COPENHAGEN CONSENSUS CENTER

Copenhagen Consensus 2008 Challenge Paper

Diseases

DISEASE CONTROL[1]

by

Dean T. Jamison[2]
Prabhat Jha [3]
David Bloom[4]

October 2007
Revised, April 2008

[1] We are indebted to the following for helpful comments or conversations: David Canning, King Holmes, Christopher Murray, Ramanan Laxminarayan and Peter Piot.
[2] T. & G. Angelopoulos Visiting Professor of Public Health and International Development, Kennedy School of Government and School of Public Health, Harvard University; and Professor, School of Medicine, University of California, San Francisco.
[3] Canada Research Chair of Health and Development, Centre for Global Health Research, St. Michael's Hospital and University of Toronto, Canada
[4] Clarence Gamble Professor of Economics and Chair, Department of Population and International Health, Harvard School of Public Health.

COPENHAGEN CONSENSUS CENTER

Contents

DISEASE CONTROL

by

Dean T. Jamison, Prabhat Jha and David Bloom

This paper identifies priorities for disease control as an input into the Copenhagen Consensus effort for 2008 (CC08). As such it updates the evidence and differs somewhat in its conclusions from the communicable disease paper (Mills and Shilcutt, 2004) prepared for Copenhagen Consensus 2004, which Lomborg (2006) summarizes.

The paper builds on the results of the Disease Control Priorities Project (DCPP).[5, 5] The DCPP engaged over 350 authors and among its outputs were estimates of 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. Some interventions are clearly low priority. Others are attractive and worth doing but either address only a relatively small proportion of disease burden or are simply not quite as attractive as a few key interventions. This paper identifies 7 key priority interventions in terms of their cost-effectiveness, the size of the disease burden they address and other criteria. Separate but related papers for CC08 deal with malnutrition (Behrman, Alderman and Hoddinott, 2007) with water and sanitation (Hutton, 2007) with air pollution (Hutton, 2007) and with education (Orazem, 2007).

[5] The DCPP was a joint effort, extending over 4 years, of the Fogarty International Center of the U.S. National Institutes of Health, the World Bank, and the World Health Organization with financial support from the Bill & Melinda Gates Foundation. While the views and conclusions expressed in this paper draw principally on the DCPP, others might draw different broad conclusions. In particular views expressed in this paper are not necessarily those of any of the sponsoring organizations.

[5] The DCPP resulted in two main volumes, both of which Oxford University Press published in 2006. One book deals with the *Global Burden of Disease and Risk Factors* (Lopez et al., 2006). The other book, *Disease Control Priorities in Developing Countries, 2nd edition* (Jamison et al., 2006) discusses interventions to address diseases and risk factors and the health systems to deliver those interventions. A first edition was published by Oxford University Press for the World Bank in 1993. This paper will refer to these two volumes as *DCP1* and *DCP2*.

Before turning to the substance of the paper it is worth briefing stating our perspectives on the roles of the state and of international development assistance in financing health interventions. There are major 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 to address needs of vulnerable groups. Our view is rather different.

Among the OECD countries only the U.S. 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 they finance at all. Private finance is explicitly crowded out by public action, even for purely private clinical services (eg. setting fractures) for which most individuals would be willing and able to pay themselves (perhaps with privately financed insurance). Arrow's (1963) classic paper points to potential theoretical justifications for this policy choice. The poor outcomes of the U.S. system with respect to health indicators and total costs (and even with respect to public sector expenditures as a percent of GDP) provide empirical evidence suggestive of the merits of universal public finance. [See Barr (2001) and Lindert (2004) for more extended discussions.] The perspective of this paper is that of universal public finance adopted by the non-U.S. OECD countries. 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 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 the poor. 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. Our perspective on public finance in health leads to less relative emphasis on infectious disease control in our short list of high priorities.

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. 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 in the private sector provides an analogy.) 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.

Section 1 of the paper documents the enormous success in much of the world in the past 40 years in improving health in low- and middle-income countries. Its conclusion is that future investments can build on past successes—increasing confidence in the practical feasibility of major additional gains in disease control. Section 2 summarizes evidence that health gains have had major economic impact, and Section 3 uses this economic context to describe the methods used for the cost-benefit analyses reported. Sections 4, 5 and 6 discuss problems and opportunities in child health, HIV/AIDS and noncommunicable disease. Section 7 concludes by identifying the few most attractive options and presenting (very approximate) cost-benefit analyses for them. This paper emphasizes, although not exclusively, opportunities relevant to low-income countries in South Asia and Sub-Saharan Africa.

1. PROGRESS AND CHALLENGES

Health conditions improved markedly throughout the world during most of the second half of the 20th century and this section begins by highlighting those achievements. Nonetheless major problems remained at the beginning of the 21st century. Parts of the world have simply not kept up with the remarkable progress in other parts; declines in mortality and fertility had led to an increasing importance of noncommunicable disease; and the altogether new problem of HIV/AIDS has rapidly become prominent in many countries. Addressing these multiple problems within highly constrained budgets will require hard choices, even in the current era of expanding domestic health spending and overseas development assistance on health. This section concludes by reviewing these challenges.

1.1 Progress

Table 1 shows progress in life expectancy by World Bank region between 1960 and 2002. For the first three decades of this period, progress was remarkably fast—a gain of 6.3 years in life expectancy per decade on average, in the low- and middle-income countries, albeit with substantial regional variation. Progress continued between 1990 and 2002 but at a much slower pace. Sub-Saharan Africa actually lost more than four years of life expectancy (although as this paper is being completed, the United Nations has revised upward its estimates of African life expectancy to suggest neither gain nor loss over the period). Eastern Europe and Central Asia realized no gains.

In addition to overall progress, since 1950 life expectancy in the median country has steadily converged toward the (steadily growing) maximum and cross-country differences have decreased markedly (Oeppen and Vaupel, 2002). 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 probably 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 infant mortality rate caused by technical progress to reductions of up to 5 percent per year (Jamison, Sandbu and Wang, 2004). Measham et al. (2003) reached a similar conclusion concerning variation in IMR decline across the states of India. Cutler, Deaton and Lleras-Muney (2006) provide a complementary and extended discussion of the importance of technological diffusion for improvements in health. Consider for example the 10 million child deaths that occur currently each year. If child death rates were that 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

COPENHAGEN CONSENSUS CENTER

Table 1 Levels and Changes in Life Expectancy, 1960-2002, by World Bank Region

Region	Life expectancy (years)			Rate of change (years per decade)	
	1960	1990	2002	1960–90	1990–2002
Low- and middle-income countries	44	63	65	6.3	1.7
East Asia and the Pacific	39	67	70	9.3	2.5
(China)	(36)	(69)	(71)	(11)	(1.7)
Europe and Central Asia	—	69	69	—	0.0
Latin America and the Caribbean	56	68	71	4.0	2.5
Middle East and North Africa	47	64	69	5.7	4.2
South Asia	44	58	63	4.7	4.2
(India)	(44)	(59)	(64)	(5)	(4.6)
Sub-Saharan Africa	40	50	46	3.3	−3.3
High-income countries	69	76	78	2.3	1.7
World	50	65	67	5.0	1.7

Source: World Bank 2004 (CD-ROM version).
— = not available.
Note: Entries are the average of male and female life expectancies.

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 worldwide and perhaps malaria in Africa (Table 2). The development of improved environmental living conditions paired with vaccination, antimicrobial chemotherapy, and the ability to identify new microbes has been central to the more than 90% reduction in communicable disease mortality in Canada and the US (US Centres for Disease Control and Prevention, 1996). Today more than 30 common infectious diseases are controllable with live or killed viral or bacterial vaccines, or those based on bacterial sugars and proteins. In 1970, perhaps only 5% of the world's children under 5 were immunized against measles, tetanus, pertussis, diptheria and polio. The Expanded Programme on Immunization has raised this to about 75% of children by 1990, saving perhaps 3 million lives a year (England et al, 2001). The clearest success in immunization is the World

Health Organization (WHO)-led eradication of smallpox, which culminated in the eradication of smallpox in human populations by 1979. More recently, WHO is engaged in an ongoing effort to eradicate poliomyelitis, which is more difficult technically than smallpox eradication. The effort has, nonetheless, reduced polio cases to a modest number in only a handful of countries.

Prior to 1950, the only major antibiotics were sulphonamides and penicillin. Subsequently, there has been remarkable growth in discovery and use of antimicrobial agents effective against bacteria, fungi, viruses, protozoa and helminths. Delivery of a combination of anti-tuberculosis drugs with direct observation (or DOTS- described below) has lowered case-fatality rates from well over 60% to 5%, and also decreased transmission. The percentage of the world's tuberculosis cases treated with DOTS has risen from 11% to about 53% (Dye et al, 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 of retroviruses, and is accelerating the number of antiviral agents. Similarly, there is increasing knowledge of the modes of action of antifungal and antiparasitic agents (Weatherall et al, 2006). Large scale studies have been able to identify smoking as a major cause of tuberculosis mortality worldwide (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

Table 2: Examples of science contribution to declines in infectious disease mortality in the 20th century

Condition and intervention	Annual deaths prior to intervention (and ref year) in thousand	Annual deaths after intervention (and ref year) in thousand
Immunization services - against polio, diphtheria, pertussis, tetanus and measles	~5,000 (1960)	1,400 (2001)
Eradication campaign – smallpox	~3,000 (1950)	0 (1979)
Diarrhea- oral rehydration therapy	~ 4,600 (1980)	1,600 (2001)
Malaria outside Africa- indoor residual spray and acute management	~ 3,500 (1930)	<50 (1990)
Malaria in Africa- limited use of indoor residual spray and acute management	~300 (1930)	1,000 (1990)

Source: Global IDEA Scientific Advisory Committee. 2004.
Health and economic benefits of an accelerated program of research to combat global infectious diseases CMAJ. NOV. 9, 2004; 171 (10)

understanding infectious disease spread (Nagelkerke et al, 2001). Finally, a new chapter is the development of molecular biology and recombinant DNA technology in the second half of the 20th Century. The benefits of DNA science to global health are as yet limited but could be extraordinary (see Weatherall et al, 2006) in DCP-2.

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 paper argues 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 19th and early 20th centuries similarly show that health conditions can improve without prior or concomitant increases in income (Easterlin 1996). A recent review 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 paper is to assist decision makers—particularly those in the public sector—to identify the highest priority low-cost intervention to rapidly improve population health and welfare health where the needs are greatest.

1.2 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 factor is 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-five mortality rate remained stagnant or increased in 23 countries. In another 53 countries (including China), the rate of decline in under-five mortality in this period was less than half of the 4.3 percent per year required to reach the fourth Millennium Development Goal (MDG-4). Meeting the MDG for under-five mortality reduction by 2015 is not remotely possible for these countries. [See Lopez, Begg and Bos (2006) 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.] 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 paper 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 10.6 million of the 49 million deaths in low and middle-income countries occur in children between birth and age 5. Table 3 summarizes what is known about the causes of deaths under the age of 5, and under the age of 28 days, in 2001. Table 3 also includes an estimate on the number of stillbirths. Figure 1 illustrates that about half of all deaths under the age of 5 (including stillbirths) occur.

Epidemiological Transition. A second challenge lies in noncommunicable disease and injury. The next two decades will see continuation of rising trends resulting from dramatic fertility declines (and consequent population aging) in recent decades. The combination of an aging

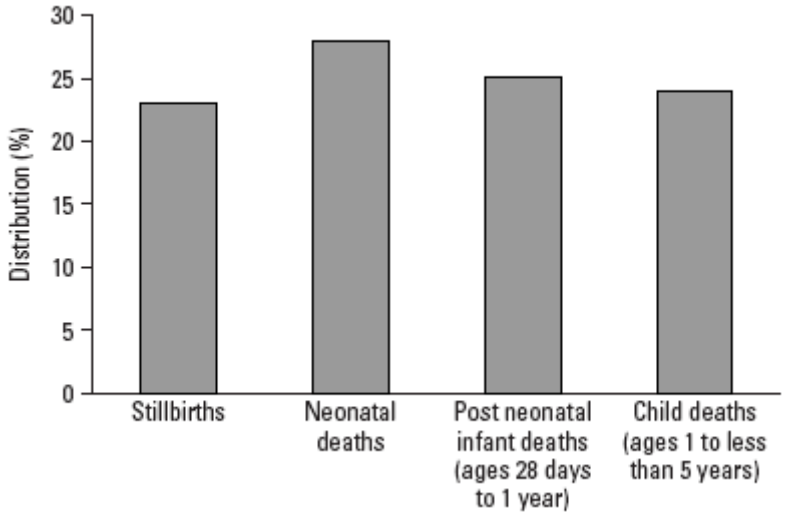
Table 3 Causes of Under-5 Mortality, Worldwide in 2001, Estimates from the GBD (in thousands)

Cause	Total	Age 0 to 4	Neonatal (age 0-27days)	Stillbirths
HIV/AIDS	340	340		
Diarrheal Disease	1,600	1,600	116	
Measles	557	557		
Tetanus	187	187	187	
Malaria	1,087	1,087		
Respiratory infection (and sepsis)	1,945	1,945	1,013	
Low birth weight	1,301	1,301	1,098	
Birth asphyxia and birth trauma	739	739	739	
Congenital anomalies	439	439	321	
Injuries	310	310		
Other	5,375	2,101	446	3,274
TOTAL	13,874	10,600	3,900	3,274

Source: Mathers, Lopez and Murray (2006); Jamison et al. (2006).

Notes: 1. Of the estimated 13.9 million under-5 deaths in 2001 only 0.9% occurred in high-income countries. Thus the cause distribution of deaths in this table is essentially that of low- and middle-income countries.

2. 'Stillbirths' are defined as fetal loss in the third trimester of pregnancy. About 33% 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 to 4 so part of what is categorized as 'other' in the total row will be distributed among the other existing rows when estimates are available.



Source: Jamison et al. (2006).

Figure 1 Age Distribution of Deaths of Children under Five in Low- and Middle-Income Countries, 2001

Table 4 Causes of Death in Low- and Middle-Income Countries, Age 5 and Older, Estimates from the GBD, 2001

	Deaths (in millions)	% of total
1. *Communicable, maternal, perninatal and nutritional conditions*		
TB	1.5 million	4.0%
AIDS	2.2	5.8
Respiratory infections	1.5	4.0
Maternal conditions	0.5	1.3
Other	2.5	6.6
Subtotal	8.2	21.7
2. *Noncommunicable disease*		
Cancers	4.9	13.0
Diabetes	0.7	1.9
Ischaemic and hypertensive heart disease	6.5	17.2
Stroke	4.6	12.2
Chronic obstructive pulmonary disease	2.4	6.3
Other	6.1	16.1
Subtotal	25.2	66.7
3. *Injuries*		
Road traffic accidents	1.0	2.6
Suicides	0.7	1.9
Other	2.7	7.1
Subtotal	4.4	11.6
TOTAL	37.8 million	100 %

Source: Aggregated from Mathers, Lopez and Murray (2006, pp. 126-131).

population paired with increases in smoking and other lifestyle changes mean that the major noncommunicable diseases—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. Table 4 provides cause-specific estimates of the number of deaths over age 5 due to major causes in low- and middle-income countries. This summary indicates that noncommunicable disease already accounts for two thirds of all deaths over age 5 in these countries, although nearly 22% of deaths continue to be from infection, undernutrition and maternal conditions, creating a "dual burden" that Julio Frenk and colleagues have pointed to (Bobadilla and others 1993).

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 epidemic is best viewed as a set of diverse epidemics in regions or sub-regions. Each scenario demands understanding the reasons for HIV growth, appropriate interventions to decrease transmission to uninfected populations, and clinical care with life-prolonging drugs for those already infected. Recent data suggest that outside parts of Eastern and Southern Africa, that growth of HIV 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.

2. THE ECONOMIC BENEFITS OF BETTER HEALTH

The dramatic health improvements globally during the 20th century arguably contributed as much or more to improvements in overall well-being as did the equally dramatic innovation in and expansion of the availability of material goods and services. To the substantial extent that appropriate investments in health can contribute to continued reductions in morbidity and

mortality, the economic welfare returns to health investments are likely to be exceptional and positive—with previously unrecognized implications for public sector resource allocation. The purpose of this section is to motivate the high values this paper places on mortality reduction in its cost-benefit analyses. Returns to better health go far beyond the contribution better health makes to per person income, which itself appears substantial (see Bloom, Canning, and Jamison 2004; Lopez-Casasnovas, Rivera, and Currais 2005). This section first summarizes the evidence concerning health's effect 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.

2.1 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 plausible observation 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 life cycle. 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 foreign direct investment 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. 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, Canning, and Sevilla (2004) found that one extra year of life expectancy raises GDP per person by about 4 percent in the long run. Jamison, Lau, and Wang (2005) estimated that reductions in adult mortality explain 10 to 15 percent of the economic growth that occurred from 1960 to 1990. Although attribution of causality is never unequivocal 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 International Monetary Fund recently published a collection of important studies of the multiple mechanisms through which a major AIDS epidemic can be expected to affect national economies (Haacker 2004).

2.2 Health and Economic Welfare

Judging countries' economic performance by GDP per person fails to differentiate between situations in which health conditions differ: 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) provides an up-to-date explication of the theory. Individual willingness to forgo income to work in safer environments and social willingness to pay for health-enhancing safety and environmental regulations provide measures, albeit approximate, of the value of differences in mortality rates. Many such willingness-to-pay 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, Philipson, and Soares (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 paper will later use a measure of 'disability-adjusted life years', or DALY, 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 nonmarket outcomes. The U.S. National Academy of Sciences has recently proposed broad changes for the United States that would include but go beyond valuation of mortality change (Abraham and Mackie 2005). Of specific relevance to this paper 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) beginning sometime after 1950, even though income inequality had continued to rise. In another important paper, Nordhaus (2003) assessed the growth of full income per capita in the United States in the 20th 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 25 years.

Three lines of more recent 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 (CMH) of the World Health Organization (WHO) (Jamison, Sachs, and Wang 2001) and the other at the International Monetary Fund (Crafts and Haacker 2004)—assessed the impact of the AIDS epidemic on full income. Both studies conclude that the 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 paper 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 2 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 AIDS appears to have only a modest effect on GDP per person but a dramatically

adverse impact on changes in full income. Becker, Philipson, and Soares (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, Jamison, and Sachs (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 Africa by 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 substantial. What are the implications of these findings for development strategy and

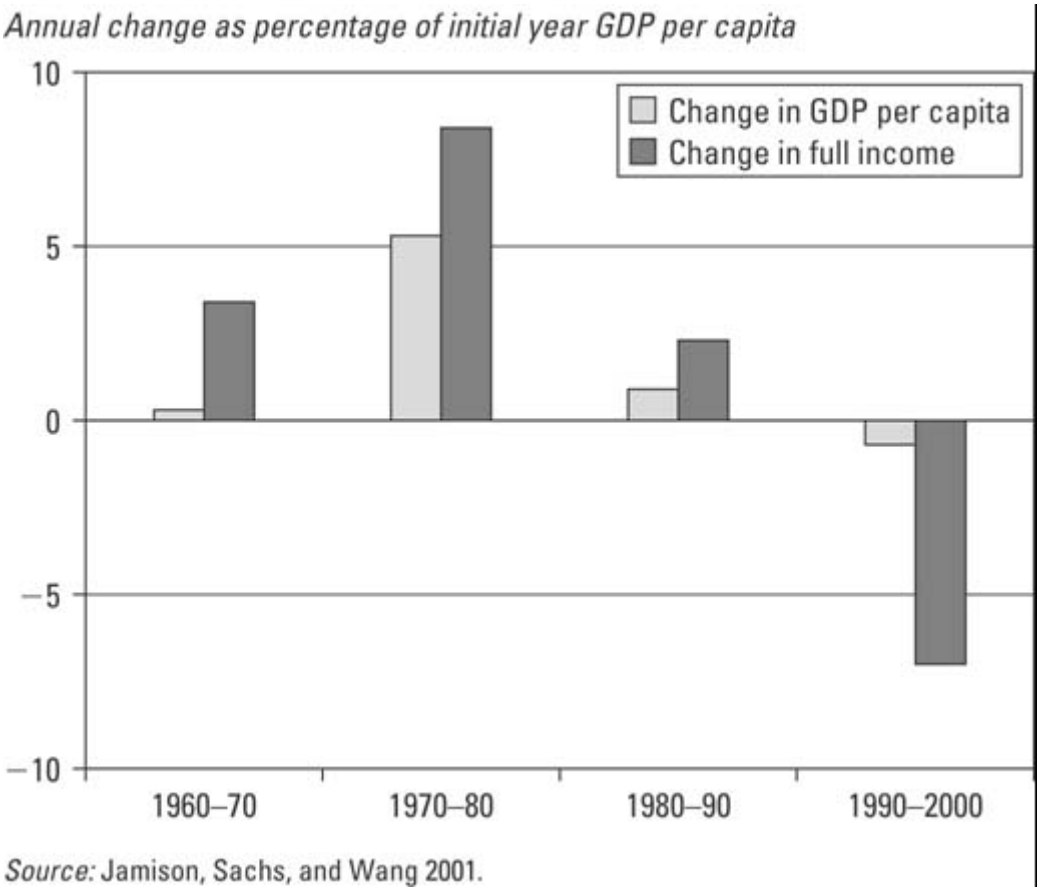


Figure 2 Changes in GDP and Full Income in Kenya, 1960-2000.

for benefit-cost analyses of public sector investment options? Using full income in benefit-cost analyses 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 comparison of investment priorities by utilizing this 'full benefit' approach.

3. COST-BENEFIT METHODOLOGY

The basic approach to cost-benefit analysis used in this paper is to start with the cost-effectiveness (CE) results from the extensive comparative analyses reported in *DCP2* (Jamison et al., 2006; Laxminarayan et al. 2006). 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.

Section 3.1 describers an idealized version of our approach to CE – idealized in the sense that it seeks to explicitly call attention to the value of financial protection and nonfinancial 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 CE ratios reported. Section 3.2 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 CB analyses, reduces the DALY cost of a typical death under age 5 by about 50% while leaving the construction of DALYs for older ages unchanged. Section 3.3 draws on Section 2 to assign, very conservatively, dollar values to DALYs for the subsequent CB assessment. Section 3.4 summarizes this paper's approach to costing.

3.1 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

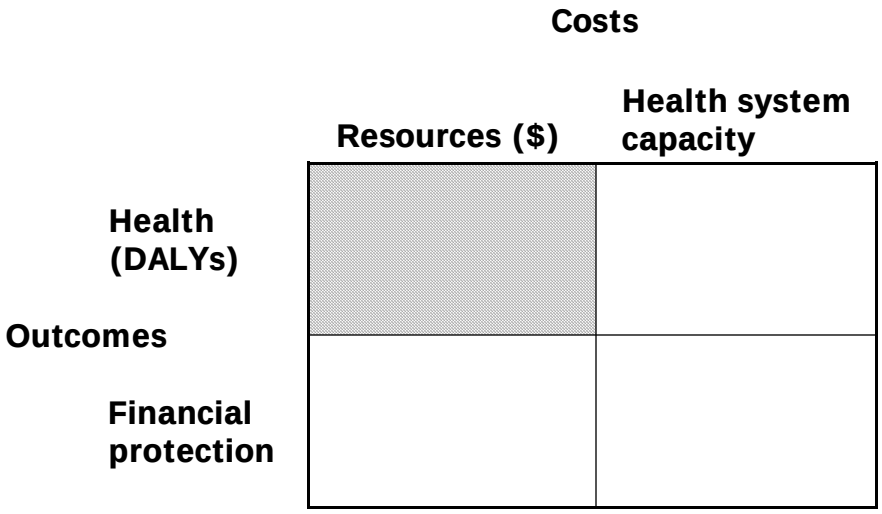
outcomes in the population and (b) to protect individuals from financial risks that are often very substantial and that are frequent causes of poverty (WHO 1999, 2000). Financial risk results from illness-related loss of income as well as expenditures on care; the loss can be ameliorated by preventing illness or its progression and by using appropriate financial architecture for the system.

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 recent report of the Joint Learning Initiative (2004). Figure 3 illustrates this broadly construed vision of CE 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 tradeoff 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. 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 economic evaluation of health projects typically reports the cost per unit of achieving some measure of health outcome—quality-adjusted life years (QALYs) or DALYs or deaths averted—and 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 70 interventions; *DCP2* does so as well, in the end

providing evidence on about 315 interventions. *DCP2* authors were asked to use methods described in Jamison (2003). Cost-effectiveness calculations provide important insights into the economic attractiveness of an intervention, but other considerations—such as consequences for financial protection and demands on health system capacity—need to be borne in mind.



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

Figure 3 Intervention Costs and Effects – A More General View

3.2 Defining and Redefining DALYs

The DALY family of indicators measures the disease burden from the age of onset of a condition by summing an indicator of years of life lost (YLL) due to the condition and an indicator of years of life lost due to disability (YLD) resulting from the condition. Disability-adjusted life years (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 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 estimates generated with the 3% discount rate but uniform age weights (Lopez, et al., 2006a). 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.

To be clear about the particular form of DALY being used, the terminology from Mathers et al. 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, Lopez and Murray (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 paper is based on DALYs (3,0), but slightly generalized.

This paper uses an extension of the DALY family generated by modeling a concept of 'acquisition of life potential' ALP. The intuition behind the ALP concept is that an infant (or fetus) only gradually acquires the full life potential reflected in a stream of life years beginning at

birth, that is, ALP can be gradual. Operationalizing this concept involves introducing a parameter, *A*, that indicates the speed of ALP (see Jamison, et al., 2006 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 global burden of disease, this is explicitly noted in the DALY nomenclature as $DALYs_{SB}(r,K,A)$. Notation around YLL is similarly extended.

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

- The DALY loss from a death seconds before birth is, in the previous formulation, 0; it jumps to more than 30 years at birth. The ALP formulation allows, but does not require, this discontinuity 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. 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, Salter, and Jang (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 (1985) review of vaccine development priorities 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 two times 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. (2006) should be viewed as only suggestive. Table 5 shows the YLLs associated with deaths at different young ages for alternative formulations of the DALY, including one with their preferred value of A = .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, .54) loss of 16.4 DALYs for a typical under-5 death, about half what is typically used. Our analyses use this figure.*

3.3 The Value of a DALY

The VSL estimates discussed in Section 2.2 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 to 4 times per capita income. Tolley, Kenkel and Fabian (1994) provide a valuable overview of relevant estimates, including estimates of the value of preventing disability. The emphasis in this paper is on low-income countries defined by the World Bank for 2001 as countries with per capita incomes of less than $745 (exchange rate). The World Bank's estimate of the average income of people living in low-income countries is $430 per year (World Bank, 2003, 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 paper uses in its main calculations as the value of a DALY. (Note that for the reasons discussed in Section 3.2 the DALY loss from a death under age 5—and hence the benefit from preventing it—is about half that used in standard DALYs.) We explore the sensitivity of our results to these assumptions by using a DALY value of $5000 and by using standard DALYs (DALYs (3,0)) for child deaths.

3.4 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. For internationally traded inputs prices were the same for all regions. (Because of tiered pricing, off-patent drugs were *not* considered to be intentionally traded.) For local costs regional estimates were used. Intervention costs, therefore, are *not* expressed in PPP dollars. 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 local costs than global costs would be.) On this point the methods of this paper differ from those of its predecessor (Mills and Shilcutt, 2004).

Table 5 Discounted YLL at Different Ages of Death for Several DALY Formulations

Age group	Representative age of death (years)	YLL(3,1)	YLL(3,0)	$YLL_{SB}(3,0,1)$	$YLL_{SB}(3,0,.54)$
Antepartum	–0.080	0	0	30.42	4.95
Intrapartum	–0.001	0	0	30.42	9.13
Neonatal	0.020	33.09	30.42	30.42	9.40
Infant	0.300	33.36	30.40	30.40	12.95
Postneonatal infant	0.500	33.56	30.39	30.39	15.42
Child	2.000	34.81	30.28	30.28	26.40

Source: Jamison, et al. (2006), Table 6.6.

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). $YLL_{SB}(3,0,.54)$ assumes gradual acquisition of life potential (A = .54). The subscript SB refers to formulations that do not give stillbirths zero weight.

4. CHILD HEALTH

A small number of conditions accounts for most of the (large) differences in health between the poor and the not so poor. Less than 1 percent of all deaths from AIDS, TB, and malaria, for example, 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. Public expenditures to address those conditions have, in the past, benefited the relatively well off, albeit within poor countries (although global inequities have decreased because many poor countries have made much progress).

4.1 Under-5 Health Problems and Intervention Priorities

The Millennium Development Goal for under-5 mortality (MDG-4) (reducing its level in 2015 by two-thirds relative to what 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), 46 countries achieved rates of decline in under-five mortality greater than 4.3 percent per year (Lopez, Begg and Bos, 2006).

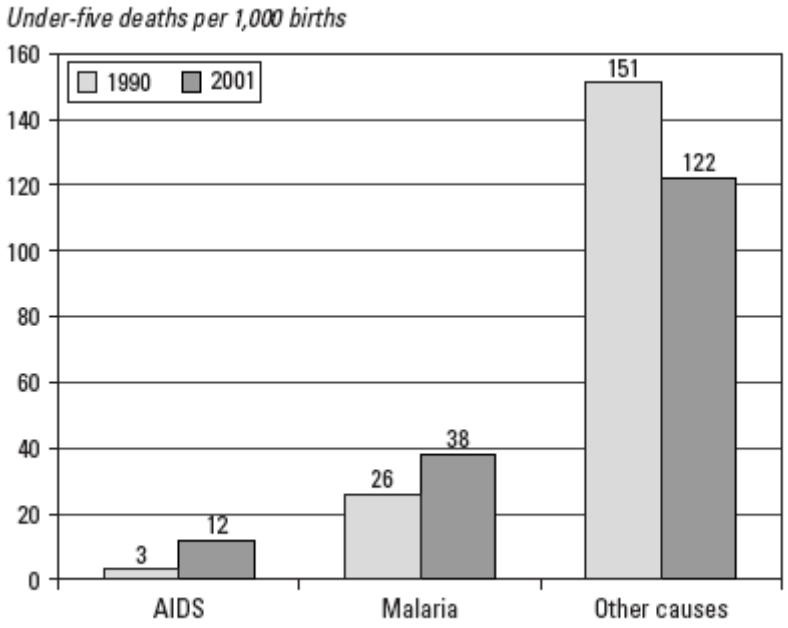
Basic knowledge about the power and the cost-effectiveness of interventions to address maternal and child health has been available from the 1980s. *DCP2*'s work makes four important relatively new points. First, major declines in childhood mortality could well be accelerated with expanded case-management 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 vacinnes 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 programmes could save 800,000 lives a year

by 2010. Further GAVI estimates suggest that rotavirus and shigella vaccines might save 600,000 by 2010.

Second, half of under-five deaths occur at ages less than 28 days, 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).

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 4 illustrates increases in malaria death rates and decreases in death rates from other causes except AIDS in under-five children in Sub-Saharan Africa in the period from 1990 to 2001. (This rate increase results in hundreds of thousands of deaths more than would otherwise have occurred.) The design of instruments for financing a rapid transition to effective new treatments—artemisinin combination therapies (ACTs)—is a high priority (Institute of Medicine, 2004; Arrow, Gelband, and Jamison 2005). The principles development assistance modality proposed – the Affordable Medicines Facility-malaria (AMFm) - to reduce the relative prices countries face for ACTs rather than to increase their budgets for purchasing them.

Fourth, although education interventions are considered in a separate paper for Copenhagen (Orazem, 2007), it is worth noting in the context of considering alternatives for reducing child mortality that improvements in the quality of basic education can plausibly have benefit to cost ratios as high as for many health interventions – even if no benefits of education other than mortality reduction are included. (By "quality" of education, we refer narrowly to quality as reflected in scores on internationally standardized achievement tests, particularly those in mathematics.) In a recent paper, Jamison, Jamison and Hanushek (2006) estimate that the effect of a one standard deviation improvement in quality would increase the annual rate of



Source: Lopez, Begg, and Bos 2006, table 2.4.

Figure 4 Under-Five Deaths from AIDS, Malaria, and Other Causes, per Thousand Births, 1990 and 2001, Sub-Saharan Africa

decline of infant mortality by about 0.6% leading, after 20 years, to something over a 10% 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% 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 1000 then education quality improvement is likely to result in a cost per (undiscounted) child death averted of around $1000. Assuming as this paper does a low DALY loss per child death of about 16 and the value of a DALY in low income countries to be $1000 then the B:C ratio will be about 13. Discounting the benefits at 6% gives a B:C of 4, again ignoring any other benefits from the education. Increasing the value of a DALY from $1000 to $5000 would increase the B:C ratio to 20 even with 6% discounting. Using the estimated effects of a year of schooling from the same paper the B:C for increasing the quantity of schooling by one year is 0.6 or (3 with $5000 DALYs), ignoring other benefits.

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

- Exclusive early breastfeeding, which has increased widely in all parts of the world over the last few years.
- Expand 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.
- Expand 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.
- Prevent transmission of and mortality from 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.
- Ensure widespread distribution of key micronutrients, most notably Vitamin A, Zinc, and iron.
- Expand the use of a antiretrovirals and breast feeding substitutes to prevent mother-to-child transmission of HIV

In addition to interventions to reduce under-five mortality, one other priority is 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. Bundy, et al. (2006)'s 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. In the long run, improved sanitation and water supplies will prevent transmission. Use of albendazole is only an interim solution, but it is one that may be required for decades if the experience of the currently high-income countries is relevant.

4.2 Delivering 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 these interventions address. However, there can be little dispute that any short list of intervention priorities for under-five mortality in low- and middle-income countries would include many on the list in the preceding section. Why not, then, simply put money into scaling up these known interventions to a satisfactory level?

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 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 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 paper's perspective is closer to that of Sachs than of Van der Gaag while emphasizing the need (in Section 3.1) to be explicit about intervention costs that are nonfinancial. 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 nonfinancial inputs. Frenk, Sepulveda and others 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% in 1980 to almost 90% 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 7000 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, and less than 50% have access to safe water, and only 3% have 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 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, 2006).

5. HIV/AIDS and Tuberculosis

For dozens of countries around the world—including several of the most populous—the 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 1917–18 influenza episode. Most governments of affected low- and middle-income countries and most providers of development assistance have only recently begun to respond more than minimally. 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 that success is potentially undermined by sharp constraints on resource availability (Bezanson 2005).

In contrast to the initially slow programmatic movement of most national leaders and international institutions, the research and development community—public and private—has made rapid progress in developing tools to control the HIV/AIDS epidemic, although both a vaccine and a curative drug remain distant objectives. 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 viral load allow radical slowing of disease progression. Tools for dealing with HIV/AIDS are thus available: Bertozzi and Padian (2006) emphasized that a number of countries show 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 prevention then antiretroviral therapy. It closes with a discussion of tuberculosis, both as an opportunistic infection of AIDS and a major global problem in itself.

5.1 Prevention of HIV Transmission

The HIV/AIDS pandemic is undoubtedly the most dramatic health challenge facing the world. HIV has reached every country in the world. In southern and eastern Africa, infection is running at unprecedented levels. However, the epidemic looks very different in different places. The dominant form of transmission worldwide is heterosexual, though other modes—the use of injected drugs and sex between men—being important in several regions. Three broad epidemiological patterns can be discerned. In eastern and southern Africa, the disease has spread quickly and widely throughout the population. HIV prevalence in antenatal clinic attendees doubled from 18% to 30% in Botswana from 1994 to 2005; in South Africa this increased from 3% to 15% over the same time period. A few other countries in Africa have shown substantial but less dramatic increases to prevalence rates over 3%. The remaining African countries, and almost every other country in the world, have rates of prevalence below 3%.

The reasons for the variations in prevalence between countries are not entirely clear and poorly researched. It is now clear that high levels of male circumcision protect against HIV 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 seen in southern and eastern Africa. However, conditions rife for rapid growth exist in many places. These conditions 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.

The key challenge for HIV/AIDS policy is to prevent HIV transmission. In the absence of a vaccine, several interventions are of key importance. The most clearly effective preventive interventions against HIV 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 to teach them high levels of condom use, control of STIs, and client negotiation skills are highly effective. Sex workers and their clients represent an important vulnerable group who are central to the spread of HIV 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) Less 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-1 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-1 peaked in the early 1990s and has stayed at below 2% seroprevalence since. Less known are Mexico (del Rio and Sepúlveda, 2002) and Cambodia, which copied the Thai "100% condom" program in commercial sex in 1997 in one state, and has shown impressive declines in HIV-1. More recent evidence from the 4 southern states of India suggest that new HIV infections might have dropped by 30%, probably due to change in sex work (either the proportion using condoms or men going less often to sex work; Kumar et al, 2006). Other interventions that complement vulnerable group interventions are effective. Despite controversy, STIs remain important as risk markers and risk factors for HIV growth. STI treatment for vulnerable and general populations is probably effective for HIV 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 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, and which currently accounts for perhaps half a million deaths a year. Short courses of single anti-retrovirals can halve transmission risk from about 40% to 20%. To be fully effective, replacement feeding is also required, given that breast milk is a source of transmission. Finally, needle exchange programmes and blood safety programmes 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 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% to 80% 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 reinforcing the message of simultaneous use of multiple interventions.

In those sub-Saharan countries with generalized epidemics that have spread far beyond vulnerable groups, the national approach is a necessity. The reasons for the sharp decline in HIV prevalence in Uganda, from about 20% in 1990 to 10% 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 is not established.

Bertozzi, Padian 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, the current U.S. administration 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. Piot, et al. (2008, forthcoming) summarize experience to date by observing that 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 there is now reasonable evidence for its general success.

In addition to prevention, better management of patients with AIDS could avert much misery, both by treating opportunistic infections and by ameliorating the often excruciating

pain associated with many AIDS deaths. Medically inappropriate restrictions on the use of inexpensive but powerful opiates for pain control continue to deny dignity and comfort to millions of patients with AIDS and cancer in their final months (Foley et al. 2006).

5.2 Antiretroviral 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 35-40 million people currently living with the infection, 95% of them in low- and middle-income countries. 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 which acts directly on the virus, has increased the life expectancy of people on treatment considerably. In developed countries, HAART has dramatically reduced but not eliminated AIDS mortality. Reduction in viral load slows or halts 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 are stopped. 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.

Early generation antiretroviral 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, antiretroviral therapy in low-income settings. WHO's "3 by 5" program had as its objective, for example, to reach 3 million people in low- and middle-income countries with antiretroviral therapy by 2005. Although that goal was far from being met, 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 drugs and, more recently, second-line drugs.

Despite the indicated progress against the problems with antiretroviral 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 and Padian et al. (2006) review those problems and how they might be addressed.

Three points concerning widespread antiretroviral 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 antiretroviral drug delivery programs could divert substantial resources from prevention or from other high-payoff 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 antiretroviral 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.
- 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 ARVs is likely to have a B:C ratio 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.

5.3 Control of Tuberculosis

Tuberculosis 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 tuberculosis globally in 2003, with over 90% of these in low and middle income countries. Tuberculosis, 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 tuberculosis bacillus go onto to active disease such as pulmonary tuberculosis. Key risk factors for active tuberculosis include poverty, household crowding, and smoking (Pai et al, 2006).

Tuberculosis control is largely based on 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 "DOTS" strategy and its variations, centered on the diagnosis and treatment of the most severe and most infectious (smear-positive) forms of TB but including treatment for smear-negative and extrapulmonary cases as well. Anti-TB drugs can also be used to treat latent M. tuberculosis infection and active TB in patients with HIV coinfection, and the widely used bacillus Calmette-Guérin (BCG) vaccine prevents (mainly) severe forms of TB in childhood (Dye et al, 2006). The cornerstone of TB control is the prompt treatment of active cases with SCC 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 3-4 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% of new infectious (smear positive) cases worldwide are detected and 8% of those cases are treated successfully with the DOTS regime. WHO and others have focused their operational efforts in the 2 "high burden countries", and progress has been impressive. The case detection rates has increased from11% globally in 1996 to 53 percent in 2004 and over 21 million TB patients were 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 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 former Soviet Union.

The cost-effectiveness of tuberculosis control has been well established (summarized in Dye et al, 2006), but more recently Laxminarayan et al (2007) have calculated the cost-benefit of the WHO DOTS strategy at currently levels relative to having no program in place. This finds that using a high statistical value of life (roughly 100 times per capital GDP), the net gain is about $1.7 trillion versus program costs of $18.3 billion in the 22 high burden countries. The ratio of marginal benefits of implementing a global plan for DOTS versus to their costs to be a factor over 15 in the 22 high burden countries, and a factor of 9 in the Africa region. These estimates are thus in the plausible range with the values shown below.

6. NONCOMMUNICABLE DISEASE

At the same time that most low- and middle-income countries need to address health problems that are now effectively controlled in high-income countries, they are increasingly sharing the high-income countries' heavy burdens of cardiovascular system disease, cancers, respiratory diseases, psychiatric disorders, and automobile-related injuries. *DCP2* has chapters addressing each of these NCDs and others. The public health research and policy community

has been surprisingly silent about these epidemics even though, for example, cardiovascular disease (CVD) in low- and middle-income countries killed over twice as many people in 2001 as did AIDS, malaria, and TB combined (see Table 4 for data on causes of deaths over age 5). An important early exception was Feachem and others (1992), who indicated approaches to treatment and prevention of these conditions that can be adapted to the tighter budget constraints of developing countries. The World Health Organization provides a valuable and more up-to-date discussion that emphasizes prevention (WHO, 2005). In addition, low-cost but effective approaches to long-term management of chronic conditions need to be developed and implemented as was emphasized in a recent World Bank policy review (Adeyi, Smith and Robles, 2007). The challenge is the identify approaches that provide genuine benefit in response to major sources of disease burden while costing sufficiently little that they can become (over time) universally available within the very tight public expenditure envelopes available in developing countries (Table 6).

The remainder of this section briefly discusses, as examples, the prevention and management of cardiovascular diseases, and smoking as a risk factor for multiple NCDs.

6.1 Cardiovascular Disease

Cardiovascular diseases in low- and middle-income countries result in about 13 million deaths each year, over a quarter of all deaths in those countries. Most cardiovascular deaths result from ischemic heart disease (5.7 million) or cerebrovascular disease (4.6 million). (A potentially substantial fraction of the heart disease deaths may result from congestive heart failure.) In both high income and low and middle income countries, these deaths occur at older ages than do infectious conditions and thus account for a substantially smaller fraction of total disease burden in disability-adjusted life years (DALYs)—12.9 percent—than they do of deaths. However, a far greater proportion of the cardiovascular deaths in low and middle income countries occur in middle age (30-69) than the proportion of these diseases in high income countries, where they are concentrated at older ages.

The main risk factors for CVD account for very large fractions of the deaths (and even more of the burden) from those diseases. For ischemic heart disease, they collectively account for 78 percent of deaths in low- and middle-income countries; for stroke, they account for 61 percent (Ezzati and others 2006). Measures to reduce the levels of those risk factors—high blood pressure, high intake of saturated animal fat, smoking, obesity, binge drinking of alcohol, physical inactivity, and low fruit and vegetable consumption—are the goals for prevention. Unlike the favorable experience with controlling tobacco use, attempts to change the behaviors leading to obesity, hypertension, adverse lipid profiles, or physical activity appear to have had little success at a population level. A notable exemption are the remarkable declines of 25% in vascular mortality in the 1990s in Poland, which appears due to macroeconomic reforms that effectively removed the government subsidy for butter overnight, and simultaneously opened up markets from Western Europe of fresh fruits and vegetables as well as products with lower amounts of saturated fat (Zatosnki et al, 2001). Willett et al. (2006) document, many promising approaches remain to be tried. Common sense suggests that they should be initiated even while more systematic efforts to develop and evaluate behavior-change packages are ramped up.

Pharmaceutical interventions to manage two major components of cardiovascular risk—hypertension and high cholesterol levels—are well established and are highly cost-effective for individuals at high risk of a stroke or heart attack. Adding aspirin to list of pharmaceutical interventions can reduce risk significantly further. From at least the time of publication of *Disease Control Priorities in Developing Countries*, 1st edition (*DCP1*), researchers have recognized that the low cost and high effectiveness of drugs to prevent the reoccurrence of a cardiovascular event made their long-term use potentially cost-effective in low-income environments. Even if sustained behavior change proves difficult to achieve, medications have the potential to reduce CVD risks by 50 percent or more. Simple combinations of cheap drugs

Table 6 Health Expenditures by Country Income Level, Public and Total, 2001

Country group	Health expenditure per capita (2001 US$)	Health expenditure (percentage of GDP)	Public sector expenditures (percentage of total health expenditures)
Low income	23	4.4	26.3
Middle income	118	6.0	51.1
High income	2,841	10.8	62.1
(Countries in the European Monetary Union)	(1,856)	(9.3)	(73.5)
World	500	9.8	59.2

Source: World Bank 2004, table 2.14.

can be highly effective in reducing mortality among the millions of adults worldwide who already have some form of vascular disease or diabetes diagnosed. For example, among patients with a history of occlusive vascular disease such as stroke or heart attack, use of aspirin, a statin and an antihypertensive drug could reduce the annual risk of major recurrence by about two-thirds; the 10-year risk of death or readmission to hospital is about 50% if people go untreated but only 16% if they receive daily treatment with 3 or 4 drugs (Peto et al, 2001). All of these drugs are inexpensive and could easily be packaged into "polypills" or "generic risk pills" for widespread use. Gaziano et al. (2006) and Rodgers et al. (2006) develop the current evidence on that point. A key problem, however, concerns the health care personnel and systems requirements associated with the need for lifelong medication use a problem also faced with antiretroviral therapy for AIDS and the use of medications to target several major psychiatric disorders. Adherence to drugs is a key issues, but unlike the challenge with AIDS drugs, resistance to the polypill drugs are unlikely, and their costs are quite low. (These problems illustrate the importance of the nonfinancial costs discussed in Sections 3 and 4 and related issues of health system development.) How to achieve effective long-term management of lifesaving drugs is a key delivery and research challenge for health system reformers.

In contrast to the lifelong requirement for drug use associated with CVD risk reduction in high-risk individuals, treatment of acute heart attacks with inexpensive drugs is both less demanding of system resources and highly cost-effective (Gaziano et al., 2006). Given the high incidence of these problems, system-wide efforts to achieve high rates of appropriate drug use in response to acute heart disease are a high priority.

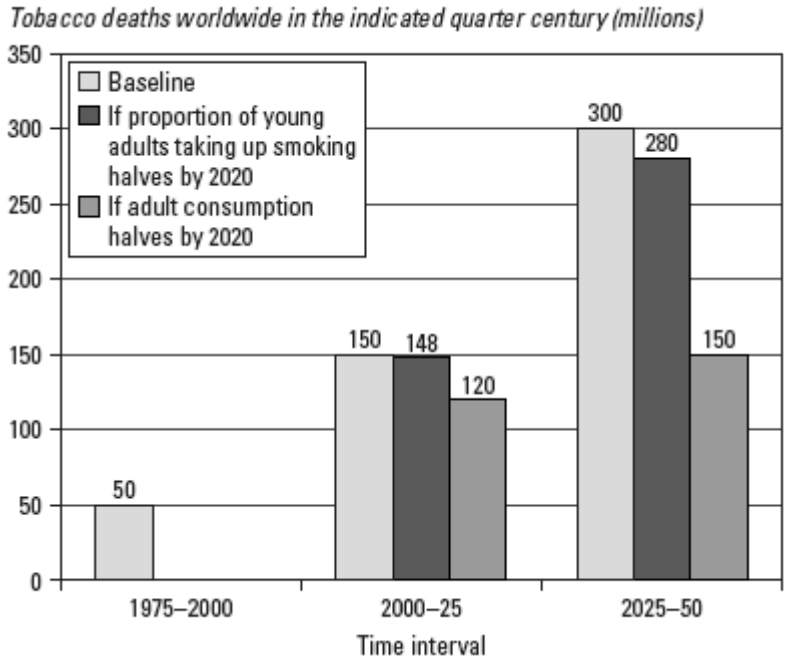
6.2 Tobacco Addiction

In most low-income countries, death in middle age increases in relative importance as the effects of smoking increase. Most adult deaths worldwide involve vascular, neoplastic and respiratory disease and smoking makes each of these more common. However, tobacco kills differently in different parts of the world. In China, the leading causes of death from smoking are chronic lung disease and lung cancer, with a noted excess also of tuberculosis deaths but much lower heart disease (Liu et al, 1998). In India, the leading causes of death from smoking are tuberculosis and heart disease, with relatively less lung cancer (Jha et al, 2007). In 2001, the number of tobacco-related deaths in developing countries was estimated to be 3.34 million or about 9% of deaths over age 5 in these countries (Lopez, et al., 2006). But on current patterns, tobacco use may account for some 10 million deaths per year by 2030, which most of these occurring in low and middle income countries. In total, some 1 billion tobacco deaths might occur this century in contrast to 100 million in the 20th century. Unless there is widespread cessation of smoking, some 100 million of China's 200 million young male smokers and about 40 million of India's 100 million young male smokers will eventually die from tobacco-related causes. Smoking is already more common to poor or uneducated males versus richer or educated males, and smoking mortality accounts for about half of the mortality risk between rich and poor men in Western countries (Jha et al, 2006b).

Preventing the initiation of smoking is important because addiction to tobacco makes smoking cessation very difficult, even for the numerous individuals who would like to do so. However, helping people quit smoking is at least as important as preventing initiation. Figure 5

portrays estimates showing that far more lives could be saved between now and 2050 with successful efforts to help people stop smoking than with efforts to keep them from starting. Reducing smoking levels is well demonstrated to be within the control of public policy. Indeed, many OECD countries have seen substantial declines in smoking deaths over the past 2 decades; for example, lung cancer deaths among young men 30–44 years of age have fallen by nearly 80% in the United Kingdom (Peto et al, 2003) a change attributable chiefly to marked increases in cessation. Also, in OECD countries more than 30% of the adult population are ex-smokers, in contrast to only 2% in India, 9% in China and 15% in Thailand (Jha et al, 2006a). Tobacco tax increases, dissemination of information about the health risks of smoking, restrictions on smoking in public and work places, comprehensive bans on advertising and promotion, and increased access to cessation therapies are effective in reducing tobacco use and its consequences (Jha et al, 2006a). Of these, tobacco tax is particularly effective- with a 10% increase in price leading to a 4 to 8% drop in consumption (roughly equally split between cessation and initiation). Young people and the poor are particularly more responsive to price (Jha and Chaloupka, 2000).

Tobacco use is substantially different that other health challenges as it involves use of a consumer good, with presumed economic benefits from that consumption. This has led to



Source: Jha, et. al., 2006.

Figure 5 Increase in Tobacco-Related Deaths as Populations Age

criticisms of tobacco control ignoring the welfare benefits of smoking (Wolf 2006). Given that smoking is addictive and that most smoking starts early in life when youths are short sighted, the calculation of welfare benefits is tricky (meaning that these benefits are simply the costs of withdrawal from smoking).). Information on tobacco hazards is often assumed to be well known. However, widespread ignorance of risks (or confusion of all risks) is well documented in developing countries. In China in 1996, 60% of adult smokers thought that smoking did little or no harm. Indeed, the recent increase in cessation in China might be related to new information on tobacco risks published in the late 1990s (Jha and Chen, 2007). In most countries with good information on tobacco risks, over three-quarters of adult smokers regret ever having started as adolescents. Gruber and Mullainathan (2002) have conducted recent economic work that incorporates addiction into consumption choices and conclude higher taxes are justified on

welfare grounds because the health costs to smokers are huge (even though the external costs to others might be small). The same work finds that higher cigarette taxes do not hurt the poor (since the self-control value of higher taxes helps the poor more).

Putting addiction into a cost-benefit framework is equally tricky. Peck et al (2000) built on an earlier framework by Barnum (1993) by comparing the consumer and producers surplus of tobacco (based on price and supply elasticities) to the value of statistical life (conservatively valued as 1 times per capita GDP) weighted by tobacco-related mortality and the degree to which health smoking risks are known. They conclude that if a typical smokers underestimates his or her own health costs by 3% to 23%, then the net benefits of consumption are zero. Similarly, the marginal costs of a 10% higher price due to taxation have net welfare gains as long as 3% of smokers or more underestimate their health risks of smoking.

While acknowledging the importance of attempts to estimate welfare losses associated with tobacco use and cessation, our approach in this paper is simpler. We use published estimates of the costs of mounting a comprehensive tobacco control program (analogous to the "combination prevention" approach to HIV transmission). CDC has recommended expenditures of $1-4 per capital but some US states have done well with less. Estimates for India from *DCP2* are for about $80 million per year. This figure includes costs of mobilizing public support, anti-smoking advertising and promotion, support for cessation programs and tax administration costs. (Proposed levels of taxation are revenue-enhancing for governments relative to the overall cost of comprehensive anti-smoking program, but our B:C analysis is based on social costs). In light of the range of published program cost we use $1 billion per year as a reasonable estimate of the cost of comprehensive programs in the low- and middle-income countries. Our specific estimates of mortality reduction are based on the effect of a 33% price (about a 50% increase in tax) on demand.

7. 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. 2006).

Laxminarayan, et. al. (2006) summarized the main findings on cost-effectiveness which form the basis for the cost-benefit analyses reported here. Appendix Table 1 provides highlights of those findings for South Asia and Sub-Saharan Africa. 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 results partly from (often highly) incomplete information and uncertainty. It results also, and even more importantly, from the responsiveness of the cost-effectiveness function to variations in prices, in the scale of the intervention (and of its substitutes and complements), and in the epidemiological environment.

Given these often broad ranges in CE ratios, and hence in CB ratios, it makes little sense to conclude with precise estimates or with attempts to quantify uncertainty. Rather we have identified 7 major opportunities for investment in interventions that address a large disease burden highly cost effectively. Even valuing DALYs at a conservative $1,000 and, again conservatively, reducing by 50% the DALY loss associated with an under-5 death (this affects the malaria and immunization numbers) the benefit to cost ratios associated with investing in these opportunities is enormously high. We do provide, however, in Appendix B a brief assessment of the sensitivity of our findings to key assumptions. Overall this suggests that the conclusions in our Table 7 are conservative.

This concluding section provides a summarizing table on these 7 interventions. Number 1 on the list in Table 7 is case finding and treatment of tuberculosis (Dye and Floyd, 2006). The 7th item, strengthening and expanding surgical capacity at the district hospital level (Debas, et. al. 2006) is an example of what Jamison (2008) calls an intervention platform. Although the list of

Table 7 DISEASE CONTROL: KEY INVESTMENT PRIORITIES

Priority Area	Indicative Benefit-Cost Ratio	Level of Capacity Required[a]	Financial Risk Protection Provided[a]	Relevance for Development Assistance[a]	Annual Costs ($ billions)	Annual Benefits[b]
1. Tuberculosis: appropriate case finding and treatment	30:1	M	H	M	1	1 million adult deaths averted or 30 million DALYs
2. Heart attacks (AMI): acute management with low-cost drugs	25:1	M	H	H	.2	300,000 heart attack deaths averted each year or 4.5 million DALYs
3. Malaria: prevention and ACT treatment package	20:1	M	L	M	.5	500,000 (mostly child) deaths averted or 7.5 million DALYs
4. Childhood diseases: expanded immunization coverage	20:1	L	L	L	1	1 million child deaths averted or 20 million DALYs
5. Cancer, heart disease, other: tobacco taxation	20:1	H	H	H	1	1 million adult deaths averted or 20 million DALYs
6. HIV: "combination prevention"	12:1	M	H	H	2.5	2 million HIV infections averted or 22 million DALYs
7. Injury, difficult childbirth, other: surgical capacity at the district hospital	10:1	H	H	H	3	30 million 'surgical' DALYs averted or about 20% of DALYs

[a] Level of capacity required, extent of financial risk protection provided and relevance for development assistance, are judged by the authors to be high (H), medium (M) or low (L).
[b] In the formulation of DALYs the benefits of averting a death in a given year all accrue in that year and are calculated as the present value (at a 3% discount rate) of the future stream of life years that would have occurred if the death had been prevented.

conditions that district hospital surgeons address is long, the most important in terms of benefits are dealing with difficult childbirths and with injury.

Table 7 orders opportunities by benefit cost-ratio—from 30:1 for appropriate TB treatment to10:1 for expansion of surgical capacity at district hospitals. Every opportunity in the table has not only a very high estimated B:C but, also, addresses major disease burden. The interventions that would address the most DALYs are TB treatment (#1) and district hospital surgery (#7). Each would provide relatively a high degree of financial protection to populations.

Experience with implementation of heart attack treatment and, to a lesser extent, tobacco taxation and surgery, is much more limited in low-income countries than is experience with the other 4 interventions on the list. There is a strong case for early, large-scale implementation trials in each of these 3 areas, and correspondingly strong arguments for international development assistance to finance these trials and learn from their results.

With the exception of surgery in the district hospital, the opportunities identified don't explicitly address the strengthening of health system capacity. It will be important to ensure that implementation includes related investments in manpower and institutions, with 'related' broadly defined. 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 involves creating specific capacity to deliver priority services in volume and with high quality. In the second model capacity strengthening spreads out from high-performing initial nodes. The approach that this paper implicitly advocates is very much in the spirit of the latter.

From national perspectives the interventions on HIV/AIDS (combination prevention), on TB, on immunization and on malaria prevention 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 (though the very substantial resources of GAVI and the Global Fund Against AIDS, Tuberculosis and Malaria). But most of these are familiar interventions with only modest international externalities. There is a reasonable argument that development assistance should deal with R&D, with reducing the risks of adapting the new and with crossborder externalities. By these criteria development assistance is doing less well in all but ignoring heart disease and

surgical capacity. There is an initiative now being considered seriously by the international community to facilitate less expensive treatment with effective malaria drugs while preventing the development of resistance to the key drug artemisinin. The Affordable Medicines Facility-malaria (AMFm) would operate by changing the prices countries face for drugs rather supporting their purchase and its support is a key priority.

In conclusion, TB treatment stands out as perhaps the most important investment on grounds of its high B:C, its high level of financial risk protection, its moderate systemic requirements and in the size of disease burden potentially averted. All the others in the table have advantages and disadvantages relative to each other and different individuals might well order them differently. The overwhelming general conclusion, however, is that even if all costs were increased by a factor of, say, 3 (Appendix Table B1, row3), there is a substantial and very specific list of major and highly attractive investment opportunities within the health sector.

Appendix A: Intervention Cost-Effectiveness in South Asia and Sub-Saharan Africa

DCP2 attempted to provide separate estimates of intervention cost-effectiveness for each of the World Bank's 6 regional groupings of low- and middle-income countries. The emphasis for the Copenhagen Consensus, and for this paper, is on low-income countries, which concentrate in South Asia and Sub-Saharan Africa. Appendix Table 1 summarizes key *DCP2*cost-effectiveness findings for the se two regions.

COPENHAGEN CONSENSUS CENTER

Appendix Table A1: Neglected Low-Cost Opportunities and High Cost Interventions in South Asia and Sub-Saharan Africa

	Cost per DALY averted ($)*	Thousands of DALYs averted*† per 20% increase in coverage	Burden of target diseases (millions of DALYs)*
Neglected low-cost opportunities in south Asia			
Childhood immunisation			
Increased coverage of traditional EPI programme	8	Not assessed	28·4
HIV/AIDS			
Voluntary counselling and testing	9–126	Not assessed	7·4
Peer-based programmes for at-risk groups (eg, commercial sex workers) to disseminate information, services (clean needles and condoms), and teach specific skills			
School-based interventions to disseminate information			
Prevention of mother-to-child transmission with antiretroviral therapy			
Surgical services and emergency care			
Surgical ward in district hospital, primarily for obstetrics, trauma, and injury	6–212	≥1·8	48·0–146·3
Staffed community ambulance			
Training of lay first-responders and volunteer paramedics			
Tuberculosis			
Childhood vaccination against endemic disease	8–263	Not assessed	13·9
Directly observed short-course chemotherapy			
Isoniazid treatment of epidemic disease			
Management of drug resistance			
Lower acute respiratory illnesses of children younger than age 5 years			
Community-based or facility-based case management of non-severe cases	28–264	0·7–1·8	9·7–26·4
Case management package, including community-based and facility-based care for non-severe cases and hospital-based care for severe cases			
Cardiovascular diseases			
Management of acute myocardial infarction with aspirin and β blocker	9–304	≥0·1	25·9–39·1
Primary prevention of coronary artery disease with legislation, substituting 2% of trans fat with polyunsaturated fat, at $0·50 per adult			
Secondary prevention of congestive heart failure with ACE inhibitors and β blockers incremental to diuretics			
Secondary prevention of myocardial infarction and stroke with polypill, containing aspirin, β blocker, thiazide diuretic, ACE inhibitor, and statin			
Tobacco use and addiction			
Tax policy to increase price of cigarettes by 33%	14–374	≥2·5	15·7
Advertising bans, health information dissemination, tobacco supply reductions, and smoking restrictions			
Nicotine replacement therapy			
Maternal and neonatal care			
Increased primary-care coverage	127–394	≥1·3	37·7–47·8
Improved quality of comprehensive emergency obstetric care			
Improved overall quality and coverage of care			
Neonatal packages targeted at families, communities, and clinics			
Neglected low-cost opportunities in sub-Saharan Africa			
Childhood immunisation			
Second opportunity measles vaccination‡	1–5	Not assessed	Not assessed
Increased coverage of traditional EPI programme			
Traffic accidents			
Increased speeding penalties, and media and law enforcement	2–12	Not assessed	6·4
Speed bumps at most dangerous traffic intersections			
Malaria			
Insecticide-treated bed nets‡	2–24	20·8–37·6	35·4
Residual household spraying‡			
Intermittent preventive treatment during pregnancy‡			
Surgical services and emergency care			
Surgical ward in a district hospital, primarily for obstetrics, trauma, and injury	7–215	1·6–21·2	25–134·2
Staffed community ambulance			
Training of lay first-responders and volunteer paramedics			

(Continues on next page)

COPENHAGEN CONSENSUS CENTER

(Continued from previous page)			
Childhood illnesses			
Integrated management of childhood illnesses‡	9–218	≥1·2	9·6–45·1
Case management of non-severe lower acute respiratory illnesses at community or facility level			
Case management package, including community-based or facility-based care for non-severe cases and hospital-based care for severe lower acute respiratory illnesses			
Breastfeeding to prevent malnutrition			
Cardiovascular disease			
Management of acute myocardial infarction with aspirin and β blocker	9–273	≥0·04	4·6
Primary prevention of coronary artery disease with legislation, substituting 2% of trans fat with polyunsaturated fat, at $0·50 per adult			
Secondary prevention of congestive heart failure with ACE inhibitors and β blockers incremental to diuretics			
Secondary prevention of myocardial infarction and stroke with polypill, containing aspirin, β blocker, thiazide diuretic, ACE inhibitor, and statin			
HIV/AIDS			
Peer-based programmes for at-risk groups (eg, commercial sex workers) to disseminate information and teach specific skills	6–377	Not assessed	56·8
Voluntary counselling and testing			
Diagnosis and treatment of sexually-transmitted diseases‡			
Condom promotion and distribution‡			
Prevention and treatment of coinfection with Mycobacterium tuberculosis‡			
Blood and needle safety programmes			
Prevention of mother-to-child transmission with antiretroviral therapy			
Maternal and neonatal care			
Increased primary-care coverage	82–409	≥2·8	29·8–37·7
Improved quality of comprehensive emergency obstetric care			
Improved overall quality and coverage of care			
Neonatal packages targeted at families, communities, and clinics			
High-cost interventions in south Asia			
Depression			
Episodic treatment with new antidepressant drug (SSRI)	1003–1449	0·4–0·8	14·6
Episodic or maintenance psychosocial treatment plus treatment with new antidepressant drug (SSRI)			
High blood pressure and cholesterol			
Primary prevention of stroke and ischaemic and hypertensive heart disease with aspirin, β blocker, and statin, incremental to policy-induced behaviour change, at 15% risk of cardiovascular disease event over 10 years	1120–1932	≥6·7	48·6
Primary prevention of stroke and ischaemic and hypertensive heart disease with a polypill, containing aspirin, β blocker, thiazide diuretic, ACE inhibitor, and statin, at 15% risk of cardiovascular disease event over 10 years			
Lifestyle diseases			
Primary prevention of diabetes, ischaemic heart disease, and stroke through policy that replaces saturated fat with monounsaturated fat in manufactured foods, accompanied by a public education campaign	1325–1865	1·3–1·8	39·5
Primary prevention of diabetes, ischaemic heart disease, and stroke through legislation that reduces salt content plus public education			
Stroke (ischaemic)			
Acute management with recombinant tissue plasminogen activator within 48 h of onset	1630–2967	0·03–0·4	2·2–9·2
Acute management with heparin within 48 h of onset			
Secondary prevention with carotid endarterectomy			
Diarrhoeal diseases			
Oral rehydration therapy if package cost is >$2·30 per child per episode	500–6390	0·02–2·5	22·3
Rotavirus or cholera immunisation			
Tuberculosis			
Isoniazid treatment for latent endemic disease in patients uninfected with HIV	5588–9189	Not assessed	13·9
Schizophrenia and biopolar disorder			
Antipsychotic medication and psychosocial treatment for schizophrenia	1743–17702	0·02–0·12	2·2–2·9
Valproate and psychosocial treatment for bipolar disorder			
Cardiovascular diseases			
Management of acute myocardial infarction with streptokinase or tissue plasminogen activator, incremental to aspirin and β blocker	638–24 040	0·04–0·3	25·9
Secondary prevention of ischaemic heart disease with statin, incremental to aspirin, β blocker, and ACE inhibitor			
Secondary prevention of ischaemic heart disease with coronary artery bypass graft			

COPENHAGEN CONSENSUS CENTER

(Continues on next page)

(Continued from previous page)

High-cost interventions in sub-Saharan Africa			
Diarrhoeal diseases			
Oral rehydration therapy if cost per episode is >$2·80 per child	500–1658	0·1–4·6	22
Rotavirus or cholera immunisation			
HIV/AIDS			
Home care treatment‡	673–1494	Not assessed	56·8
Antiretroviral therapy in populations with low adherence‡			
Traffic accidents			
Random driver breath tests	973–2146	≥0·05	6·2–6·4
Enforcement of seatbelt laws			
Child restraint promotion			
High blood pressure and cholesterol			
Primary prevention of stroke and ischaemic and hypertensive heart disease with aspirin, β blocker, and statin, incremental to policy-induced behaviour change, at 15% risk of cardiovascular disease event over 10 years	1920	Not assessed	10·6
Lifestyle diseases			
Primary prevention of diabetes, ischaemic heart disease, and stroke through policy that replaces saturated fat with monounsaturated fat in manufactured foods, accompanied by a public education campaign	1766–2356	1·4–1·8	9·6
Primary prevention of diabetes, ischaemic heart disease, and stroke through legislation that reduces salt content plus public education			
Stroke (ischaemic)			
Acute management with recombinant tissue plasminogen activator within 48 h of onset	1284–2940	0·02–0·3	0·9–3·6
Acute management with heparin within 48 h of onset			
Secondary prevention with carotid endarterectomy			
Tuberculosis			
Isoniazid treatment for latent endemic disease in patients uninfected with HIV	4129–5506	Not assessed	8·1
Cardiovascular diseases			
Management of acute myocardial infarction with streptokinase or tissue plasminogen activator, incremental to aspirin and β blocker	634–26 813	0·03–0·2	4·6
Secondary prevention of ischaemic heart disease with statin, incremental to aspirin, β blocker, and ACE inhibitor			
Secondary prevention of ischaemic heart disease with coronary artery bypass graft			

*Ranges represent variation in point estimates of cost-effectiveness, DALYs averted, or burden of disease for different interventions. Point estimates of cost-effectiveness and DALYs averted obtained from DCP2 [4] or calculated as midpoint of range estimates reported. Burden of disease estimates obtained from reference 7. †Avertable DALYs per 20% increase in treatment coverage in a hypothetical sample population of 1 million people. ‡Only assessed for sub-Saharan Africa.

Source: This table is based on chapters in *Disease Control Priorities in Developing Countries, 2nd edition* (Jamison, et al. 2006) as summarized in Laxminarayan, et al. (2006), Table 2.

Appendix B: Sensitivity Analysis

The analysis upon which we based the conclusions reported in Table 7 were undertaken under the following assumptions:

1. The discount rate is 3% per year and the version of the DALY that was used us based on this 3% 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, 2006a, 2006b). Earlier tabulations of disease burden used age weighted DALYs which give broadly similar results except that somewhat more weight is given to conditions of middle (TB, maternal deaths, trauma, psychiatric illness).

2. Chapter 6 (Jamison, et al, 2006) of Lopez (2006a) points to the mathematical impossibility, under plausible assumptions, having the standard formulation of a DALY give a loss from a death at age 25 differ by more than 20% or so from then loss from a death at age 1 day. An alternative version of the DALY is proposed there [DALY (3,0, .54)] and used in this chapter. The effect is to reduce the DALY loss of a death under age 5 by about 50% 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 as based on long-run average costs (at least in principle as there is some variation in actual costing methods).

4. The chapter assumes zero deadweight loss from taxation.

5. The chapter assumes the value of a DALY to be $1000.

Appendix Table B1 reports assessments of the robustness of our conclusions with respect to changes in these assumptions. On the most optimistic alternative assumption of Appendix

Table B1 the B:C 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 B:C of all interventions would decline by a factor of 10.

Appendix Table B1: Sensitivity Analysis

Change in assumption	Consequence
1. Change the discount from 3% to 6% per year, i.e. change to DALYs (6,0,.54)	The number of DALYs gained from each of the interventions and hence B:C will decline by about 50%.
2. Change from DALYs (3,0,.54) to DALYs (3,0)	The number of DALYs gained from immunization and from malaria control will approximately double, as will the B:C for the related interventions.
3. Since *ex ante* costs are typically underestimated, often substantially, multiply all costs by 3.	B;C will decline to 1/3 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, Shoven and Whalley, 195, provide estimates in this range).	B:C value decline by 1/3.
5. The value of a DALY is $5000 rather than $1000.	B:C values go up by a factor of 5.

References

Abdool Karim Q. Prevention of HIV by male circumcision. 2007. *BMJ*. Jul 7;335(7609):4-5

Acemoglu, D. and Johnson, S. 2007. "Disease and Development: The Effect of Life Expectancy on Economic Growth". *Journal of Political Economy*, **115,** 925-986.

Adeyi, S., C. Smith and S. Robles. 2007. *Public Policy and the Challenge of Chronic Noncommunicable Diseases*. Washington, D.C.: The World Bank.

Aral, S. O., M. Over, L. Manhart, and K. K. Holmes. 2006. "Sexually Transmitted Infections." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 311-330. Oxford and New York: Oxford University Press.

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.

Ballard, C., J. Shoven and J. Whalley. 1985. General Equilibrium Compuatations of the Marginal Welfare Costs of Taxes in the United States. *American Economic Review*, **74**, 128-138.

Barnum, H. 1994. "The Economic Burden of the Global Trade in Tobacco." *Tobacco Control* 3:358-61.

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

Bates MN, Khalakdina A, Pai M, Chang L, Lessa F, Smith KR. 2007. Risk of tuberculosis from exposure to tobacco smoke: a systematic review and meta-analysis. Arch Intern Med. Feb 26;167(4):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*, v. 95: 277-291.

Behrman, J. R., H. Alderman and J. Hoddinott. 2007 "Hunger and Malnutrition." Prepared for CC08.

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 *Disease Control Priorities*

in Developing Countries, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 331-370. Oxford and New York: Oxford University Press.

Bloom, D. E., D. Canning, and D. T. Jamison. 2004. "Health, Wealth and Welfare." *Finance and Development* 41 (1): 10-15.

Bloom, David E., and David Canning. 2006. "Booms, Busts and Echoes: How the Biggest Demographic Upheaval in History is Affecting Global Development." *Finance and Development*, v. 43: 8-13.

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 *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 413-432. Oxford and New York: Oxford University Press.

Brenzel, L., L. J. Wolfson, J. Fox-Rushby, M. Miller, and N. A. Halsey. 2006. "Vaccine-Preventable Diseases." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 389-412. Oxford and New York: Oxford University Press.

Chen L, Jha P, Stirling B, Sgaier SK, Daid T, 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

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 *The Macroeconomics of HIV/AIDS*, ed. M. Haacker, 182–97. Washington, DC: International Monetary Fund.

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 (4): 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** (2), pp.333-358.

Cutler, D., A. Deaton, and A. Lleras-Muney. 2006. "The Determinants of Mortality." *Journal of Economic Perspectives*, Vol. 20 (no. 3, summer): 97-120.

Davis, K. 1956. "The Amazing Decline of Mortality in Underdeveloped Areas." *American Economic Review* (Papers and Proceedings) 46 (2): 305-18.

Debas, H. T., R. Gosselin, C. McCord, and A. Thind. 2006. "Surgery." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 1245- 1260. Oxford and New York: Oxford University Press.

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

Del Rio, C. and Sepúlveda, J. 2002. "AIDS in Mexico: Lessons Learned and Implications for Developing Countries". *AIDS,* **16**, 1445-57.

Dye, C., and K. Floyd. 2006. "Tuberculosis." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 289-310. Oxford and New York: Oxford University Press.

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

England S, Loevinsohn B, Melgaard B, Kou U, Jha P. The evidence base for interventions to reduce mortality from vaccine-preventable diseases in low and middle-income countries. CMH Working Paper Series WG5 Paper No. : 10. http://www.cmhealth.org/docs/wg5_paper10.pdf.

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

Gajalakshmi V, Peto R, Kanaka TS, et al. Smoking and mortality from tuberculosis and other diseases in India: retrospective study of 43000 adult male deaths and 35000 controls. *Lancet* 2003;362:507-15.

Gaziano, T., K. S. Reddy, F. Paccaud, S. Horton, and V. Chaturvedi. 2006. "Cardiovascular Disease." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 645-662. Oxford and New York: Oxford University Press.

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 *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 499-530. Oxford and New York: Oxford University Press.

Global IDEA Scientific Advisory Committee. 2004. Health and economic benefits of an accelerated program of research to combat global infectious diseases *CMAJ*. NOV. 9, 2004; 171 (10).

Gruber, J., and S. Mullainathan. 2002. "Do Cigarette Taxes Make Smokers Happier?" NBER Working Paper No. 8872. Cambridge, Mass.: National Bureau of Economic Research.

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

Hutton, G. 2007. Air Pollution Paper prepared for CC08.

Hutton, G. 2007. "Unsafe Water and Lack of Sanitation." Prepared for CC08.

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

James JS. 2005. Uganda study found that death reduced HIV prevalence; did the public take home the wrong message? *AIDS Treat News*. Feb 25;(410):5-6.

Jamison, D. (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. 2006. "Investing in health." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 3-34. Oxford and New York: Oxford University.

Jamison, D. T. 2006. "The Neglected Problems of Stillbirths and Neonatal Deaths." Paper prepared for the Global Forum on Health Research, 10th Meeting, Cairo.

Jamison, D. T., J. Breman, A. R. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills and P. Musgrove, Eds. April 2006. *Disease Control Priorities in Developing Countries*, 2nd edition. Oxford and New York: Oxford University Press. 1401 pages.

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., and S. Radelet. 2005. "Making Aid Smarter." *Finance and Development* 42 (2): 42-46.

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., 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., S. Shahid-Salles, J. S. Jamison, J. Lawn, and J. Zupan. 2006. "Incorporating Deaths Near the Time of Birth into Estimates of the Global Burden of Disease." In *Global Burden of Disease and Risk Factors*, ed. A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray, 427-462. New York: Oxford University Press.

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*.

Jha P, Chaloupka FJ. 2000. The economics of global tobacco control. *BMJ;* 321: 358-361.

Jha, P., F. J. Chaloupka, J. Moore, V. Gajalakshmi, P. C. Gupta, R. Peck, S. Asma, and W. Zatonski. 2006a. "Tobacco Addiction." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 869-886. Oxford and New York: Oxford University Press.

Jha P, Peto R, Zatonski W, et al. 2006b. Social inequalities in male mortality, and in male mortality from smoking: indirect estimation from national death rates in England and Wales, Poland, and North America. *Lancet* 368, 367-70.

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. Geneva: World Health Organization.

Jha P, Nagelkerke NJD, Ngugi E, Wilbond B, Prasada-Rao JVR, Moses S, Plummer FA. Reducing HIV transmission in developing countries: Science 2001; 292(5515):224-5.

Jha P, Mills A, Hanson K, Kumaranayake L, et al. Improving the health of the global poor. Science 2002; 295(5562):2036-9.

Jha P and Z. Chen Z. 2007. Poverty and chronic diseases in Asia: challenges and opportunities: *Canadian Medical Association Journal* (in press).

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

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

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 *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 371-388. Oxford and New York: Oxford University Press.

Lawn, J. E., J. Zupan, G. Begkoyian, and R. Knippenberg. 2006. "Newborn Survival." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 531-550. Oxford and New York: Oxford University Press.

Laxminarayan, R., J. Chow, and S. A. Shahid-Salles. 2006. "Intervention Cost-Effectiveness: Overview of Main Messages." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 35-86. Oxford and New York: Oxford University Press.

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. 2006. Advancement of global health: key messages from the Disease Control Priorities Project. *The Lancet*, 367:1193-1208, April 8, 2006.

Laxminarayan, R, E. Kelin, C. Dye, K. Floyd, S. Darly, O. Adeyi. 2007. Economic Benefit of Tuberculosis Control. *Resource for the Future Working Paper.*

Levine, R. and the What Works Working Group. 2007. *Millions Saved: Proven Successes in Global Health.* Subbury, Massachusetts, Jones and Bartlett Publishers.

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

Liu BQ, Peto R, Chen ZM, et al. Emerging tobacco hazards in China: 1. Retrospective proportional mortality study of one million deaths. *BMJ* 1998;317:1411-22.

Lomborg, Bjørn, ed. 2004. *Global Crises, Global Solutions.* Cambridge: Cambridge University Press.

Lomborg, Bjørn, ed. 2006. *How to Spend $50 Billion to Make the World a Better Place*. Cambridge: Cambridge University Press.

Lopez, A. D., S. Begg, and E. Bos. 2006. "Demographic and Epidemiological Characteristics of Major Regions of the World, 1990 and 2001." In *Global Burden of Disease and Risk Factors*, ed. A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J .L. Murray, 17-44. New York: Oxford University Press.

Lopez, A. D., C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray (eds.). 2006a. *Global Burden of Disease and Risk Factors*. Oxford and New York: Oxford University Press, 475 pages.

Lopez, A. D., C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray. 2006b. "Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data." *The Lancet*, 367: 1747-1757, May 27, 2006.

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

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 *Global Burden of Disease and Risk Factors*, ed. A. D. Lopez, C. D. Mathers, M. Ezzati, D. T. Jamison, and C. J. L. Murray, 45-240. New York: Oxford University Press.

Measham, A.R., Rao, K.D., Jamison, D.T., Wang, J. and Singh, A. 1999 "The Performance of India and Indian States in Reducting Infant Mortality and Fertility, 1975-1990." *Economic and Political Weekly* 34(22):1359-1367.

Meltzer, D. 2006. "Economic Approaches to Valuing Global Health Research." In *Disease Control Priorities in Developing Countries*, 2nd edition. ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 157-164. Oxford and New York: Oxford University Press.

Mills, A., and S. Shillcutt. 2004. "Communicable Diseases." In *Global Crises, Global Solutions*, ed. B. Lomborg, 62-114. Cambridge: Cambridge University Press.

Mulligan, J., J. A. Fox-Rushby, T. Adam, B. Johns, and A. Mills. 2003. "Unit Costs of Health Care Inputs in Low and Middle Income Regions. Bethesda, Maryland: Fogarty International Center, National Institutes of Health, Disease Control Priorities Project Working Paper 9.

Nagelkerke NJ, Jha P, de Vlas SJ, Korenromp EL, Moses S, Blanchard JF, Plummer Modelling HIV/AIDS epidemics in Botswana and India: impact of interventions to prevent transmission. Bull World Health Organ. 2002;80(2):89-96.

Nordhaus, W. 2003. "The Health of Nations: The Contributions of Improved Health to Living Standards." In *Measuring the Gains from Health Research: An Economic Approach*, ed. K. M. Murphy and R. H. Topel, 9-40. Chicago: University of Chicago Press.

Oeppen, J., and J. W. Vaupel. 2002. "Demography, Broken Limits to Life Expectancy." *Science* 296 (5570): 1029-31.

Orazem, PF. 2007. Lack of Education. Paper prepared for CC08.

Peabody, J. W., M. M. Taguiwalo, D. A. Robalino, and J. Frenk. 2006. "Improving the Quality of Care in Developing Countries." In *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 1293-1308. Oxford and New York: Oxford University Press.

Peck R, Chaloupka FJ, Jha P and Lightwood J. 2000. Welfare analyses of tobacco. In Jha P and Chaloupka FJ, eds. Tobacco Control in Developing Countries. Oxford: OUP;, pp. 131-152.

Peto R., Collins R., Parish S. et al,. Cholesterol, diastolic blood pressure, and stroke: 13,000 strokes in 450,000 people in 45 prospective cohorts. Prospective studies collaboration. *Lancet* 1995;346:1647-53.

Peto, R. & Baigent, C. Trials: the next 50 years. Large scale randomised evidence of moderate benefits. BMJ 1998; 317: 1170-1.

Peto, R., Lopez AD., Boreham J., et al. Mortality from smoking in developed countries, 1950–2000. 2nd ed. Oxford (UK): Clinical Trial Service Unit; 2006. Available: *http://www.ctsu.ox.ac.uk/~tobacco/* (accessed 2007 Sept 24).

Piot, P., Banton, M., Larson, H., Zewdie, D. and Mane, P. 2008, forthcoming. "Coming to Terms with Complexity: A Call to Action for HIV Prevention." *The Lancet*.

Preston, S. H. 1975. "The Changing Relation between Mortality and Level of Economic Development." *Population Studies* 29 (2):231-48.

_____. 1980. "Causes and Consequences of Mortality Declines in Less Developed Countries during the Twentieth Century." In *Population and Economic Change in Developing Countries*, ed. R. Easterlin, 289-360. Chicago: University of Chicago Press.

Pritchard, C. 2004. "Developments in Economic Evaluation in Health Care: A Review of HEED." OHE Briefing 40, Office of Health Economics, London, March 2004.

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

Schelling, T. 1968. "The Life You Save May Be Your Own." In Chase, S.B., jr (ed.), *Problems in Public Expenditure Analysis*, Washington, D.C.: Brookings Institution.

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 *Disease Control Priorities in Developing Countries*, 2nd edition, ed. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove, 483-498. Oxford and New York: Oxford University Press.

Tolley, G., D. Kenkel and R. Fabian. 1994. "State of the Art Health Values." In Tolley, G., D. Kenkel and R. Fabian (eds.), *Valuing Health for Plicy: An Economic Approach.* Chicago: University of Chicago Press, pp. 323-344.

US Centres for Disease Control. 1999 Achievements in Public Health, 1900-1999: Changes in the Public Health System, MMWR, Vol 48, No 50;1141 12/24/1999 (available at http://www.cdc.gov/mmwr/PDF/wk/mm4850.pdf).

Weatherall D, Greenwood B, Chee HL, Wasi P. 2006. Science and technology for disease control: past, present, and future. In *Disease Control Priorities in Developing Countries*, 2nd edition. D. T. Jamison, J. Breman, A. Measham, G. Alleyne, M. Claeson, D. Evans, P. Jha, A. Mills, and P. Musgrove (eds.). Oxford and New York: Oxford University Press. Pp.119-138.

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

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

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

World Economic Forum. 2008. Tacking Tuberculosis: The Business Response. Davos: The World Economic Forum.
Yamey, G. on Behalf of Interviewees. 2007. Which Single Intervention Would do the Most to Improve the Health of Those Living on Less than $1 per Day? *PLoS Med.*, **4.**