adherence, development of resistance, interruptions in drug supplies) is likely to lead to very limited health gains, even for individuals on therapy. (This outcome is unlike that of a weak immunization program in which health gains still exist in the fraction of the population that is immunized.) Poorly implemented anti-retroviral drug delivery programs could divert substantial resources from prevention or from other high-pay-off activities in the health sector. Even worse, they could lead to a false sense of complacency in affected populations: evidence from some countries suggests that treatment availability has led to riskier sexual behavior and increased HIV transmission.

The injunction to "do no harm" holds particular salience.

- Unless systematic efforts are made to acquire hard knowledge about which approaches work and which do not, the likelihood exists that unsuccessful implementation efforts will be continued without the appropriate reallocation of resources to successful approaches. Learning what works will require major variations in approach and careful evaluation of effects. Failing to learn will lead to large numbers of needless deaths. Most efforts to scale up anti-retroviral therapy unconscionably fail to commit the substantial resources required for evaluation of effects. Such evaluations are essential if ineffective programs are to be halted or effective ones are to receive more resources. While this point about learning from evaluation applies more generally, it is particularly salient for HIV/AIDS treatment.

- Many programs rely exclusively on the cheapest possible drugs, thereby risking problems with toxicity, adherence, and drug resistance. From the outset a broader range of drug regimens needs to be tested.

Use of anti-retrovirals is likely to have a BCR greater than 1 in many circumstances. However if it competes with other highly attractive health investments in environments with limited human and financial resources, widespread adoption needs to be carefully sequenced.

Control of TB

TB is the leading cause of adult death from infectious disease after HIV/AIDS. Nearly 9 million new cases and perhaps 1.6 million deaths were caused by TB globally in 2003, with over 90 percent of these in LMICs. TB, like HIV/AIDS, causes deaths in productive working age, and can thus be a trigger into household poverty. Only a small percentage of those infected with the TB bacillus go onto to active disease such as pulmonary TB. Key risk factors for active TB include poverty, household crowding, and smoking (Pai *et al.*, 2006).

TB can be controlled by preventing infection, by stopping progression from infection to active disease, and by treating active disease. The principal intervention is the "directly observed therapy, short-course" (DOTS) strategy and its variations, centered on the diagnosis and observed treatment of the most severe and most infectious (smear-positive) forms of TB but including treatment for smear-negative and extra-pulmonary cases as well. Anti-TB drugs can also be used to treat latent infection and active TB in patients with HIV coinfection. The widely used BCG vaccine prevents severe forms of TB in childhood (Dye and Floyd, 2006).

The cornerstone of TB control is the prompt treatment of active cases using first-line drugs, administered through the DOTS strategy which has five elements: (i) political commitment; (ii) diagnosis primarily by sputum-smear microscopy among patients attending health facilities; (iii) short-course chemotherapy with three–four drugs including effective case management (including direct observation of treatment); (iv) a regular drug supply; and (v) systematic monitoring to evaluate the outcomes of every patient started on treatment.

The MDGs call for halting and beginning to reverse new cases of TB by 2015 and the Stop TB Partnership calls for halving prevalence and deaths by 2015 relative to 1990 rates. It has been estimated that these goals can be reached if 70 percent of new infectious (smear-positive) cases world-wide are detected and 8 percent of those cases are treated successfully with the DOTS regime.

WHO and others have focused their operational efforts in high-burden countries, and progress has been impressive. The case-detection rates has increased from 11 percent globally in 1996 to 53 percent in 2004 and over 21 million TB patients have been treated in DOTS programs in the decade since 1994. China and India have been noted as having particularly strong programs – although rigorous evaluation of the mortality impact of TB programs awaits. Key challenges remain the spread of HIV/AIDS infection in parts of Africa and drug resistance, especially in Eastern Europe. This suggests that DOTS alone might not be able to bring TB under control, especially in Africa and in the countries of the FSU.

The cost-effectiveness of TB control has been well established (summarized in Dye and Floyd, 2006), but more recently Laxminarayan *et al.* (2007) have calculated the cost-benefit of the WHO DOTS strategy at current levels relative to having no program in place. This finds that using VSL of roughly 100 times *per capita* GDP, the net gain is about $1.7 trillion versus program costs of $18.3 billion in the twenty-two high-burden countries. The ratio of the marginal benefits of implementing a global plan for DOTS to their costs were a factor over 15 in the twenty-two high-burden countries, and a factor of 9 in the Africa region. These estimates are thus in the plausible range with the values shown on p. 418.

The minor change in the 2012 Copenhagen Consensus recommendation on TB relative to CC08 lies in an explicit concern for dealing with multi-drug-resistant (MDR) TB as an integral part of an overall control strategy. This helps preserve available drugs for continued use and provides (partial) insurance against a disastrous breakout of MDR TB. However, addressing resistance increases costs, despite the long-term insurance value, and the short-term benefits in averted deaths are limited. Although TB treatment remains on our solutions list it appears slightly less attractive than before for reason of cost.

Opportunities for disease control

The preceding three sections identified a range of attractive options for disease control based, for the most part, on the 315 interventions that DCP2 reviewed (Jamison *et al.*, 2006b). Laxminarayan *et al.* (2006a) summarized DCP2's main findings on cost-effectiveness which form the basis for the CBAs reported here. One thing that is clear in the summarization of the cost-effectiveness information is that there is a broad range of reasonable estimates for most interventions. This is partly due to incomplete information and uncertainty. Even more importantly, it is also due to the responsiveness of the cost-effectiveness function to variations in prices, to the scale of application of the intervention (and of its substitutes and complements), and to the epidemiological environment.

Given these often broad ranges in cost-effectiveness ratios, and hence in BCRs, it makes little sense to conclude with precise estimates of uncertainty or effect size. Rather we have identified six solutions for investment in interventions that address a large disease burden highly cost-effectively even granted substantial uncertainty and variability in the underlying estimates. Even valuing DALYs at a conservative $1,000 and, again conservatively, reducing by 50 percent the DALY loss associated with an under-5 death (this affects the malaria and immunization numbers) the BCRs associated with investing in these opportunities is enormously high. In the Appendix we provide a brief assessment of the sensitivity of our findings to key assumptions.

This concluding section provides three summarizing tables on our six solutions. Table 7.6 summarizes what the solutions consist of and the sources of our economic evaluations. Table 7.7 summarizes our results in a simple "dashboard" and Table 7.8 relates our conclusions to the conclusions in the related areas of the 2008 Copenhagen Consensus.

Table 7.6 presents our solutions. Three are interventions in the traditional sense (those dealing with TB, immunization, and deworming). One is a pricing policy instrument (AMFm), one is a product development investment (HIV vaccines), and one is a platform carrying multiple, diverse interventions (essential surgery). All promise extraordinary benefit for cost. Two of the six solutions are preventive (the two dealing with vaccines) and the other four provide treatments.

Table 7.7 is presents a "dashboard" rather than a league table to summarize our solutions. Every opportunity in the table has not only a very high estimated BCR but also addresses a major disease burden. The interventions that would address the most DALYs are TB treatment (1) and district hospital surgery (5). Both would provide relatively a high degree of financial protection to populations.

Table 7.8 compares the results in Table 7.7 to those of CC08 and shows substantial carryover. The early success of the AMFm and increasing signs of promise in AIDS vaccine development led to their inclusion for CC12.

With the exception of surgery in the district hospital, the opportunities identified do not

Table 7.6 Summary of solutions

Solution	Economic evaluation
1. Tuberculosis treatment This solution involves expansion of coverage of the WHO-recommended treatment algorithm, directly observed therapy, short course (DOTS). Despite the label "short course" treatment requires six months of observed drug use with concomitant expense, but DOTS has proved highly effective in practice in reducing mortality. For CC12 we include attention to dealing with multi-drug resistance TB (MDR-TB).	Cost-effectiveness numbers are drawn from DCP2 (Jamison *et al.*, 2006a). The resulting cost per DALY is converted to a BCR by valuing a DALY at $1,000 (or $5,000). See also Laxminarayan *et al.* (2007a).
2. Malaria: support for AMFm The two previous mainline anti-malarial drugs, chloroquine and SP, lost efficacy in much of the world in the 1990s because of resistance. Both drugs were highly efficacious and inexpensive, whereas artemisinin derivatives, although effective, are far more expensive. The AMFm operates from the Global Fund to provide manufacturers' subsidies for artemesinin in combination with another drug in order to provide access to the effective treatment while undercutting prices of monotherapies.	CBAs match total costs, including subsidies, against the DALY gains (drawing on DCP2) then convert to dollar benefits at $1,000/DALY. See also Laxminarayan *et al.* (2010).
3. Childhood immunization This solution involves increased coverage of the six vaccines in the WHO-designated "Expanded Program on Immunization"	CBAs are based on DCP2 cost-effectiveness analyses with DALYs valued at $1,000. The estimates here are broadly consistent with assessments of the economic value of ongoing global immunization programs (Ozawa *et al.*, 2011; Stack *et al.*, 2011).
4. HIV: accelerated vaccine development This solution involves increasing the rate of expenditure on HIV vaccine development from about $500 million per year to about $1 billion per year.	The CBA was undertaken for the Copenhagen Consensus RethinkHIV project using methods like those of CC12.
5. Essential surgery This solution involves strengthening surgical capacity at the district hospital to better deal with trauma or obstructed labor.	CBAs are based on DCP2 cost-effectiveness analyses with DALYs valued at $1,000.
6. Deworming schoolchildren Over a billion individuals are infected by intestinal worms for which there is inexpensive, highly effective drug treatment. Children are the worst affected. Reinfection entails the need for continual deworming at a rate of once or twice a year. Great heterogeneity in the intensity of infection implies similar heterogeneity in the benefits, which are here measured in increased quantity of schooling valued in terms of its impact on subsequent earnings.	CBAs for deworming are drawn but (subjectively) modified from those of CC08. The CC08 education paper (Orazem *et al.*, 2009) assessed deworming schoolchildren and the malnutrition paper (Horton *et al.*, 2008) assessed both school-based and community-based (for younger children) deworming. Numbers here follow the nutrition paper more closely.

explicitly address the strengthening of health system capacity. (Option 2, support for the AMFm, can in part be viewed as a substitute for strengthening capacity.) It will be important to ensure that implementation includes related investments in personnel and institutions, with "related" broadly defined. (By using long-term average costs for the cost-effectiveness analysis, these issues were implicitly, although mechanically, dealt with.) One might consider there to be two broad approaches to strengthening health systems. One involves

relatively non-specific investments in capacity and reforms of process. The second relies on learning by successfully doing and involves creating specific capacity to deliver priority services in volume and with high quality. In Option 2, capacity-strengthening spreads out from high-performing initial nodes. The approach that this chapter implicitly advocates is very much in the spirit of the latter.

From national perspectives the interventions on TB, on essential surgery, and on immunization and

Table 7.7 Disease control: investment solutions*a*

Solution	Indicative BCR	Level of capacity required	Financial risk protection provided	Relevance for development assistance	Annual costs ($ billion)	Annual benefits
1. Tuberculosis: appropriate case finding and treatment, including dealing with MDR-TB	15:1	M	H	M	1.5	1 million adult deaths averted or 30 million DALYs
2. Malaria: subsidy for appropriate treatment via AMFm	35:1	L	M	H	0.3	300,000 (mostly child) deaths averted or 10.5 million DALYs
3. Childhood diseases: expanded immunization coverage	20:1	L	L	L	1	1 million child deaths averted or 20 million DALYs
4. HIV: accelerated vaccine development	11:1	L	H	H	0.1	24% reduction in HIV/AIDS incidence fifteen years after introduction
5. Essential surgery: to address difficult childbirth, trauma and other	10:1	H	H	H	3	30 million DALYs
6. Deworming schoolchildren	10:1	L	L	L	0.3	About 300 million children dewormed

Note:
a This refers to level of capacity required for implementation in a developing country. While HIV vaccine development, for example, requires enormous scientific capacity, that capacity is functionary already where the development work would be undertaken.

malaria treatment appear as very high priorities. Given that, for whatever reason, these interventions remain underfunded, there is a reasonable argument that development assistance funds should address these needs and to an important extent they do (through the very substantial resources of GAVI and the Global Fund Against AIDS, Tuberculosis and Malaria).

Most valuable interventions are familiar interventions with only modest international externalities. There is a reasonable argument that development assistance should finance international public goods such as R&D (e.g. AIDS vaccine development) and help reduce the risks of adopting new areas of public investment (e.g. essential surgery in many countries). Development of resistance to effective drugs in one country generates very substantial negative externalities affecting all the others. AMFm, proposed by an IOM committee Kenneth Arrow, explicitly addresses these negative

externalities through pricing mechanisms that work through both the public and private sector. International support for TB control indirectly addresses these negative externalities by attempting to diffuse appropriate drug use protocol.

In the 2008 Copenhagen Consensus, TB treatment stood out as perhaps the most important investment on grounds of its high BCR, its high level of financial risk protection, its moderate systemic requirements, and in the size of disease burden potentially averted. Because of the explicit recognition in the 2012 Consensus of the costs of dealing with MDR TB we now list it overall on a par with the other five. Each of the other solutions have advantages and disadvantages relative to each other and different individuals might well order them differently. Our most general conclusion, however, is that even if all costs were increased by a factor of, say, 3 there is a substantial and very specific list of major and highly attractive investment

Table 7.8 Infectious disease, injury, and reproductive health: solutions in 2008 and 2012 Copenhagen Consensus exercises

Solution in CC08	Expert Panel ranking in 2008 Copenhagen Consensus (out of 30)	Related solution in the 2012 Copenhagen Consensus, Infectious diseases, reproductive health and injury chapters
1. TB treatment	13	Very similar but with more explicit emphasis on the need to treat multi-drug resistant (MDR-) TB as part of the treatment package H.
2. Malaria: package of treatment and preventative measures	12	The 2012 solution provides a much more focused malaria recommendation: financial support for the AMFm, which provides manufacturer-level subsidies for ACTs. By reducing the price of a resistance-postponing combination therapy the AMFm makes effective treatment affordable and undercuts prices of resistance-inducing monotherapies.
3. Childhood immunization	14	No change
4. HIV: combination prevention package	19	Proposes the rate of expenditure on HIV vaccine development. This recommendation was ranked number 1 by the CC Rethink HIV Expert Panel.
5. Injury, difficult childbirth: invest in surgical capacity at district hospital	21	No change except to be relabeled as "essential surgery" to reflect current nomenclature.
6. Deworming children at schools[a]	6	Little changed

Note:
[a] The deworming solutions proposed for 2012 were addressed in both the education and the nutrition Challenge Papers. The decision was made to have deworming addressed by this Challenge Paper.

opportunities for dealing with infectious disease, reproduction health, and injury. Table 7.8 compares the solutions proposed for the 2012 with those proposed for 2008 Consensus.

Appendix: sensitivity analysis

The analysis upon which we based the conclusions reported in Table 7.8 were undertaken under the following assumptions:

(1) The discount rate is 3 percent per year and the version of the DALY that was used is based on this 3 percent and no age-weighting. These are the assumptions used in the most recent presentation of methods, data sources, and results on the global burden of disease (Lopez *et al*., 2006b, 2006c). Earlier tabulations of the disease burden used age-weighted DALYs which give broadly similar results except that somewhat more weight is given to conditions of middle age (TB, maternal deaths, trauma, psychiatric illness).

(2) Jamison *et al*. (2006) of (Chapter 6 in Lopez *et al*. (2006b)) points to the mathematical impossibility of having the standard formulation of a DALY give a loss from a death at age 25 that is more than 20 percent greater than the loss from a death at age 1 day. An alternative version of the DALY is proposed there [DALY (3,0, 0.54)] and used in this chapter. The effect is to reduce the DALY loss of a death under age 5 by about 50 percent without changing the DALY loss from deaths at older ages.

(3) In an attempt to include relevant health systems costs and to take a long-run view, cost estimates in this chapter are based on long-run average costs (at least in principle, as there is some variation in actual costing methods).

(4) Cost analyses in this chapter assumes 0 dead-weight losses from taxation, but the analyses in this Appendix explore sensitivity to their valuation

Table A7.1 Sensitivity analysis

Change in assumption	Consequence
1. Change the discount rate from 3% to 6% p.a., i.e. change to DALYs (6, 0, 0.54)	The number of DALYs gained from each of the interventions and hence the BCR will decline by about 50%.
2. Change from DALYs (3, 0, 0.54) to DALYs (3,0)	The number of DALYs gained from immunization and from malaria control will approximately double, as will the BCR for the related interventions.
3. Since *ex ante* costs are typically underestimated, often substantially, multiply all costs by 3	The BCR will decline to one-third of its otherwise estimated value for all interventions.
4. The deadweight loss from taxation is increased from 0 to 50% of the revenue raised (Ballard *et al.*, 1985, provide estimates in this range).	The BCR value declines by one-third.
5. The value of a DALY is $5,000 rather than $1,000.	The BCR values go up by a factor of 5.

5. The chapter assumes the value of a DALY or of a VSLY to be $1,000.

Appendix Table A7.1 reports assessments of the robustness of our conclusions with respect to changes in these assumptions. On the most optimistic alternative assumption of Appendix Table A7.1 the BCR for immunization and for malaria would increase by a factor of 10; for the other interventions the factor is 5. Taking the least optimistic assumptions the BCR of all interventions would decline by a factor of 10.

If the BCR is being used by a government to decide whether to fund the relevant health program compared with other programs or saving the money, it should adjust the value of a DALY in line with its GNI *per capita*. To do so, it should multiply it by its GNI *per capita* and divide by 500. The BCR will move by the same factor.

If the BCR is being used to compare the interventions in this chapter with interventions that affect people in richer countries, it needs to be significantly increased to avoid discounting the value of the health effects just because they accrue to the world's poorest people. To do so, multiply the BCR by the GNI *per capita* of the country for whose citizens the WTP of the other interventions was estimated and then divide by 500. This could increase these ratios by as much as a factor of 100. Note that the "500" in each of these is because that is the current implicit estimate of the country's GNI *per capita*, so if you change the $1,000 per DALY figure, you would want to adjust these

proportionally – e.g. if you use $1,500 per DALY, then make these 750.

Bibliography

Abdool Karim, Q., 2007: Prevention of HIV by male circumcision, *British Medical Journal* **335**, 4–5

Abraham, K. G. and C. Mackie (eds.), 2005: *Beyond the Market: Designing Nonmarket Accounts for the United States*, The National Academies Press, Washington, DC

Acemoglu, D. and S. Johnson, 2007: Disease and development: the effect of life expectancy on economic growth, *Journal of Political Economy* **115**, 925–86

Aids2031 Costs and Financing Working Group, 2010: *The Long Term Fight Against AIDS*, Results for Development Institute, Washington, DC

Aral, S. O., M. Over, L. Manhart, and K. K. Holmes, 2006: Sexually transmitted infections, in A. R. Measham, D. T. Jamison, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn.

Arrow, K. J., 1963: Uncertainty and the welfare economics of medical care, *American Economic Review* **53**, 851–83

Arrow, K. J., H. Gelband, and D. T. Jamison, 2005: Making antimalarial agents available in Africa, *New England Journal of Medicine* **353**, 333–35

Bailey, R. C., S. Moses, C. B. Parker, K. Agot, I. Maclean, J. N. Kreiger, C. F. M. Williams, R. T. Campbell, and J. O. Ndina-Achola, 2007: Male

circumcision for HIV prevention in young men in Kisumu, Kenya: a randomised controlled trial, *Lancet* **369**, 643–56

Ballard, C., J. Shoven, and J. Whalley, 1985: General equilibrium computations of the marginal welfare costs of taxes in the United States, *American Economic Review* **74**, 128–38

Barr, N., 2001: *The Welfare State as Piggy Bank: Information, Risk, Uncertainty, and the Role of the State*, Oxford University Press

Bates, M. N., A. Khalakdina, M. Pai, L. Chang, F. Lessa, and K. R. Smith, 2007: Risk of tuberculosis from exposure to tobacco smoke: a systematic review and meta-analysis, *Archives International Medicine* **167**, 335–42

Becker, G. S., T. J. Philipson, and R. R. Soares, 2003: The quantity and quality of life and the evolution of world inequality, *American Economic Review* **95**, 277–91

Behrman, J. R. and H. P. Kohler, 2010: Assessment Paper, Sexual Transmission of HIV, Copenhagen Consensus on RethinkHIV

Bertozzi, S., N. S. Padian, J. Wegbreit, L. M. DeMaria, B. Feldman, H. Gayle, J. Gold, R. Grant, and M. T. Isbell, 2006: HIV/AIDS prevention and treatment, in D. T. Jamison, A. R. Measham, J. Berman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn.

Bezanson, K., 2005: *Replenishing the Global Fund: An Independent Assessment*, Global Fund, Geneva, 35

Bhagwati, J., F. Bourgignon, F. Kydland, R. Mundell, D. North, T. Schelling, V. Smith, and N. Stokey, 2009: Expert Panel Ranking, in B. Lomborg (ed.), *Global Crises, Global Solutions*, 2nd edn., Cambridge University Press, 657–79

Bloom, D. E. and D. Canning, 2006: Booms, busts and echoes: how the biggest demographic upheaval in history is affecting global development, *Finance and Development*, **43**, 8–13

Bloom, D. E., D. Canning, and G. Fink, forthcoming: Comment on Acemoglu and Johnson, *Journal of Political Economy*

Bloom, D. E., D. Canning, and D. T. Jamison, 2004: Health, wealth and welfare, *Finance and Development* **41**, 10–15

Bloom, D. E., D. Canning, and J. P. Serilla, 2004: The effect of health on economic growth: a production function approach, *World Development* **32**, 1–13

Bollinger, L., 2012: Assessment Paper on prevention of non-sexual transmission of HIV, Copenhagen Consensus on RethinkHIV

Bourguignon, F. and C. Morrisson, 2002: Inequality among world citizens: 1820–1992, *American Economic Review* **92**, 727–44

Breman, J. G., A. Mills, R. W. Snow, J. Mulligan, C. Lengeler, K. Mendis, B. Sharp, C. Morel, P. Marchesini, N. J. White, R. W. Steketee, and O. K. Doumbo, 2006: Conquering malaria, in D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 413–32

Brenzel, L., L. J. Wolfson, J. Fox-Rushby, M. Miller, and N. A. Halsey, 2006: Vaccine-preventable diseases, in D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 389–412

Bundy, D. A. P., M. S. Chan, G. F. Medley, D. Jamison, and L. Savioli, 2004: Intestinal nematode infections, in C. J. L. Murray, A. D. Lopez, and C. D. Mathers (eds.), *The Global Epidemiology of Infectious Disease*, World Health Organization, Global Burden of Disease and Injury Series, Vol. **IV**, Geneva, 243–300

Bundy, D. A. P., S. Shaeffer, M. Jukes, K. Beegle, A. Gillespie, L. Drake, S. F. Lee, A. M. Hoffman, J. Jones, A. Mitchell, D. Barcelona, B. Camara, C. Golmar, L. Savioli, M. Sembene, T. Takeuchi, and C. Wright, 2006: School-based health and nutrition programs, in D. Jamison, A. R. Measham, J. G. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 1091–1108

Canning, D., 2009: Perspective Paper 3.1 on disease control, in B. Lomborg (ed.), *Global Crises, Global Solutions*, 2nd edn., Cambridge University Press, 164–71

Chen, L., P. Jha, B. Stirling, S. K. Sgaier, T. Daid *et al.*, 2007: Sexual risk factors for HIV infection in early and advanced HIV epidemics in Sub-Saharan Africa: systematic overview of 68 epidemiological studies, *PLoS ONE* **2**(10), e1001 doi:10.1371/journal.pone.0001001

Claeson, M., D. Evans, P. Jha, A. Mills, and P. Musgrove, Oxford University Press, New York, 331–70

Clemens, M., S. Radelet, and R. Bhavnani, 2004: Counting chickens when they hatch: the short-term effect of aid on growth, *Working Paper* **44**, Center for Global Development, Washington, DC

Crafts, N. and M. Haacker, 2004: Welfare implications of HIV/AIDS, in M. Haacker (ed.), *The Macroeconomics of HIV/AIDS*, International Monetary Fund, Washington, DC, 182–97

Crawford, C. B., B. E. Salter, and K. L. Jang, 1989: Human grief: is its intensity related to the reproductive value of the deceased?, *Ethology and Sociobiology* **10**, 297–307

Crogan, T. W., A. Beatty, and A. Ron, 2006: Routes to better health for children in four developing countries, *The Milbank Quarterly* **84**, 333–58

Cutler, D., A. Deaton, and A. Lleras-Muney, 2006: The determinants of mortality, *Journal of Economic Perspectives*, **20**, 97–120

Davis, K., 1956: The amazing decline of mortality in underdeveloped areas, *American Economic Review* (*Papers and Proceedings*) **46**, 305–18

Debas, H. T., R. Gosselin, C. McCord, and A. Thind, 2006: Surgery, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 1245–60

de Savigny, D., H. Kasale, C. Mbuya, and G. Reid, 2004: *Fixing Health Systems*, International Development Research Centre, Ottawa

Del Rio, C. and J. Sepúlveda, 2002: AIDS in Mexico: lessons learned and implications for developing countries, *AIDS* **16**, 1445–57

Deworm the World, 2009: *Annual Report: Increasing Access to Education by Expanding School-Based Deworming*, www. dewormtheworld.org/sites/default/files/pdf/ DtW_AnnualReport_2009.pdf

Dye, C. and K. Floyd, 2006: Tuberculosis, in D. T. Jamison, A. R. Measham, J. Breman *et al.*, (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 289–310

Easterlin, R. A., 1996: *Growth Triumphant: The Twenty-First Century in Historical Perspective*, University of Michigan Press, Ann Arbor MI

England, S., B. Loevinsohn, B. Melgaard, U. Kou, and P. Jha, 2001: The evidence base for interventions to reduce mortality from vaccine-preventable diseases in low and middle-income countries, *CMH Working Paper Series* **WG5 10**, www.cmhealth.org/docs/wg5_ paper10.pdf

Ezzati, M. *et al.*, 2006: Comparative quantification of mortality and burden of disease attributable to selected risk factors, in A. D. Lopez *et al.*, *Global Burden of Disease and Risk Factors*, Oxford University Press, 241–396

Feachem, R. G. A., T. Kjellstrom, C. J. L. Murray, M. Over, and M. Phillips (eds.), 1992: *Health of Adults in the Developing World*, Oxford University Press, New York

Frenk, J. *et al.*, 2006: Bridging the divide: global lessons from evidence based health policy in Mexico, *Lancet* **368**, 954–61

Gajalakshmi, V. *et al.*, 2003: Smoking and mortality from tuberculosis and other diseases in India: retrospective study of 43,000 adult male deaths and 35,000 controls, *Lancet* **362**, 501–15

Gericke, C. A., C. Kurowski, M. K. Ranson, and A. Mills, 2003: Feasibility of scaling-up interventions: the role of interventions design, *Working Paper* **13**, Disease Control Priorities Project, Bethesda, MD

Graham, W. J., J. Cairns, S. Bhattacharya, C. H. W. Bullough, Z. Quayyum, and K. Rogo, 2006: Maternal and perinatal conditions, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 499–530

Global IDEA Scientific Advisory Committee, 2004: Health and economic benefits of an accelerated program of research to combat global infectious diseases, *Canadian Medical American Journal* **171**,

Haacker, M. (ed.), 2004: *The Macroeconomics of HIV/AIDS*, International Monetary Fund, Washington, DC

Hall, A. and S. Horton, 2009: Best practice paper: new advice from CC08 – deworming, Paper prepared for the 2008 Copenhagen Consensus www.copenhagenconsensus.com/Admin/Public/ DWSDownload.aspx?File=%2fFiles% 2fFiler%2fCCC%2fBest±Practice±Papers% 2fdeworming . . . .pdf

Hecht, R. J. and D. Jamison, 2012: Vaccine research and development, in B. Lomborg (ed.), *Rethink HIV*, Cambridge University Press

Hecht, R. J., J. Stover, L. Bollinger, F. Muhib, K. Case, and D. de Ferranti, 2010: Financing of

HIV/AIDS programme scale-up in low-income and middle-income countries, 2009–2031, *Lancet* **376**, 1254–60

Hoddinott, J. *et al.*, 2012: Chapter 6 in this volume

Horton, S., H. Alderman, and J. A. Rivera, 2008: Hunger and malnutrition, in B. Lomborg (ed.), *Global Crisis, Global Solutions*, 2nd edn., Cambridge University Press, 305–33

Hotez, P. *et al.*, 2006: Helminth infections: soil-transmitted helminth infections and schistomiasis, in D. T. Jamison *et al.*, *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University, Press, 467–82

Institute of Medicine (IOM), 1985: *New Vaccine Development: Establishing Priorities*. Vol. **1** of *Diseases of Importance in the United States* National Academies Press, Washington, DC

International AIDS Vaccine Initiative (IAVI), 2009: Estimating the potential impact of an AIDS vaccine in developing countries, IAVI, New York

James, J. S., 2005: Uganda study found that death reduced HIV prevalence: did the public take home the wrong message?, *AIDS Treat News*, February 25, 5–6

Jamison, D. T., 2006: Investing in health, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 3–34

  2008: Priority setting in health, Presentation at the Institution for Health Metrics and Evaluation-*Lancet* Conference on Global Metrics and Evaluation, Current State and Future Directions, Seattle, Washington

Jamison, D. T., L. J. Lau, and J. Wang, 2005: Health's contribution to economic growth in an environment of partially endogenous technical progress, in G. Lopez-casasnovas *et al.* (eds.), *Health and Economic Growth*, MIT Press, Cambridge, MA, 67–91

Jamison, D. T. and J. Leslie, 1990: Health and nutrition considerations in educational planning II: the cost and effectiveness of school-based interventions, *Food and Nutrition Bulletin* **12**, 204–14

Jamison, D. T. and S. Radelet, 2005: Making aid smarter, *Finance and Development* **42**, 42–6

Jamison, D. T., J. Sachs, and J. Wang, 2001: The effect of the AIDS epidemic on economic welfare in Sub-Saharan Africa, *CMH Working Paper* **WG1:13**, Commission on Macroeconomics and Health, World Health Organization, Geneva

Jamison, D. T., E. A. Jamison, and J. D. Sachs, 2003: Assessing the determinants of growth when health is explicitly included in the measure of economic welfare, Paper presented at the 4th World Congress of the International Health Economics Association, San Francisco, June

Jamison, D. T., M. Sandbu, and J. Wang, 2004: Why has infant mortality decreased at such different rates in different countries?, *Working Paper* **21**, Disease Control Priorities Project, Bethesda, MD

Jamison, D. T., A. R. Measham, J. Breman *et al.* (eds.), 2006a: *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York

Jamison, D. T., S. A. Shahid-Salles, J. Jamison, J. E. Lawn, and J. Zupan, 2006b: Incorporating deaths near time of birth into estimates of the global burden of disease, in A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray (eds.), *Global Burden of Disease and Risk Factors*, Oxford University Press, New York, 427–62

Jamison, E. A., D. T. Jamison, and E. A. Hanushek, 2007: The effects of education quality on income growth and mortality decline, *Economics of Education Review* **26**, 771–88

Jamison, D. T., P. Jha, and D. E. Bloom, 2008: Disease Control, in B. Lomborg (ed.), *Global Crisis, Global Solutions: Costs and Benefits*, Cambridge University Press, New York, 126–63

Jamison, D. T., P. Jha, V. Malhotra, and S. Verguet, 2012: The 20th century transformation of human health: its magnitude and value, in B. Lomborg (ed.), Cambridge University Press

Jha, P. and Z. Chen, 2007: Poverty and chronic diseases in Asia: challenges and opportunities, *Canadian Medical Association Journal* **177**, 1059–62

Jha, P. and A. Mills, 2002: Improving health of the global poor: The Report of Working Group 5 of the Commission on Macroeconomics and Health, World Health Organization, Geneva

Jha, P., A. Mills, K. Hanson, L. Kumaranayake *et al.*, 2002: Improving the health of the global poor, *Science* **295**, 2036–9

Jha, P., N. J. D. Nagelkerke, E. Ngugi, B. Wilbond, J. V. R. Prasada-Rao, S. Moses, F. A. Plummer, 2001: Reducing HIV transmission in developing countries, *Science* **292**, 224–5

Jha, P., R. Nugent, S. Verguet, D. Bloom, and R. Hum, 2012: Chapter 3 in this volume

Jha, P., D. Brown, N. Nagelkerke, A. S. Slutsky, and D. T. Jamison, 2005: Health and economic benefits of an accelerated program of research to combat global infections, *Canadian Medical Association Journal*, 172–6

Johansson, P. O., 1995: *Evaluating Health Risks*, Cambridge University Press

Joint Learning Initiative, 2004: *Human Resources for Health: Overcoming the Crisis*, Harvard University Press, Cambridge, MA

Kanbur, R. and T. Sandler, 1999: *The Future of Development Assistance: Common Pools and International Public Goods*, Overseas Development Council, Washington, DC

Keusch, G. T., O. Fontaine, A. Bhargava, C. Boschi-Pinto, Z. A. Bhutta, E. Gotuzzo, J. A. Rivera, J. Chow, S. A. Shahid-Salles, and R. Laxminarayan, 2006: Diarrheal diseases, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 371–88

Kohler, A.-P., 2012: Chapter 9 in this volume

Kumar, D. *et al.*, 2006: Trends in HIV-1 in young adults in South India from 2000 to 2004: a prevalence study, *Lancet* **367**, 1164–72

Lawn, J. E., J. Zupan, G. Begkoyian, and R. Knippenberg, 2006: Newborn survival, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 531–50

Laxminarayan, R., J. Chow, and S. A. Shahid-Salles, 2006a: Intervention cost-effectiveness: overview of main messages, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 35–86

Laxminarayan, R., E. Kelin, C. Dye, K. Floyd, S. Darly, and O. Adeyi, 2007: Economic benefit of tuberculosis control, *Resource for the Future Working Paper*

Laxminarayan, R., A. J. Mills, J. G. Breman, A. R. Measham, G. Alleyne, M. Claeson, P. Jha, P. Musgrove, J. Chow, S. Shahid-Salles, and D. T. Jamison, 2006b: Advancement of global health: key messages from the Disease Control Priorities Project, *Lancet* **367**, 1193–208

Laxminarayan, R. *et al.*, 2006: Will a global subsidy of new antimalarials delay the emergence of resistance and save lives? *Health Affairs* **25**, 325–36

Laxminarayan, R., I. W. H. Parry, E. Klein, and D. L. Smith, 2010: Should new antimalarial drugs be subsidized?, *Journal of Health Economics* **29**, 445–56

Levine, R. and the What Works Working Group, 2007: *Millions Saved: Proven Successes in Global Health*, Jones & Bartlett, Sudbury, MA

Lindert, P. H., 2004: *Growing Public: Social Spending and Economic Growth since the Eighteenth Century*, Vol. **1**, Cambridge University Press

Liu, L., H. L. Johnson, and S. Cousens, 2012: Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000, *Lancet* **379**, 2151–61, Epub May 11

Lomborg, B. (ed.), 2004: *Global Crises, Global Solutions*, Cambridge University Press
  2006: *How to Spend $50 Billion to Make the World a Better Place*, Cambridge University Press

Lopez, A. D., S. Begg, and E. Bos, 2006a: Demographic and epidemiological characteristics of major regions of the world, 1990 and 2001, in A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J .L. Murray (eds.), *Global Burden of Disease and Risk Factors*, Oxford University Press, New York, 17–44

Lopez, A. D., C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray (eds.), 2006b: *Global Burden of Disease and Risk Factors*, Oxford University Press, New York
  2006c: Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data, *Lancet* **367**, 1747–57

Lopez-Casasnovas, G., B. Rivera, and L. Currais (eds.), 2005: *Health and Economic Growth: Findings and Policy Implications*, MIT Press, Cambridge, MA

Lozano, R., H. Wang, K. J. Foreman, J. Knoll Rajaratnam, M. Naghavi, J. R. Marcus, L. Dwyer-Lindgren, K. T. Lofgren, D. Phillips, C. Atkinson, A. D. Lopez, and C. J. L. Murray, 2011: Progress toward Millennium Development Goals 4 and 5 on maternal and

child mortality: an updated systematic analysis, *Lancet* **378**, 1139–65

Mathers, C. D., C. J. L. Murray, and A. D. Lopez, 2006: The burden of disease and mortality by condition: data, methods and results for the year 2001, in A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray (eds.), *Global Burden of Disease and Risk Factors*, Oxford University Press, New York, 45–240

Maurice, J., 2011: Quest for an effective AIDS vaccine takes a new tack, *Lancet* **378**, 213–14

McCord, C. and Q. Chowdhury, 2003: A cost-effective small hospital in Bangladesh: what it can mean for emergency obstetric care, *International Journal of Gynecology and Obstetrics* **81**, 83–92

Measham, A. R., K. D. Rao, D. T. Jamison, J. Wang, and A. Singh, 1999: The performance of India and Indian states in reducing infant mortality and fertility, 1975–1990, *Economic and Political Weekly* **34**, 1359–67

Meltzer, D., 2006: Economic approaches to valuing global health research, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 157–64

Million Death Study Collaborators, 2010: Causes of child and neonatal mortality in India: nationally-representative mortality survey, *Lancet* **376**, 1853–6

Mills, A. and S. Shillcutt, 2004: Communicable diseases, in B. Lomborg (ed.), *Global Crises, Global Solutions*, Cambridge University Press, 62–114

Mills, A. *et al.*, 2006: Strengthening health systems, in D. T. Jamison *et al.*, *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press

Mock, C., M. Cherian, C. Julliard, P. Donker, S. Bickler, D. Jamison, and K. McQueen, 2009: Developing priorities for addressing surgical conditions globally: furthering the link between surgery and public health policy, *World Journal of Surgery* **34**, 381–5

Mulligan, J. A., J. A. Fox-Rushby, T. Adams, and A. Mills, 2003, revised 2005: Unit costs of health care inputs in low and middle income countries, *Disease Control Priorities Paper Working Paper* 9, http://dcp2.org/file/24/wpg.pdf

Nagelkerke, N. J., P. Jha, S. J. de Vlas, E. L. Korenromp, S. Moses, J. F. Blanchard, and F. A.

Plummer, 2002: Modelling HIV/AIDS epidemics in Botswana and India: impact of interventions to prevent transmission, *Bulletin of the World Health Organization* **80**, 89–96

Nordhaus, W., 2003: The health of nations: the contributions of improved health to living standards, in K. M. Murphy and R. H. Topel (eds.), *Measuring the Gains from Health Research: An Economic Approach*, University of Chicago Press, 9–40

Oeppen, J. and J. W. Vaupel, 2002: Demography, broken limits to life expectancy, *Science* **296**, 1029–31

Orazem, P., 2012: Chapter 5 in this volume

Orazem, P., P. Glewwe, and H. Patrinos, 2009: The benefits and costs of alternative strategies to improve educational outcomes, in B. Lomborg (ed.), *Global Crisis, Global Solutions*, 2nd edn., Cambridge University Press, 657–79

Over, M., 2011: *Achieving an AIDS Transition*, Brookings Institution Press, Baltimore

Over, M. and G. Garnett, 2011: Assessment paper on treatment. Rethink HIV, Copenhagen Consensus on RethinkHIV

Ozawa, S., M. L. Stack, D. M. Bishai, A. Mirelman, I. K. Friberg, L. Niessen, D. G. Walker, and O. S. Levine, 2011: During the "decade of vaccines," the lives of 6.4 million children valued at $231 billion could be saved, *Health Affairs* **30**, 1010–20

Pai, M. *et al.*, 2006: Lethal interaction: the colliding epidemics of tobacco and tuberculosis, *Expert-Review of Anti Infective Therapy* **5**, 385–91

Peabody, J. W., M. M. Taguiwalo, D. A. Robalino, and J. Frenk, 2006: Improving the quality of care in developing countries, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 1293–308

Piot, P., M. Banton, H. Larson, D. Zewdie, and P. Mane, 2008: Coming to terms with complexity: a call to action for HIV prevention, *Lancet* **372**, 845–59

Preston, S. H., 1975: The changing relation between mortality and level of economic development, *Population Studies* **29**, 231–48

    1980: Causes and consequences of mortality declines in less developed countries during the twentieth century, in R. Easterlin (ed.),

Population and Economic Change in Developing Countries, University of Chicago Press, 289–360

Pritchard, C., 2004: Developments in economic evaluation in health care: a review of HEED, *OHE Briefing* **40**, Office of Health Economics, London, March

Radelet, S., 2003: *Challenging Foreign Aid*, Center for Global Development, Washington, DC

Rijsberman, F. and A. P. Zwane, 2012: Chapter 10 in this volume

Schelling, T., 1968: The life you save may be your own, in S. B. Chase, Jr. (ed.), *Problems in Public Expenditure Analysis*, Brookings Institution, Washington, D.C

Sepúlveda, J. *et al.*, 2006: Improvement of child survival in Mexico: the diagonal approach, *Lancet* **368**, 2017–27

Simoes, E. A. F., T. Cherian, J. Chow, S. A. Shahid-Salles, R. Laxminarayan, and T. J. John, 2006: Acute respiratory infections in children, in D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 483–98

Stack, M., S. Ozawa, D. M. Bishai, A. Mirelman, Y. Tam, L. Niessan, D. G. Walker, and O. Levine, 2011: Estimated economic benefits during the "decade of vaccines" include treatment savings, gains in labor productivity, *Health Affairs* **30**,

Stephenson, L. S., 1987: *Impact of Helminth Infections on Human Nutrition: Schistosomes and Soil Transmitted Helminths*, Taylor & Francis, New York

Stiglitz, J., A. Sen, and J. P. Fitoussi, 2009: *Report of the Commission on the Measurement of Economic Performance and Social Progress*, Paris, www.stiglitz-sen-fitoussi.fr

Strauss, J. and D. Thomas, 1998: Health, nutrition and economic development, *Journal of Economic Literature* **36**, 251–86

Tolley, G., D. Kenkel, and R. Fabian, 1994: State of the art health values, in G. Tolley, D. Kenkel, and R. Fabian (eds.), *Valuing Health for Policy: An Economic Approach*, University of Chicago Press, 323–44

UNAIDS *et al.*, 2010: *Report on the global AIDS epidemic*, UNAIDS, Geneva, www.unaids.org/globalreport/global_report.htm

United Nations, 2009: UN Population Division, *World Population Prospects* (2008 revision), 28 June

US Centers for Disease Control, 1999: Achievements in public health, 1900–1999: changes in the public health system, *Morbidity and Mortality Weekly Report (MMWR)* **48**, www.cdc.gov/mmwr/PDF/wk/mm4850.pdf

Usher, D., 1973: An imputation to the measure of economic growth for changes in life expectancy, in M. Moss (ed.), *Measurement of Economic and Social Performance*, Columbia University Press for the National Bureau of Economic Research, New York

Vallin, J. and F. Meslé, 2010: Will life expectancy increase indefinitely by three months every year?, *Population & Societies* **473**, 1–4

Viscusi, W. K. and I. E. Aldy, 2003: The value of a statistical life: a critical review of market estimates throughout the world. *Journal of Risk and Uncertainty* **27**, 5–76

Weatherall, D., B. Greenwood, H. L. Chee, and P. Wasi, 2006: Science and technology for disease control: past, present, and future, In D. T. Jamison, A. R. Measham, J. Breman *et al.* (eds.), *Disease Control Priorities in Developing Countries*, 2nd edn., Oxford University Press, New York, 119–38

Wolf, M., 2006: The absurdities of a ban on smoking, *Financial Times*, June 22

World Bank, 1993: *World Development Report: Investing in Health*, Oxford University Press, New York

   2003: *World Development Indicators*, World Bank, Washington, DC

   2011: World Development Indicators, World Bank, Washington, DC

WHO CMH, 2001: *Report on the Commission on Macroeconomics and Health*, WHO, Geneva

World Economic Forum (WEF), 2008: *Tackling Tuberculosis: The Business Response*, World Economic Forum, Davos

World Health Organization (WHO), 1999: *World Health Report*, WHO, Geneva

   2000: *World Health Report*, WHO, Geneva

   2011: *World Health Report*, WHO, Geneva

Yamey, G., 2007: Which single intervention would do the most to improve the health of those living on less than $1 per day?, *PLoS Med.* **4**,