

7



Forward Linkages

■ *In this chapter we explore the implications of changes in health for outcomes in human development more generally.* ■

A long and healthy life is fundamentally important in and of itself as a central priority for human development. This priority justifies large expenditures on health, regardless of the contributions of such expenditures or changes in health to other aspects of human development, including economic growth.

Nonetheless, policy decisions involve trade-offs. We therefore have every reason to investigate the broader implications of changes in health in order to better understand the relationships between improvements in health and improvements in the general human condition. The International Futures (IFs) health model, embedded in the larger IFs modeling system, offers a tool with which to explore the long-term implications of health status for other outcomes in human welfare and security, what this volume often refers to as forward linkages. There is an ongoing debate surrounding the benefits of health for development, which IFs cannot resolve. However, it is our hope that by exploring how potential investments,

achievements, and setbacks in health might alter societal and global trajectories we may contribute positively to the continuing conversation.

All 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 (Behrman 1996) strongly supports. 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, the view that relative position might change but not overall economic progress. More recently, models of forward linkages have been enhanced by more detailed measurement and specification of microeconomic pathways to macroeconomic impacts, as well as by a better understanding of the behavioral and political pathways by which health can affect development very generally. Our discussion begins with the effects of health on the economy.

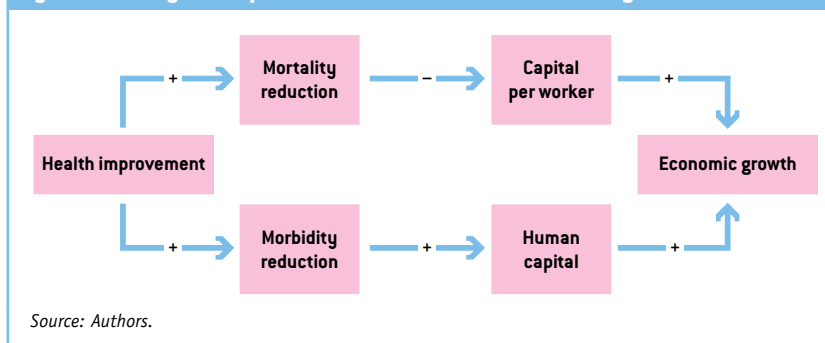
From Health to Growth

A core controversy

The most historically significant model of forward linkages comes from the neoclassical school of economics, in which the ratio of capital to labor determines worker productivity and therefore strongly shapes economic growth. According to this model, all else being equal, if the stock of capital remains unchanged, improvements in health—by reducing mortality and driving up population growth—will reduce the capital/labor ratio, reduce productivity, and reduce growth in per capita income (Acemoglu and Johnson 2007; Weil 2007).¹ Looking at the same phenomenon from a different perspective, a number of historical studies have tied the industrial takeoff of Europe, Britain in particular, to reduced resource pressures resulting from the great plagues of the 14th and 15th centuries (see Young 2005). By extension, many suggest that the HIV/AIDS epidemic, while a tragedy in terms of individual human suffering, will result in increased per capita GDP growth and productivity (Young 2005).

Many have questioned the neoclassical approach for ignoring the health benefits experienced by the living, for assuming that capital will remain constant in the face of changes in health, and for implying that lower mortality will necessarily lead to population growth. In fact, a growing consensus is emerging around a limited but significant role of health as a stimulus to growth. This consensus draws on Sen's support-led model of human development (Dreze and Sen 1989; Sen 1999b). It also follows from Becker's theory of human capital, which introduced a number of microeconomic behavioral changes in the allocation of capital resulting from improved health and survival, including increased public and private investments in children's education, increased life-course savings rates, and reduced fertility (Becker 1962). Fogel's theory of technophysio evolution integrates these disparate threads, noting how the gradual accumulation of micro-level biological and behavioral improvements can eventually lead to the wholesale restructuring of society around the productive capabilities and behaviors of long-lived, healthy populations (Fogel 2004a; Fogel and Costa 1997). Placed within the broader dynamics of a highly globalized economy, healthier societies might

Figure 7.1 Two general paths between health and economic growth



Source: Authors.

also attract external investment flows. Taken together, these threads point to a virtuous or synergistic cycle of development and productivity for which health is a necessary, if not sufficient, precursor.² Historically, Fogel (1994) attributed one-third of the economic growth in England between 1790 and 1980 to improvements in health and nutrition, and Arora (2001) attributed 30 to 40 percent of developed-country growth from the 1870s to the 1990s to improvements in health. In contrast to the neoclassical approach, then, these theories would suggest that the HIV/AIDS epidemic could pose grave threats to economic productivity.

The two perspectives on the relationship between health and growth are, of course, not mutually exclusive; Figure 7.1 sketches the main elements of both, showing the negative relationship between health and growth above and the positive one below. We seek in this chapter to elaborate the many important paths linking health and broader human development (not simply economic growth) and to consider with the help of the IFs system the complex feedback systems that those paths create.

Empirical analysis

A quick review of cross-national regression studies of health and economic growth illustrates the limitations and opportunities of modeling forward linkages. Bloom, Canning, and Sevilla (2004) conducted a review of 12 regression-based studies. Of these, 11 found a positive effect of life expectancy on growth, but the size of the effects ranged considerably, from a 0.15 percent increase in GDP growth associated with a five-year improvement in life expectancy (Bloom et al. 1999) to a 0.58 percent increase (Barro and Lee 1994).³

■ A growing consensus is emerging around a limited but significant role of health as a stimulus to economic growth. ■

Acemoglu and Johnson (2007) conducted a careful, cross-national regression analysis of the impact of health improvements on economic growth in the post-World War II era, a period of epidemiologic transition in much of the developing world. The authors looked separately at changing population, total economic growth, and growth per capita in order to separate out the effect of health on total GDP and the effect of increased population in diminishing per capita trends. The authors found positive but not very significant effects of health on total GDP, increasing over time. Nonetheless, population growth swamped these growth effects, resulting, if anything, in a decline in GDP per capita. Countries with improved health did experience reductions in fertility, but they were insufficient to counteract the effects of population growth on per capita income.

The Acemoglu and Johnson paper offered two notes of caution with respect to the potential impacts and equilibrium dynamics of future health interventions:

First . . . the international epidemiological transition was a unique event, and perhaps similar changes in life expectancy today would not lead to an increase in population and the impact on GDP per capita may be more positive. Second, the diseases that take many lives in the poorer parts of the world today are not the same ones as those 60 years ago; most notably HIV/AIDS is a major killer today but was not so in 1940. Many of the diseases we focus on had serious impacts on children (with the notable exception of tuberculosis), whereas HIV/AIDS affects individuals at the peak of their labor productivity and could have a larger negative impact on growth. (2007: 975–976)

The authors also noted that in today's increasingly globalized markets for labor, capital, and trade, poor countries may be better able to leverage improved health into economic growth. Thus, the neoclassical assumption of constant capital in the face of improved health

(and population size) may now be less binding.

Nevertheless, the literature points to a gap between the value we ascribe to health, our expectations for the impacts of health, and empirical results with respect to the impact of improved health on growth. Theorists, policymakers, and academics continue to search for ways to circumvent what one paper refers to as a “repugnant conclusion”—essentially that mortality may be good for development (Grimm and Harttgen 2008). One simple solution involves incorporating the perceived losses associated with mortality, or the benefits of longevity, into a measure of human development (Sen 1998). A number of papers have opted to measure health impacts with a “full income” approach, which incorporates the value of statistical life lost due to premature death (Becker, Philipson, and Soares 2005; Bloom, Canning, and Jamison 2004); another alternative is to move away from income-dominated approaches to those such as the Human Development Index (HDI) that focus more directly on human well-being. While such approaches neatly resolve any questions regarding the general value of health investments, they do so by avoiding specification of the actual forward linkages that could nonetheless shape the fates of societies. We wish to explore those further.

Decomposing the pathways between health and growth

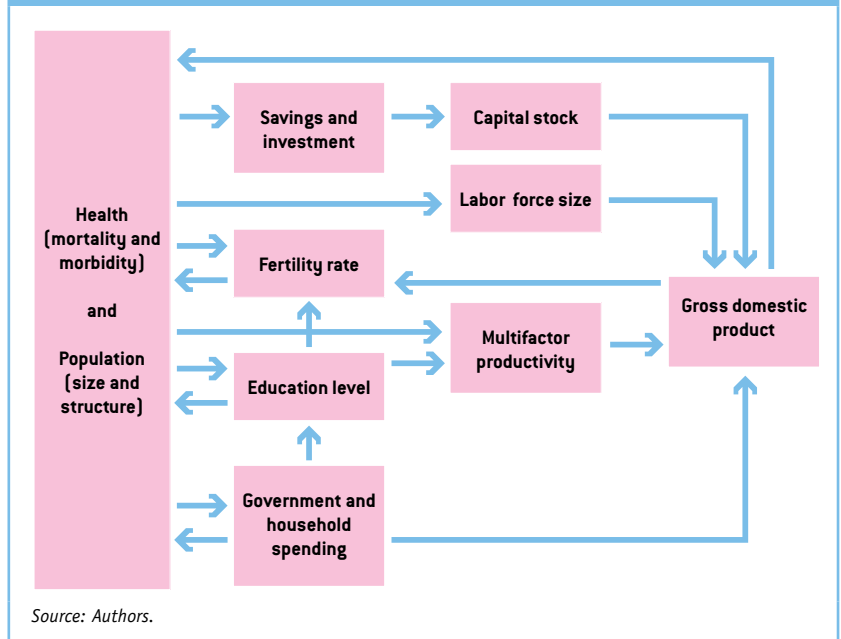
An increasingly popular alternative to aggregate statistical analysis involves the development of general equilibrium models and forecasts that incorporate existing “stylized facts” from the empirical literature, in particular some powerful relationships replicated in population-based and cross-national analysis. A general equilibrium model approach generally represents the interaction of profit-seeking producers and welfare-maximizing households in equilibrating markets for labor as well as goods and services. These models have produced three important benefits. First, theoretical analysis can identify the relative importance of particular forward linkages and the conditions under which health improvements could lead to improved or diminished growth.⁴ Second, empirical forecasts can help identify the health contributions underlying historical growth trajectories or

counterfactual growth scenarios (Abegunde et al. 2007; Weil 2007). Finally, analysts can use historical forecasts to reconstruct the likely health contribution to past growth, adding valuable depth to growth regression results (Bloom, Canning, and Sevilla 2004; Gyimah-Brempong and Wilson 2004; Shastry and Weil 2003).

Needless to say, like more aggregate and less elaborate approaches, such approaches produce similarly divergent estimates of the impact of health on economic outcomes. Nonetheless, a rapidly growing micro-level empirical literature, a substantial number of equilibrium studies, and a smaller number of cross-national regressions have produced a general consensus on the more significant pathways linking health to growth (see Figure 7.2 to see some of those as they relate to the three elements of most production functions, namely, capital, labor, and productivity). In analysis with IFs, we focus on multifactor productivity, the output per unit of labor and capital in combination. In the next section, we proceed to discuss pathways, following in particular the models employed by Ashraf, Lester, and Weil (2008) and Weil (2007).

Ideally, an exploration of health and economic growth via such an elaborated set of paths should not restrict itself to the representation of general equilibrium in economics. It should link the economic model to a population model that endogenously adjusts fertility and, therefore, to the trajectory of population growth in light of changes in income per capita that result from improved health. The approach should also consider the implications of improved health for societal expenditures on health and, in turn, the implications of potential savings in those expenditures for shifting money to education or other uses—in fact, the implications of changes in total government spending for the crowding out or facilitation of savings and investment in the economy. Even better would be embedding the economic model inside a social accounting matrix (SAM) that represents the financial transfers among households, firms, and governments. The IFs modeling system does tie an equilibrium-seeking economic model to a full population model and does embed it in a SAM framework that assures balances of

Figure 7.2 Elaborated paths between health and economic growth



Source: Authors.

financial flows. The discussion of the various possible paths below will outline also the IFs approach to representation of them.⁵

The Paths of Forward Linkages from Health to Economic Growth

Following the structure of linkages between health and economic growth that Figure 7.2 laid out, we will look in turn, and in different order for ease of presentation, at the impact of health (morbidity and mortality) on economic growth via labor, productivity, and capital. After identifying some of the important literature and arguments with respect to each linkage, we in turn sketch the approach represented in IFs.

Health and labor

The forward effects of health on economic growth via population and labor force size and structure work through changes in mortality and fertility. These changes have both automatic or “mechanical” components and behavioral components. We consider first the mechanical components.

To the extent that health improvements lead to improved survival, they lead—at least in the short run until fertility adjusts downward—to an automatic increase in population size and in the total labor supply (see Figure 7.3), with potentially positive consequences for economic

Health connects with economic outcomes through impacts on all three elements of most production functions: capital stocks, labor, and productivity.

■ **Changes in mortality have both mechanical and behavioral impacts on population size and structure, including the absolute and relative size of the labor force.** ■

growth. However, as discussed earlier, not all impacts of the increase in population size are necessarily positive for health and economic outcomes. If capital stock is held constant in the face of increased population and labor supply, the increased population would lead to a reduced amount of capital per population or per worker, reflected in greater competition for jobs or agricultural plots. In addition to capital dilution, mortality reductions among infants lead to an increased youth dependency ratio (before they result in a larger labor force), with possible short-run burdens on nutritional and educational resources for children.

On the other hand, if mortality is rising there is a direct mechanical effect that lowers fertility through the death of women who are or would be mothers. Furthermore, the morbidity associated with diseases such as HIV/AIDS might reduce the rate of childbearing among the living, through increased levels of sterility, through women being too weak to bear children, through fears of transmitting HIV/AIDS to children through the mother-to-child transmission or breastfeeding pathway, and through fears of sexual intercourse due to the risk of HIV/AIDS (Glynn et al. 2000; Gray et al. 1998).

Going beyond the simple mechanical implications of mortality for population and labor supply, we also must consider the behavioral effect of mortality on fertility via its implications for family formation strategies.

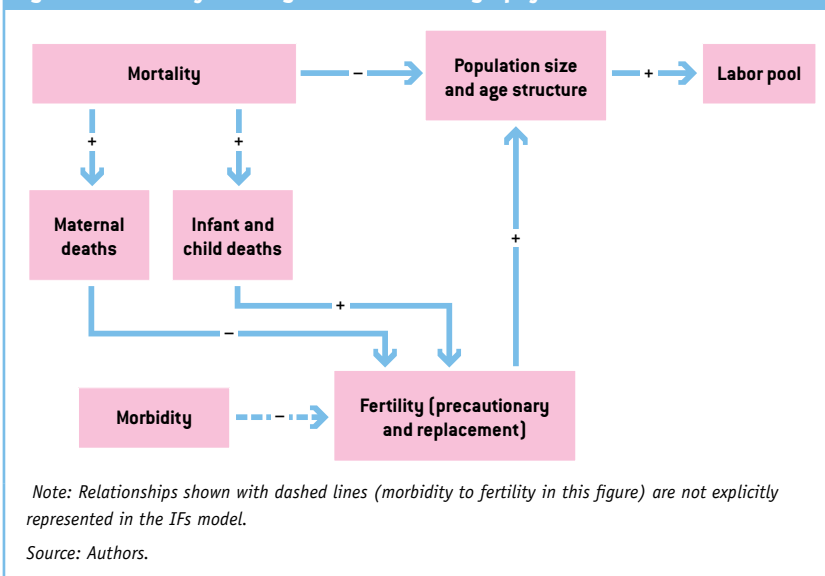
In classical demographic transition theory, declining mortality is the cause of declining fertility; high mortality causes parents not only to replace those children who already died but also to have a much larger number of children to insure against the future death of multiple children (Coale 1986; Eckstein, Mira, and Wolpin 1999; Galloway, Lee, and Hammel 1998; Preston 1978; Wolpin 1997). Modern demographic transitions display a strong correlation over time between mortality decline and fertility decline. Such a fertility decline not only mitigates the population increase effect noted above, it leads to a so-called *demographic dividend*, in which a final, large cohort of young children is followed by an increasingly small number of siblings, generating improved welfare outcomes for all siblings and serendipitous dependency ratios as these large, healthy cohorts move into prime age (Bloom, Canning, and Graham 2003).

Becker's (1962) theory of human capital implies another pathway by which parents who value child success, whether for evolutionary reasons or to ensure old-age support, engage in a quality-quantity trade-off, preferring to have fewer, well-educated, and healthy children rather than a large number of children with little investment in each. Previous research attributed the quality-quantity trade-off to increasing returns to human capital (via economic development) and decreased costs of human capital investment, typically through reductions in the price of schooling (Bloom, Canning, and Chan 2006; Galor and Moav 2002; Galor and Weil 1999; 2000). More recent work has incorporated decreases in the cost of health investment (for instance through child health and nutrition programs) in promoting this trade-off, suggesting a pathway from mortality (or at least morbidity) reductions to fertility reductions (Behrman 1996).

The result of the interactions of the mechanical and behavioral linkages between overall mortality and fertility is a generally positive relationship (higher mortality and fertility are linked). Yet the patterns can be complex, as in the case of HIV/AIDS (see Box 7.1)

Turning to the forecasting of this volume, the IFs demographic model captures the mechanical or accounting effects of mortality on population (see the solid paths in Figure 7.3).

Figure 7.3 Pathways linking health and demography



Box 7.1 HIV/AIDS and fertility

A number of national and cross-national studies find positive, behaviorally based effects of the level of adult mortality associated with malaria and tuberculosis on the level of fertility, even after controlling for income and child mortality (Bleakley and Lange 2009; Ehrlich and Lui 1991; Kalemli-Ozcan, Ryder, and Weil 2000; Lorentzen, McMillan, and Wacziarg 2008; Soares 2005). Young (2005) points out the ways in which the HIV/AIDS context is quite different. Not only does HIV/AIDS reduce fertility through the death, sterility, or incapacity of women, but the very cause of adult mortality is doubly intertwined with the childbearing process: uninfected women may avoid childbearing in order to avoid the risk of contracting the infection, while infected women may avoid childbearing so

as to avoid transmitting the virus to their children. Furthermore, Young argues, the very high levels of mortality associated with HIV/AIDS could dramatically increase women's wages, reinforcing opportunity costs of childbearing and driving down fertility. He supports his case with cross-sectional evidence of a negative association between HIV/AIDS and fertility in South Africa.

Yet, Kalemli-Ozcan (2006), using data from a poorer set of HIV-affected countries, offers compelling evidence to the contrary, estimating that women in high HIV settings could have as many as two extra children compared to those in low HIV settings as they replace lost children and prepare for the future loss of children. In short, the argument and evidence remain mixed.

A key pathway passes from mortality through adult age population to labor supply (including aging-related lags).⁶ Similarly, IFs captures the mechanical effect of mortality on fertility through the death of women of childbearing age.

The most important non-mechanical linkage is almost certainly the relationship between child mortality and fertility, and IFs represents this also. As discussed earlier, couples may increase their fertility in the face of children's deaths both to replace those children and to have extra children against the perceived risk of future child mortality. GDP per capita drove the earliest formulations in IFs for forecasting fertility because that relationship is very strong. We subsequently replaced the more distal formulation using GDP per capita with driving variables closer to human agency, namely, the log of educational level of those age 15 and older (neither the education of women alone nor the education of those 15–24 works as well) and the percentage of the population who use modern contraception. Adding the rate of infant mortality boosted the overall adjusted R-squared to 0.81.⁷ Child mortality did not work quite as well.

Health and productivity

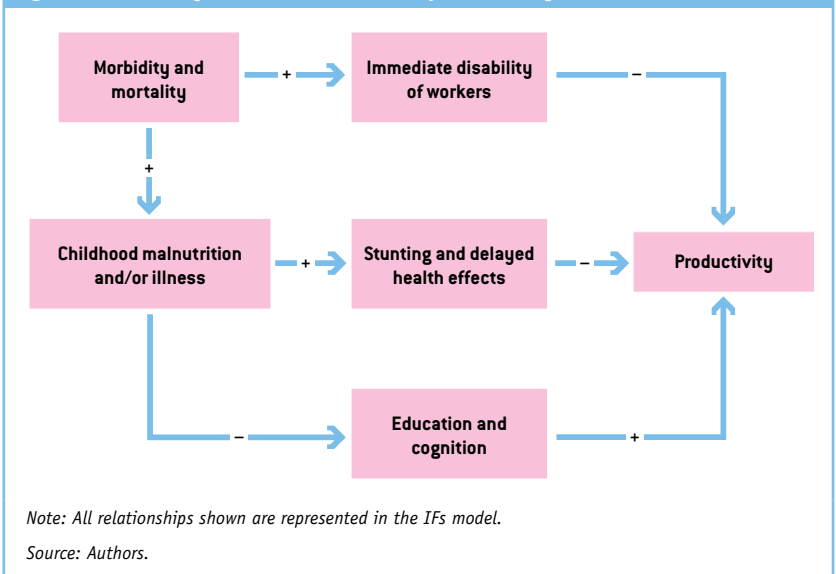
The scientific literature recognizes that health is a form of human capital (Sen 1987), and we know that health in early life has profound implications for health later in life. Health affects the ability to acquire further human capital through processes of cognitive development and educational attainment and

the application of that attainment in productive work. Figure 7.4 sketches the linkages of particular interest to us.

Immediate effects of disability on productivity

A discussion of health and productivity begins with the effects of current disability on work attendance, employment, and productivity at work. Chapter 2 noted that it is possible to assign a disability weight to measure disability on a scale of severity ranging from full health (equal to 0) to death (equal to 1, a complete loss). Similarly, we can characterize worker productivity on a relative scale between "no loss of productivity" (equaling 0) and "full loss

Figure 7.4 Pathways between health and productivity



■ Disability (morbidity) has both immediate and delayed effects on productivity. ■

of productivity” (equaling 1). This suggests the potential of using the disability weights that the Global Burden of Disease (GBD) project developed as proxies for the concurrent loss of productivity (Abegunde et al. 2007; Ashraf, Lester, and Weil 2008).

Some concerns arise immediately, however. First, problems often attend generalization from the micro to the macro level. The temporary loss of a worker could be filled by colleagues or through overtime labor, and the lost wages could be paid to another worker. Yet as a societal disease burden accumulates, particularly in the prime ages, it may become increasingly difficult to replace workers. A good illustration of this possibility is reflected in the earliest antiretroviral treatment campaigns in sub-Saharan Africa, which were instituted not by governments but by major employers, such as AngloAmerican Mining and Coca Cola, who recognized that the potential death or disability of multiple workers on the same shift or in the same job could lead to a wholesale loss of production (Rosen et al. 2003).

The use of disability weights to get at the relationship between morbidity and productivity raises a particular concern since they are intended to capture a great deal more than productivity—including pain, suffering, and financial burden. Yet many of these variations may average out as long as disability weights capture a proportionate element of lost productivity across diseases. A fairly substantial literature assesses the costs in terms of absenteeism, unemployment, and on-the-job productivity for many of the world’s leading causes of disability, including cardiovascular diseases, diabetes, obesity, and even HIV/AIDS.⁸ But such estimates only cover a moderate proportion of all disability, and mostly only for rich countries, which could either experience less substantial losses due to better treatment and accommodations for the disabled, or more substantial losses due to higher levels of survival among individuals experiencing severe morbidity.

Delayed effects of disability on productivity

A bigger set of concerns revolves around the effect of health not merely on current productivity but also on the accumulation of work-related human capital over the life course, whether referring to

seniority, job training, or education itself (see the second path in Figure 7.4). With regard to seniority and job-specific training, the disability weights may also capture these effects, because the panelists assigned to estimate disability weights considered duration in their calculations. One study of the economic impacts of chronic disease used disability-adjusted life years (DALYs), which immediately account for the full loss due to disability and death at the time of illness (Abegunde et al. 2007). Yet this approach may dramatically overstate the losses associated with a particular disease by counting all DALYs lost up to the standard age (80 for men, 85 for women) as lost years of productivity when many of those years are typically ones of retirement and dependency (Mathers et al. 2002).⁹

While it is relatively straightforward to estimate the productivity costs associated with concurrent morbidity, it is a bigger challenge to address throughout the life course the cumulative effects of health, many of which transcend a particular disease. Perhaps the most important arena of health impacts research, both in terms of the volume of microeconomic knowledge and the macroeconomic significance, lies in the study of life-course effects of health in early life. Specifically, we now understand that health and nutrition early in life—in the womb, as a newborn, through the early years of childhood, and even in adolescence—can have measurable and macro-economically significant effects on levels of cognitive performance, on levels of education attained, and on the occurrence of disease and mortality in adulthood. These impacts are intimately connected to one another through processes of human skeletal, metabolic, and immunological development. The nexus of developmental delay and resulting life-long compromise in health status also ties together nutritional and health pathways through a pathological synergy: undernutrition creates vulnerability to disease, which leads to further undernutrition. This synergy results in what is frequently referred to as “stunting,” often measured by the proxy of achieved height, which makes an appropriate focal point for our discussion.

Paleontologists and developmental biologists have long been aware of a relationship between achieved height and outcomes such as immunological strength and cognition.

Box 7.2 The extent of child stunting

Grantham-McGregor et al. (2007) constructed a rough estimate of 200 million stunted children in the world and assessed the implications for life-course development. They arrived at this figure first by estimating the percentage of children who are stunted. They found a substantial rate of stunting in all developing regions, 28 percent of all children, or more than 150 million out of the 550 million children in those countries. They found especially high rates in sub-Saharan Africa (37 percent) and the highest rates in South Asia (39 percent), even though the latter region has lower rates of poverty than the former.

To supplement their stunting estimates (and to capture better the more extreme level of deprivation in sub-Saharan Africa), they estimated the number of children in poverty who were not officially recorded as stunted, and incorporated these children into an estimate

of children who are potentially stunted. In summarizing the existing literature on stunting and poverty, the authors estimated lost years of schooling of 0.91 for stunted children, 0.71 for impoverished children, and 2.15 years for children who are both impoverished and stunted. They further noted evidence of a deficit due to stunting in the rate of learning per completed year of schooling. When they combined this evidence with known relationships between schooling, cognition, and earnings, the authors calculated that children who are stunted are losing about 22.2 percent of their future adult earnings, while those who are stunted and poor are losing 30.1 percent.

For example, the work leading up to Fogel's theory of technophysio evolution brought widespread attention to the relationship between height, health, and productivity (Fogel 1994; 2004b; Fogel and Costa 1997). Fogel's historical study of the health system records of U.S. Army veterans from 1848 to 1920 demonstrated a strong relationship between the study subjects' heights and rates of morbidity and mortality due to a range of medical conditions as well as productivity. Subsequent to Fogel's work, numerous historical, micro-level, and cross-national studies have validated the relationship of height to conditions of childhood and the effects of height on outcomes later in life.¹⁰ (See Box 7.2 for information on the extent of stunting globally.)

Macro analysis of health and productivity

So far in this section, we have been trying to learn from the micro literature and to consider how that might aid in forecasting. A significant macro literature also explores the relationship between health and productivity. That literature generally relies on cross-sectional data, often with panels across time so as to introduce longitudinal analysis. The good news is that the literature most often finds a positive relationship between measures of health and economic growth. For instance, Barro and Sala-i-Martin (1998: 432) found that an increase in life expectancy by one standard deviation, which they calculated to be 13 years in the 1965–1975 period, raised economic growth by 1.4 percent per year. Updated analysis (Barro and Sala-i-Martin 2003: 525) found a slightly lower growth impact (1.1 percent) from the

reciprocal of life expectancy. Bloom, Canning, and Sevilla (2001: 5 and 16) found that a rise of one year in life expectancy raised output by 1–4 percent.¹¹

Jamison, Lau, and Wang (2005: ii) used a “meta-production function” approach around a Cobb-Douglas function to explore a wide range of factors that drive multifactor productivity (MFP) and concluded that health improvements had accounted for 11 percent of economic growth in 53 countries over the 1965–1990 period (compared to 14 percent from education and 67 percent from expansion of capital stocks). Similarly, Weil (2007: Abstract) found that the fraction of cross-country variance in income explained by variation in health ranged from 8 to 20 percent, depending on the measure of health (he moved away from life expectancy to alternative measures such as average height, body mass, adult survival age, and age of menarche).

Health and productivity in IFs

The approach IFs uses to represent changes in multifactor productivity as a function of multiple drivers, including elements of human and social capital, combines a meta-production function with an elasticity-like approach (see Hughes 2005). We compare values of driving forces (such as completed years of formal education by adults, spending on education, or stunting levels) with the “expected” value for those variables given the development level of the country (using GDP per capita at PPP as a proxy for development). Improvements or deterioration in drivers relative to the initial variations from expected levels determine changes in productivity attributed to that variable.

■ *Macroeconomic studies most often find a positive relationship between measures of health and economic growth.* ■

IFs includes adult stunting, child morbidity, years of adult disability, and life expectancy as interacting components of the human capital drivers of multifactor productivity.

The long-standing approach in IFs to the impact of investments and improvements in health and education on productivity has been to draw on macroeconomic statistical studies from the cross-sectional/panel literature, many of which go to great length to control for other variables likely to affect the relationship. To operationalize education, we have used completed years of education at age 15 or older (we could have used 25 and older as in the GBD formulations, but 15- to 25-year-olds also often work) and education spending as a percentage of GDP. For health, we have used life expectancy and health spending as a percentage of GDP. Volume 2 of this series (see Dickson, Hughes, and Irfan 2010: Chapter 8) documented the approach with respect to education.

While maintaining the more aggregate relationships of life expectancy and health spending to multifactor productivity as options in the background, this volume's analysis disaggregated the relationships consistent with the above literature discussion (see Figure 7.4). We initialize adult stunting in a long-term lagged relationship (using a moving average of 25 years)¹² with child undernutrition and forecast it as a function of both undernutrition and child mortality as a proxy for morbidity. Initial values in 2005 range up to about 55 percent for India and Bangladesh and even over 80 percent for Somalia; in the base case these generally but not universally decrease.¹³

To this undernutrition-based stunting term we add one related to child morbidity (using change in mortality as a proxy for change in morbidity). We follow the analysis of country-age-specific variations in height by Bozzoli, Deaton, and Quintana-Domeque (2009), which predicts average height for a cohort of women as a function of "pre-adult mortality," or an estimated probability of dying between ages 0 and 14, dependent upon their year of birth.¹⁴ We compare the reduction related to actual mortality with that related to an expected mortality rate from a cross-sectional relationship of mortality with income (thereby controlling for the effect of expected undernutrition in the first term). We lag the childhood mortality effect on adult height with a 25-year moving average. Using a somewhat comparable series of values from the USAID's Demographic and Health Surveys (DHS), we found that a 1 centimeter increase in height

corresponded to a 2 percentage-point decrease in the percentage of adults who are stunted, and we adjust the stunting computation from undernutrition accordingly. In forecasts, changes in the relationship between stunting rates and those expected at changing development levels add to or reduce the human capital contribution to productivity.¹⁵

Childhood undernutrition and related stunting do not give rise to all disability in working years; much also comes from disabilities arising during the working years. The IFs approach adds another term to the growth of economic productivity that reflects the changing difference between expected and forecasted values of disability incurred in the working lifetime. For the expected value, we used contemporary data on the world average years of living with disability across a global worker's lifetime—in 2005 that value was 0.097 (poor mental health is the biggest disability source and accounts for 0.025 years).¹⁶ For the forecasted value, IFs calculates millions of years of living with disability that can be associated with mortality rates specific to the working-age population (see the discussion around Table 3.2 of the changing relationship over time between mortality and morbidity).¹⁷ Because mental health disability rates tend to be quite constant, and because mental health is a large element of working-age disability, forecasts of disability exhibit considerable stability over time.

The fact that the literature describes the relationship between health and educational attainment in many different ways complicates the representation of a relationship in IFs between health and educational attainment and on to productivity (see again Figure 7.4). For instance, Baldacci et al. (2004: 25–26) found that a 1 point increase in spending on health as a percentage of GDP would increase the net school enrollment rate at the primary level in developing countries by about 2 percentage points. In the IFs model, however, GDP per capita is the principal driver of demand for education in the model and for public spending on education, as well as for spending on health. Thus, there was already an implicit relationship between health spending and enrollment.

Other literature focuses on the relationship between stunting and educational attainment (see Grantham-McGregor et al. 2007); we

have already discussed, however, a direct path from stunting to productivity and wish to avoid duplicate representation of impacts. More directly relevant to a path from health to educational attainment, Soares (2006: 72) found in cross-sectional analysis that 10 years of additional life expectancy add 0.7 years to the average years of education attained. And Ashraf, Lester, and Weil (2008: 10) built on other work concerning seven sub-Saharan African countries to conclude that 20 years of additional life expectancy add 0.386 average years of education. We used this analysis to support our relationship between life expectancy (as a proxy for morbidity, including that of children) to productivity via increased education.¹⁸

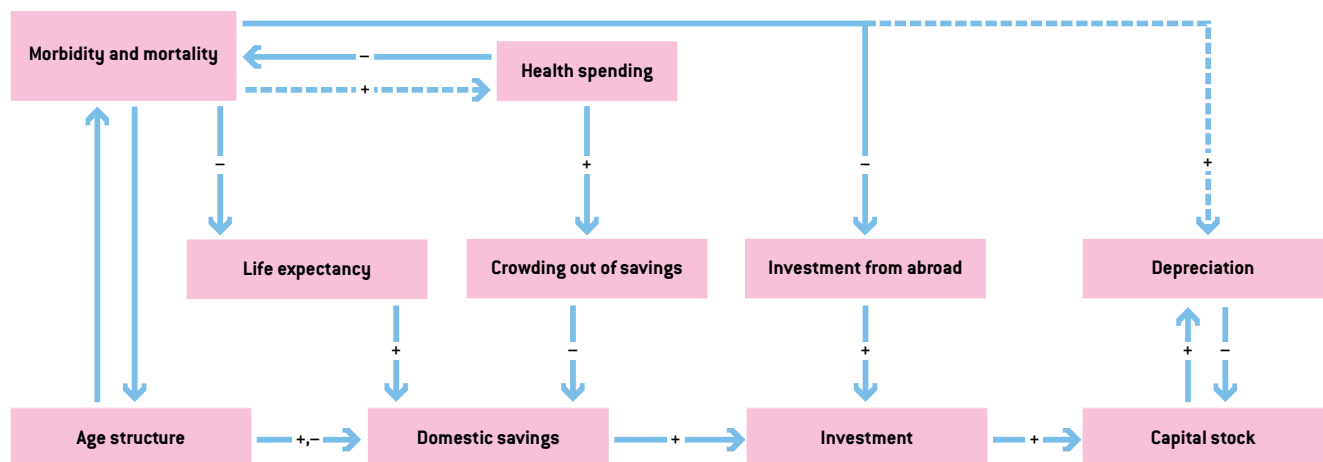
Health and capital stocks

Even the fairly substantial individual-level gains in human capital and productivity that the previous section ascribed to improved health would have limited impact on macroeconomic change if concomitant increases in population size were to result in a diminished capital/labor ratio. For health to generate substantial positive development impacts, we ought also to observe increases in the stock and allocation of financial and physical capital available per person. To this point, we have discussed the role that health-related demographic change can play in changing the size of the labor force (which

also affects the capital/labor ratio, potentially perversely in the case of mortality reductions). And we have considered how improved health and human capital can increase productivity. Now we turn to the extent to which health can impact the availability of capital, the third major factor of production and therefore potential route of connection between health and changes in economic growth (see again Figure 7.2)

Figure 7.5 sketches the primary paths between health (morbidity and mortality) and capital stock. Most capital stock consists of buildings and machinery for producing goods and services; some representations may include land also, but most treat land separately and largely as a constant (although land developed for crop production or grazing can, in fact, be highly variable). Most immediately, investment increases capital stock and depreciation reduces it. Although there is certainly some impact of morbidity and mortality on the rate of depreciation of both built physical and natural capital, the relationship may not be substantial, and we do not understand it well enough to model it. Turning our focus to the paths that affect investment, the two major ones run through health spending, which can crowd out savings and investment in capital stocks, and through the age structure of societies, which affects the savings rate. We explore each in turn.

Figure 7.5 Pathways between health and capital stock



Note: Relationships shown with dashed lines (the pathways from morbidity and mortality to health spending and to depreciation in this figure) are not explicitly represented in the IFs model.

Source: Authors.

■ *Through its impact on population size and age structures, health affects the availability of capital via savings rates and the allocation of public and private resources.* ■

■ *Health spending, by both households and governments, competes with other spending and with savings.* ■

Health expenditures: Competition with savings
Health spending, by both households and governments, competes with other spending and with savings. It can crowd out other uses of income, reducing domestic savings and investment (Aísa and Pueyo 2004; 2006; Goldman et al. 2004; Tabata 2005). This is a fundamentally important path via which societal commitments to health affect capital stock. The path is, of course, a major concern for high-income societies now facing growing pressures for health spending from aging populations.

In thinking more generally, however, about the impact of health expenditures on growth, at least two other issues demand consideration. The first is the forecasting of health expenditures as a result of changing morbidity patterns associated in part with changing age structures. The impact of aging on health expenditures will depend significantly on whether extra years of life are healthy or unhealthy and also on the relative costs of both good health and ill-health at older ages versus younger ages (Payne et al. 2007). In general, of course, the old demand more health care than the young. The key question is how much more they demand. Even as prevalence of some diseases increases due to greater survivorship, reductions in the average severity of disease may be so great as to reduce the overall burden of morbidity (Crimmins 2004; Mathers et al. 2004).

The second issue that complicates thinking about the implications of health spending for economic growth involves the path of health spending back to mortality and morbidity (the upper left corner of Figure 7.5). In the process of (hopefully) reducing mortality and morbidity, health expenditures also have potential positive impacts on economic growth, via the path from morbidity to productivity that we discussed earlier in association with Figure 7.4 and via the impact of changed mortality on age structure and life cycle-related savings (to which we return later). One important aspect of the issue is that not all health spending is equal in its impact on morbidity and mortality. Ideally, health expenditures are investments in better current and future health with associated productivity enhancement. Unfortunately, some health expenditures may primarily add to financial burdens of individuals and governments (Aísa and Pueyo 2004; Bhattacharya and Qiao

2007; Ehrlich and Chuma 1990; Grossman 1972; Tabata 2005), thereby crowding out savings without significant reductions in morbidity and mortality that could provide offsetting productivity gains.

Two prominent examples merit particular consideration. First, expenditures on the treatment of HIV/AIDS, which are much higher than the costs of preventing it, may reduce the societal disease burden (and potentially prevent further transmission), but they are also incredibly costly and may pose an especially great drain on consumption in more productive sectors, on investment in other social sectors, and on savings rates (Azomahou, Diene, and Soete 2009; Boucekkine, Diene, and Azomahou 2007; Freire 2002). The second example returns to the costs of health care for the elderly in developed and developing countries alike (Goldman et al. 2004; Rannan-Eliya and Wijesinghe 2006; Seshamani and Gray 2004; Shang and Goldman 2008; Stearns and Norton 2004). Rapidly growing elderly cohorts can place increasing burdens on savings and productivity as they cash out their private savings and then turn to public safety nets for health care and pension funds over long periods of retirement (Preston 1984). In pre-modern societies a retired person consumes very few resources in the absence of any savings mechanism or many resources to consume. Modern medical technologies and public health insurance programs, however, allow elders to more than make up for reduced consumption in other sectors through the consumption of health care resources, particularly in the final years of life (Seshamani and Gray 2004). As a result, most of today's developed countries have seen relatively unchecked increases in the percentage of GDP devoted to health expenditures (Goldman et al. 2004). Far more than pension systems, old-age health expenditures could pose a potential impediment to economic growth (Aísa and Pueyo 2004; Tabata 2005).

Longevity, the incentive to save, and the supply of investment

On the other hand, increased longevity (whether as a result of greater health spending or other forces) may create an incentive to save more.¹⁹ Individuals who can expect to live an uncertain number of years past the typical age

of retirement (in contrast to ancestors who most often died in prime age or shortly thereafter) may begin preparing to pay for that additional longevity (Hurd, McFadden, and Gan 1998; Tsai, Chu, and Chung 2000), while those with a low likelihood of surviving will value future wealth accumulation less (Ben-Porath 1967).

Any increments in the savings rate of individuals planning for retirement are temporary, of course, and will reverse as retirees draw on accumulations (Ando and Modigliani 1963; Higgins 1998; Kelley and Schmidt 1996; Mason 1988; Willis 1982). At a societal level we can therefore expect that a dramatic increase in longevity should lead first to a rise and then to a fall in savings rates (Ando and Modigliani 1963).²⁰ For example, a World Bank study concluded that:

An increase in the young age dependency ratio of 3.5 percentage points leads to about a 1 percentage point decline in private saving; an increase in the old age dependency ratio has a negative savings effect more than twice as large. (1999: 4)

The societal supply of savings and investment will also depend on the availability of viable savings mechanisms and the returns to savings, each of which health also affects. With respect to the returns to savings in a market economy, productivity of the economy drives in substantial part the rate of return on savings. To the extent that health drives up productivity through the pathways outlined earlier, this will increase the overall rate of return on investments, adding a further stimulus to savings rates. With respect to viable savings mechanisms, investment in physical capital is not always the only or best alternative, especially in low-income societies. In populations where families form the principal basis of education financing and old-age support, for instance, increasing returns to children's education, driven by labor market improvements and better health, can encourage rapid parental investment in children's education and job market opportunities.²¹

The same logic that we apply to internal rates of savings and investment can be applied to external capital flows. If increased productivity

and reduced labor market uncertainty increase the profitability of business enterprises, then the flow of foreign direct investment (FDI) would increase and capital markets would receive greater liquidity. Thus, good and improving health tends to increase the inflows of foreign investment (Jamison 2006: 8).

Health and capital stock in IFs

The IFs modeling system treats capital stock dynamically over time, investing in it and allowing it to depreciate (see again Figure 7.5). Investment is responsive to both domestic savings and foreign flows. Thus, the necessary elements for considering the impact of morbidity and mortality, via paths such as those across health spending and age structure, are part of the economic model's core structure. In addition, as described earlier, the IFs model uses a social accounting matrix (SAM) structure. Thus, the flow of funds into health spending automatically competes with other consumption uses and with savings and investment. In addition, health spending does affect mortality (Chapter 3 discussed the linkage back to communicable diseases of children).

For the analyses of this volume we have also added paths that link morbidity and mortality to domestic savings. That important linkage has two elements. The most fundamental one, via the age structure of the population, represents the understanding of life-cycle dynamics in income, consumption, and savings. The cycle for income is fairly clear-cut with a peak in the middle-to-latter periods of the working years. Workers set aside some portion of income as savings and that portion, too, tends to peak in the middle and late period of working years. The second fundamental element is that both the horizon of life expectancy and the average income level can have an impact on the portion set aside for savings and the degree to which it rises and then falls. That is, the life-cycle "bulge" of savings may be earlier and/or flatter in developing countries.

We implemented the relationships within IFs in accord with that understanding. The IFs economic model generates total income and the household consumption portion of income. Relying on analyses of selected countries undertaken by Fernández-Villaverde and Krueger (2007) and Deaton and Paxson (2000), we developed vectors

■ For the analyses of this volume we have added paths that link morbidity and mortality to domestic savings and to foreign direct investment flows. ■

■ *We explore how widely varying health forecasts might affect other elements of the human development system, especially population size and economic growth.* ■

■ *We explore the consequences of increases or decreases of 30 percent in mortality, and associated changes in morbidity, relative to the base case.* ■

■ *Our mortality interventions affect regions differently because of regional starting differences in disease burdens and population age structures.* ■

(across five-year age categories) based on general stylized patterns of the savings life cycle to represent more and less developed countries. In forecasting we use the pattern for less developed countries when life expectancy falls below 40 years, use that for more developed countries when life expectancy exceeds 80 years, and interpolate in between for all other countries.

Another important piece in the logic of Figure 7.5 is the potential for morbidity to force up health spending (and to a generally lesser degree for near-mortality to do the same, especially in cases such as the massive late-life health interventions that occur in the United States). Currently in IFs, health expenditures as a portion of GDP are linked to income (generally rising), with some protection of country-specific variations around the curve, such as the high level of U.S. spending. Our search for health-outcome variables (such as morbidity rates) that could supplement, if not replace, income in explaining/forecasting health expenditures has not been productive. We have found, however, that some political economy variables appear to affect health expenditures.²² This analysis suggests the somewhat provocative conclusion that political-economic variables may be more important in determining health spending than are morbidity and mortality patterns, but we have not incorporated such a relationship into IFs.²³

Finally, the path linking health to foreign direct investment is potentially quite important. Alsan, Bloom, and Canning (2006: 613) report that one additional year of life expectancy boosts FDI inflows by 9 percent, controlling for other variables. We have implemented that relationship in IFs.²⁴

Exploring Forward Linkages

In the remainder of this chapter, we explore how widely varying health forecasts might affect other elements of the human development system. Specifically and somewhat arbitrarily, but consistently with the wide uncertainty around health futures, we explore the implications of increases or decreases of 30 percent in disease-specific mortality rates relative to the base case, phased in through 2060 (and these changes in mortality pass through to associated changes in morbidity rates as discussed in Chapter 3).²⁵ This type of “brute force” intervention or model run, lacking the

subtlety of exploration of individual alternative assumptions about proximate drivers in the last two chapters or the sophistication of integrated scenario intervention in the coming chapter, allows us to explore the broader implications of health changes very directly.

Reductions in communicable diseases affect primarily infants and children (although AIDS affects adults heavily), and reductions in noncommunicable diseases affect the elderly especially. The age profile of impact from injuries differs from both, affecting working adults in particular. Given these patterns and significant variation in regional disease burdens, the implications of our interventions will differ across regions.

The three major paths from health (and demographics more generally) to economic growth, which the first half of this chapter detailed, can usefully frame discussion of the impact of alternative health forecasts. Therefore, we look first at the interventions themselves, and at their aggregate demographic and economic impacts, before turning to exploration of the three more specific paths of economic impact of alternative health forecasts via labor supply, productivity, and capital stock.

The interventions

Figure 7.6 shows the total global mortality profiles in 2060 of the high and low mortality interventions (30 percent higher and lower than the base case, respectively). The pattern between the two scenarios shows little difference until about 50 years of age, reinforcing what we saw in Chapter 4—namely, that chronic disease patterns (which predominantly affect older adults) will most likely dominate the global “story” with respect to mortality by mid-century.

Especially in terms of years of life lost, and especially in sub-Saharan Africa and South Asia, the mortality story today has two clear story lines, that of infant and child mortality and that of chronic disease. At 91 per 1,000 in sub-Saharan Africa and 61 per 1,000 in South Asia, infant mortality continues to loom horrendously large. But in 2060 those numbers could well, even in the high mortality case, be nearer 24 and 8 per 1,000, with even the higher figure close to that of upper-middle-income countries today, thereby fundamentally completing a

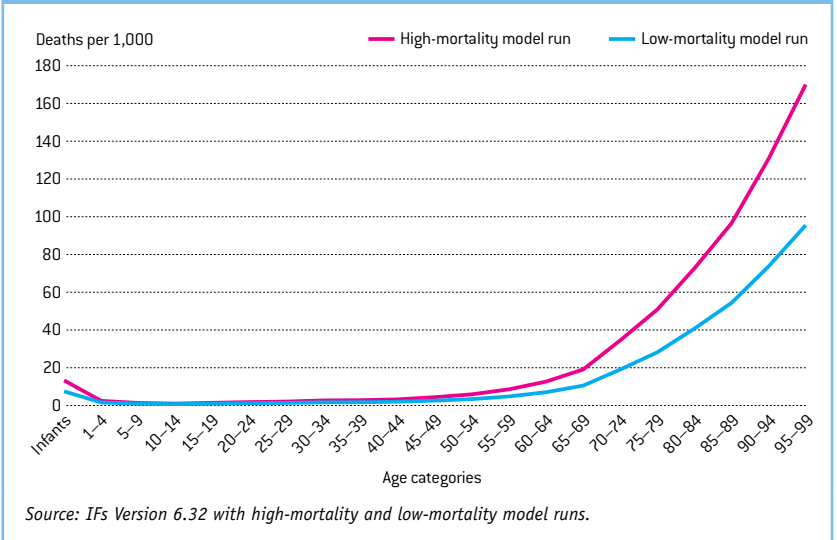
transition from numbers that were near 160 as recently as 1960.

The year 2060 is, of course, quite distant. In the nearer-term horizon of 2030 to 2040, a probable temporal focal range as the world community moves attention beyond the Millennium Development Goals, communicable diseases will continue to claim a large number of lives, especially of infants and children. Figure 7.7 shows us more about that transition in cause-groups. It moves below the global level, distinguishing explicitly between low- and high-income countries, using sub-Saharan African countries as a proxy for the former (as we did in Chapter 4). Although the range of uncertainty is clearly large, probably even larger than that of the figure, it appears likely that by 2060 the burden of disease in sub-Saharan Africa will be either roughly equally divided between communicable and noncommunicable diseases or tilted toward the noncommunicable diseases.

The aggregate demographic and economic effects of the interventions

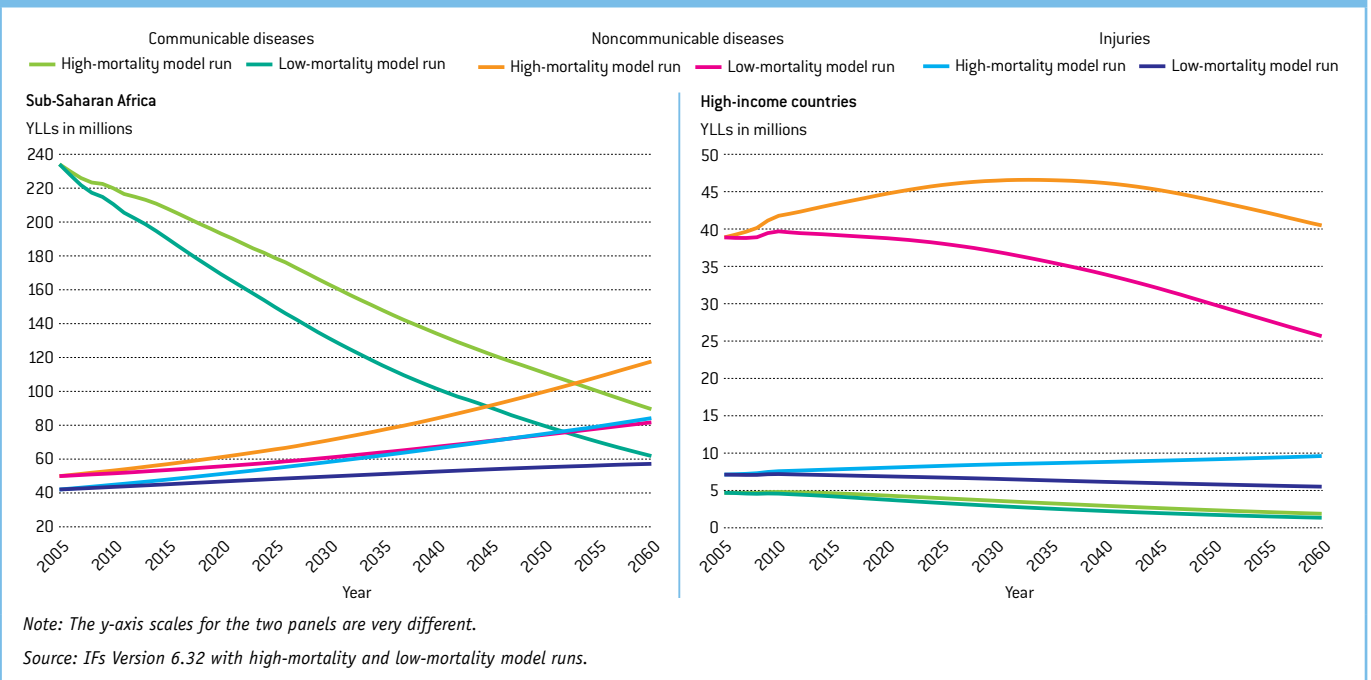
Before turning to the paths of each specific forward linkage from health, it is useful to consider the aggregate impact that might arise from the modeled variation in future

Figure 7.6 High and low global mortality rate profiles, all causes, 2060



mortality and associated morbidity rates. The range of mortality rates chosen for this analysis may not appear terribly large across the two interventions (30 percent above and below the base case, phased in through 2060). Yet by 2060 life expectancy varies by about eight years between the two interventions in sub-Saharan Africa and by about six years in high-income countries.

Figure 7.7 Years of life lost (YLLs) over time by major disease group in high and low mortality profiles: Sub-Saharan Africa and high-income countries



■ Globally, in 2100 there would be about 1 billion more people as a result of the low mortality intervention compared to the high one. ■

■ Over time, the low mortality intervention generates somewhat higher GDP for the world as a whole (about 16 percent higher by 2060) and for all regions. ■

The demographic consequences of such variation in assumptions about mortality and resultant life expectancy are significant. Figure 7.8 shows the global population results, extending the horizon to 2100 so as to indicate also the full impact across the century. The difference grows to a global population variation of about 1 billion people. Most of that outcome is a mechanical result of the differences in mortality rates. All else equal, an extension of global life expectancy by nearly 10 percent translates into a population about that same amount larger, once it plays out over a period of average life expectancy. (In contrast, high mortality affects population not just directly but also in many indirect ways, including the reinforcing secondary reduction of population via the death of potential parents.)

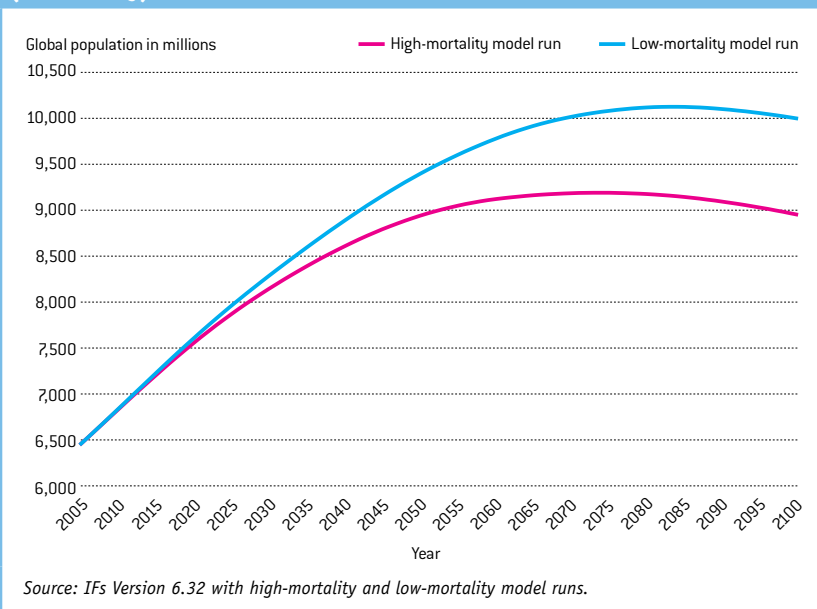
As Figure 7.3 and the discussion around it indicated, there is a relationship between life expectancy increase and fertility decrease that could offset some of the increase in population size that would mechanically result from life expectancy increase alone. Yet there is a lag in that counteracting effect, long enough that movement from high mortality to low mortality does significantly increase population overall throughout this period. This has been, of course, the pattern of the epidemiologic transition in developing countries since World War II—

significant drops in mortality followed only later by drops in fertility. Thus, it should be no surprise that an acceleration of the completion of that transition would exhibit the same result.

Turning to the economic impact of different mortality trajectories, Figure 7.9 suggests that, rather than high mortality leading to more capital and other resources per capita and therefore to higher average income (the simple neoclassical story of the relationship between population and growth), the low mortality intervention generates somewhat higher GDP over time for the world as a whole (about 16 percent higher by 2060) and for all regions. The boost to GDP is potentially greatest in Europe and Central Asia (26 percent) and least for East Asia and Pacific (4 percent), with sub-Saharan Africa in the middle (18 percent). Taking into account the higher population of the low mortality case, however, reduces the global gain in GDP per capita to 8 percent by 2060 and that of sub-Saharan Africa to 11 percent. GDP per capita in East Asia and Pacific is actually 4 percent lower with the low mortality intervention than in the high mortality one. Although a reasonable hypothesis for that result might be that China already has a potential problem with a rapidly aging population that low mortality would actually exacerbate, we turn below to the various paths by which mortality affects economic growth and drill down for explanations of these patterns.

First, however, it is important to emphasize that the great gap shown in Figure 7.8 between the size of the global population under the high and low mortality interventions, which considerably reduces the economic impact of the lower mortality case (the GDP per capita affect of Figure 7.9), is by no means a certain outcome of reduced mortality. The international community mobilized family planning programs very rapidly in the 1950s and 1960s to address the surges in population that followed the post-World War II drops in mortality. We may be underestimating the potential for similar accelerations of fertility decline in the low mortality case. Therefore, we have explored a variation on that case with a modestly more rapid but still historically reasonable fertility decline, one that still leads to a higher population than in the high mortality case but only marginally higher. Specific to regions, the

Figure 7.8 Size of global population with high and low mortality profiles (full century)



variation has the greatest impact on sub-Saharan Africa (reducing the total fertility rate there by about 0.5 points relative to the low mortality case). Subsequent discussion will return to the impact of this and other *counterfactuals* (by which we mean variations) relative to the assumptions of the low mortality intervention.

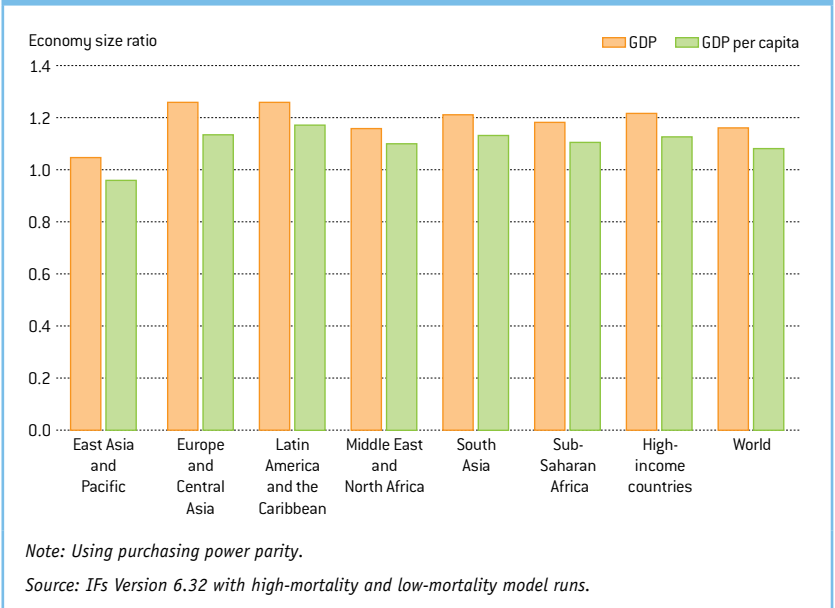
Exploring paths between health and growth: Demographics and labor supply

The earlier discussion identified three paths that link changes in mortality and morbidity to economic growth: via demographics (especially labor supply); via multifactor productivity; and via capital stock. While we have just seen (Figure 7.9) that in the aggregate the low mortality scenario has a modestly positive impact on economic growth, the impacts across the three paths are varied and, in fact, are not all in the same direction. We consider each in turn, beginning with labor supply (see again Figure 7.3).

Although demand for labor has its own critical importance, the portion of total population that falls into the typical years of a working career shapes the labor supply of societies. When that working-age demographic segment is relatively large, as when population growth rates and young dependent population portions decline, a society experiences a demographic dividend. By some estimates (Bloom and Canning 2004: 22), such a dividend can explain as much as one-third of the rapid growth of East Asian countries in recent decades. Although the dividend is poised for rapid and accelerating decline, about 70 percent of the population of East Asia was of working age as recently as 2005.

Thus the demographic patterns of Figure 7.10—both the overall patterns and the variations across interventions—are significant. High-income countries benefitted substantially from having about 67 percent of their total population of working age at the beginning of the 21st century, while South Asia and Latin America and the Caribbean had about 62–64 percent and sub-Saharan Africa had just 54 percent. However, whereas the share of the population at working age in high-income countries is decreasing under both the high mortality and the low mortality interventions (and will be soon in East Asia and Pacific), the

Figure 7.9 Ratio of economy size: Low mortality profile compared to high mortality profile by region (2060)



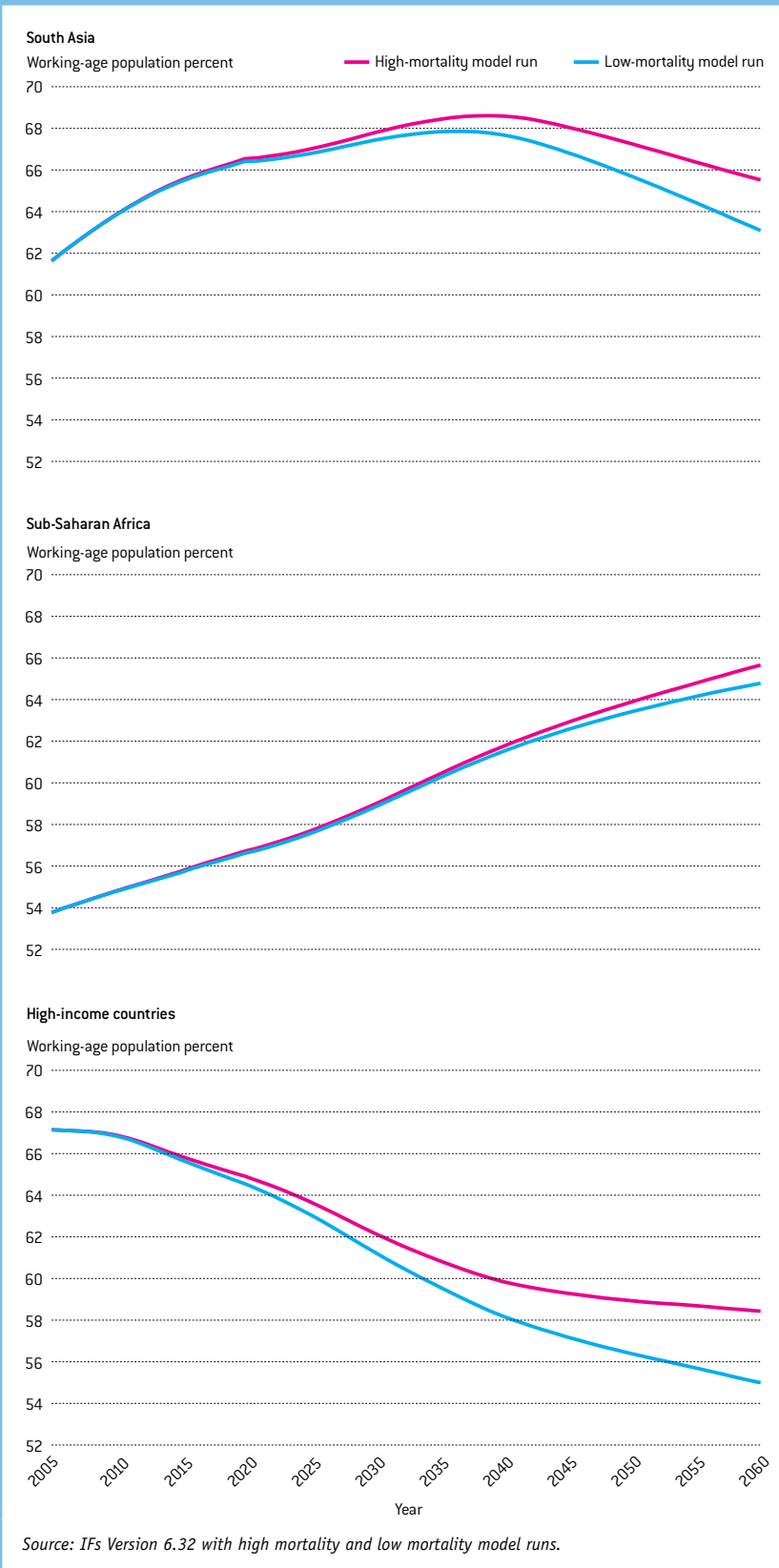
shares in sub-Saharan Africa will rise sharply throughout our forecast horizon under both mortality assumptions, as will those in South Asia before beginning to decline in about 2040.

Given fundamentally different starting points and trajectories, the impacts of the mortality pattern changes would be quite different across regions. In the high-income countries, low mortality would accelerate the decline in the proportional share of the labor force by increasing the share of elderly in the population, thereby tending (in terms of labor force implications alone—we return later to savings rates) to create some drag on economic growth. With a lag, the same is true for South Asia. In contrast, the impact of lower mortality on the labor force population share in sub-Saharan Africa would largely wash out—it appears that the continent can look forward to an almost inevitable long-term increase in the working-age population (although growth in the population over 65 would accelerate with lower mortality, it is still not likely to exceed 10 percent by 2060). In fact, in the low population variant (from a faster rate of fertility decline) of the low mortality case, the share of working population grows even more rapidly, reaching 68 percent by 2060 (the low population variant affects South Asia and high-income countries relatively little).

■ The global gain in GDP per capita with low mortality is about 8 percent by 2060, but highly variable by region (East Asia and Pacific actually declines). ■

■ Various supplemental interventions (such as additional fertility reduction or increased crop yields) could boost the positive impact of lower mortality. ■

Figure 7.10 Working-age population as percent of total population: Selected country groups



Overall, on this dimension the low mortality intervention contributes negatively to long-term economic growth in most of the world (with a time lag of course) by reducing the productive labor force relative to the dependent population, particularly the older population. The effects are most pronounced in the middle- and higher-income countries of the world, where the mortality reduction most immediately increases life expectancy of post-working-age people. The exception would be sub-Saharan Africa, were it able to couple mortality reduction with accelerated fertility reduction; the region has plenty of “working room” to do that.

Age structures have socio-political as well as economic consequences. For example, populations heavy with young men have traditionally been less stable socially and politically. From 1970 to 1999, countries in which 60 percent of the population was less than 30 years of age experienced 80 percent of all civil conflicts.²⁶ Demographers define *youth bulge* in various ways but direct much attention to the portion of 15- to 29-year-olds in a population and to values above 40 percent (Cincotta, Engelman, and Anastasion 2003). The percentage within that age category in two of the least stable areas of sub-Saharan Africa, the middle or central region and the eastern region, now exceeds 50 percent, and although near peak values in both regions, will remain high for many years even in the low mortality intervention. But better health, through its secondary impact on fertility rates, would bring down the bulges more quickly. Given the devastating impact that domestic conflict often has on economies, and the cycles of broad socio-political failure it sets up (Collier 2007), this important path should augment the discussion that Figure 7.3 framed. The absence in IFs of linkages from youth bulge to conflict and on to economic growth will cause us to somewhat underestimate the economic contribution of improved health via demographics.

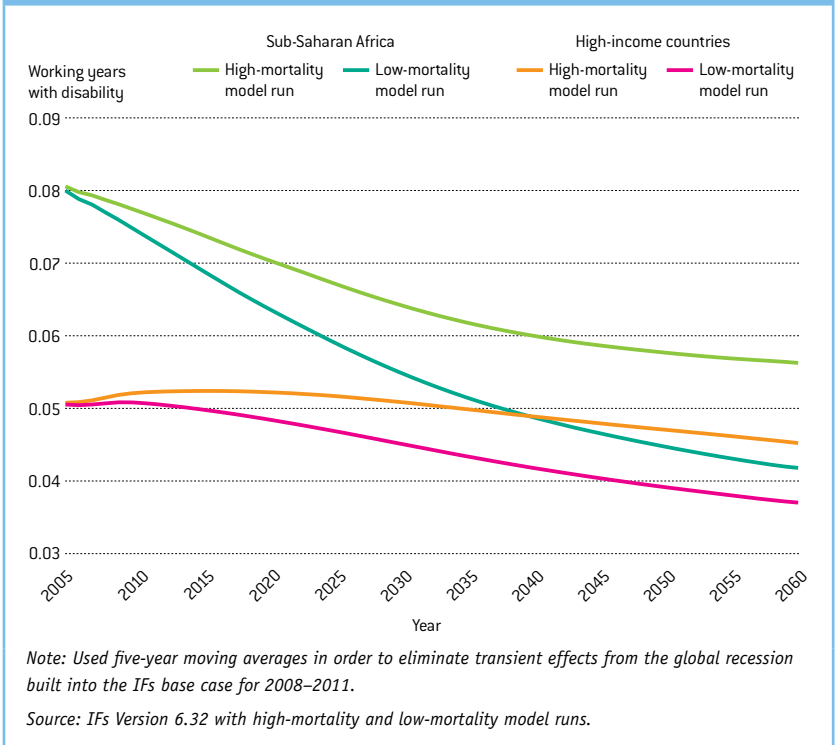
Exploring paths between health and growth: Productivity

Earlier discussion (see Figure 7.4) traced multiple paths by which mortality and morbidity can affect multifactor productivity, including a direct path via disability of workers and more indirect paths via stunting and delayed

health effects related to undernutrition and via education and cognition. Because of the close association between mortality and morbidity, reductions in mortality rates more often than not reduce morbidity of those in the work force (although generally not in direct proportion; see again Table 3.2). Figure 7.11 shows the significant differences in worker years of morbidity between the high and low mortality cases, showing both sub-Saharan Africa and high-income countries. The difference between the scenarios is considerably greater for sub-Saharan Africa because of its relatively higher burden of communicable diseases. Lower mortality associated with communicable diseases reduces society-wide morbidity to a greater degree than does lower mortality from noncommunicable diseases, in part because communicable diseases strike younger populations and can leave longer morbidity “footprints.” Thus, this pathway can contribute increased productivity to lower-income regions such as sub-Saharan Africa.

An additional contribution to productivity from lower mortality is via decreased stunting of the work force, which lags changes in child undernutrition and morbidity by 25 years or so. Figure 7.12 shows that such stunting for sub-Saharan Africa would likely be somewhat lower in the low mortality case. The effect is not great, however—a somewhat counterintuitive result that appears because two forces work against each other. On one side is the direct contribution of better health to both lower mortality and morbidity, and the translation of lower morbidity into greater height and less stunting. On the other side is a perverse effect that lower mortality can have on undernutrition and that does appear in sub-Saharan Africa. In 2060 the low mortality scenario does not significantly change undernutrition in Latin America; it increases rates by about 0.50 percent in sub-Saharan Africa and on a global basis increases rates by about 0.25 percent (and raises total numbers by about 2.5 million). We need to remember that the low mortality scenario adds nearly 1 billion people to the global population by 2100. Were mortality to decline for a single country or region, it would not likely affect the global food market a great deal. Such a large population increase would do so, however, and even in the face of increased labor supply

Figure 7.11 Working years with disability per worker across high and low mortality profiles: Sub-Saharan Africa and high-income countries



for production, it is likely that the impacts on global food costs and/or availability would be adverse. Moving analysis of alternative health futures from the local to the global level has important consequences.

Yet it is possible that greater agricultural productivity could accompany a low mortality future, not least because healthy workers could produce more, both through direct labor effects and through more rapid adoption of improved technology. The global community could also more intentionally couple health and agricultural production initiatives around the world. The linkages of morbidity decline to productivity in IFs may underestimate such effects. We therefore created a second variation or counterfactual for the low mortality intervention (in addition to the first one leading to lower fertility) that increases agricultural productivity for the developing countries of the world by an additional 0.4 percent annually through 2060, roughly a 20 percent cumulative increase relative to the low mortality case by 2060. Because it essentially relieves the somewhat Malthusian food restrictions on the higher population of the low mortality case,

Overall, the low mortality intervention reduces the size of the labor force relative to the dependent population and increases especially the older population.

Figure 7.12 Stunting rate in sub-Saharan Africa with high and low mortality profiles

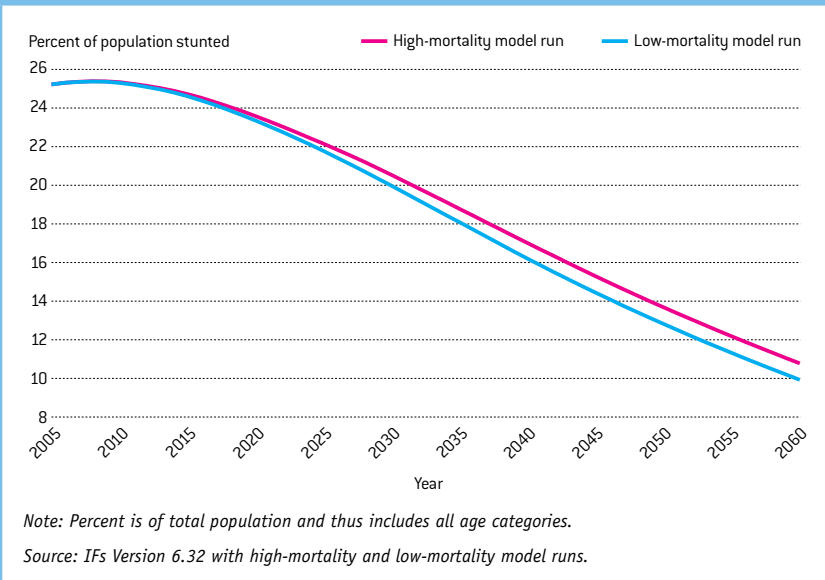
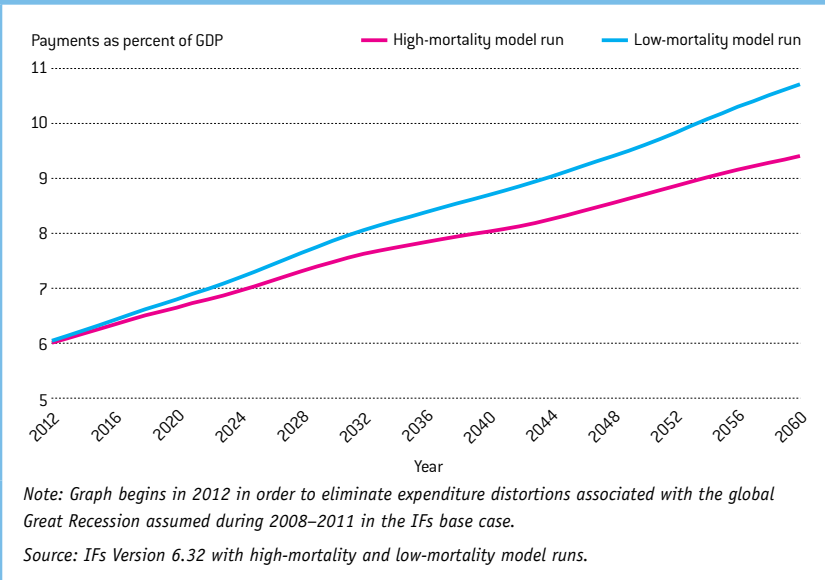


Figure 7.13 Government retirement and pension payments (global) as portion of GDP under high and low mortality profiles



it further reduces stunting for regions like sub-Saharan Africa. Stunting in 2060 would be nearly 1 percent lower across the continent in this case. (We will return later to the economic implications of these modifications for the low mortality case.)

More generally, analysis with IFs shows that there is limited overall difference in the paths of multifactor productivity across the high and low mortality cases. Again, that is

somewhat surprising. Why would that be? The determinants of productivity in the real world, and in the IFs system, are numerous and complex, as we have attempted to describe. And there are trade-offs.

Turning explicitly to social trade-offs, the larger and older global populations in the low mortality intervention require the direction of additional resources to those populations, including old-age security and pension spending (see Figure 7.13). On a global basis, the low mortality scenario could require 1.3 percent of GDP more for such purposes than would the high mortality scenario. That additional increment of spending appears roughly comparable across regions at currently different levels of economic development. This increased spending on the elderly would divert some potential funding from all other government expenditure categories, including education, and the IFs forecast for education expenditures is therefore lower. Moreover, at least in the short and mid-terms, until fertility patterns adjusted, lower mortality would mean larger student-age populations, especially in regions with current high communicable disease burdens, thereby diluting educational expenditures per student. And the absence in IFs of a linkage from aging to higher health care spending means that our analysis probably actually underestimates somewhat the diversion of expenditures from education.

Proposals for boosting spending on health with the expectation of economic return to help pay the costs of such increases (see, for example, Commission on Macroeconomics and Health 2001) often recommend that external resources augment locally generated ones. This analysis suggests one good argument in support of that recommendation, namely, the need to protect other and complimentary investments in human capital.

For that reason we created a third (and final) counterfactual for the low mortality case, one in which the global community helps relieve the constraint of these trade-offs by increasing foreign aid. We were not so rash as to posit that major aid-giving countries would move transfers to the long-requested 0.7 percent of GDP, but we did move them to 0.5 percent, leaving countries already above that level unchanged. (As before, we will return later to

the economic implications of our variations for the low mortality case.) We ultimately find that global multifactor productivity rises negligibly in the low mortality scenario in the early years relative to the high mortality scenario, and that by 2060 the high mortality scenario actually produces annually higher gains of about 0.1 percentage points, with the advantage returning marginally to low mortality by the end of the century. The temporal pattern reflects demographic ones, with some immediate benefit from lower disability of working-age populations, offset in the mid-range by growing proportions of the elderly, and reaching a new equilibrium in the long run.

Overall, the two mortality interventions make surprisingly little difference for multifactor productivity. The fact that our basic scenario targeted only mortality is important in that outcome, because incremental population gains with low mortality pose a number of challenges for productivity. Although fertility adjusts, it does so slowly. As our counterfactuals suggest, scenario variations that simultaneously target fertility, that place additional emphasis on agricultural productivity, or that benefit from additional outside resources, have more positive impacts on productivity. In the discussion of Figure 7.14 near the end of this chapter we return to analysis of those impacts.

Exploring paths between health and growth: Savings and capital

The third general linkage between health and economic growth works through capital stock, and Figure 7.5 elaborated its more specific

paths. Those paths include the potential crowding out of savings by spending on health, the higher savings of populations with longer life expectancy, and the greater attractiveness with respect to foreign direct investment of economies with healthier and more productive populations. Collectively, those paths in analysis with IFs lead to higher capital stock by 2060 across all regions (especially high-income countries) in the low mortality intervention than in the high mortality intervention (see Table 7.1). To put the numbers for 2060 in context, the capital stock per worker in high-income countries in 2005 was \$120,000.

Table 7.1 suggests three somewhat surprising and perhaps counterintuitive results. First and most fundamentally, simplified analysis with a neoclassical framework might suggest that the lower mortality and associated higher population would dilute capital and lead to smaller values per person. Why then does Table 7.1 suggest the opposite outcome? It does so first because it focuses on capital per worker, not per person. Because those who expect to live longer beyond retirement age will generally save more in preparation for it, savings for the society as a whole will normally rise with greater longevity, pushing up capital per worker. Second, although those who live past retirement will draw on their savings, life-cycle pattern analysis suggests that many will save more than they subsequently draw out, passing the excess to the next generations. Finally, positive effects and higher growth compound over time, producing quite large gains even from relatively small increments.

■ *The association of mortality and morbidity, other things being equal, means reductions in mortality rates translate into a healthier and more productive work force. ■*

■ *On the other hand, the 1 billion more people in the low mortality case put pressure on the global food supply and could result in some increase in undernutrition. ■*

■ *The low mortality case requires additional spending on behalf of the larger and older global population, redirecting some public resources from other human development. ■*

Table 7.1 Capital stock per worker (thousands of dollars) by region under high and low mortality profiles (2060)

	High-mortality model run	Low-mortality model run
East Asia and Pacific	162.5	168.9
Europe and Central Asia	66.4	117.9
Latin America and the Caribbean	64.4	116.3
Middle East and North Africa	51.8	78.4
South Asia	38.8	58.5
Sub-Saharan Africa	13.9	18.1
High-income countries	284.7	477.7
World	90.0	124.8

Source: IFs Version 6.32 with high-mortality and low-mortality model runs.

Overall, the low and high mortality interventions make surprisingly little difference for multifactor productivity. ■

Analysis with IFs suggests that savings and capital stock would be higher in all regions in 2060 in the low mortality case. ■

Increase in capital stock appears to be the path to economic growth with the most potential in the low mortality intervention. ■

Second, it may be somewhat surprising that there is such a large difference between the two scenarios for high-income countries. The explanation lies in the fact that for such societies most of the additional longevity is that of post-retirement-age populations and requires higher savings for an extended retirement period. Again, some increased savings may prove to be an excess safety cushion and may pass to subsequent generations. But even if they do not, the interim higher savings boost the total for the economy and per worker.

A third possible surprise from Table 7.1 is that the forecast for capital per worker in East Asia and Pacific countries is only marginally different between the high and low mortality model runs. The reason is that savings and gross capital formation as a portion of GDP in that region are already exceptionally high; additional longevity results in a draw-down of lifelong savings by the elderly that roughly balances the relatively small impetus for still higher savings levels.

Although it would not necessarily increase global totals of capital stock, movement of capital stock to regions with improved health (e.g., via foreign direct investments) should also improve overall productivity of the system. Our analysis suggests that FDI flows into sub-Saharan Africa could be higher by as much as 1 percent of GDP in the low mortality scenario.

Conclusions concerning the three paths between health and economic growth

We have obviously not undertaken here a cost-benefit analysis of investment in health.²⁷ Some individual interventions, such as the use of insecticide-soaked bed nets and the provision of micronutrients, have such a low cost and high health return that there can be no doubt of a large and quite fast return in terms of human well-being. Many other interventions, however, and unfortunately even the expenditures that governments make on health care systems, have very uncertain returns with respect to health outcomes. Instead of systematic cost-benefit analysis, we have shown that there are positive returns in the aggregate to investments in better health.

Of the three major paths from reduced mortality and morbidity to economic growth, rise in capital stock from higher savings for

older age appears to have the greatest potential for boosting economic growth. With respect to the labor path, decreased childhood mortality provides a direct boost to labor force size, but decreases in noncommunicable diseases can cause rapid increases in the post-retirement populations. The net result for most regions (with sub-Saharan Africa being a partial exception) is an overall decrease in the working-age population as a share of the total population. With respect to the productivity path, increased spending on pensions and other expenses associated with aging populations may squeeze productivity gains from health and education that roughly offset the economic advantages of reduced stunting of workers and adult incidence of disability. (We should not forget that this improved health would mean that people had a better quality of life overall, even if GDP per capita did not increase.)

We should not assume that even the path via capital stock is rock-solid with respect to gains from lower morbidity or that there is completely convincing evidence that lower mortality will boost economic growth in the long run. The higher savings rate as a percent of GDP associated with the low mortality intervention narrows beyond 2060, in part because the continually aging population eventually draws on accumulated savings (and our omission from the analysis of direct use of savings by the elderly for health spending may also lead to some upward bias in the conclusion that low mortality has economic benefit). Even with the savings effect, the economic growth advantage of the low mortality scenario overall erodes somewhat for all regions between the middle and the end of the century.

In short, our conclusion is that lower mortality does not, as some analyses would suggest, actually reduce GDP per capita, but that its contribution to higher levels of GDP per capita is likely to be more modest than still other studies conclude. We also recognize, of course, that many of the paths we have represented remain contested; also, although we have provided a fairly rich treatment of the subject, we have not explored all possible paths.

Even with all appropriate caveats, this analysis still suggests the potential for real contributions of health improvements to economic growth and income levels. Figure 7.9 showed a 16 percent rise

in global GDP and an 8 percent increase in GDP per capita between the high and low mortality cases. And this discussion has emphasized the potential that additional levers have to complement the impact of health improvements, commenting specifically on fertility reduction, agricultural yield improvement, and increases in foreign assistance.

Figure 7.14 contrasts not only the low mortality intervention again with the high mortality case but also the three “augmented” low mortality interventions with the high mortality case. Finally, it compares a combined case (the low mortality intervention with all augmentations) with the high mortality case. The impact of these additional interventions would be felt most strongly in sub-Saharan Africa and Latin America and the Caribbean. Effective fertility reduction (coming on the tail of a more rapid mortality decline) would boost the relative increase in future GDP per capita from 11 to 21 percent in sub-Saharan Africa and from 17 to 18 percent in Latin America and the Caribbean. Improvements in crop yield and fiscal balance sheets (with higher financial aid) generate less relative increase in GDP per capita for sub-Saharan Africa than does fertility reduction, but the three together could boost the region’s GDP per capita in the low mortality scenario 28 percent above that of the high mortality scenario.

Not surprisingly, a final conclusion must be that there is no simple relationship between improved health and economic performance. It depends on the balance of mortality causes within a region, on the underlying demographic and economic structures of the region, and on the policies with which health interventions might be combined. The good news, nonetheless, is that there seems to be clear potential for positive micro- and macroeconomic impacts of reductions in mortality.

Returning to the intrinsic benefits of health

Even if reduced mortality (without supplemental policy interventions) may not greatly boost GDP per capita, we all know it to have large intrinsic value, and it is important to return to that foundational reality. Increased life expectancy is arguably the highest human value, most especially when it comes also with improved

Figure 7.14 Ratios of GDP per capita of assorted changes to high mortality profile by region (2060)



quality of life, as the disability forecasting formulations of the Global Burden of Disease analysis (and therefore our own) suggest is generally the case. If we were to add the value of extra and often healthier years of life to income per capita, thereby moving toward a “full income” assessment that accounts for the monetary value of longevity gains, our analysis would obviously support a very large investment in improved health (Becker, Philipson, and Soares 2005).

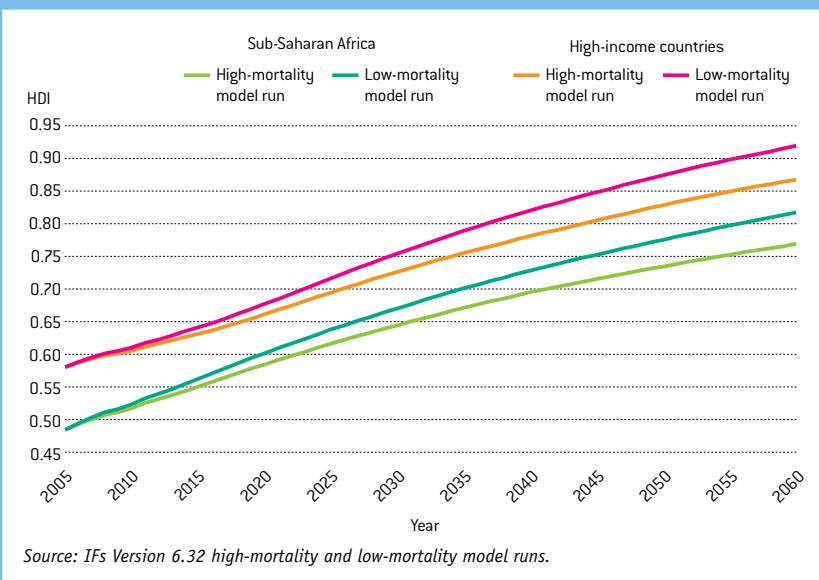
As a step in that direction, Figure 7.15 shows the difference in the Human Development Index²⁸ values to which high and low mortality assumptions give rise for sub-Saharan Africa and South Asia. By mid-century the HDI for both regions is about 5 percentage points higher in the lower mortality case. The figure almost certainly underestimates the benefits of lower mortality and morbidity for the Human Development Index because our analysis does not directly pass through the impact of reduced morbidity to educational achievement.²⁹

Conclusion

At the individual level, no one questions the benefits of improved health. Good things at the individual level do not always scale, however, to

- Augmenting the low mortality case with variations in fertility, foreign aid, and crop yield boosts the economic returns to low mortality alone, especially in sub-Saharan Africa. ■
- The low mortality case boosts values on the Human Development Index for developing regions. ■

Figure 7.15 Human development index (HDI) across mortality profiles: South Asia and sub-Saharan Africa



■ Across many paths of relationship, the positive impacts of improved health on economic outcomes outweigh the negative effects. ■

good things at the aggregate level. In the case of the (over)use of common property resources, such as tuna from the ocean or timber from tropical forests, scaling ultimately produces bad things; in the case of connections to the internet and contributions to human knowledge, scaling has at least the possibility of producing good things.

With respect to health, there may be a mixture of scaling effects. Overall, our analysis of health and economic growth suggests that the positive impacts of improved health on economic outcomes outweigh the negative effects, and

that when we add the intrinsic value of health, the return to improved health is sharply positive at both micro and macro levels.

It is again important to emphasize, however, that not all implications of health for economic growth and social well-being more generally are unambiguously positive. We did not even consider, for instance, the impact on the environment of more and richer people. A comparison of the environmental footprints of the citizens of North America and the European Union with sub-Saharan Africa, two groupings having roughly the same population, would most likely suggest that creating healthier and richer people, as well as more of them, could have decidedly mixed aggregate implications.

There is little forecasting of the potential broader economic and social effects of different health futures. Given the number of paths that this chapter identified and explored, that may not be surprising—the causal picture is very complicated and this discussion has needed to push analytic frontiers. Even while pushing the limits of analysis of health’s broader impacts (and we hope making a contribution by doing so), we began and concluded by emphasizing the great uncertainty of analysis around health futures. That reiteration takes us to the next chapter, devoting attention specifically to uncertainty.

- 1 Solow’s extension of the Harrod-Domar version of the neoclassical model added an exogenous and generally constant technological change term. That extension allows labor productivity to grow without increase in capital. Yet improvements in health or other human capital do not affect production with that extension. Endogenous growth theory and its representations, like that in IFs, break that limitation and move beyond the traditional neoclassical form.
- 2 See Bloom, Canning, and Jamison 2004; Bloom and Sachs 1998; Commission on Macroeconomics and Health 2001; Gallup and Sachs 2001; Lorentzen, McMillan, and Wacziarg 2008.
- 3 Barro (1996) found the effect of life expectancy on economic growth to be larger than the effect of education. Another study looked at the effects of adult survival rate and found positive overall returns but lower returns at higher levels of GDP per capita (Bhargava et al. 2001). Another modeled diminishing returns to life expectancy by using a square term, finding small effects for the average country but

- quite large effects for those with the lowest life expectancy (Sachs and Warner 1997). Jamison, Lau, and Wang (2005) found that improvements in health accounted for about 10 percent of all economic growth in a sample of 50 countries between 1965 and 1990. Age- or disease-specific studies have found increased growth associated with reductions in the occurrence of malaria (Bleakley and Lange 2009; Gallup and Sachs 2001; Gallup, Sachs, and Mellinger 1999; Sachs and Malaney 2002), HIV/AIDS (Ainsworth and Over 1994; Cuddington 1993; Dixon, McDonald, and Roberts 2001; Over 1992), and cardiovascular diseases (Suhrcke et al. 2006; Suhrcke and Urban 2006).
- 4 See Aisa and Pueyo 2004; Ashraf, Lester, and Weil 2008; Azomahou, Diene, and Soete 2009; Boucekkine, Diene, and Azomahou 2007; 2008; Cervellati and Sunde 2007; Chakraborty, Papageorgiou, and Pérez-Sebastián 2005; DeLeire and Manning 2004; Gollin and Zimmermann 2007; Kalemli-Ozcan 2002; Strulik 2004; van Zon and Muysken 2001.

- 5 For full documentation of IFs, see its help system and project documents on the website.
- 6 IFs also includes income-based formulations for changing the female participation rate in the labor force.
- 7 The function is thus Total Fertility Rate = 3.8812 + 0.0217 * Infant Mortality – 0.8327 * ln(Adult Education) – 0.00948 * Percent using Modern Contraception. Even though the GBD used years of education for those 25 and older, we used years of education for those 15 and older for two reasons: (1) women between the ages of 15 and 25 bear many children and (2) the statistical relationship was as strong as for those older than 25.
- 8 See Alavinia and Burdorf 2008; Arndt 2006; Arndt and Wobst 2002; DeLeire and Manning 2004; Jusot et al. 2008; Stewart 2001; Thirumurthy, Zivin, and Goldstein 2008; Tunceli et al. 2005; van de Mheen et al. 1999.

- 9 With good prevalence data for a wide range of diseases (such data are not currently available), it would be possible to allow burdens to accumulate by increasing the disability weight associated with a disease as cohorts experiencing a morbidity burden progress through the age pyramid. For example, given a disability weight for a chronic disease of 0.3, we could compound that disability weight by a certain percentage for each additional year with the disease. This increasingly large disability weight would of course be applied to the standard age-specific productivity/earnings profile, so that compounded productivity losses for a 50-year-old versus a 40-year-old would be set against the relatively higher wages of the average 50-year-old. Similarly, impact of the disability effect would be diminished as cohorts moved towards the lower earnings and productivity of the retirement ages.
- 10 See the following resources for evidence on the effects of height on earnings: Hoddinott et al. 2008; Schultz 2002; 2005; Thomas and Frankenberg 2002; and Thomas and Strauss 1997. With respect to the relationship of height and adult health, see Blackwell, Hayward, and Crimmins 2001; and Crimmins and Finch 2006. For experimental and quasi-experimental evidence on the long-term determinants and consequences of height, see Alderman et al. 2001; Alderman, Hoddinott, and Kinsey 2006; Almond, Chay, and Lee 2005; Barham 2009; Cutler and Miller 2005; Hoddinott et al. 2008; and Miguel and Kremer 2004. For historical and cross-national perspectives, see Deaton 2007; and Steckel 1995. For evidence on the effects of early life conditions on achieved height, see Bozzoli, Deaton, and Quintana-Domeque 2009; Scrimshaw 2003; and Stephensen 1999. For next-generation effects on cognitive skills of women, see Behrman et al. 2009.
- 11 Focusing on health spending, Baldacci et al. (2004: 25–27) analyzed 120 countries from 1975 to 2000 and concluded that spending an additional 1 percent of GDP on health raises growth in annual GDP per capita by 0.5 percent, as well as reducing under-five child mortality by 0.6 percentage points.
- 12 The lag is the difference from the midpoint of childhood (7.5) to the midpoint of adulthood (32.5).
- 13 Global data on stunting among adults appear nearly nonexistent. UNICEF (2009: 5) suggests that under-five stunting exceeds that of undernutrition (200 million versus 130 million) and that stunting is nearly irreversible with aging; these facts suggest very high percentages of stunting among global adults, concentrated in Africa and Asia.
- 14 That function is $HEIGHT(NOW) = -0.06746 * PREADLTMORT + 0.00014 * PREADLTMORT^2$ (where PREADLTMORT is pre-adult mortality per 1,000). The study uses only women because the Demographic and Health Surveys, which interview just women, provide the only reasonable multi-country height series for poor countries. The analysis actually measures not pre-adult mortality but infant mortality and then uses model life tables to transform that into pre-adult mortality.
- 15 To parameterize this relationship, we analyzed the extent of deviations in stunting levels of countries from the function and found that it seldom exceeds 10 percent. In the most extreme cases it can reach 40 percent. We assigned a parameter value of -0.025, which means that, in the extreme cases, stunting might be costing close to 1 percent in annual economic growth.
- 16 Dividing disability years for the working population by the population age 15–65 generates worker-specific lifetime rates in 2005 that range from around 0.20–0.27 at the top end of the range (Afghanistan, Cambodia, Montenegro, Puerto Rico, Timor-Leste, and other [mostly African] countries) to 0.05–0.06 at the bottom end (Algeria, Cape Verde, Japan, Kuwait, UAE, and other [mostly rich] countries).
- 17 Assigning a parameter to the relationship between changes in forecasted disability levels relative to expected ones and productivity is problematic, and we set it at -0.5. That means that the initial implicit impact of the YLD rate on MFP for Timor-Leste at 0.278 million years of disability per million workers (relative to a world average of 0.097) would be a drag of -0.09 percentage points of growth per year. Japan at 0.055 would be gaining a boost of 0.02 percent in productivity and growth. In reality, we should use a disability weight instead of YLD, because the latter is a cumulative lifetime measure rather than an annual incidence measure (i.e., it incorporates not just this year's morbidity but all subsequent morbidity for those afflicted in a current year). Yet the disability weight and YLD will essentially change in parallel, meaning that the difference between them is largely a scaling factor, already captured by the parameter assigned in the linkage to productivity.
- 18 We associated each year of incremental life expectancy with a value of 0.035 years of education for those 15 years of age and older (thus, in essence, using education years as a proxy for quality as well as quantity of educational attainment).
- 19 See Deaton and Paxson 1994; and Lee, Mason, and Miller 2000 for single-country results; see Bloom, Canning, and Graham 2003; and Lorentzen, McMillan, and Wacziarg 2008 for cross-country results.
- 20 A number of recent equilibrium simulation experiments have found that we can only explain longitudinal variations in growth, particularly those for today's developed nations, if we incorporate relationships between longevity and increased savings rates (Aisa and Pueyo 2004; Bloom, Canning, and Graham 2003; Boucekine, Diene, and Azomahou 2007; 2008; Lorentzen, McMillan, and Wacziarg 2008; Soares 2005).
- 21 In such societies, the survival risks imposed by HIV/AIDS could, however, drive down both the incentives to save for capital investment and the incentives to invest savings in children. Prime-age adults may save less if they anticipate their own premature mortality. Those anticipating a long life for themselves, and thus needing retirement savings, may doubt the reliability of their children as a source of old-age support, thereby discouraging intergenerational investments. This may push savings into alternative investments, such as land, or simply reduce savings significantly overall.
- 22 For instance, adding the Fraser Institute's measure of economic freedom (focused on free use of property; see www.freetheworld.com) raises the cross-sectional variation explained by GDP per capita (32 percent) by 15 percentage points. The t-value is not significant; the sign is interestingly negative in spite of the United States being highly free and high spending. The Freedom House measure of civil and political liberties (www.freedomhouse.org) does almost as well, and Polity's (www.systemicpeace.org) democracy measure adds 16 percentage points with strong significance. The Polity democracy measure and economic freedom together take the R-squared from 0.32 with GDP per capita alone to an impressive 0.60 (the sign on economic freedom remains negative and the t-value approaches 2).
- 23 There is also no linkage between health and capital depreciation in IFs; as discussed earlier, that pathway is not very certain.
- 24 The representation of FDI in IFs captures the accumulation over time of FDI inflows and outflows in stocks. In addition, the stocks set up their own dynamics, including the tendency for stocks to reinforce flows. For that reason, we have set the base case parameter for the impact of each year of life expectancy on FDI flows to 0.05 (5 percent), lower than the estimate of Alsan, Bloom, and Canning (2006).
- 25 This is not an extreme range of intervention assumptions. The report of the Commission on Social Determinants of Health (CSDH 2008: 197) called for a 95 percent reduction in under-five mortality rates between 2000 and 2040. In sub-Saharan Africa the 30 percent reduction relative to the base accomplishes only a 70 percent decline in 2040 relative to 2005 and produces a mortality rate that is only 50 percent lower than the high intervention.
- 26 See the analysis by Population Action International at <http://www.cfr.org/publication/13093/>.
- 27 The Patterns of Potential Human Progress volume *Advancing Global Education* (Dickson, Hughes, and Irfan 2010) did undertake such an analysis with respect to education because the costs of educating children at different levels are relatively easier to quantify and compare against the return. That study found that the break-even point with respect to contribution of more spending on education to economic growth could be two or more decades in the future, depending on the country and region, but that the return continued to grow over the long term. That is a result quite different from the one suggested by this chapter.
- 28 The HDI is a composite measure of several human development factors—namely, income, literacy, education, and life expectancy. It was developed by the United Nations Development Programme (UNDP) in 1990 under the guidance of Mahbub ul Haq. The UNDP updates the HDI for all countries each year in the annual UNDP Human Development Report.
- 29 We do represent the probable education-related contribution of morbidity reduction to multifactor productivity but do not show it in educational attainment.