

IMPROVING GLOBAL HEALTH: FORECASTING THE NEXT 50 YEARS

PATTERNS OF POTENTIAL HUMAN PROGRESS



VOLUME 3

EXECUTIVE SUMMARY



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The Patterns of Potential Human Progress (PPHP) series is the work of the Frederick S. Pardee Center for International Futures at the University of Denver's Josef Korbel School of International Studies. The PPHP series is jointly published by Paradigm Publishers and Oxford University Press India. This executive summary of the third volume in the series, *Improving Global Health: Forecasting the Next 50 Years*, was prepared by Janet R. Dickson, a member of the IFs team.

Cover Art

The cover art is a representation of an oil painting by Margaret Lawless, artist for the PPHP series. Ms. Lawless is a contemporary abstract artist whose works in various media portray aspects of the human condition, human progress, and the interaction of humans with nature. In this particular painting, she emphasizes the potential inherent within all human beings to experience the full life cycle that health and a healthy environment enable. The S-curve suggested by the red band represents global transitions in health and life expectancy, the further improvement of which is the focus of this volume.

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Preface

The Frederick S. Pardee Center for International Futures at the University of Denver's Josef Korbel School of International Studies is the home of the International Futures (IFs) computer simulation modeling project. Over a period of more than three decades, the IFs team has developed an integrated system of models for exploring possible global futures and also assists individuals and organizations in the use of the IFs system in support of research and policy direction.

The IFs system of models and its applications are continually evolving. Even so, its foundation continues to rest on two defining characteristics:

1. it is long-range (its forecasting horizon extends to the year 2100), and
2. it encompasses multiple domains of human and social systems for 183 countries (e.g., population, the economy, health, education, energy, agriculture, and aspects of socio-political systems) and the interaction effects among them.

While the system itself is very complex, it is packaged with an interface designed to facilitate ease of use.

IFs should be regarded as a thinking tool, not a predictive one. Its forecasts represent explorations of what might happen under different assumptions about trends and driving variables. It can help us understand the consequences of change already underway (such as the aging of populations as infant and child mortality have declined) and of interventions (for example, addressing risk factors as diverse as obesity, smoking, road traffic accidents, water and sanitation, and indoor and outdoor air pollution) to help us shape the future in desired directions. The use of IFs highlights the importance of human analysis and choice in interaction with environmental contexts in influencing human futures, and the long-range nature

of its forecasts encourages us to explicitly consider the possible consequences of our choices over a longer time frame than that addressed by most policy studies.

Patterns of Potential Human

Progress (PPHP) is a series of volumes using IFs to explore, over the next 50 years, the future of issues that are critical to continued human development. The first three volumes focused, respectively, on reducing global poverty, advancing global education, and improving global health. The next two will focus on transforming infrastructure and strengthening governance across the globe. Each of the volumes concludes with an extensive set of country- and region-specific tables with forecasts of key demographic, economic, health, education, infrastructure, and governance variables over the same 50-year period. The volumes, published by Paradigm Publishers and Oxford University Press India, are the work of IFs teams at the Frederick S. Pardee Center for International Futures at the University of Denver.

This executive summary conveys key messages and other highlights from *Improving Global Health: Forecasting the Next 50 Years*. The questions addressed in the volume are:

- What health outcomes would we expect given current patterns of human development?
- What opportunities exist for intervention and the achievement of alternate, improved health futures?
- How might alternative health futures affect broader economic, social, and political prospects of countries, regions, and the world?

The executive summary begins with key messages about longer-term global health futures—global goals; the context for explorations with IFs; and, most important, the implications of a base case

and alternate scenarios on population health and human development more broadly. These messages are followed by a brief discussion of the current state of global health, what global health might look like under a base case that builds on recent patterns, and what it might look like under alternate more optimistic and more pessimistic assumptions. The document concludes with some additional information about the IFs system of models, and includes our thoughts about needed next steps in the modeling of global health futures.

For more information about IFs and the PPHP series, as well as technical documentation of the model, go to www.ifs.du.edu or email pardee.center@du.edu. The PPHP volumes themselves may be downloaded from www.ifs.du.edu, and the IFs forecasting system is also freely available.

Key Messages

Motivations for Forecasting Health

- *An increasing number of global actors and governments are taking a longer-term approach to setting goals for health.* In 2009, for example, the World Health Organization (WHO) Commission on Social Determinants of Health set ambitious global targets for 2040 for the reduction of levels and gaps in life expectancy, under-five mortality, and adult mortality.
- *Although forecasting of human population size and characteristics routinely extends to mid-century, and often to the end of the century or beyond, forecasting of health has for the most part not looked beyond 2030, and has been relatively rare in general.* Few forecasts of future health cover a wide range of nations over a long time-span. Even fewer situate changes in age-specific mortality rates into an integrated framework to account for the effects of mortality variation on population size and age structure and on drivers of mortality such as income (thereby “closing the loop” and exploring the interaction of health and larger human development systems).
- *Societies and global actors not only want to understand the possible future health of citizens—they also want to know how to improve it.* Forecasts from dynamic structural models that integrate emerging health risks, population trends, and economic and socio-political variables are analytic tools that can help on both counts.

A Tool for Forecasting Health

- *We first use the International Futures (IFs) software tool to produce a country-specific base case to 2060 for 183 countries and then explore the consequences for the future of global health from what we view as realistic*

optimistic and pessimistic scenarios around that base case. Our approach builds on the groundbreaking work of the WHO Global Burden of Disease project and broadens it in a variety of ways—extending the forecast period, allowing users to explore country-level outcomes, embedding mortality and morbidity patterns within larger global systems, forecasting a number of health risk factors (for which the earlier work of the WHO Comparative Risk Assessment project was also critical), and replacing a number of regression-based formulations with richer structural formulations.

- *IFs forecasts of health outcomes are the result of “distal drivers” (income, education, and technology) interacting with specific health risk factors or “proximate drivers” (childhood undernutrition; obesity; smoking; road traffic accidents; unsafe water, sanitation, and hygiene; indoor air pollution; urban outdoor air pollution; and the effect of climate change on crops and childhood undernutrition) in a broader and heavily human-influenced social and physical environment whose characteristics constitute “super-distal drivers.”* The existence of these multiple categories of factors affecting health provides opportunities for multiple and varied approaches to improving health. These approaches include short- and long-term strategies reflecting societal commitments (both those that are directly health related, such as health care systems, and those that are broader, such as the reduction of poverty and the development and adoption of sustainable infrastructures), as well as personal choices regarding risk behaviors.

Health and Human Development Futures

- *Our analysis reinforces and extends the understanding of changing global and regional health patterns and their broader implications for human well-being.* These patterns include a continued dramatic trend toward improvement in life expectancy almost everywhere, coupled with a relative increase in deaths from noncommunicable diseases and injuries (and an absolute increase in the mortality rates from road traffic accidents and intentional injuries) as the health burden from communicable diseases continues to decline. There are consequent shifts in population size and age structure, and in productivity and health care requirements.
- *Improvements in health will result not only in larger populations but also in changed population age structures.* Communicable diseases disproportionately affect the young, and the continued reduction of these diseases will result in a significant shift to older populations as the premature deaths of children decrease and average life spans are extended. For example, of 1 billion additional people in our optimistic scenario (where communicable diseases decline especially rapidly), the great majority—about 800 million—are 65 or older.
- *Integrated analysis of forward linkages from health strongly suggests a positive (albeit modest) contribution of health to economic growth, even with the aging of larger populations from lower mortality rates.* Many analysts have debated whether improvements in health generate societal economic returns or perhaps even have a negative impact on economic growth. Through analysis of multiple

pathways from health to productivity, we conclude that improvements in health have a positive net impact on per-capita GDP. The modest level of economic return in our analysis, however, suggests the need for care in using incremental economic growth as a simple justification for health investments; the best justification remains better and longer lives.

- *As significant as continued health improvements in our base case are, achievement of the mortality rate reduction goals of the Commission on Social Determinants of Health (CSDH) are met only in an optimistic scenario, and even then often not until around 2060. And while in our optimistic scenario the gaps in life expectancy between less- and more-developed countries are much reduced, they do not fully reach the CSDH targeted reduction levels by 2060. In a pessimistic scenario, sub-Saharan Africa's life expectancy remains 23 years behind that forecast for today's high-income countries in 2060 (63 versus 86).*
- *While health outcomes are quite strikingly different between the optimistic and pessimistic scenarios—and especially so for developing countries and regions—even in the pessimistic scenario there are modest increases in life expectancy almost everywhere. Globally, life expectancy increases from 69 in 2005 to 73 in 2060 in the pessimistic scenario (versus almost 87 in the optimistic scenario), and in sub-Saharan Africa it increases from 52 in 2005 to 63 in 2060 (versus just over 80 in the optimistic scenario).*
- *Interventions that reduce proximate health risks can result in significant positive health outcomes in a quite short period of time. In a comparison between IFs optimistic and pessimistic scenarios (where the prevalence of risk factors varies by one standard deviation in both directions from the base case), 438 million deaths are averted between 2005 and 2060 by the reduction of seven proximate risks that are amenable to public policy interventions: childhood undernutrition; obesity; smoking; road traffic accidents; unsafe water, sanitation, and hygiene; indoor air pollution; and urban outdoor air pollution.*
- *Over the long-term, sustained improvements in global health will require ongoing attention to the higher-level kinds of action called for by the Commission on Social Determinants of Health. Some of these higher-level actions can take place in what has traditionally been thought of as the "health sector." However, human action across a range of broader systems is perhaps even more critical to global health outcomes: the extent to which we address inequality within and across societies, the progress and character of globalization processes, our investments in infrastructure (e.g., safe road systems and improved water and sanitation), and our actions to reduce and ameliorate anthropogenic climate change are but a few examples.*

The Story of Global Health

The Story So Far

Health lies at the heart of human development. Yet, for most of human history, the average person's life has been difficult, constrained, and short. When John Graunt first constructed the *Bills of Mortality* for the city of London in 1650, he found that life expectancy was about 27 years.¹ In general, up to the time of the industrial revolution in Great Britain, human life displayed a Malthusian pattern of high mortality with transitory deviations, upwards in times of plenty and downwards in times of want or plague.

Since the mid-1700s, however, there has been incredible ongoing advance in human health—Great Britain itself has gained more than one year of life expectancy for every seven calendar years since 1650. Extensions in the length and quality of life first moved across Europe. Especially since World War II, health improvements have spread throughout the world, and the pace has advanced further. Global life expectancy rose from 46 years in 1950 to 69 years in 2007. And put another way, people in the world's poorer countries in 2000 were longer-lived than those in the wealthier countries of 1950.

A major reason behind the low life expectancy in Graunt's London was that about 300 per 1,000 children died before the age of five. Between 1950 and 2006, however, the world's infant mortality rate dropped from 153 to 36 deaths per 1,000 (see Figure 1 for regional progress since 1960), and the number of children who die before reaching five years of age has fallen to about 70 per 1,000. This global pace of improvement is unprecedented.

The changes in global health described above reflect the patterns and stages over time of an "epidemiologic

transition." First articulated by Omran, the concept of epidemiologic transition describes changes in health fueled by economic, social, and political development processes which, in turn, are themselves fueled by improvements in health.² In other words, the theory asserts that the epidemiologic transition is not merely a result of economic and social change but very much an integrated, dynamic part of it. The early stages of the epidemiologic transition involve a reduction in infectious and communicable diseases, such as diarrheal and respiratory infections, which largely affect young children and other vulnerable populations. The resulting increased survival of children through the highly vulnerable years

of early childhood sets the stage for the large majority of most populations to survive well into adulthood, absent high levels of exposure to violence, accidents, infections of adulthood such as HIV/AIDS, or the early onset of chronic disease. Thus, the epidemiologic transition implies a shift in the predominant causes of death and morbidity from infectious diseases to noncommunicable conditions such as cardiovascular disease, diabetes, and cancer, mostly affecting people at older ages and creating new and different health challenges for society.

While countries enter into and proceed through the stages of the epidemiologic transition at different times and rates, on a global basis we are

Figure 1 Infant mortality rates by region (1960 and 2005)



1 John Graunt, "Natural and Political Observations Mentioned in a Following Index, and Made upon the Bills of Mortality" (London, 1662). Republished with a foreword by B. Benjamin, *Journal of the Institute of Actuaries* 90 (1964):1-61.

2 Abdel R Omran, "The Epidemiologic Transition: A Theory of the Epidemiology of Population Change," *Milbank Memorial Fund Quarterly* 49, no. 4 (1971): 509-538.

beyond the stage of the epidemiologic transition when communicable diseases were the major cause of death. Even so, communicable diseases claimed about 17 million lives globally in 2005, and they accounted for the vast bulk of child deaths. The communicable disease burden for adults and the elderly also remains large in some regions. The AIDS epidemic (accounting for about 2 million deaths) heavily affects adults; it lowered life expectancy in all of sub-Saharan Africa by 0.4 years between 1990 and 2000 and contributed to declines of more than 14 years in Botswana and 15 years in Zimbabwe. AIDS is not, however, the only culprit in such setbacks—even with low HIV rates, countries such as Afghanistan and Sierra Leone have experienced recent sustained declines in life expectancy from communicable diseases, largely due to the unwinding of disease control mechanisms attributable to conflict and political disorganization.³

Noncommunicable diseases were responsible for almost twice as many deaths (32 million globally) as communicable diseases in 2005, and injuries killed another 5 million (deaths from injuries are rising rapidly with the global spread of vehicle ownership). These categories are the primary causes of adult deaths, and they are by far the largest killers in high-income countries. And many developing countries increasingly face a double burden of premature deaths—unnecessarily high rates of both communicable and noncommunicable diseases.

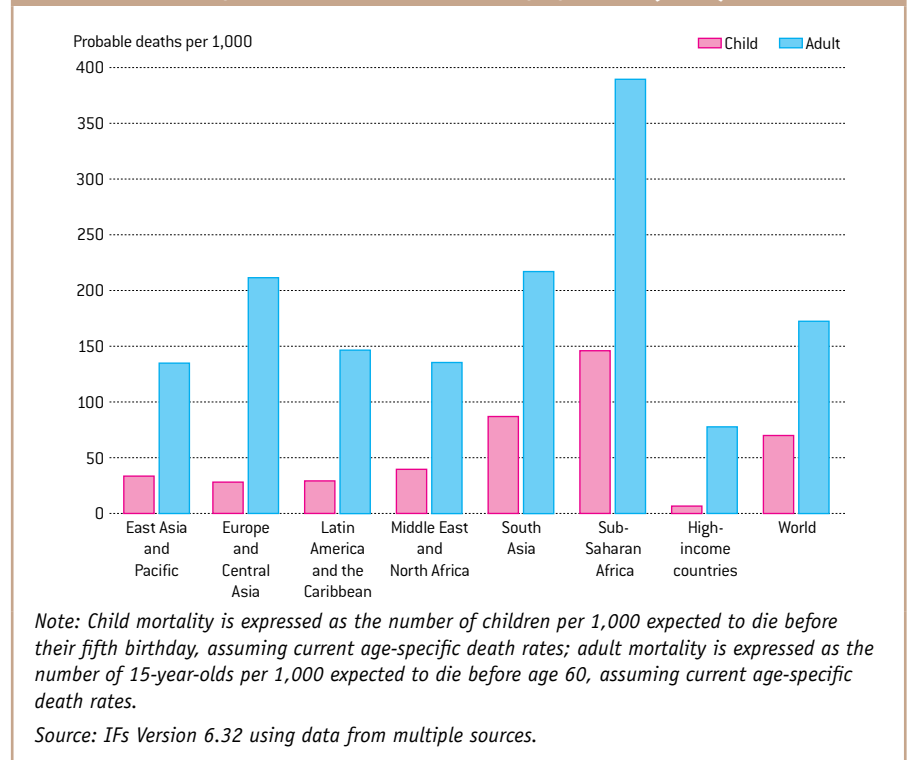
In summary, despite extraordinary advances in global health over the last 50 years, daunting problems remain. In 2005, about 10.1 million children died before their fifth birthdays, with 99 percent of those deaths occurring in developing countries. That distribution of child deaths illustrates a critical health

issue: the great disparity that exists in health prospects across the regions of the world. Had children in poorer countries died at the same rate as those in high-income countries, there would have been about 9 million fewer child deaths that year. These disparities exist across all age groups (Figure 2 compares child and adult mortality probabilities across regions, and Figure 1 shows great disparities in infant mortality rates by region despite the remarkable overall progress since 1950). The distributions of deaths within countries are also very unequal across income, education, ethnicity, and other social divisions.⁴

In combination, differences in child and adult mortality probabilities resulted in a nearly 28-year gap in life expectancy between sub-Saharan Africa and the high-income countries

of the world as recently as 2005. A substantial burden of unnecessary mortality and disability also remains in high-income countries. As Figure 2 shows, in high-income countries—where death before the age of retirement is now considered very premature—77 of 1,000 15-year-olds still die before reaching their 60th birthdays. And beyond mortality are the burdens of chronic disease and disability, which have increased for both high-income and developing countries as premature mortality has declined. Globally, then, the story of disease and mortality decline hopefully is far from over.

Figure 2 Probability of child and adult mortality by region (2005)



3 Dean T. Jamison, "Investing in Health," in *Disease Control Priorities in Developing Countries*, 2nd ed., Dean T. Jamison and others, eds., 3–34 (New York and Washington, DC: Oxford University Press and World Bank, 2006).

4 Commission on Social Determinants of Health (CSDH), *Closing the Gap in a Generation: Health Equity Through Action on the Social Determinants of Health* (Geneva: World Health Organization, 2008).

Base Case Forecast for the Next 50 Years

The International Futures (IFs) approach

We need to consider a variety of driving forces and their interaction if we want to understand and shape the future trajectory of global health. The epidemiologic transition, for example, suggests an essentially automatic positive relationship between development (e.g., economic growth and the spread of education) and health outcomes. These deep-driving variables or *distal drivers* of health outcomes are in fact very powerful. Still, the distal drivers of health leave considerable unexplained variation in health outcomes across countries with similar levels of income and education, signaling the importance also of other more immediate causes of health outcomes— risk factors or *proximate drivers* that are affected, but not fully determined, by distal drivers. For example, malaria and type 2 diabetes do not require expensive or sophisticated cures; the widespread use of bed nets could dramatically decrease malaria, while dietary changes could prevent many cases of type 2 diabetes. And indeed, most modern global health action has focused on reducing proximate risks through vaccination, disease eradication, and delivery of basic disease-prevention services, including health education.

Even with the identification of distal and proximate drivers, the picture of changing global health remains incomplete. Much of what we want to understand about change in the distal and proximate drivers and the relationships among and between them lies still deeper, at the level of what might be called *super-distal* drivers. Human activity that builds this still-deeper context includes investment in technological advance, human-based

changes that affect risk factors in the natural environment and our exposure to them, and change within the social environment (including the quality of governance and the development and character of health care systems).

A hybrid model in IFs captures key distal drivers and selected proximate and super-distal drivers, their interactions and their impacts on health outcomes, and the further impacts of those health outcomes on population and development, as represented in Figure 3. We first explored a base case—what the future of global health might be if current dynamic patterns and relationships continue to unfold and evolve. We then explored alternate (optimistic and pessimistic) scenarios around that base case. We summarize some of the key findings of the base case in the remainder of this section and in the next section consider the optimistic and pessimistic scenarios.

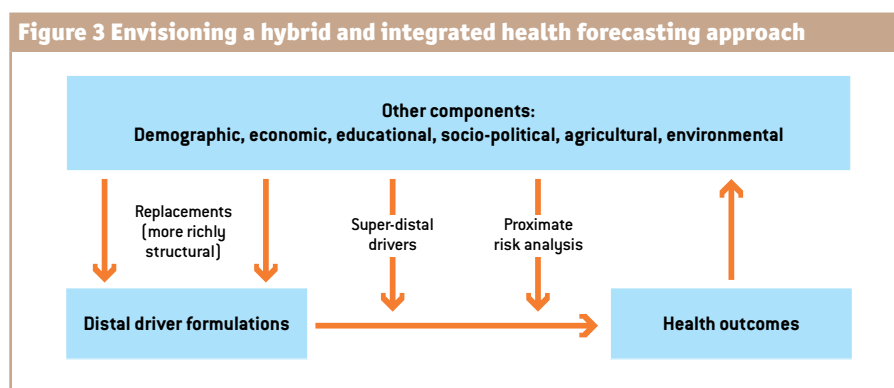
What might the future look like if the current path continues to unfold?

Using United Nations Population Division (UNPD) data through 2005 and forecasts from the IFs base case, Figure 4 depicts historical and forecast life expectancy at birth by region from 1960 through 2100. Trends for both males and females suggest dramatic

improvement in all regions. We forecast the greatest rates of improvement in poorer regions, especially sub-Saharan Africa (the result of a decline in HIV/AIDS and communicable diseases more generally). We forecast a gradual slowing of improvements in life expectancy in high-income countries, particularly for males.

Comparing our results for 2050 to those from the UNPD (not shown), we anticipate generally comparable but somewhat better life expectancy outcomes, with more-developed countries performing about one year better in our forecasts (life expectancy of 84 versus 83 years), less-developed countries performing up to two years better (76 to 74) and least-developed countries performing about one and a half years better (70 versus 68.5).⁵

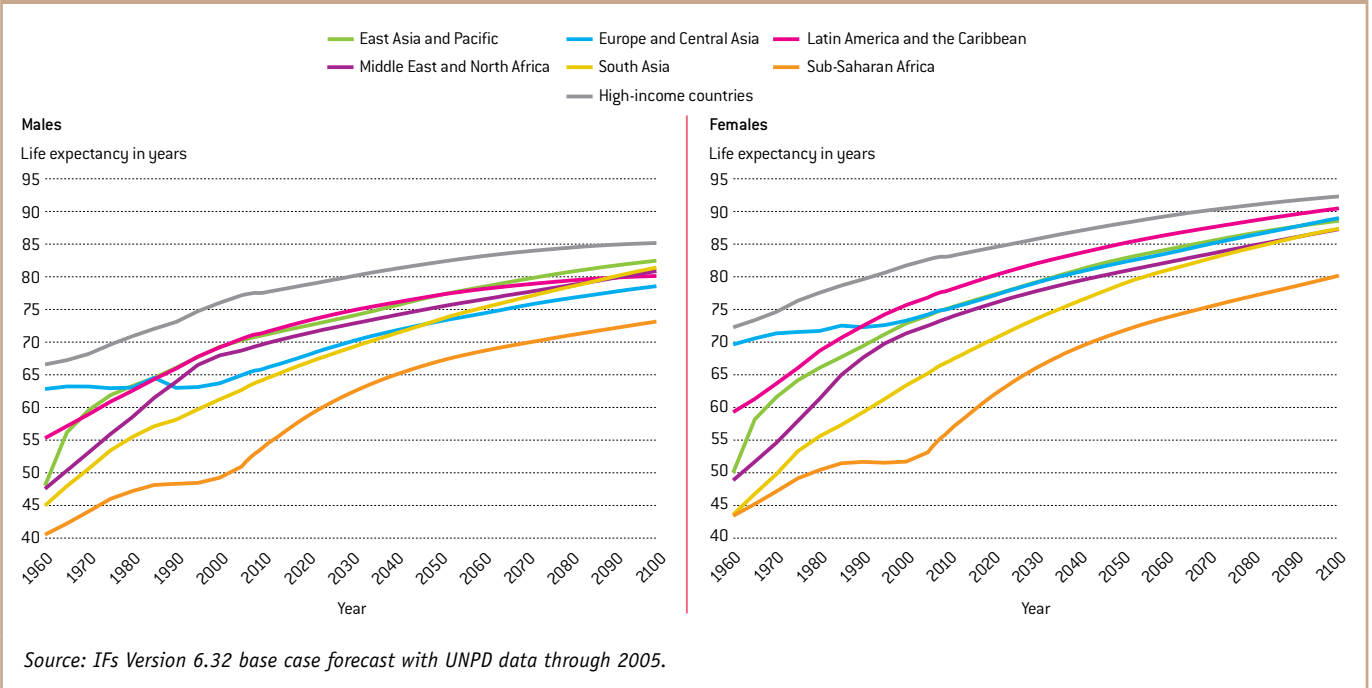
The Commission on Social Determinants of Health (CSDH) set the goal of reducing the gap in life expectancy at birth between the populations of the 60 longest- and shortest-lived countries by 10 years, or from 18.8 years in 2000 to 8.8 years in 2040.⁶ Figure 5 depicts this gap historically and in the IFs base case forecast. This target appears unlikely to be met until after 2060—in fact, an extension of Figure 5 would show it is not until near the end of the century. This is due to how aggressive the goal



5 United Nations Population Division, "World Population Prospects: The 2008 Revision, Highlights," Working Paper no. ESA/P/WP 210 (New York: United Nations, 2009), 11.

6 CSDH, *Closing the Gap*, 197.

Figure 4 Life expectancy for males and females by region: History and extended forecasts



is for those countries (mostly poor or lower-middle income) with the largest current gaps, in combination with the continued (though slowed) increase in life expectancies of the populations of current longest-lived countries (all

of which are high-income or higher-middle-income).

The prospects for achieving such goals—or even for substantially narrowing the gaps—depend on continued reduction in communicable

disease mortality and action against the rising burden of noncommunicable diseases and injuries. Globally, the IFs base case shows a continued shift away from communicable to noncommunicable disease deaths, with noncommunicable diseases already the major cause of deaths in 2005. We forecast a reduction of communicable disease deaths of just over 40 percent by 2030 and almost 70 percent by 2060 (see Figure 6) in spite of substantial population increases. This is consistent with historical patterns of progress against most communicable diseases, though there is considerable uncertainty around the pace of reduction in HIV/AIDS and malaria. However, even in sub-Saharan Africa, we forecast that the balance of deaths will shift to noncommunicable diseases before 2030 and that sub-Saharan Africa's noncommunicable disease deaths will outnumber its communicable disease deaths by more than 5-to-1 by 2060. Changing age-specific death rates and an older population structure both result from and reflect these shifts.

Figure 5 Life expectancy gap between countries with the longest and shortest life expectancies

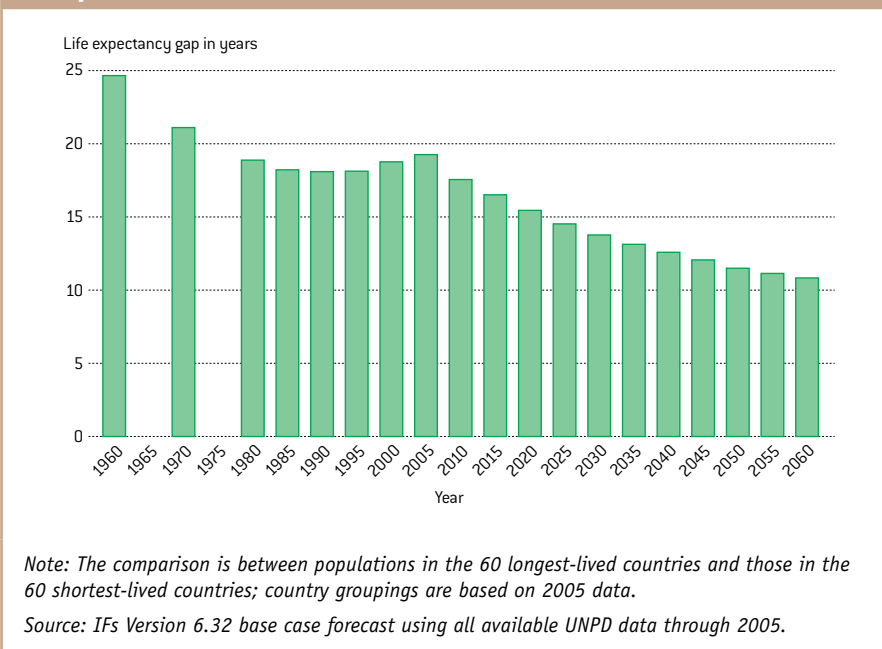
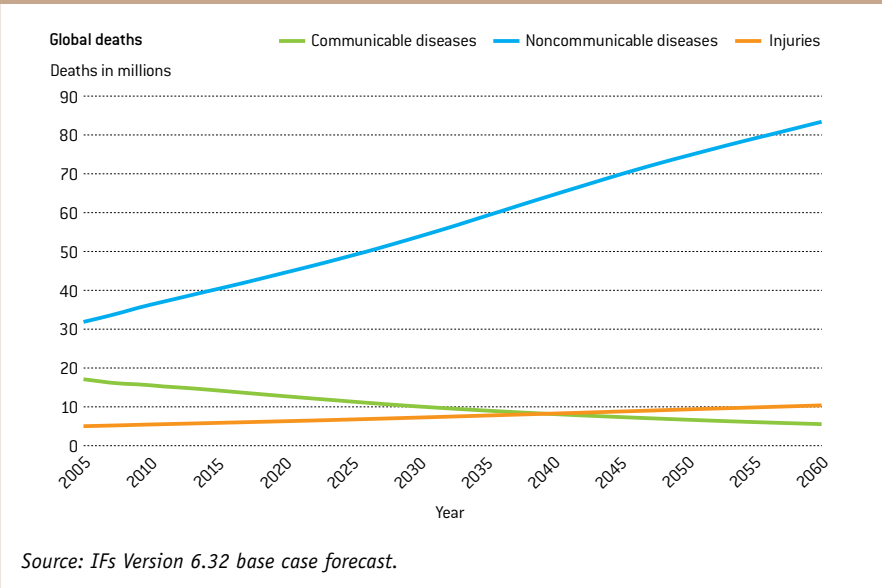


Figure 6 Global deaths by major disease groups



progress in health would greatly slow or potentially even reverse.

Our focus in this summary is a comparison of the optimistic Luck and Enlightenment (L&E) and pessimistic Things Go Wrong (TGW) scenarios, both of which are based on assumptions that we believe represent realistic possibilities.⁷ Our assumptions incorporate elements aimed at capturing variations in technology (via a 50 percent increase or decrease over time in the pace of mortality reduction due to technology compared to the base case) and in our proximate drivers of health (via a one standard error increase or decrease in each proximate risk factor compared to the base case, again phased in over time). To better capture potential positive human action affecting proximate risks beyond the eight explicitly included in IFs, in L&E we also allow those countries that are currently underperforming projections based on our formulations to gradually converge toward expectation. Two further adjustments capture a realistic pessimistic scenario (TGW), especially for low-income countries. First, to account for lingering effects of the Great Recession (2008–2011 in the IFs base case), we model lower GDP

Exploration of Alternate Future Health Scenarios

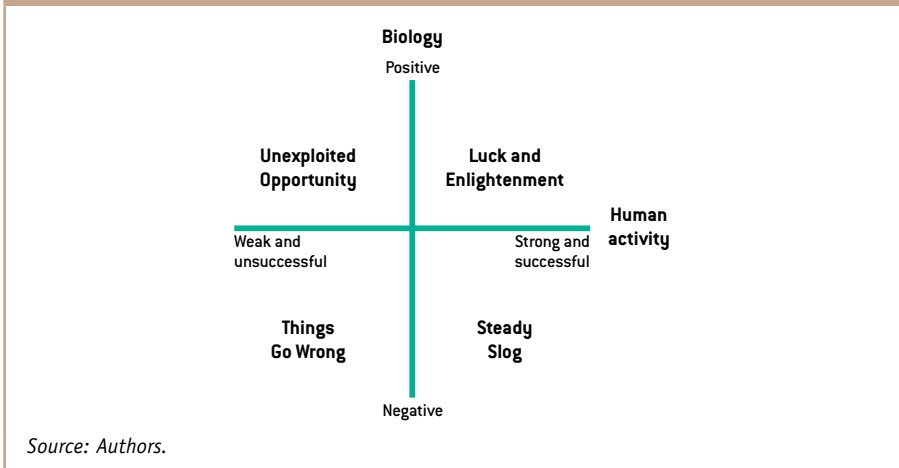
Creating the alternate scenarios

In addition to exploring a base case (and also a base case with some modifications), *Improving Global Health: Forecasting the Next 50 Years* also includes an exploration of the interaction of distal, proximate, and super-distal drivers within a scenario space whose axes are biology and human activity. Four very different global health futures result from this exploration, as described below and as shown in Figure 7.

Good human biological prospects and strong and positive human activity could create a desirable future that combines Luck and Enlightenment. Should biological prospects prove less accommodating than we would hope, we could still aggressively and thoughtfully continue within that constraint a Steady Slog toward better health futures and continued convergence of health outcomes. On the other hand, although it seems perverse that we would be so foolish as not to take advantage of a favorable biological context, one can in fact imagine a future of Unexploited Opportunity, especially in selected

countries and regions, one major consequence of which might be further divergence in health outcomes across nations. And, unfortunately, it is quite possible also to imagine a future in which rising resistance to drugs and other treatment modalities and/or the emergence of new threats is accompanied by a failure of global and state-level governance to respond well to the setbacks or new challenges. In this future, a future in which Things Go Wrong,

Figure 7 Alternative health futures in broad context



⁷ Our pessimistic scenario does not include global collapse or massive disruption from unforeseen shocks. Similarly, our optimistic scenario does not assume positive effects from extraordinary new interventions.

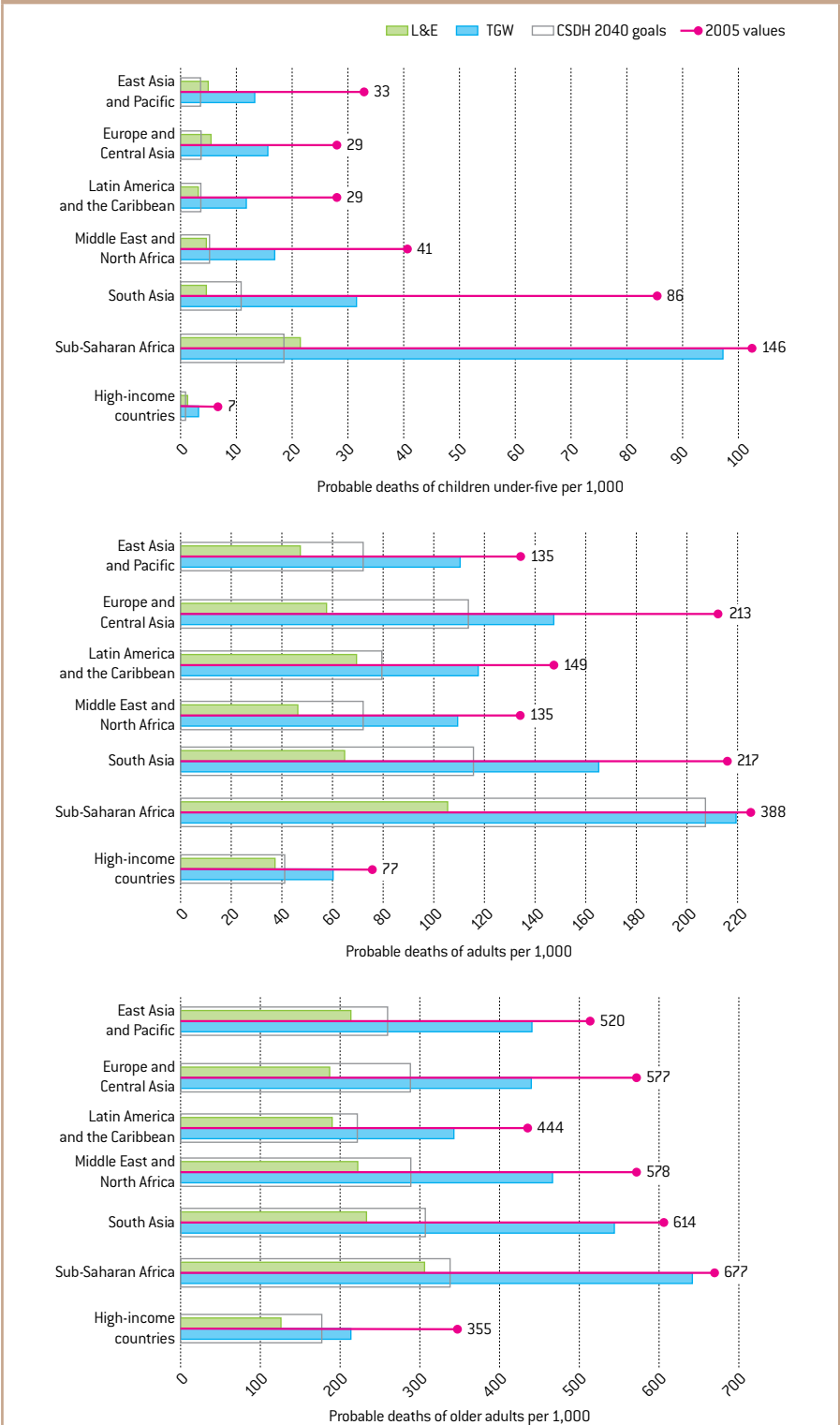
growth rates in all countries, with greater reductions in GDP growth rates in low-income countries. Finally, TGW incorporates slowed reductions in communicable disease mortality, particularly for HIV/AIDS.

Impacts on deaths, mortality probabilities, and population size

The optimistic L&E and pessimistic TGW scenarios carry significant global implications. Annual global deaths in the pessimistic scenario grow to be 34 million more by 2060 than in the optimistic scenario. In terms of death rates, the gap is still larger, because population diverges markedly between the two scenarios, from just over 9 billion (pessimistic) to just over 10 billion (optimistic), compared to a base case value of 9.4 billion. Of 1 billion additional people in the L&E scenario, the great majority—about 800 million—are 65 and older, with an additional 236 million working-age adults and 39 million fewer children and youth under 15 years of age. Due to population aging and the high probability of some reduction in communicable disease risks, both scenarios suggest an ongoing global shift from communicable to noncommunicable disease burdens. In neither scenario do communicable diseases account for more than 12 percent of deaths by 2060, though communicable disease burdens remain much higher in the pessimistic scenario.

Figure 8 shows the difference between the two scenarios in mortality probabilities for children, adults, and older adults by region. The relative differences in probabilities are very large across all regions and mortality levels, varying quite often by a factor of two or even more. Relative differences are especially great for infant mortality, and those for South Asia and sub-Saharan Africa stand out; for example, child mortality probability in South Asia and sub-Saharan Africa is between five and six times greater in 2060 in TGW than in L&E. In fact, for low-income countries

Figure 8 Comparison of mortality probabilities for 2060 in Luck and Enlightenment (L&E) and Things Go Wrong (TGW) by region



Note: Mortality probability is shown as the number of probable deaths per 1,000 before reaching end of age range (0–4 for child mortality; 15–59 for adult mortality; 60–79 for older adult mortality).

Source: IFs Version 6.32.

TGW really means things go *very* wrong, with an actual increase in child deaths in coming years and a gap exceeding 3 million child deaths annually for most of the forecast horizon between the patterns of that scenario and the optimistic Luck and Enlightenment.

The level of absolute variation in adult and older adult mortality probabilities is also striking, again particularly for sub-Saharan Africa and South Asia. In the case of sub-Saharan Africa, the scope of the HIV/AIDS epidemic is so sweeping, and the likelihood of some progress so great, that the probability of adult mortality falls from 388 per 1,000 to 219 per 1,000 even under TGW; in L&E it falls much further, to 105 per 1,000. The two scenarios also differ dramatically in the rate of progress over the next 50 years in the regions where noncommunicable diseases largely drive adult mortality. In South Asia, for instance, adult mortality probability in 2005 was 217 per 1,000. In the L&E scenario, South Asia's adult mortality rate plunges to 64 per 1,000, comparable to today's high-income societies, whereas in TGW the rate only falls to 165 per 1,000. Despite these very large differences in health outcomes between L&E and TGW, child, adult, and older adult mortality probabilities decline between 2005 and 2060 in all regions in the pessimistic scenario. In other words, progress in improving health is slowed (sometimes dramatically), but it is neither stopped nor reversed.

Figure 8 also compares the mortality probabilities of children and adults with the target levels set by the Commission on Social Determinants of Health—a 95 percent reduction in the mortality rates of children under 5 and a 50 percent reduction in adult mortality rates. The gap between the outcomes in our two scenarios has significant impacts on the likelihood of meeting those targets. If something even close to TGW came to pass, child and adult mortality rate reduction targets for 2040 would not be met even by 2060 almost anywhere. However, if something close to L&E came to pass, both child and adult

mortality rate reduction targets would be reached almost everywhere by 2060 (as seen in Figure 8), and many even by 2040 (not shown).

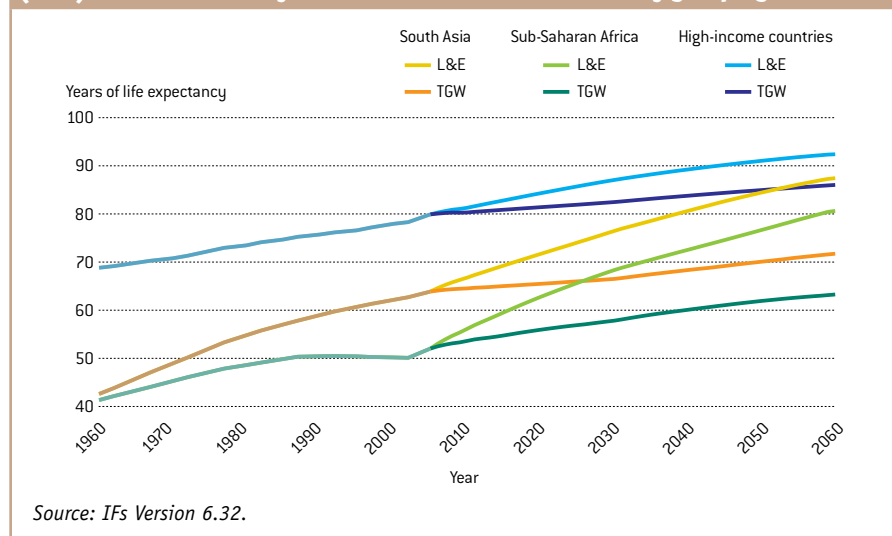
Impacts on life expectancy

Regional life expectancy also differs dramatically by scenario, as shown for South Asia, sub-Saharan Africa, and high-income countries in Figure 9. Note that although the range of uncertainty indicated for high-income countries is considerable (a difference of six years of life expectancy in 2060), the stakes are much higher for developing regions. The differences in life expectancy between the two scenarios are 17 years for sub-Saharan Africa and 16 years for South Asia. Specifically, in 2005 aggregate life expectancy for sub-Saharan Africa was 28 years below that of high-income countries (52 versus 80), while South Asia had a 15-year gap (65 versus 80). In the optimistic scenario, sub-Saharan Africa's life expectancy gap falls to 12 years and South Asia's life expectancy climbs to only five years less than that in high-income countries, a remarkable potential convergence. In TGW, however, sub-Saharan Africa's life expectancy gap is still at 23 years even though in absolute terms its life expectancy has increased

by 12 years since 2005; in South Asia the gap is reduced by only one year in TGW (from 15 to 14 years) even though in absolute terms its life expectancy has also increased by seven years. The gains in life expectancy in sub-Saharan Africa vis à vis the high-income countries reflect the high likelihood of some improvement in HIV/AIDS mortality in sub-Saharan Africa even under pessimistic circumstances, while the very small gains in South Asia in TGW reflect the predominant dependence of future gains in that region on even more uncertain noncommunicable disease mortality reductions.

The regional stories cannot, of course, convey the rich diversity of situations across individual countries. There are more than 50 countries whose life expectancies in 2060 vary by 15 years or more between the two scenarios, a variation that at its maximum reaches 31 years. The countries that stand to benefit most in life expectancy from L&E are those whose life expectancy trajectories have been held down by a variety of socio-political factors, both domestic and international. The countries at the top of the list include Afghanistan, Angola, Central African Republic, Chad, Democratic Republic of Congo, Republic of Congo, Equatorial Guinea, Gabon,

Figure 9 Life expectancy in Luck and Enlightenment (L&E) and Things Go Wrong (TGW) scenarios: History and forecasts for selected country groupings



Ghana, Rwanda, Somalia, and Tajikistan. Russia is also high on the list. Countries that have unusually poor levels of health and life expectancy relative to income and education levels (as many of the countries on this list do) are perhaps likely to converge upward over time, and we built such convergence into L&E. Still, as in TGW, the forces that have suppressed their life expectancies may either continue to exert a hold on these countries or even reach out to affect still other countries.

Impacts of variations in risk factors

As mentioned previously, variations in assumptions about proximate risk factors were an important component of the optimistic and pessimistic scenarios and had significant impacts on the number of forecasted deaths occurring between 2005 and 2060. In a comparison between favorable and unfavorable risk factor interventions (where the prevalence of risk factors varies by one standard deviation in both directions from the base case), 438 million deaths are averted between 2005 and 2060 by the reduction of seven proximate risks that are most amenable to public policy interventions: childhood undernutrition; obesity; smoking; road traffic accidents; unsafe water, sanitation, and hygiene; indoor air pollution; and urban outdoor air pollution. Note that super-distal drivers that affect the prevalence of proximate risk factors (for example, the presence or absence of agricultural policies and advances in technology that increase crop yields, regulation of tobacco use and health education programs about the effects of smoking, enforcement of air quality standards, and investment in infrastructure that allows electricity to be substituted for household use of solid fuels) are critical to these outcomes.

Table 1 shows the cumulative differences in global forecasts of deaths, years-of-life lost,⁸ and disability-adjusted life years⁹ between 2005 and 2060 between the favorable and unfavorable interventions for the eight proximate risk factors included in *Improving Global Health: Forecasting the Next 50 Years*. We comment briefly on two perhaps surprising results.

First, among the proximate risk factors we analyzed, the greatest number of cumulative averted deaths (as well as averted years of life lost and disability adjusted life years) result from interventions to enhance road traffic safety. Why might this be? The first reason is that road traffic accidents account for a significant number of deaths and disabilities; in fact, they are one of only two causes of death in which our base case forecasts an increase in age-standardized death rates per 100,000 on a global basis between 2010 and 2060 (from 20 per 1,000 in 2010 to 28 per 1,000 in 2060). The second reason is that there is wide divergence in road traffic accident death rates across countries for which similar values would be expected based on other similarities (primarily GDP per capita),

suggesting the potential for significant positive impacts from attention to road traffic safety. However, to date this is a subject that has received relatively little attention in health risk factor assessments.

The second perhaps surprising result, on the other hand, is that we see a forecast of only 1 million cumulative averted deaths related to a favorable vs. unfavorable climate change scenario over the same period. Why might this be? First, we are looking only at one component of climate change's possible health impacts— that of deaths of children under five years of age from communicable diseases related to undernutrition. Second, the dynamic nature of the IFs model includes the interacting effects of other variables that, at least in the short run, substantially offset the negative effects of climate change on crop production (for example, higher crop yields from advances in technology and rising income levels that somewhat ameliorate and compensate for increases in food prices). Our climate change formulations are exploratory and should not be used to downplay the potential consequences of climate change; however, at the same

Table 1 Cumulative differences in global forecasts of deaths, YLLs, and DALYs between less and more favorable scenarios of individual proximate risk factors (2005–2060)

Risk factor	Cumulative deaths (millions)	Cumulative YLLs (millions)	Cumulative DALYs (millions)
Undernutrition	70	2,254	2,855
Obesity	68	1,054	1,064
Smoking	31	258	272
Road traffic accidents	107	2,712	3,248
Unsafe WSH	53	1,696	2,103
Indoor air pollution	22	471	649
Outdoor air pollution	87	1,033	1,167
Climate change	1	67	123

Source: *IFs Version 6.32*

8 Years of life lost (YLLs) is the number of years of life an individual or a group loses on dying compared to the life expectancy of a standard (long-lived) population; the concept and measure were developed as part of the WHO Global Burden of Disease study (see footnote 12).

9 Disability-adjusted life years (DALYs) is a measure that combines years of life lost with years lived with disability; this concept and measure were also developed as part of the WHO Global Burden of Disease study (see footnote 12).

time, our analysis suggests fruitful avenues for further exploration of the complexity of climate change and possible mitigating responses to at least some of its impacts.

Impacts of Improved Health on Demography and Economic Growth

The context for exploration and our approach

A long and healthy life is fundamentally important in and of itself as a central priority for human development and is the basis for large expenditures on health, regardless of the contributions of such expenditures or changes in health to other aspects of human development, including economic growth. Even so, there is intense competition for public funds and programs, and intelligent policy decisions require some understanding of how improvements in health might relate to human well-being more broadly. Consequently, we used the IFs system of models to explore some of the relationships between improvements in health and the general human condition. Specifically, we looked at impacts on demography and on economic growth.

Typically, discussions of the forward linkages from health share the assumption that an individual in better health will experience greater productivity, a relationship that microeconomic evidence strongly supports.¹⁰ Yet, until recently, many have concluded that the interaction of healthier individuals in a structurally unchanged economy would remain insignificant at the macroeconomic level—in other words, that relative position of individuals might change but there would not be an impact on overall economic progress. Recent more detailed measurement and specification of microeconomic pathways to macroeconomic impacts, as well as better understandings of the behavioral and political pathways by which health

can affect development, have begun to alter this view.

Our analysis includes the impacts of health on economic growth through three pathways: demographics and labor supply; productivity; and savings and capital, including foreign direct investment. We explore these by looking at forecasts of economic outcomes associated with mortality rates 30 percent higher and lower than those in the base case, phased in through 2060. Our exploration also considers the impact of different rates of illness and disability associated with the higher and lower mortality rates (e.g., the productivity gains associated with a healthier labor force).

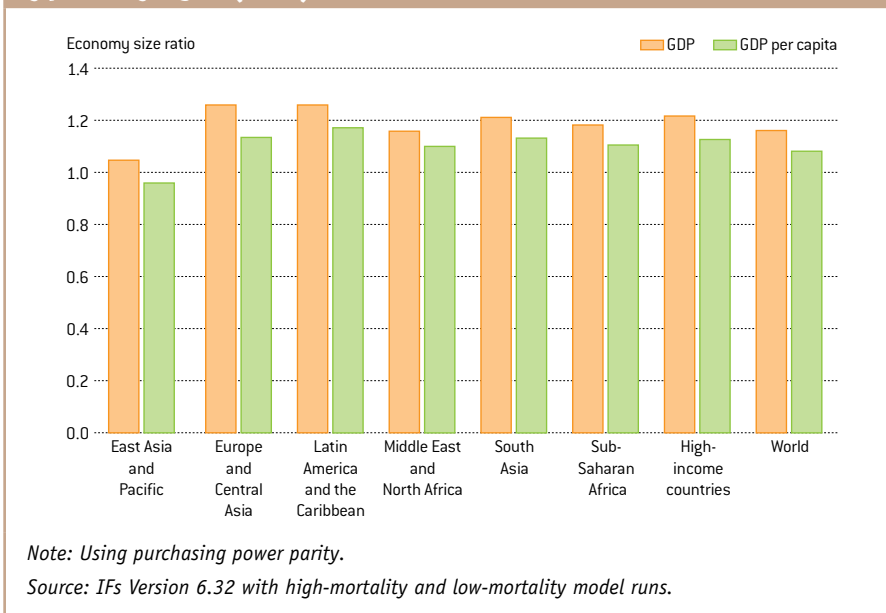
Impacts on population, economy size, and income per capita

In the low mortality (healthier) profile, the global population would be almost 1 billion persons larger by 2060 than in the high mortality (less healthy) profile, and almost 80% of those individuals would be 65 years of age or older. Perhaps surprisingly, despite the larger population size and

the quite greatly increased portion of adults beyond typical working ages, we found a pattern of modest benefits from the low mortality scenario in terms of both the size of the economy and GDP per capita. On a global level, in fact, a 16 percent rise in global GDP and an 8 percent increase in GDP per capita resulted from the low mortality profile (see Figure 10). These outcomes were related to productivity gains from a healthier workforce and to increased capital investment from higher savings rates among longer-lived populations (including higher foreign direct investment in response to improvements in human capital). During the time horizon of our forecasts, some regions also benefitted from a “demographic dividend” in terms of a larger labor force relative to dependent populations as greater proportions of children survived to working age and fertility rates declined.

As Figure 10 also shows, in all regions there are increases in total GDP (some very modest, but others more sizeable). And in all regions except

Figure 10 Ratio of economy size: Low mortality profile compared to high mortality profile by region (2060)



10 Jere R. Behrman, “The Impact of Health and Nutrition on Education,” *World Bank Research Observer* 11, no. 1 (1996): 23–37.

East Asia and Pacific, the low mortality scenario also increases per capita GDP. The different result in East Asia and Pacific flows from the extremely large number of older adults (60–79) and the elderly (those 80 and older) that China will experience relative to its working-age population in coming years even in the base case—most of the reduced mortality for the region with positive intervention would occur in the older age categories, further intensifying fiscal pressures on the society. On the other hand, the swing in per capita GDP for South Asia between the two scenarios reaches about 13 percent in 2060 in spite of increased population (South Asia’s relative gains stem from the imminent arrival of larger cohorts into prime working ages). A similar phenomenon would create about an 11 percent increase in GDP per capita in sub-Saharan Africa by 2060.

We also explored the impacts on GDP per capita of a number of other interventions in combination with improved health. Specifically we looked at the results of changes in

three variables in comparison with our base case: further reductions in fertility, higher agricultural yields, and increased foreign aid. We looked first at the impact of each of these with health separately, and then in combination (also with low mortality) in a final profile (see Figure 11). The most dramatic improvement from the combined interventions would be in sub-Saharan Africa, where we estimate the improvement in GDP per capita from the combined interventions would be 28 percent rather than the 11 percent from improved health alone, emphasizing the potential that additional levers have to complement the impact of health improvements.

In conclusion, while there are fairly clear forward linkages from health to population size and age structures over time, the relationship between improved health and economic performance is not a simple one. The relationship depends on the balance of mortality causes within a region or country, on the underlying demographic and economic structures of the region or country

at a given point in time, and on the extent to which health interventions are combined with policy interventions in other arenas. The good news, nonetheless, is that there seems to be clear potential for positive micro- and macroeconomic impacts of reductions in mortality.

The Future of Global Health

Remarkable improvements in health have occurred throughout the world over the last 50 years. Our analysis of selected health risk factors and the positive impacts of interventions that reduce their prevalence points to one pathway to continued improvements. And the still large discrepancies between the health of individuals in many developing regions and those in high-income countries are simultaneously both a challenge and an opportunity—clearly, lower life expectancy in those regions is not the result of a fixed biological constraint.

Certainly we cannot rule out the possibility of major new disease epidemics, and we do not know the limits of the biological potential of the human genome for continued advance in leading life expectancies. However, a very large portion of the uncertainty around future health revolves around human action: the advance of our medical technology, the strength of our health care systems, and our will and our access to means to change unhealthy lifestyles. Human action across a range of broader systems is perhaps even more critical to global health outcomes: the extent to which we address inequality within and across societies, the progress and character of globalization processes, our investments in infrastructure (e.g., safe road systems and improved water and sanitation), and our actions to reduce and ameliorate anthropogenic climate change are but a few examples.

Figure 11 Ratios of GDP per capita of assorted changes to high mortality profile by region (2060)



The International Futures (IFs) Forecasting System

The System of Models

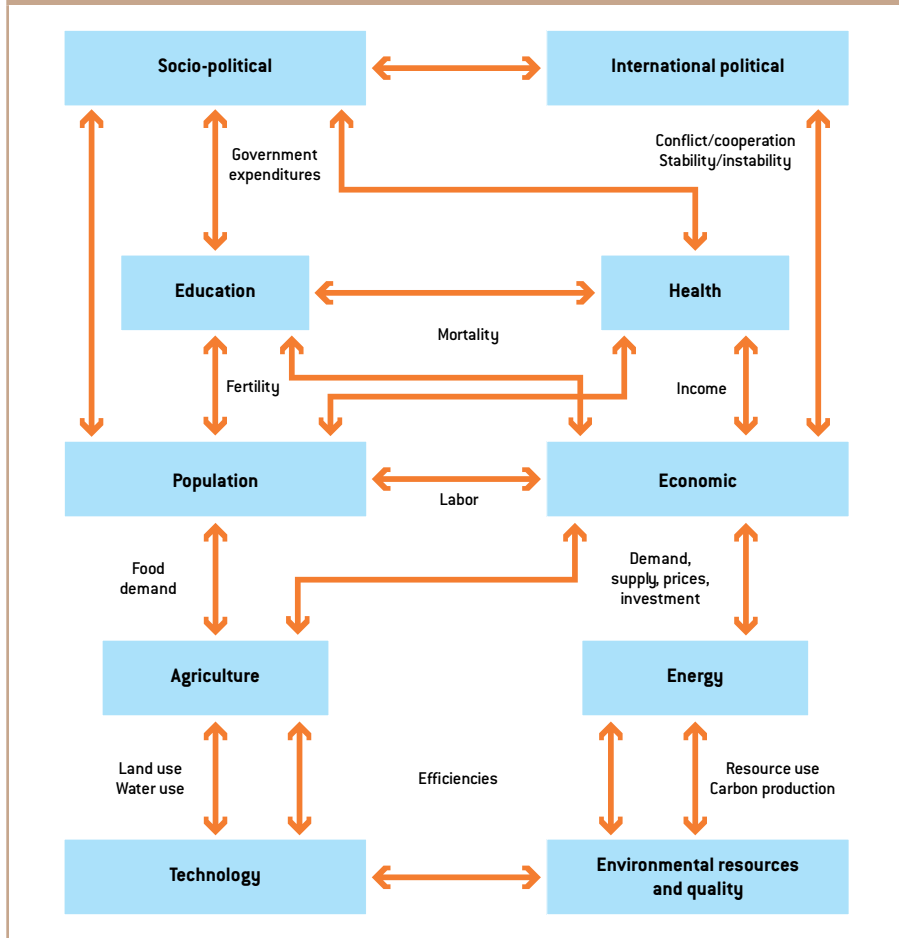
IFs is a software tool whose central purpose is to facilitate exploration of possible global futures through the creation and analysis of alternative scenarios. It is large-scale and long-term, and incorporates and integrates models of population, economics, energy, food and agriculture, aspects of the environment, and socio-political change. In support of the **Patterns of Potential Human Progress** series, we have added models of education and health; an infrastructure model is currently being developed and added. Figure 12 shows the major conceptual blocks in the system (the elements of the technology block are actually dispersed throughout the model). The named linkages between blocks are only a small illustrative subset of the dynamic connections between the components.

IFs represents the dynamic connections among all these systems for 183 interacting countries, drawing on standard approaches to modeling specific issue areas whenever possible, extending those as necessary, and integrating them across issue areas.¹¹ As well as being rooted in the theory of various disciplines and subspecializations, IFs incorporates country-specific data across the issue areas from the family of United Nations member organizations and other sources for as much of the period since 1960 for which various data are available.

Fundamentally, IFs is a thinking tool, allowing variable time horizons through 2100 for exploring human leverage in pursuit of key goals in the face of great uncertainty. IFs assists with:

- understanding the state of the world and the future that appears to be unfolding by

Figure 12 Major models in the IFs modeling system and example connections



- identifying tensions and inconsistencies that suggest political, economic, or other risk in the near and middle term
- exploring long term trends and considering where they might be taking us
- working through the complex dynamics of global systems.
- thinking about the future we want to see by
 - clarifying goals and priorities
 - developing and exploring alternative scenarios (“if-then” analyses)

- investigating the leverage we may have in shaping the future.

The IFs Health Model

Turning specifically to the IFs health model, we forecast mortality and morbidity for the following individual diseases and disease clusters:

- diarrheal diseases, HIV/AIDS, malaria, respiratory infections, other communicable diseases;
- cardiovascular diseases, diabetes, digestive disorders, malignant neoplasms, mental health, respiratory

¹¹ For example, the population model in IFs is based on a typical “cohort-component” representation, tracking country-specific populations and events (including births, deaths, and migration) over time by age and sex; IFs then extends this representation by adding education and health.

- conditions and diseases, other non-communicable diseases;
- intentional injuries, road traffic accidents, other unintentional injuries

The World Health Organization's Global Burden of Disease (GBD) project served as the foundation for the IFs health model. The GBD project broke new ground not only by providing the first comprehensive forecasts of global health, but also through its methodology and approach. Rather than relying heavily on extrapolative techniques (as most population forecasting has done), it identified and used independent variables—income, education, and time—to understand and anticipate health outcomes and changes in them through 2020. Second, it disaggregated total mortality into multiple causes of death, important because the driver-outcome relationships vary with cause of death as well as with sex and age. Together these changes made possible a shift to a structural approach to understanding and forecasting health.¹² Shortly after the publication of the first GBD study, Mathers and Loncar incorporated more extensive data, updated driver-variable forecasts, created regression models specific to low- and lower-middle-income countries, and developed separate projection models for some diseases (e.g., HIV/AIDS) that are not easily forecast using distal drivers.¹³ A subsequent study extended the forecast horizon to 2030.¹⁴

We began the development of the IFs health model by incorporating the GBD formulations, with some modifications

and extensions, into the already-existing IFs forecasting framework.¹⁵ Some of these modifications and extensions were motivated by a need to refine forecasts in those cases where mortality rates tend not to monotonically increase or decrease with changes in income, education, and time. Smoking is such an example. As incomes start to rise, smoking rates tend to increase. However, as incomes reach a certain level, smoking rates typically begin to decline. Thus we chose to develop a forecast of smoking rates themselves as a driver of health impacts.

To further enhance and refine our model's forecasting capability, we added a number of other proximate risk factors, including four environmental risk factors, in interaction with the distal drivers of income, education, and time. Our total set of eight proximate risks included childhood undernutrition; obesity; smoking; road traffic accidents; unsafe water, sanitation, and hygiene; indoor air pollution; urban outdoor air pollution; and climate change. Our approach built on the work of the World Health Organization's Comparative Risk Assessment (CRA) project.¹⁶ That project had earlier identified major disease risk factors and analyzed the burden of disease in populations with varying levels of a risk factor, in comparison with a population with a theoretically minimum level of the risk, in order to quantify the relationship between specific risk factors and diseases. We extended the work of the CRA project to a new level by incorporating selected risks into health forecasts in conjunction with income,

education, and time (the distal drivers), thereby taking a significant step toward the hybrid health forecasting system presented earlier in Figure 3.

The dynamic connections among the various models in IFs (see again Figure 12) also allowed us to connect health with the larger human, social, and natural systems represented in IFs, such that change in health both drives change in those larger systems and, in turn, is affected by change in them. The "natural" progression of outcomes across these systems produces the endogenous forecasts of our base case, while levers in the model allow users to vary assumptions about the values of variables and their relationships with one another (a proxy for assumptions about super-distal drivers beyond those endogenously specified in the model), creating alternative scenarios and profiles.

In summary, our health model has advanced the exploration of future health by:

- extending the forecasting time frame to 2060 in *Improving Global Health: Forecasting the Next 50 Years* and to 2100 in the model itself
- providing the first model that is based at the country level and that allows flexible aggregation of country-based results to any country grouping desired by model users
- beginning the integration of individual proximate drivers into a health forecasting system
- building a more richly structural (as opposed to more extrapolative)

12 Christopher J. L. Murray and Alan D. Lopez, eds., *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020* (Cambridge, MA: Harvard University Press, 1996).

13 Colin D. Mathers and Dejan Loncar, Protocol S1 Technical Appendix to "Projections of Global Mortality and Burden of Disease from 2002 to 2030," *PLoS Med* 3, no. 11 (2006): 2011–2030.

14 World Health Organization, *The Global Burden of Disease: 2004 Update* (Geneva: World Health Organization, 2008).

15 We are especially indebted to Dr. Colin Mathers for generously sharing with us his original database and regression models and for responding to our many queries about them.

16 Majid Ezzati and others, eds., *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors* (Geneva: World Health Organization, 2004).

representation of health drivers and outcomes through endogenous connections between health and other domains (e.g., population size and age structure, fertility rates, economy size, and per capita income)

There is, of course, more modeling work that we wish to do or see done. A relatively short but very ambitious list includes the following:

- extending the set of proximate drivers to include other major health risks, such as alcohol abuse and physical inactivity
- better capturing the social and political context of health, including representation of sub-national

variation (beyond the sex differences that IFs already represents) to account for the role of inequality within and across countries as a distal driver of health

- modeling the spatial and social transmission of health risks from country to country
- exploring the impact that extreme events such as major plagues or dramatic breakthroughs in life extension might have on health and on well-being more broadly
- evaluating the potential health and economic impacts of specific policy and governance scenarios (as we expect to do in the near future with the Global Framework Convention on Tobacco Control)

There is little doubt that the global community will continue to set goals for health, and there is also little doubt that insights gained from modeling over longer-term horizons can inform that process and contribute to policy discussions and decisions. We hope our work will be helpful in those efforts, and we invite others to explore potential applications of the IFs platform in their own investigations and analyses. Documentation of the health model and the full model system is freely available at www.ifs.du.edu for replication of our scenarios, for alternative analyses, and for further development.

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PATTERNS OF POTENTIAL HUMAN PROGRESS

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