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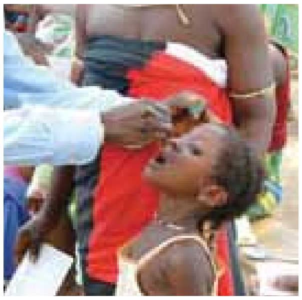


The Current Path as It Seems to Be Unfolding

How might global patterns of health change as this century unfolds?

Assuming that historical relationships among income, education, and health outcomes remain relatively stable, how might global patterns of health change as this century unfolds? Should countries currently beset mostly by communicable diseases expect more of the same or instead (or additionally) start to prepare themselves for an onslaught of chronic diseases? In higher-income countries how rapid might be the seemingly inexorable rise in the portion of citizens who are retired and how long might they live in good and ill health? How could health outcome forecasts vary with different projections of income or education? Such questions matter greatly for policymakers and stakeholders seeking to develop systems that best support population health and well-being.

The attempt to explore changing patterns of health drives both this chapter and the rest of this volume. This chapter begins by presenting the International Futures (IFs) base case or reference case forecasts of global health (where current conditions of the system and its dynamics appear to be taking us).[1] We also compare our base case with other forecasts, to the extent that such are available.

We know, of course, that forecasts even 10 years into the future will be wrong. Thus, we must not only present our base case but also direct attention in this analysis to some of the greatest uncertainties with respect to that forecast—uncertainties with respect to the key drivers of health and their relationships with health systems, uncertainties with respect to leverage of human interventions, and uncertainties that could result from even greater surprises in the system. This chapter begins the analysis of uncertainty, and subsequent chapters will continue it.

The Base Case

While distal or broad factors such as income or education do not directly cause mortality and morbidity, historical relationships between these factors and outcomes provide a starting point for thinking about probable health futures. Thus, as discussed in Chapter 3, we begin our exploration of the path of global health with analyses rooted in the distal-driver formulations created for the 2002 and 2004 versions of the Global Burden of Disease (GBD) analysis (Mathers and Loncar 2006; WHO 2008a), supplemented by inclusion of selected health risk factors. Most of our results extend the IFs base case (see Box 4.1) to 2060, and in some cases to the end of the century. (In Chapters 5 and 6, we will turn our attention to the potential impact of alternative forecasts of the proximate risk factors.)

Box 4.1 The base case of IFs

The base case is not a simple extrapolation of variables in multiple issue areas, including health, but rather the dynamic, nonlinear output of the fully integrated IFs system. The integrated system of the base case includes the health model that Chapter 3 described, with both its distal and proximate formulations activated. Thus, health forecasts respond to demographic, economic, education, and other models of IFs and, in turn, affect their behavior. Among the most obvious consequences of this integration are that changes in health result in changes in population and GDP, which can either accelerate or retard further changes in health outcomes (via positive and negative feedbacks). Chapter 7 will explore these linkages and dynamics in some detail.

The forecasts that other IFs system models produce of key drivers, such as GDP per capita and educational attainment of adults, are thus foundational underpinnings of its health forecasts. Hughes et al. (2009: 56–71) explored those forecasts, comparing them to other forecasts such as those of the UNPD and World Bank. As a general rule, the IFs base case produces behavior that tends to be quite similar to medium variant or base forecasts of such analyses (see also Hughes 2004 and 2006). We note that our forecasts of African economic growth tend to be slightly more optimistic than most other analyses. We note too that we build in the "great recession" with International Monetary Fund-based assumptions, beginning in 2007 and ending for most of the world by 2011, and we forecast peak global oil production between 2030 and 2040, with some consequences for economic growth of oil producers and consumers.

Life expectancy

We begin by looking at the most widely used aggregate health measure, that of life expectancy. Figure 4.1 shows historical increases in life expectancy separately for females and males since 1960 and the IFs forecast through 2100 for each World Bank developing region and a single high-income country grouping (see Box 4.2 for discussion of country groupings). The long horizon of Figure 4.1 provides context for subsequent analyses focusing on the period until 2060.

The historical patterns themselves are of considerable interest. They clearly show the power of disruptive events and periods, three in particular. First, in East Asia and Pacific there was a substantial jump in life expectancy in the earliest years of the historical period. In 1960, the life expectancy of China had fallen to 36 years because of the horrendous turmoil associated with the ironically named "Great Leap Forward." By 1967, it had rebounded to nearly 60 years. Given China's sizable population, the impact on regional and even global averages was substantial. Second, the HIV/AIDS epidemic is clear in the pattern of sub-Saharan Africa. The probable peaking of AIDS deaths (to which we will return) explains the reversal in the early years of the post-2005 forecast of the dip in life expectancy we see in the late years of the historical series. For instance, in Botswana life expectancy fell from 64 years in 1985–1990 to 48 years in 2000–2005; the United Nations Population Division forecasts a return to 55 years in the 2005–2010 period (UNPD 2009b: 13). Third, in Europe and Central Asia (which in the absence of the high-income countries consists mostly of former communist countries), life expectancy was fundamentally flat across the historical period, with male life expectancy actually dropping in the post-Soviet era. Again, some reversal of the decline is underway. Collectively, these historical patterns constitute a warning with respect to the forecasts—the future is unlikely to unfold as smoothly as those lines suggest.

More generally, these historical patterns also show us how regional stories can change quite significantly over a period of a few decades. In 1960, life expectancies of countries in developing Europe and Central Asia and in the high-income grouping were very nearly the same, as were those in sub-Saharan Africa and South Asia. By 2005, however, the regions in each of these pairings had diverged. On the other hand, over the same period the Middle East and North African region had quite dramatically narrowed its gap with the high-income countries.

Looking forward, several issues of interest are apparent in the historical and forecast series of life expectancy by region, shown from 1960 through 2100 in Figure 4.1. One is the gap between the rich and poor of the world, which the figure clearly shows to be narrowing, but nonetheless quite slowly until well into the century. A second concerns the unfolding of HIV/AIDS, especially given the recent character of the possible peaking of the epidemic; more

We begin with a base case that combines GBD distal-driver formulations with our analyses of selected proximate risk factors.

Historical patterns in life expectancy show how significantly regional stories can change over a period of a few decades.

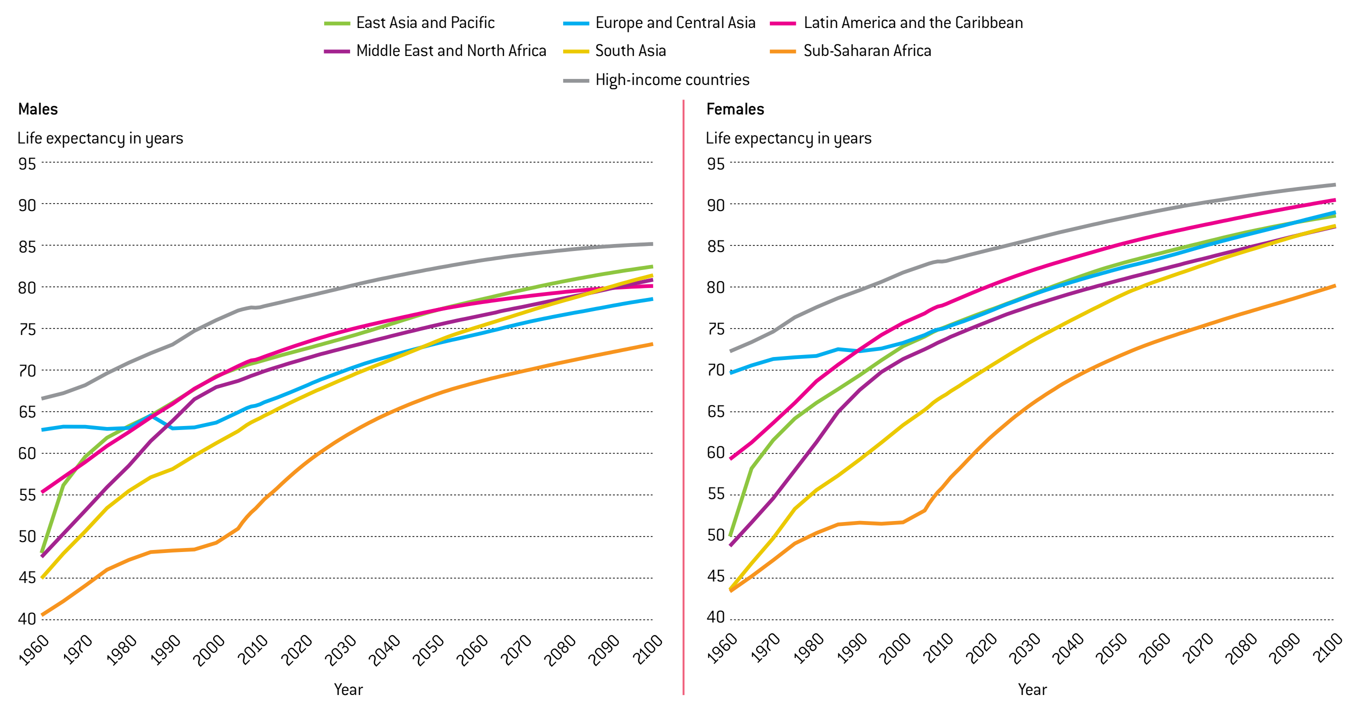
generally, the rate of decline in communicable diseases will especially affect the forecasts for the developing regions. A third issue is the rate of potential expansion in life expectancy of those countries and populations at the leading edge of the fight against chronic diseases. In Figure 4.1, especially for males, there is a slowing in the forecasted growth pattern of the rates of extension in life expectancy in the high-income countries between the historical pattern and the forecasts.

The life expectancy gap between the rich and poor of the world narrows in our forecast, although too slowly to meet the CSDH goal.

Following the lead of the Commission on Social Determinants of Health (CSDH 2008) in looking at the gap in life expectancy at birth (LEB) between the sixty countries with the longest and shortest LEBs, Figure 4.2 shows that gap historically and in our base case forecast (life expectancies in 2005 define the two country sets). The CSDH goal is a reduction of that gap by 10 years between 2000 and 2040. Figure 4.2 suggests the complications of attaining that goal and the very great improbability that we will do so. One historical complication is that, after several decades of decline, the gap began increasing in the 1990s as a direct result of the HIV/AIDS epidemic. The epidemic may have peaked (to be discussed below), but the recentness of that turn gives us less confidence than we would like in the forecast that the historical rate of decline in the gap after 1960 will resume, perhaps even with some catch-up. Another factor that makes goal achievement difficult is more positive—life expectancies of high-income countries continue to advance. Even with renewed decline in the gap, movement of the difference in life expectancy from 18.8 years in 2000 to 8.8 appears unlikely to happen until after 2060 (in fact, not until near the end of the century). The goal, unfortunately, appears overly ambitious.

The forecasts of advance in regional life expectancy in Figure 4.1 and of reduction in the global gap in Figure 4.2 depend on what will happen with respect to advances against communicable and chronic diseases. With respect to communicable diseases, there are many wild cards, including the possible mutation of known diseases and/or emergence of new ones that are not responsive to existing modes of prevention and treatment. The best-recognized wild card is the continued unfolding

Figure 4.1 Life expectancy for males and females by region: History and extended forecasts



Source: IFs Version 6.32 base case forecast with UNPD data through 2005.

Box 4.2 Groupings of country-level data and forecasts

Every major international organization divides the world into regions differently. Because the World Health Organization (WHO) and the World Bank are both active in global health analysis and forecasting, their divisions are most relevant to this volume.

WHO aggregates data for six WHO-defined global regions: Africa, Americas, Eastern Mediterranean, Europe, Southeast Asia, and Western Pacific. For analysis they sometimes divide these regions by levels of child and adult mortality or income. WHO also provides data tables organized by two standard World Bank classifications.

One World Bank classification combines income and geographic groupings to create six developing-country regions (namely East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia, and sub-Saharan Africa) and a seventh category that is an aggregation of all high-income countries. The other World Bank classification divides countries into four groups based on income characteristics alone: low-income, lower-middle-income, upper-middle-income, and high-income countries respectively.

The World Bank geographic and income classifications are more widely used in development studies and facilitate comparisons with broader sets of data and, unless otherwise noted, are used throughout this volume. We use the World Bank groupings based on 2008 GNI per capita. The GBD forecasts to 2030, however, used World Bank groupings based on 2004 GNI per capita, so there are slight differences in the group members between the GBD and the IFs forecasts.

The Appendix to this volume on global regions identifies the members of the World Bank regions based on their 2008 GNI per capita.

of the HIV/AIDS epidemic. Globally, annual deaths due to AIDS rose very rapidly from about 225,000 in 1990 to 2 million just 14 years later. Although UNAIDS estimates of deaths drop from that peak in 2004 to 1.85 million in 2007, forecasts are very challenging.

As we turn to Figure 4.3, recall that we use the term "communicable diseases" to refer to all Group I diseases or conditions even though the category also includes maternal and perinatal conditions and nutritional deficiencies (about 75 percent of Group I diseases are communicable, and the large majority of the remainder are perinatal conditions). In Figure 4.3 we show separate IFs base case forecasts of deaths for four major communicable diseases (AIDS, diarrhea, malaria, and respiratory infections) and a combined category—"other communicable diseases"—modeled in the aggregate, which includes deaths from maternal and perinatal conditions and nutritional deficiencies as well as other communicable diseases (e.g., tuberculosis, measles, and parasitic infections). Our forecast of deaths in the combined category is slightly less than the sum of deaths from the four separately modeled categories.

Overall, our forecasts for decline in global deaths from all communicable diseases are very positive, with a reduction of just over 40 percent by 2030 and almost 70 percent by 2060. This is generally consistent with historical patterns of progress against most of the diseases. The greatest uncertainty most likely attends the magnitude of decline we forecast for AIDS deaths; our forecast for decline in deaths from malaria may also be somewhat optimistic given the disease's historical persistence and propensity for resurgence. Importantly, with forecasted continuing increases in population, communicable disease mortality rates (not shown) are forecast to drop even more rapidly than numbers of deaths.

Whereas our forecasts for deaths from communicable disease might appear optimistic, our forecasts for mortality more generally

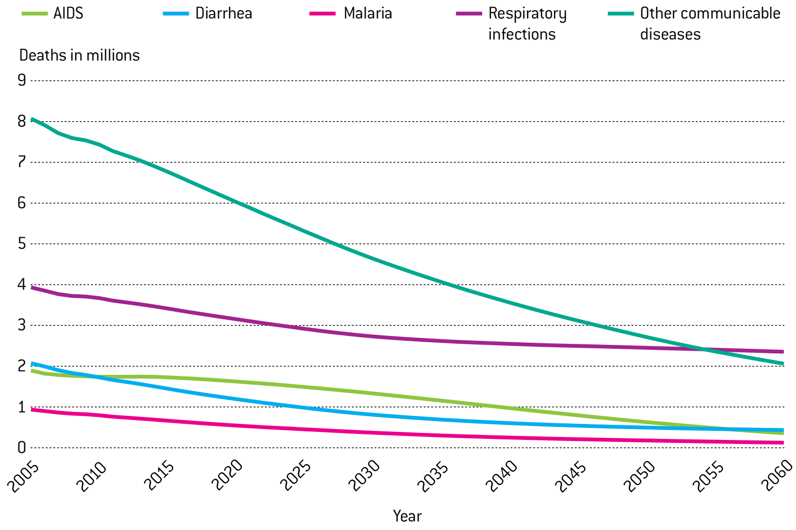
Overall, our forecasts for continued decline in deaths from communicable diseases are very encouraging (about 70 percent by 2060).

Figure 4.2 Life expectancy gap between countries with the longest and shortest life expectancies

Note: The comparison is between populations in the 60 longest-lived countries and those in the 60 shortest-lived countries; country groupings are based on 2005 data.

Source: IFs Version 6.32 base case forecast using all available UNPD data through 2005.

Figure 4.3 Global deaths (millions) by major communicable diseases



Note: Recall that in IFs discussion and displays the term "other communicable diseases" is used to describe all Group I diseases that we do not forecast separately. Thus, the term as we use it includes maternal and perinatal conditions and nutritional deficiencies as well as the communicable diseases that we do not forecast separately. Tuberculosis and perinatal conditions are the major diseases in our undifferentiated category.

Source: IFs Version 6.32 base case forecast.

At the same time, we forecast a slowing of life expectancy gains for system leaders.

may appear more pessimistic. Our base case forecasts suggest that, after a long period of quite steady gains, countries and regions on the leading edge of life expectancy may experience decreasing incremental gains in future decades (see Table 4.1).

Such slowing of gains by system leaders may not be unreasonable, especially given 2005 data that indicate the pace of increase for the life expectancy of Japanese women had already slowed significantly relative to the rate of the prior decade. Moreover, given that the life expectancy of Japanese women has come to exceed that of the nearest following population by more than a full year, even catch-up by other countries will be challenging, much less the forging of a faster pace of increase.[2]

One key reason that life expectancy gains may slow is that the room for further dramatic reduction of infant and child mortality due to communicable diseases and maternal and perinatal diseases (key reasons for past major advances in life expectancy even in high-income countries) has greatly decreased. Future mortality reductions need to come from adult and older adult populations, where they have historically been more difficult to achieve and where they proportionately add many fewer years of life expectancy. And they require attention to a different kind of disease burden—that caused primarily by noncommunicable diseases.

Changing disease burden

The nature of the global burden of disease is changing. As the previous section indicated, a rapid reduction is underway, and forecast to continue, in death rates and deaths from communicable diseases. Figure 4.4 reinforces this point by comparing communicable disease death rates in sub-Saharan Africa with those in high-income countries at three different points in time. According to the base case forecast, by 2060 communicable disease death rates in sub-Saharan Africa will have declined dramatically and almost reached the extremely low death rates forecast for those of the high-income countries.

Figure 4.5 shows a similar comparison for noncommunicable disease death rates, again contrasting those of sub-Saharan Africa with

The global burden of disease is shifting to noncommunicable diseases and conditions.

Table 4.1 Life expectancy of females in globally leading country: History and forecast

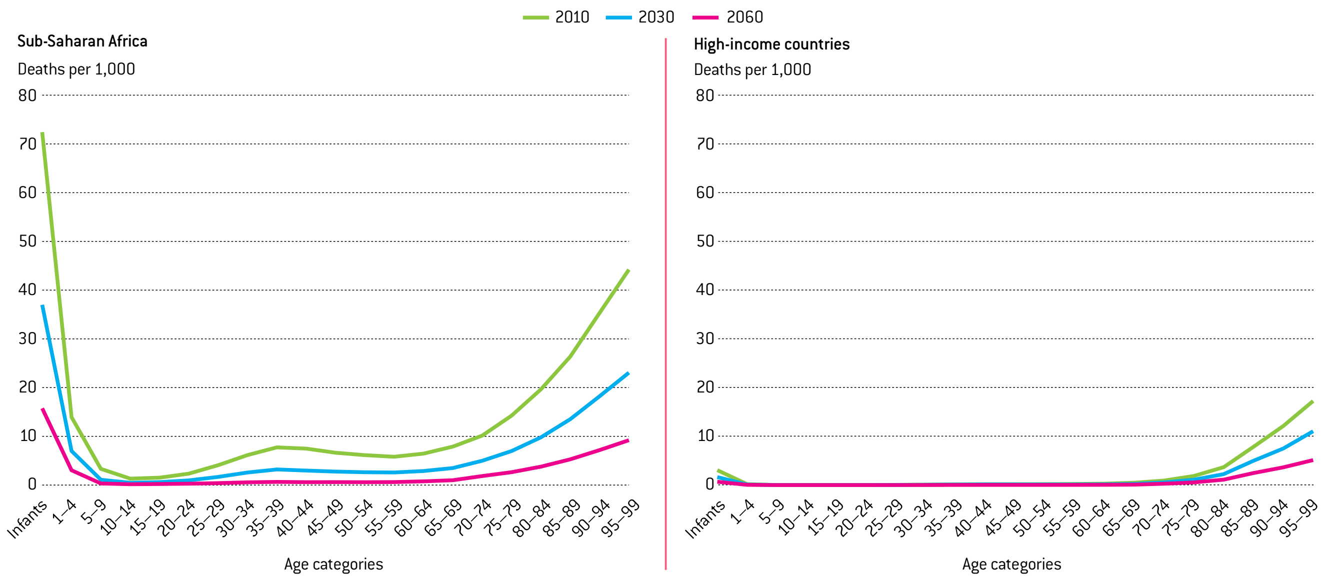
	Expected years of life	Increase in years per decade	Globally leading country
1960	76.1		Iceland
1970	77.6	1.5	Norway
1980	79.8	2.2	Iceland
1990	82.5	2.7	Japan
2000	85.7	3.2	Japan
2010	86.8	1.1	Japan
2030	89.3	1.3	Japan
2060	92.5	1.1	Japan

Source: IFs Version 6.32 base case forecast with UNPD data through 2000.

those of high-income countries. The gaps between the two groups today are much less dramatic than those for communicable diseases. While we forecast progress in both country groupings over the period, we also forecast a more modest rate of decline than for communicable diseases. We also expect that the smaller inter-regional gaps will close much more slowly than those for communicable diseases.

Rooted in these changing patterns of death rates, the aggregate global burden of disease (see the Forecast Tables at the end of this volume for country and regional values) is changing in several ways, including (1) the relative balance of disease types, and (2) the

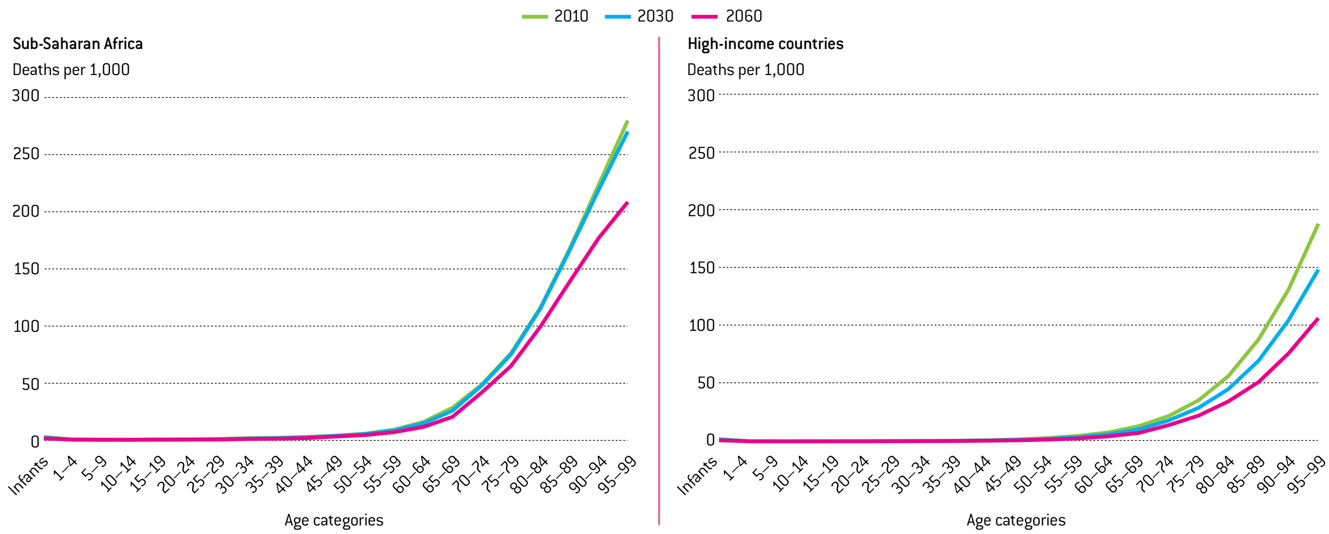
Figure 4.4 Communicable disease mortality across age categories and time: Sub-Saharan Africa and high-income countries



Note: The bulge in young-adult mortality in 2010 for sub-Saharan Africa is largely due to deaths from AIDS.

Source: IFs Version 6.32 base case forecast.

Figure 4.5 Noncommunicable disease mortality across age categories and time: Sub-Saharan Africa and high-income countries



Source: IFs Version 6.32 base case forecast.

We expect progress against noncommunicable diseases, but at a more modest rate than against the remaining communicable disease burden.

The MDG goal of a two-thirds reduction in infant and child mortality rates by 2015 is unlikely to be met in any region.

balance between mortality and morbidity. Figure 4.6 shows the changing relative burden of global disease across the major disease groups.

In the top panel of Figure 4.6, global deaths in millions show the rapid ongoing shift away from deaths due to communicable diseases to deaths from noncommunicable diseases (already the major cause category in 2005). Even in sub-Saharan Africa, the balance will shift to the latter around 2030 in the base case, and in 2060 sub-Saharan Africa's deaths from noncommunicable diseases will outnumber those from communicable diseases by more than 5 to 1. These shifts reflect changing death rates (as illustrated in Figures 4.4 and 4.5) in combination with a changed (older) population structure.

The picture is rather different, however, when we turn to years of life lost (discounted and age-weighted), calculated in IFs as the number of years between the age at death and the gender-specific life expectancy in the country with the longest life span at that time. Communicable diseases cause most deaths in the early years of life (see again Figure 4.4) and therefore result in more years of life lost per individual. The middle panel of Figure 4.6 shows that they currently account for most years of life lost, and that it will not be until the 2020s, and then only if communicable diseases continue the forecasted dramatic decline, that noncommunicable diseases will cause the majority of years of life lost worldwide (and not until the early 2050s in sub-Saharan Africa). The balance is, however, shifting very rapidly.

The third panel in Figure 4.6 provides still another perspective on change in global disease burden. When we consider years of living with disability (again with discounting and age-weighting), chronic diseases heavily dominate the global pattern. In fact, by the late 2030s, injuries are projected to create a heavier total disability burden than do communicable diseases, one reason to be increasingly concerned with road traffic accidents. (The reality is that the methodology for forecasting change in disability rates is sufficiently simple and uncertain that we should read these as indications of possible tendencies rather than as forecasts per se.)

Overall, Figures 4.4, 4.5, and 4.6 show the remarkable transition we expect will occur around the world during the first half of this century in the burden of disease (Box 4.3 and Table 4.2 look at the likely progress of Brazil, Russia, India, and China). Whereas the story historically has been the fight against communicable diseases, the world is now in the midst of a dramatic shift to chronic conditions as the primary source of death and disability—a shift that is occurring also in sub-Saharan Africa, despite its very large remaining communicable disease burden.

Attention to global goals

In recent years, the health indicators that have received the most attention have been those of the Millennium Development Goals (MDGs), which explicitly call for reduction of infant and child (under-five) mortality rates by two-thirds between 1990 and 2015 and maternal mortality rates by three-fourths. The goals also call for halting and reversing growth in incidence of malaria, HIV/AIDS, and tuberculosis by 2015.

With respect to the disease-specific goals, our forecasts do suggest major reductions in those disease rates (see again Figure 4.3). However, with respect to the age-specific goals,

Box 4.3. Will the large and rapidly developing BRICs (Brazil, Russia, India, and China) catch up with the high-income countries?

Yes and no. Setting aside child mortality, which by 2060 will likely drop to the quite low level of about three children per 1,000 dying before reaching age five, we can focus on the probability of a 15-year-old dying before reaching the age of 60. Table 4.2 suggests that the BRICs will substantially narrow the absolute gap between themselves and the high-income countries, but that even so their probability of such death will remain about twice as high in 2060, and that even then the BRICs will not have reached the level of the high-income countries in 2010. In short, although their aggregate economic size will likely have passed that of the high-income countries, they will lag behind system leaders in important aspects of human development. Moreover, there is great variation among the BRICs now (the probable number of 15-year-olds dying before age 60 is now about 280 per 1,000 in Russia versus 124 per 1,000 in China), and the variation is likely to remain high in 2060.

Table 4.2 Probable number of 15-year-olds per 1,000 dying before age 60: BRICs and high-income countries

	2010	2030	2060
BRICs	165	133	97
High-income countries	76	62	48

Source: IFs Version 6.32 base case forecast.

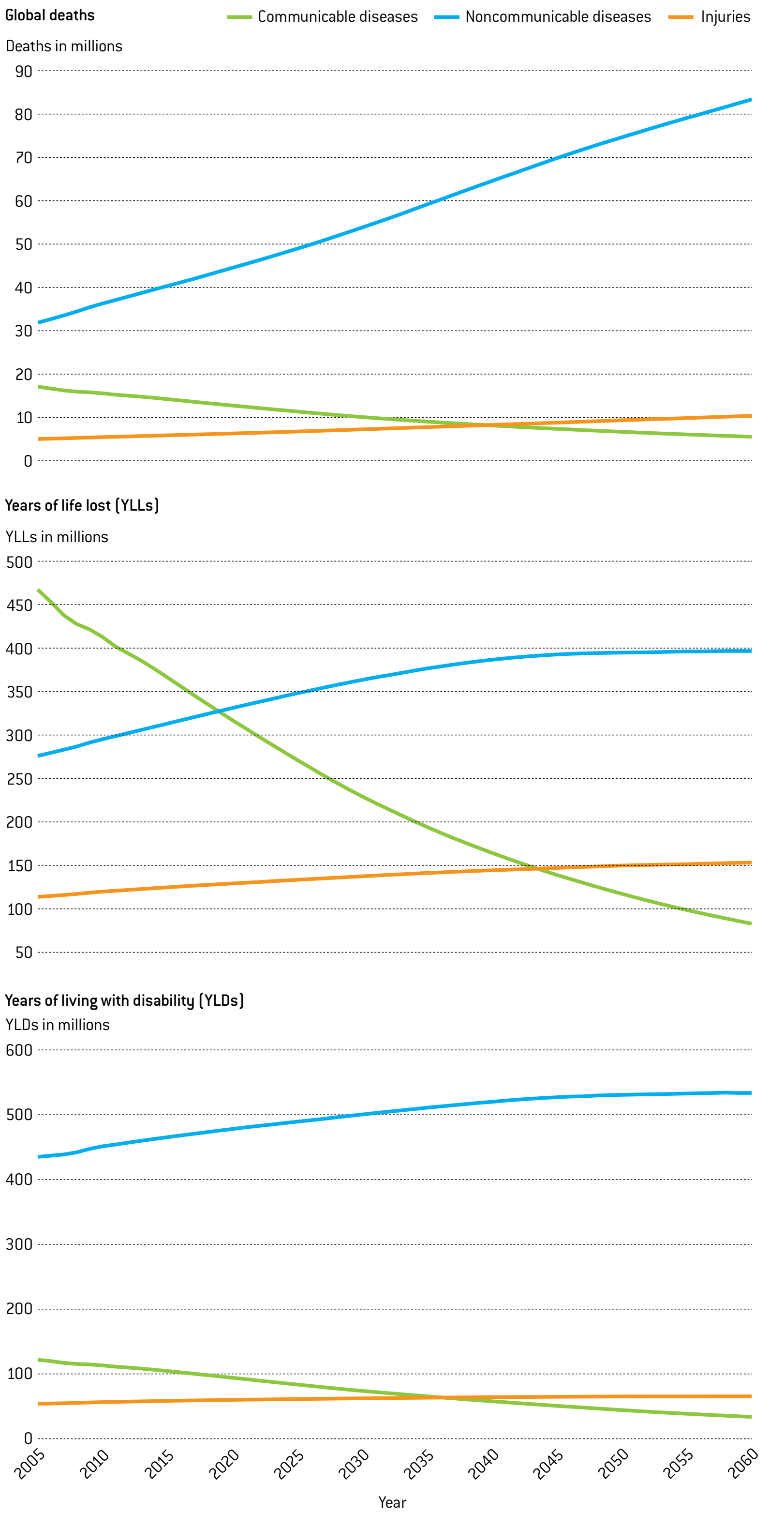
the left panel of Figure 4.7 suggests that not a single region of the world is likely to meet the infant mortality goal—and therefore, by implication, the child mortality goal with which it is closely correlated. Latin America and the Caribbean and East Asia and Pacific are likely to come reasonably close, with reductions near 60 percent. Europe and Central Asia, South Asia, Middle East and North Africa, and the high-income countries are all likely to post close to 50 percent reductions over that period. Sub-Saharan Africa, although it will likely make substantially greater absolute progress than any other region, will have, in the base case experience, a reduction closer to one-third (about the rate of reduction between 1960 and 1990). Rates of reduction in the next 25-year period, between 2015 and 2040, are likely to be quite a bit faster for sub-Saharan Africa but slower in other regions than in recent years (as the values get very low in other regions, rates of progress will logically begin to decline).

More recently, WHO's Commission on Social Determinants of Health (CSDH 2008) called for 90 percent reductions in under-five mortality between 2000 and 2040. In the case of sub-Saharan Africa that would require a decrease from about 150 per 1,000 to 7.5 per 1,000, and our base case forecast for 2040 is several times higher than that. In fact, that target rate is about the level of high-income countries today, and our forecasts show it unlikely to be attained in sub-Saharan Africa until near the end of the century.

Although there is no set global goal around it, another widely watched number is the global number of deaths of children under five years of age. Only recently has that number fallen below the widely watched figure of 10 million per year (Black, Morris, and Bryce 2003). In the base case we see that figure dropping to 5.8 million in 2040 and 3.2 million in 2060, a remarkable potential accomplishment. As context for these numbers, IFs forecasts a global total of 623 million children in 2005, 621 million in 2040, and 577 million in 2060.

Earlier (Figure 4.2) we saw that the CSDH's goal for closing the gap in life expectancy at birth between longest- and shortest-lived country sets was unlikely to be met. The CSDH also called for halving adult morality rates in all countries, and in all social groups within them, between 2000 and 2040 (CSDH 2008: 107).

Figure 4.6 Global deaths, years of life lost, and years of living with disability by major disease groups



Source: IFs Version 6.32 base case forecast.

Only sub-Saharan Africa is likely to meet the CSDH's goal of halving adult mortality rates between 2000 and 2040.

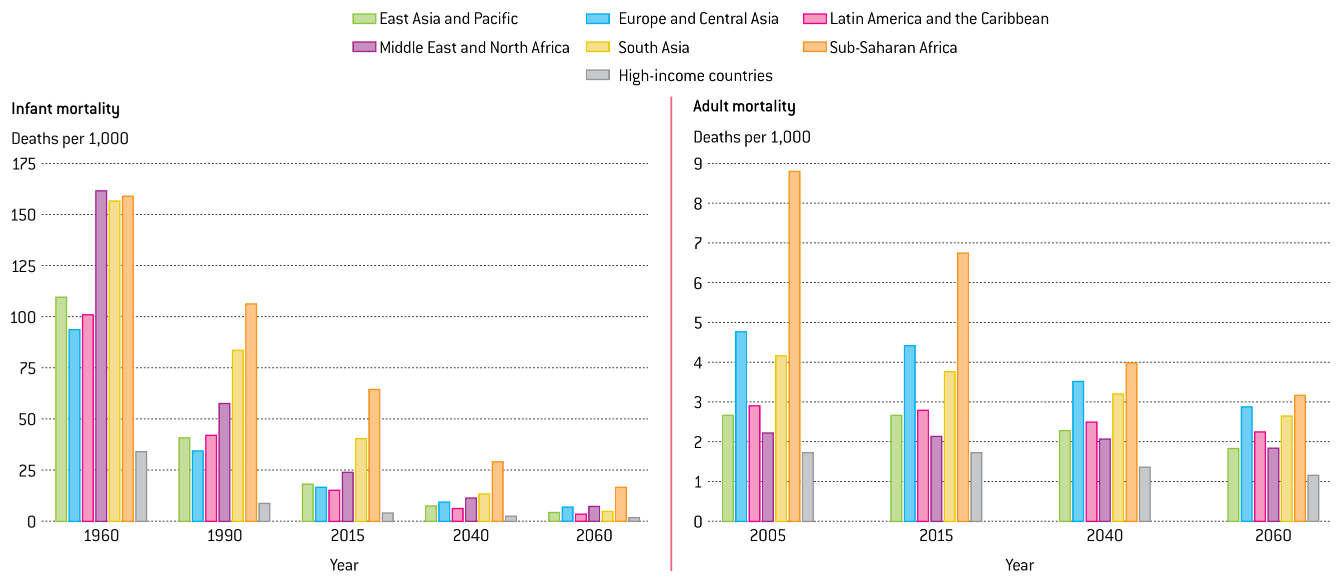
Even though it does not include 2000, the right panel of Figure 4.7 suggests that sub-Saharan Africa may well meet that goal at a regional level, with a reduction from 380 per 1,000 in 2005 to 186 per 1,000 in 2040, partly because there is such considerable room for reduction. Such reduction would require significant progress against AIDS as well as a variety of other adult death causes, because the base case shows essentially no decline in the region's age-specific cardiovascular death rates (forecast patterns of the effects of both smoking and obesity work against progress there). The adult mortality goal is, however, unlikely to be met in any other region (Europe and Central Asia and South Asia will likely have one-third or more reductions), in part because the adult mortality rates in most other regions are very considerably below the current high levels of sub-Saharan Africa.

In regions where adult mortality rates are already low, we expect the pace of further reductions in adult mortality to slow.

Although there is much room for progress in reducing adult mortality, the process has proceeded quite far in many parts of the world, especially in high-income countries. Adult mortality rates through age 59 have been pushed to quite low levels, with mortality then jumping considerably for those 60 and older, making the right-hand corner of the J-curve more of a right-angle (a process called *rectangularization*). As that process continues, we would expect rates of gain for adults below the age of 60 to slow.

In spite of likely failure to meet most established global health goals, it is important to end this discussion of the base case with some very positive statements about the story of improvements in global health (in particular, reductions in communicable diseases). Progress with respect to reducing disease has been remarkably fast in recent decades and appears to be on track to continue at a strong pace. Although HIV/AIDS and the resurgence of malaria have devastated many countries and communities and obviously slowed the narrowing of the life expectancy gap across countries in the last two decades, progress in narrowing the gap also appears likely to resume, thanks to a great many strong local and global efforts. The fact that many global goals appear unlikely to be met reflects in part an understandable sense of urgency with respect to health progress and a desire to assure that targets are high. It also reflects the quite recent emergence of global health forecasting as a foundation for realistic targeting. Goal setting, if it includes consideration of aggressive but reasonable forecasts, can and almost certainly will improve.

Figure 4.7 Infant and adult mortality rates over time and regions



Note: Despite the quite similar appearance of the two panels, note that their scales are very different.

Source: IFs Version 6.32 base case forecast using WDI data for historical infant rates and multiple sources to initialize adult rates.

Comparison with Other Forecasts

Chapter 3 reviewed alternative approaches for providing forecasts relevant to understanding the future of global health, including aggregate (mainly extrapolative) analyses, integrated structural approaches, and specialized disease-specific forecasts. To provide some context for the base case forecasts of IFs, which rely heavily on the distal-driver approach of the GBD project, we compare IFs forecasts with others in each of the three major approaches, considering both the magnitude of differences and the reasons for them.

Life expectancy forecasts: United Nations Population Division

In recent years IFs forecasts of life expectancy have been somewhat higher than those used in the UNPD's population forecasts because the IFs forecasts of AIDS deaths have been lower (we will return to this comparison later). However, the UNPD substantially lowered its forecasts of AIDS deaths in its 2008 revision (UNPD 2009a), and now the magnitude of difference between the two forecasts of life expectancy has declined. As Table 4.3 shows, IFs forecasts a global life expectancy in 2050 of almost two years more than the UNPD projects (the fact that the UN forecast is a period rather than a point forecast complicates exact comparison).[3] Most of this difference results from more optimistic forecasts in IFs for developing regions, but some also arises from somewhat more optimistic forecasts in more developed regions. With respect to Africa, where the difference is the greatest (three full years), both the economic and the education forecasts of IFs for Africa are somewhat more optimistic than those of many analysts, and these two variables heavily shape the distal-driver health formulations used in the IFs base case.

Earlier we pointed out that patterns of growth in the global average of life expectancy reflect a combination of growth in life expectancy at the leading edge and of the extent of convergence of populations with low life expectancies toward the longer life expectancies at the leading edge. Table 4.4 compares the UNPD forecast for life expectancy of the 10 countries that it anticipates will have the highest values in 2050 with the numbers produced by IFs for the same 10 countries. IFs identifies six of the same 10 countries as likely candidates for the top 10 list (adding France, Norway, Singapore, and the United Kingdom). In general, the expectations from IFs are slightly above those of the UNPD.

Probing more deeply into the basis for forecast differences in life expectancy, we see that recent UNPD forecasts for reductions in

IFs forecasts of life expectancy are somewhat more optimistic than those of the UNPD, particularly for Africa.

Table 4.3 UNPD and IFs life expectancy forecasts in years by region

	UNPD		IFs	
	2005–2010	2045–2050	2005	2050
Africa	54.1	67.4	55.3	70.4
Asia	68.9	76.8	69.3	78.2
Europe	75.1	81.5	75.8	82.7
Latin America and Caribbean	73.4	79.8	73.7	81.2
Northern America	79.3	83.5	79.3	85.2
Oceania	76.4	82.1	76.8	82.2
More developed regions	77.1	82.8	77.2	83.8
Less developed regions	65.6	74.3	67.0	76.3
Least developed countries	55.9	68.5	56.7	70.0
World	67.6	75.5	69.0	77.3

Note: Rather than the World Bank regions commonly displayed in this volume, for comparative purposes this table is organized by the standard UN regions and groupings used in UNPD forecasts.

Source: UNPD (2009: 11) and IFs Version 6.32 base case forecast.

> IFs base case forecasts of deaths and disabilities are generally comparable to those of the GBD project.

Table 4.4 UNPD and IFs forecasts of countries with longest life expectancies

	UNPD 2045–2050	IFs 2050
Australia	86.0	86.9
Canada	85.3	85.6
Hong Kong	86.7	84.7
Iceland	86.1	87.4
Israel	85.4	86.0
Japan	87.1	87.7
Macao	85.7	NA
Spain	85.4	85.4
Sweden	85.2	87.0
Switzerland	86.1	86.8

Note: Males and females combined.

Source: UNPD (2009a: 72) and IFs Version 6.32 base case forecast.

under-five mortality are more conservative than those of IFs. Specifically, in 2009 the UNPD's forecast for 2050 of deaths of children under five was about 65 per 1,000 births for sub-Saharan Africa (reading from Figure 6 in UNPD 2009a: 16) and just over 30 for the world as a whole. The corresponding values from IFs are 41 for sub-Saharan Africa and 20 for the world as a whole. The difference for sub-Saharan Africa would account for a substantial portion of IFs higher life expectancy forecasts.

In summary, the forecasts from the IFs base case are slightly more optimistic than those of the UN. In particular, our forecasts for sub-Saharan Africa (and therefore for the reduction of its communicable disease burden) are more positive. We will return to this issue later in this chapter and also in Chapter 8.

Death and disability forecasts: GBD project

The GBD project's 2004 update (WHO 2008a) provides regional forecasts of deaths by age, sex, and cause out to 2030. As we might expect, given the similarities in our base case approach with the GBD approach and our use of their death data to initialize our model, base case forecasts from IFs largely mirror those that the GBD project produced (Table 4.5 summarizes them by region and major disease category). On the whole, the IFs model forecasts somewhat higher total mortality in terms of numbers of deaths. This could reflect some differences in underlying population forecasts, which differ between GBD and IFs.

Table 4.6 turns to disability-adjusted life years (DALYs), and compares the GBD project's forecasts with those of IFs in 2008 and 2030. Because DALYs combine years of life lived with disability (YLD) with years of life lost (YLL), and because of the difficulty in forecasting YLDs (see again Chapter 3), considerable differences in GBD

Table 4.5 GBD and IFs forecasts of regional deaths (millions) in 2030 by major disease group

	Communicable diseases		Noncommunicable diseases		Injuries	
	GBD	IFs	GBD	IFs	GBD	IFs
East Asia and Pacific	1.2	1.3	15.9	16.6	1.5	1.9
Europe and Central Asia	0.3	0.1	4.6	4.5	0.3	0.4
Latin America and the Caribbean	0.4	0.4	4.0	4.0	0.6	0.5
Middle East and North Africa	0.4	0.2	2.4	2.1	0.4	0.3
South Asia	2.4	2.6	10.9	11.2	1.9	1.9
Sub-Saharan Africa	4.3	4.7	5.1	4.9	1.6	1.3
High-income countries	0.5	0.6	8.8	10.3	0.6	0.6
World	9.4	9.9	51.6	53.7	6.8	7.0

Notes: Region members are not identical in the GBD and IFs forecasts because of movement of some countries out of developing regions into the high-income category in the most recent World Bank classifications.

Source: WHO projections of mortality and burden of disease, 2002–2030, available at http://www.who.int/healthinfo/global_burden_disease/projections/en/index.html (see Mortality-Baseline Scenario, World Bank regions Excel download) and IFs Version 6.32 base case forecast.

Table 4.6 GBD and IFs forecasts of DALYs (millions) in 2030 by major disease group

	Communicable diseases		Noncommunicable diseases		Injuries	
DALYs in 2008	**GBD**	**IFs**	**GBD**	**IFs**	**GBD**	**IFs**
East Asia and Pacific	59.6	59.9	210.2	208.8	44.0	41.1
Europe and Central Asia	12.6	10.7	69.0	64.6	14.0	12.8
Latin America and the Caribbean	17.6	18.3	63.0	63.5	15.6	14.7
Middle East and North Africa	18.4	13.5	37.0	29.5	13.0	6.6
South Asia	158.1	169.6	182.7	173.2	51.9	48.4
Sub-Saharan Africa	252.5	259.5	87.4	85.2	35.6	36.0
High-income countries	6.2	7.4	102.0	111.6	9.1	9.5
World	525.1	539.0	751.1	739.9	183.9	169.2
	Communicable diseases		**Noncommunicable diseases**		**Injuries**	
DALYs in 2030	**GBD**	**IFs**	**GBD**	**IFs**	**GBD**	**IFs**
East Asia and Pacific	26.3	27.4	242.3	243.6	33.7	42.2
Europe and Central Asia	6.9	4.9	56.8	57.8	7.3	10.1
Latin America and the Caribbean	8.4	8.9	77.7	77.8	18.4	17.4
Middle East and North Africa	11	6.1	51.2	38.8	15.0	8.7
South Asia	68.2	75.9	236.8	216.6	51.7	55.9
Sub-Saharan Africa	146.8	171.3	131.2	119.7	55.2	52.4
High-income countries	4.1	5.1	103.6	121.7	9.7	10.0
World	271.6	299.6	899.6	880.9	191.1	196.7

Notes: Region members are not identical in the GBD and IFs forecasts because of movement of some countries out of developing regions into the high-income category in the most recent World Bank classifications.

Source: WHO projections of mortality and burden of disease, 2002–2030, available at http://www.who.int/healthinfo/global_burden_disease/projections/en/index.html (see Mortality-Baseline Scenario, World Bank regions Excel download) and IFs Version 6.32 base case forecast.

and IFs forecasts might be expected. However, they are again generally comparable, with the exception of the forecasts for DALYs from communicable diseases in sub-Saharan Africa and in Middle East and North Africa in 2030.

Child mortality and death cause forecasts: GISMO

The Global Integrated Sustainability Model (GISMO) of the Netherlands Environmental Assessment Agency forecasts mortality rates for males and females separately for 27 world regions and 13 age groups (see Chapter 3 for more detail). The system covers environmental health risks especially well, and those make a disproportionate contribution to the disease burden for children under five.

Using assumptions from the World Bank and the Food and Agricultural Organization of the United Nations on economic growth and food consumption, the GISMO team produced forecasts through 2030 for the health measures in the Millennium Development Goals (Hilderink, Lucas, and Kok 2009). We focus here on their forecasts of child mortality (see Figure 4.8) and see that while the GISMO team forecast substantial progress in reducing child mortality rates, it also forecast that none of the developing regions will fully meet its MDG target for 2015 (although East Asia and Pacific and Latin America and the Caribbean would be very close) and that South Asia and sub-Saharan Africa will still be far from their targets.

The GISMO team also concluded that many of the risk factors related to the environment, such as food, water, energy, and climate, will still make a relatively high contribution to health loss in 2030. Of these factors, water supply and sanitation are forecast to show the greatest

Figure 4.8 GISMO forecasts of child mortality in 2015 and 2030

Source: Hilderink, Lucas, and Kok (2009: 38, Figure 3.9); reproduced with permission of authors.

progress, partly due to continuing urbanization and the generally higher rates of access to improved water and sanitation in urban areas. On the other hand, inadequate food intake is forecast to still exact a high toll among children. Projected population growth partly offsets the progress in rate reductions, such that in 2030, analysis with GISMO anticipates that 1.2 million children will still die of pneumonia caused by indoor air pollution and that 0.8 million children will still die of diarrhea related to unsafe drinking water and sanitation. And as Figure 4.8 indicates, sub-Saharan Africa is expected to still have by far the highest child death rates.

Similar patterns in infant and child mortality are suggested by IFs and GISMO, including child deaths specifically related to diarrhea.

While Figures 4.7 and 4.8 are not directly comparable (Figure 4.7 shows IFs forecasts of infant mortality rates and Figure 4.8 shows GISMO's forecasts of child mortality rates), nonetheless a comparison of the figures and the discussion around them suggests very similar conclusions from the two models with respect to likely progress by 2015 on reducing infant and child mortality.

The GISMO model also identifies deaths by a variety of specific causes (as does IFs), and Figure 4.9 compares its forecasts for child deaths from diarrhea with those of IFs. The declines forecast by the two models are very similar, both trending to a total of about 0.8 million annual deaths in 2030.

HIV and AIDS forecasts: UNAIDS

The future course of the AIDS epidemic is one of the greatest unknowns in thinking about the future of global health and, because of its importance, even in the forecasting of global population more generally. UNAIDS has produced the forecasts of AIDS deaths to which other forecasters have been widely attentive in recent years, including the UNPD in its population reports and revisions.

As the HIV/AIDS epidemic has evolved, so also have the data, modeling, and forecasting emerging from UNAIDS and used in the UNPD reports.[4] For example, in comparison to the forecast in the 2004 Revision (UNPD 2005), the UNPD's 2006 Revision (UNPD 2007) foresaw 32 million fewer deaths between 2005 and 2020 in 62 countries. Even with that adjustment, assumptions regarding possible alternative scenarios spanned an extreme range, consistent with great uncertainty. The alternative scenarios were forecasts around a No-AIDS assumption; a High-AIDS assumption (no decline in high-risk group membership rates or infection rates ["force of infection"] among those individuals); and an AIDS-vaccine assumption (with a perfectly effective vaccine posited to be fully available by 2010 and therefore cutting new HIV infections to zero).

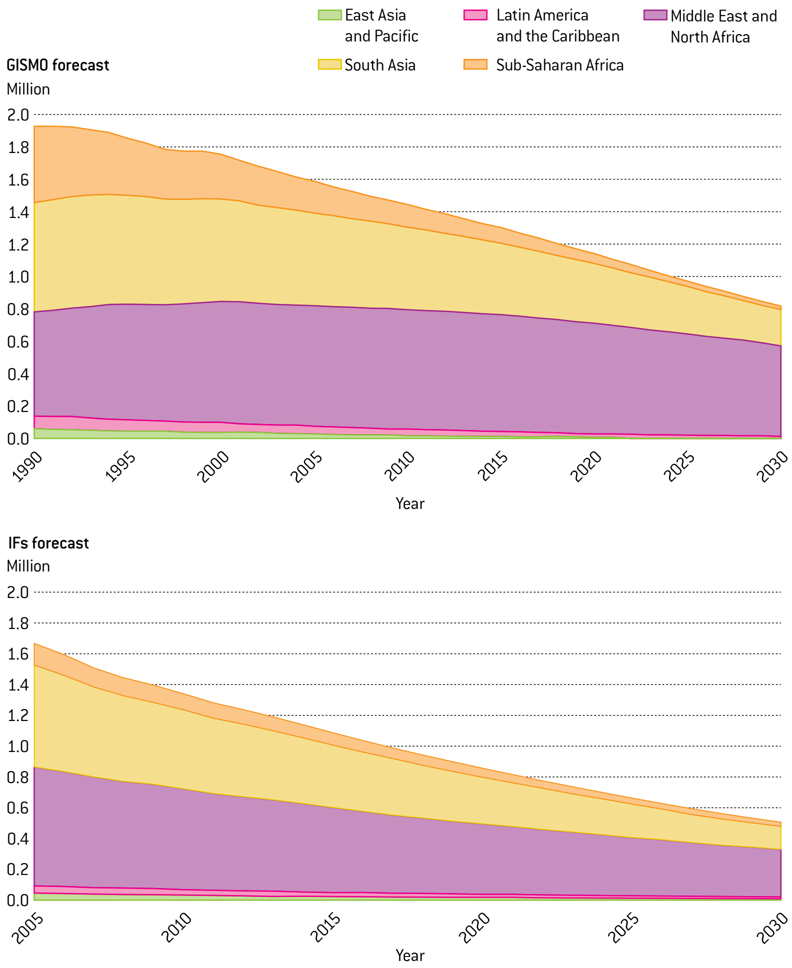
Further refinements in the UNAIDS tools are reflected in the UNPD's 2008 Revision (UNPD

2009a), which builds on 2007 UNAIDS estimates and forecasts. The 2007 estimates focused on 58 countries, compared to 62 in the 2006 Revision.[5] Fifty-three were countries with HIV prevalence rates of 1 percent or more, and five were countries with lower prevalence rates but populations large enough to result in more than 500,000 people with HIV. The 2007 UNAIDS estimates changed some parameters in the projection methodology. Specifically, the major changes in parameters were an assumption that every 20 years there will be a 50 percent decline in the movement of new individuals into high-risk groups and that every 30 years there will be a 50 percent decline in the chances of transmission due to changes in behavior among those at risk and increases in access to treatment for those infected. Elaborative analyses gave special attention to mother-to-child transmission and to the coverage levels of antiretroviral therapy. For instance, the UNPD's 2008 forecasts reflected the assumption that 26 of the 58 focus countries would achieve levels of antiretroviral treatment of 70 percent or more by 2015 and that those receiving treatment would survive 27.8 years, versus 11.7 years for those not receiving it (UNPD 2009a: viii and 24).

The result both of rapidly changing patterns of the HIV/AIDS epidemic and of changing understandings of it (including refinement in estimation and projection methodologies) was a substantial downward adjustment in the estimates in the 2008 Revision (UNPD 2009b) of those infected with HIV (from 39.5 million to 33.2 million) and strikingly reduced projections of cumulative AIDS deaths from 2005 and 2020 (from 42 million to 26 million).

Overall, it appears that the newest generation of forecasts of AIDS deaths emerging from the UN is moving toward relatively stable numbers until about 2015 with decline thereafter, and that is roughly the pattern in the forecasts of IFs also. The cumulative global death forecast for IFs is 27.8 million between 2005 and 2020, not surprisingly somewhat higher than the total reported in the 2008 Revision, which is focused on the most afflicted 58 countries. The IFs project has taken the medium estimates of historical and current HIV prevalence and AIDS deaths and built its own forecasting model taking those into account (see Chapter 3). For several years, however, the forecasts of IFs were

Figure 4.9 GISMO and IFs forecasts of child deaths (millions) due to diarrhea



Note: The two panels have different starting dates; note also that regional memberships may not be identical.

Source: Top panel from Hilderink, Lucas, and Kok (2009: 51, Figure 4.6), reproduced with permission of authors; bottom panel from IFs Version 6.32 base case forecast.

lower than those published in the UNPD reports, so with the recent UN revisions the two sources of forecasts have increasingly converged.

Turning to specific highly affected countries, it is possible to use the UNAIDS Estimation and Projection Package (EPP) and Spectrum model to forecast HIV/AIDS through 2015, and we have done that. Table 4.7 compares the results of those forecasts with values in IFs; although they are generally quite similar, there are instances of large differences (the largest differences are in the HIV rate of Kenya and AIDS deaths in Mozambique). Again, we note the uncertainty that attends HIV/AIDS forecasting.

The year 2015 is not, however, a very long forecasting horizon, so in addition Table 4.7

Much uncertainty attends HIV/AIDS forecasting, and there are both similarities and differences between IFs and UNAIDS forecasts.

includes forecasts from IFs for 2040. Those values show the very long tail that the HIV epidemic could have, even if the assumptions of its current peaking are correct. The overall profile of it in the long term now appears to be that of extremely sharp rise in the 1980s and 1990s, some leveling in the 2000s, and then the long tail of decline. Once again, however, a caution about very great uncertainty is in order. For instance, if the death pattern for South Africa of Table 4.7 were to unfold, it would mean that a little less than 13 million South Africans would die of AIDS between 2005 and 2060. In a population that is likely to range from 50 to 55 million at any one time over this period, that is a quite incredible prospective burden of morbidity and mortality.

Road traffic accident deaths: World Bank and GBD

Chapter 3 discussed the significant differences that moving from aggregate to structural models, with their explicit representation of drivers, can make in forecasting capabilities and results. There are, however, very different kinds of structural models, representing drivers and causality in very different ways.

The GBD project followed the same approach to forecast road traffic deaths as it did deaths in all but a very small number of cases—that is, through regression-based distal-driver structural formulations rooted in income, education, and a time term.

As we have stated before, the GBD researchers did not intend for their formulations to be used beyond 2030. In contrast, a World Bank study by Kopits and Cropper (2005) used a more deeply structural approach—in which they forecast vehicles per person and fatalities per vehicle—that can reasonably be extended across a longer time span. Although income change remains the key driver in their approach, they capture the saturation of vehicle ownership and combine that with decreasing fatality rates per vehicle above an income threshold. As we indicated in Chapter 3, our desire to extend the GBD approach beyond 2030 led us to adopt the more structural approach of Kopits and Cropper for IFs, with our own formulations of vehicle ownership and fatality rates per vehicle.

Table 4.8 shows the results. The top half compares the rate of growth in road traffic deaths from 2000 to 2020 from Kopits and Cropper with the rate of growth from 2005 (the initial year) to 2025 from IFs. The initial data are obviously not comparable, even taking into account different starting years; for Kopits and Cropper (2005: 177) they come from yearbooks of the International Road Federation, and for IFs they are rooted in the GBD 2004 detailed update of deaths. The global growth patterns are quite similar, but many regional ones differ considerably. Relative to Kopits

Table 4.7 Spectrum and IFs forecasts of HIV prevalence and AIDS deaths for countries with highest numbers of deaths

	HIV prevalence rate (percent)			AIDS deaths (thousands)		
	Spectrum	IFs		Spectrum	IFs	
	2015	2015	2040	2015	2015	2040
Ethiopia	1.3	1.2	0.6	59	62	44
Kenya	1.6	2.8	1.5	81	77	47
Mozambique	7.4	6.2	3.4	120	59	39
Nigeria	1.9	1.8	1.0	194	136	90
South Africa	12.3	11.2	6.1	370	391	167
Tanzania	3.7	3.4	1.9	95	95	65
Uganda	2.4	2.8	1.5	55	66	48
Zambia	9.1	8.0	4.4	68	57	40
Zimbabwe	6.1	7.4	3.9	47	42	19

Note: Prevalence rates are expressed as a percent of the total population.

Source: UNAIDS Spectrum system at http://www.unaids.org/en/KnowledgeCentre/HIVData/Epidemiology/EPI_software2009.asp and IFs Version 6.32 base case forecast.

Table 4.8 Estimates and forecasts of road traffic fatalities (thousands) by region using three forecasting systems

	Kopits and Cropper			IFs		
	2000	2020	% change	2005	2025	% change
East Asia and Pacific	188	337	79.3	358	694	93.9
Europe and Central Asia	32	38	18.8	74	81	9.5
Latin America and the Caribbean	122	180	47.5	96	141	46.9
Middle East and North Africa	56	94	67.9	68	127	86.8
South Asia	135	330	144.4	231	473	104.8
Sub-Saharan Africa	80	144	80.0	222	358	61.3
High-income countries	110	80	(27.3)	98	102	4.1
World	723	1,204	66.5	1,149	1,979	72.2
	GBD formulation in IFs			**IFs**		
	2005	**2100**	**% change**	**2005**	**2100**	**% change**
East Asia and Pacific	358	274	(23.5)	358	527	47.2
Europe and Central Asia	74	41	(44.6)	74	45	(39.2)
Latin America and the Caribbean	96	88	(8.3)	96	135	40.6
Middle East and North Africa	68	180	164.7	68	251	269.1
South Asia	231	622	169.3	231	1,043	351.5
Sub-Saharan Africa	222	4,279	1827.5	222	1,286	479.3
High-income countries	98	50	(49.0)	98	68	(30.6)
World	1,149	5,535	381.7	1,149	3,355	192.0

Note: The GBD formulations were not intended for forecasting beyond 2030 and are shown for illustrative purposes only, using IFs distal-driver forecasts.

Source: Kopits and Cropper (2005: 176); GBD formulation forecasts by IFs system; IFs Version 6.32 base case forecast.

and Cropper, IFs provides generally lower growth rates for the lowest-income regions and somewhat higher values for middle- and high-income regions.

Framing Scenario Analysis

Although base case forecasts (see again Box 4.1 for a brief discussion of the key characteristics of the IFs base case) are a useful device for beginning to think about the future of global health, the uncertainty surrounding such forecasts requires that we fairly quickly extend thinking to alternative possible futures. To a very large degree, human action will shape those alternatives through behavioral choices and through the development and transfer of medical technology. Before the coming chapters in which we begin to explore alternative health futures tied to variations in assumptions concerning more proximate drivers (and the specific causes of death that they influence), it is useful here to use the distal-driver formulations to think about the range of alternatives that the distal drivers themselves might generate.

Alternative futures for GDP per capita and education

Alternative assumptions about the future of the three key distal drivers in the GBD and IFs formulations generate quite different health forecasts. The exploration of alternative assumptions also shows that the three drivers have inherent characteristics that strongly shape their own likely variation and therefore the degree to which they might give rise to alternative health forecasts.

Most significant, perhaps, is the difference in character of GDP per capita and years of

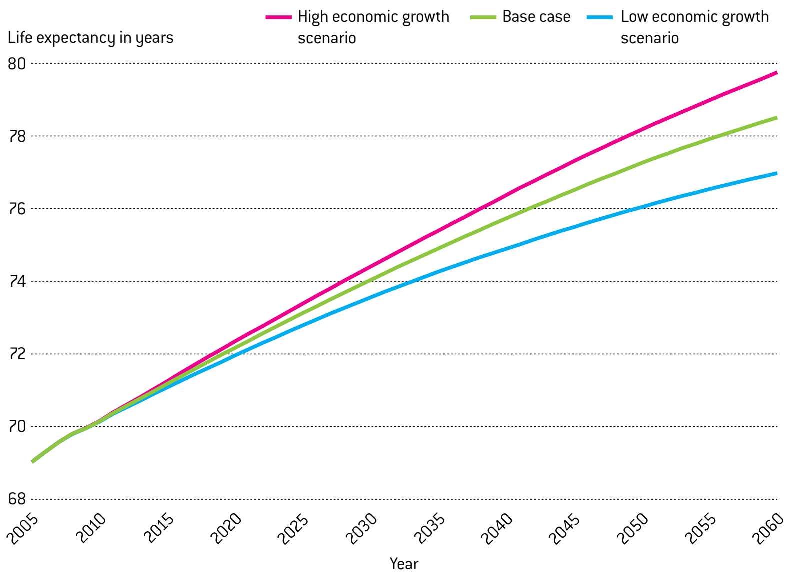
Relative to a World Bank study, IFs tends to forecast lower traffic accident growth rates for low-income regions and higher ones for middle- and high-income regions.

education in an adult population. As a general rule, there is considerably more uncertainty around the magnitude of future GDP per capita than there is around adults' educational levels. GDP per capita is an annual flow variable (that is, it is generated anew each year), driven by multiple underlying stocks, such as capital supply, years of adult education, and multifactor productivity. Scenarios for the future annual growth rate of the global GDP can reasonably be a percentage point higher or lower than the base case over prolonged periods of time (and several percentage points different over shorter time horizons, such as the years of the global recession that began in 2008). Such variation can set in motion feedbacks to a substantial number of underlying stocks and can create significant long-term divergence of future paths.[6] Between 2005 and 2060 the base case takes global GDP per capita at purchasing power parity from $7,700 to $25,000. Alternative scenarios with one percentage point lower and one percentage point higher GDP growth rates set up a range in 2060 from $13,600 to $37,900, a 2.8 factor of difference.

Exploring health impacts of alternative assumptions about the future of our distal drivers helps us frame uncertainty.

Figure 4.10 shows the possible implications of the three alternative economic growth scenarios for global life expectancy (which we understand, of course, to represent not the impact of income itself, but the wide range of health improvements income makes possible). The scenarios set up a spread of almost three years in life expectancy by 2060. Not surprisingly, the high-growth scenario, relative to the low-growth scenario, has a greater impact on low-income regions than on middle- and high-income regions. The greatest impact is on South Asia, with a life expectancy gap of 3.4 years between the low- and high-growth scenarios; in sub-Saharan Africa the difference is nearly three years. In sub-Saharan Africa, differing impacts across economic growth scenarios on the rate of reduction in communicable diseases lead to the greatest and rather dramatic differences in years of life lost. Between 2005 and 2060, the high-growth scenario reduces cumulative years of life lost in sub-Saharan Africa by a rather astounding 2,267 million years relative to the low-growth scenario, a reduction of 16 percent. A significant portion of that reduction is, however, not a direct result of reduction in mortality rates, but rather an indirect effect that results from reduced fertility and population size associated with higher economic growth (Chapter 7 returns to an analysis of the larger, complex systems in which health sits).

Figure 4.10 Global life expectancy forecasts across three economic growth-rate scenarios



Source: IFs Version 6.32 base case forecast and high and low economic growth rate scenarios.

In rather sharp contrast to analysis of economic futures, the variation in likely educational futures is much less. Countries around the world invest heavily in education and are increasing their flow of students through primary, secondary, and tertiary programs at relatively steady rates (in recent years very rapidly by historical standards). It takes, however, more than 40 years, even in countries with relatively low life expectancies, for those who complete secondary education to pass through their life span, carrying with them their formal education attainment levels (represented in both the GBD and IFs models by the common indicator of years of attainment by adults 25 years of age and older; see Barro and Lee 1996; 2000; and 2001). Thus, the difference between the base case for the advance of education attainment levels in sub-Saharan Africa and an "aggressive but reasonable" normative scenario, which accelerates enrollment rates significantly, is not that great—in fact, levels of attainment differ by less than one year and therefore by about 10 percent in 2060 (see Dickson, Hughes, and Irfan 2010 for extended exploration of educational futures and the normative scenario; were we also to explore a low-growth scenario for education, the full range of results would be roughly twice those reported here). The resultant impact on life expectancy in 2060 is proportionately modest. At the global level it is only 0.5 years, and even in sub-Saharan Africa, where the normative education scenario creates the greatest difference in adults' years of education, the incremental life expectancy in 2060 is only 1.1 years—hardly insignificant, but quite modest in comparison to the differences across economic scenarios. (Education has, of course, other important health-related impacts in the IFs model, including its implications for fertility and overall population growth; see again Dickson, Hughes, and Irfan 2010.)

It is probable that the uncertainty around the parameterization of the contribution of education attainment in the GBD model and the IFs base case approach (or the parameterization of the other distal drivers for that matter), is a greater source of uncertainty in the overall contribution of education to health than the difference between the base case and the normative scenario. The complex structure of the distal-driver equations, however, makes true sensitivity analysis very complicated (see Box 4.4).

Alternative futures for time/technology

In addition to GDP per capita and education, the third principal distal driver in the GBD project's formulations is time. The coefficients on the time term reduce mortality by steady annual amounts (albeit different amounts across geography, cause of death, and age or gender) independent of the impacts of income and education.

The time-term is often understood to be a proxy in substantial part for technology, but it is in reality a catchall term for all else beyond income and education that is changing dynamically in the system, including change in any of the super-distal drivers described in Chapter 2. Thus, for example, the term could pick up ideational and associated behavioral changes, such as changed dietary, exercise, or smoking patterns in response to new knowledge about their health impacts. It could also pick up negative dynamics, such as increasing social violence related to changed mores and/or greater inequality.

Box 4.4. Alternative forecasts

The relationship between rising income and declining mortality is as challenging to forecast as it is to theorize. Alternative forecasting commonly looks to changes in parameters of the forecasting formulations. We might wish, for instance, to explore the "change in gearing" in the income-mortality relationship (Wilkinson 2007) that helps give rise to the tendency for the gap between rich and poor countries to narrow over time. If the income-mortality relationship were based on a single coefficient we could simply change it. That is not the case, however.

The GBD project's regressions for each age-sex-cause cluster include separate terms for the log of GDP per capita (LGDPC) and a square term (LGDPCSQ), a combination that defies any simple interpretation of individual relationships. Whatever the theory might say about the overall relationships, many regressions fail to produce a simple relationship between income increase and mortality decrease. Most communicable diseases are negatively related to LGDPC and unrelated to LGDPCSQ. In contrast, death rates for most noncommunicable disease groups actually rise with LGDPC before declining with LGDPCSQ, creating a set of parabolic relationships that often peak at relatively high levels of income. Accidents and violence rise monotonically with LGDPC (giving rise to the high road traffic fatality numbers for Africa discussed earlier).

Income effects are further confounded by the fact that the other distal drivers, most notably education, also tend to rise with income. Further, the income coefficients for the same disease in one age-sex group might look quite different from those for another age-sex group. Finally, the separate GBD formulations for rich and poor countries would yield stagnating life expectancy gains for today's poor countries if we did not throw a switch to move countries into the high-income group (discussed in Chapter 3).

Therefore, our analysis throughout this volume is tied to variation in the distal drivers (or around alternative values of proximate drivers, to be discussed in Chapters 5 and 6), rather than to change in the parameters that relate income or education to health outcomes.

To explore the sensitivity of health outcomes to this representation of the impact of technological and other time-related changes, we arbitrarily considered the implications of increasing or decreasing the annual change by 50 percent. The impact on global life expectancy of that significant percentage change is very considerable, even somewhat larger than that associated with economic growth. In 2060, global life expectancies in the high and low time-term scenarios differ by 3.5 years—the high time-term scenario increases life expectancy by about 1.5 years relative to the base case and the low time-term scenario reduces it by 2 years relative to the base case. The difference between the high and low time-term cases varies across country groupings, reaching 4.5 years in South Asia, compared to 2.5 years in Latin America and the Caribbean.[7]

The gains in life expectancy from accelerating the impact of the time term are seen in reduced mortality from communicable and noncommunicable diseases. In contrast, accelerating the impact of time has negative consequences for mortality from injuries. Globally, the cumulative years of life lost due to injuries between 2005 and 2060 are more

With our formulations, alternative income and time/technology scenarios impact health outcomes more than the education scenarios.

than 13 percent higher in the high time-term scenario than in the low one. Because deaths in that cause-group are lower than those from noncommunicable diseases and close to those from communicable diseases, the higher years of life lost to injuries do not offset the combined reductions in communicable and noncommunicable disease deaths, but they do hold down the overall improvement in life expectancy, particularly because many deaths from injuries occur in the middle years of life. The increase in mortality from injuries in the high time-term scenario is almost entirely from intentional injuries (such as murders), not from unintentional injuries or road traffic accidents. Clearly, growing levels of gun and other violence in recent decades in many areas of the world (including sub-Saharan Africa and North America) influenced the sign of the coefficients on the time term for the injury category. It is, of course, uncertain whether such increases will continue.

Overall, this analysis of uncertainty around the distal drivers of health outcomes suggests there is the potential for interventions around each of them to improve health futures. It also suggests, however, that the greatest uncertainty, and therefore potential leverage, exists around the economic growth and time/technology drivers and perhaps, somewhat surprisingly, that there may be considerably less potential leverage around education. It is important to emphasize, however, that we must treat carefully and somewhat skeptically estimates of model coefficients in areas where variables are highly correlated, such as GDP per capita and education.

Conclusion

The health forecasts of the IFs base case—relying heavily on the methodology of the GBD forecasters but extended in a number of ways that Chapter 3 discussed (including the addition of eight proximate risk factors)—portray a world through 2060 in which health outcomes continue on a path of rapid and generally positive change, albeit with significant differences from historical patterns. Life expectancy continues to rise, but at a slowing pace (a slowing that Chapter 2 discussed as being somewhat controversial). While death rates continue to fall in the aggregate, opportunities for progress with respect to reducing deaths at younger ages from communicable diseases play out largely before 2060—in fact, that is a key reason that gains in life expectancy become harder to attain.

The primary causes of death nearly everywhere are now noncommunicable diseases, and the shift to that pattern will become more pronounced. As a result of this shift to dominance of deaths from noncommunicable causes, global patterns of death will increasingly converge.

Relatively few forecasts of health outcomes exist. The aggregate life expectancy forecasts of the UNPD and the cause-specific projections of the GBD modelers are the most notable. Not surprisingly, given the rooting of the IFs distal-driver health formulations in those of the GBD project, the forecasts of IFs tend to be similar to them. Still, the IFs forecasts provide both an extended time horizon and the value of some specialized structural formulations. In addition, the IFs forecasts offer the value of dynamic interactions across IFs demographic, health, economic, and education models. These interactions have allowed us to begin exploring the range of uncertainty in some of our base case forecasts (recognizing of course that uncertainties related to specification and estimation throughout the model may dwarf those related to drivers such as educational attainment).

Most health policy does not focus on increasing GDP or educational attainment, however. Instead, it is more closely tied to what the health community and the framework used in this volume term proximate drivers. We turn next to that analysis.

1 For a more extended discussion of forecasting with IFs and the meaning and use of base case analysis, see Hughes et al. 2009 (especially Chapter 5).

2 In technical terms this pattern of declining gains at the leading edge of life expectancy partly reflects the logarithmic functional form of the GBD forecasting equations in which incremental gains in income and education have decreasing marginal impacts on mortality.

3 Forecasts from the UNPD, the GBD project, and other projects use different country groupings and cover varying time periods and specific points of time, and we match the groupings and time frames of the individual projects in our comparisons with them.

4 The UNAIDS Reference Group on Estimates, Modeling and Projections has refined over time its tools for forecasting HIV prevalence and AIDS deaths. The EPP projects prevalence, which the Spectrum suite of models can use to calculate forecasted AIDS cases, deaths, and other variables. See http://www.unaids.org/en/KnowledgeCentre/HIVdata/Epidemiology/epi_software2007.asp.

5 Gambia, Madagascar, Moldova, Myanmar, and Niger moved out of the 1 percent or more prevalence group, and Mauritius moved into it.

6 One percentage point higher or lower GDP growth is fairly widely used in scenario sets for the analysis of long-term economic, energy, or other impacts. We close the loops from health back to the population and economy (see Chapter 7) in order to analyze the full effects of the difference.

7 This seems counterintuitive and should be reviewed in future model work.