

# 5



## Analysis of Selected Proximate Risk Factors

■ *Changes in disease-predisposing behaviors can have powerful impacts on overall health.* ■

When communities or governments seek to improve health outcomes across both broad populations and specific population subgroups, they most often focus on specific health risk factors over which they can exercise leverage. Efforts to reduce obesity and lower smoking rates are examples of attempts to reduce the prevalence of noncommunicable diseases, such as cardiovascular diseases and cancer. Similarly, distributing information about safe sex practices and providing access to contraceptives are examples of efforts in the fight against sexually transmitted infectious diseases. Positive changes in such disease-predisposing behaviors (in this case, poor nutrition, smoking, and unsafe sex), while often difficult to achieve in practice, can have powerful impacts on overall health.

While behaviorally linked proximate risks are certainly related to the distal drivers explored in Chapter 4, the relationship is mutable; collectively and individually people can quite possibly alter at least some aspects of their

risk factor profile at any level of development.<sup>1</sup> This observation raises critical questions for those seeking to understand and improve population health outcomes. For example, what relationships exist between proximate and distal factors currently, and how might those change over time? And how might our forecasts of mortality change with favorable (or unfavorable) changes in exposure to specific risks?

This chapter and the next therefore introduce alternative levels of proximate risk factors into the forecast of health outcomes. Specifically, we look further at the relationship between proximate risks and both distal drivers and mortality outcomes, exploring how our base case health forecasts might change if the extent of various risk factors changes.

We chose four such risk factors to explore in this chapter: childhood undernutrition, adult overweight and obesity, tobacco use, and road traffic safety. In Chapter 6, we turn to selected risk factors in the physical environment—namely, water and sanitation, indoor air pollution, urban

outdoor air pollution, and climate change. Then at the end of Chapter 6 we step back and look at health impacts across the proximate-driver scenarios explored in both chapters.

### Health Risk Transition

We can situate a health risk transition within the broader epidemiologic transition (see Figure 5.1 in relationship to Figure 1.3). Traditional risk factors—such as undernutrition, indoor air pollution, and unsafe water, sanitation, and hygiene—begin at very high levels in the first phase of the epidemiologic transition and decline across phases. Modern risks—such as smoking and obesity—rise across the phases and reach high levels only in the third phase. Other risks tend to rise and then fall as the epidemiologic transition proceeds and might best be called “transition risks.” For example, both urban outdoor air pollution and road traffic accidents tend to rise sharply in the first and/or second phase of the epidemiologic transition and then fall gradually in subsequent phases.

Time itself is obviously not the true driver of the risk transition, and many factors interact to give rise to changing patterns of risks. Income tends to increase over time and influences risk-related behaviors and societal contexts. Social change provides (and is marked by) new options and choices (including in sexual behaviors). Health systems and their technologies evolve. Energy systems, economic structures, and other aspects of infrastructure transform quite dramatically, giving rise to changing physical environments (and a related environmental risk transition to which we will return in Chapter 6) as well as helping shape new lifestyles. It is within this framework of changing health risks over time and across a range of circumstances that we begin our exploration of proximate health risks.

### Risk Analysis with IFs

As Chapter 3 explained, the International Futures (IFs) health model has a hybrid character that combines the distal- and proximate-driver formulations, the former as a foundation for forecasting and the latter as a way of exploring variations in risk relative to expectations consistent with the distal variables. Chapter 4 explored the implications for health futures of alternative assumptions concerning the distal drivers. This chapter and the next

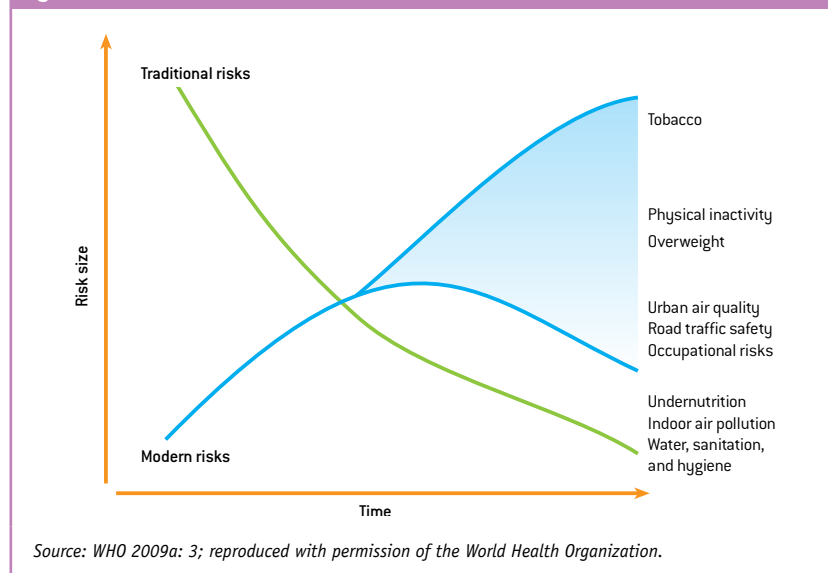
do the same with respect to proximate drivers across the phases of the risk transition.

We focus on a subset of proximate health risks. As discussed in Chapter 3, WHO’s Comparative Risk Assessment (CRA) project within the broader Global Burden of Disease (GBD) project has provided a map for estimating the mortality and burden of disease associated with individual and joint risk factors. The CRA project’s 2004 update (WHO 2009a) included 24 risk factors across seven risk categories,<sup>2</sup> selected from a much larger potential set of risks because of their clear connection to health outcomes, potential for global impact, data availability, and potential for modification through interventions (see again Table 2.1 for a list of the risk categories and risk factors in the CRA 2004 update).

From the CRA project’s list, we selected seven for initial inclusion in the IFs health model: childhood undernutrition (as measured by childhood underweight); overweight and obesity (as measured by high body mass index [BMI]); smoking (a subset of smoking and oral tobacco use); unsafe water, sanitation, and hygiene; urban air pollution; indoor air pollution from household use of solid fuels; and global climate change. All but global climate change were within the top 14 risk factors in terms of global deaths in 2004 according to the CRA 2004 update (WHO 2009a: 10).<sup>3</sup> To these seven we added road traffic safety, identified as a modern risk in the CRA report’s depiction of the health

■ Different health risk factors tend to be associated with different stages of the epidemiologic transition, leading to the concept of a “health risk transition.” ■

Figure 5.1 The transition in health risk factors over time



risk transition (see again Figure 5.1) but not included in the CRA's list of 24 quantified risks.<sup>4</sup>

At this time, we have not modeled alcohol use or sexual and reproductive health risk behaviors, despite their very significant mortality and morbidity impacts. Nor have we directly treated

physical (in)activity. In addition to the influence of magnitude of deaths on our choice of factors to explore in this volume, historical and cross-sectional data for most of the risks that we do not treat are more limited than for those we analyze. Future extension of the hybrid modeling approach of this volume will hopefully push further into this more difficult terrain.

Our approach to exploration of proximate drivers, as in our earlier analysis of distal drivers, involves exploring high and low scenarios around the base case forecasts of the various drivers. In order to frame reasonable magnitudes for the high and low scenarios, we considered contemporary variation in risks across countries; Box 5.1 and Figure 5.2 serve as an example by elaborating our approach with respect to undernutrition at different levels of national income. Presumably such variation encompasses and reflects both good and bad health practices. We posit that increasing risks by one standard error above those forecast in the base case constitutes a reasonable basis for a high-risk scenario, while decreasing them by one standard error similarly can represent a low-risk scenario. And as a general rule, we assumed that such shifts in risk relative to initial conditions (and a dynamically changing base case) could not occur instantaneously, however lenient or intense policy might be with respect to such shifts. We therefore phase in the shifts over a 25-year period ending in 2030.

Four of our risk factors (childhood undernutrition, overweight and obesity, smoking, and road traffic safety) are the subject of this chapter, and Chapter 6 groups and presents the analysis and forecasts of the four environmental risk factors. We begin the analysis of proximate risks in this pair of chapters by exploring childhood undernutrition. As in our discussion of other risks, we seek to understand its historical evolution, its key drivers, and the possible health implications around the world of alternative high- and low-risk scenarios.

### Childhood Undernutrition

While far from perfect, the nutritional status of most populations today is much improved from historical experience. The foundational approach to nutritional sufficiency in developing countries lies in increasing available calories per capita, with the caveats that increases can eventually lead to overnutrition and that people may eat

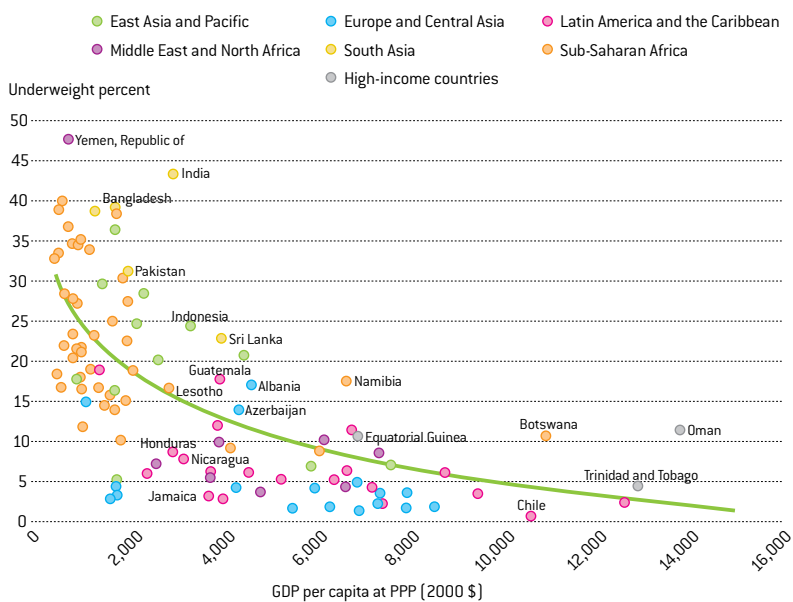
#### Box 5.1 Risk factor variability and exploring potential impacts of interventions in IFs

Risk factor estimates often vary quite dramatically across countries at the same general level of development. Figure 5.2 shows, for example, the percentage of children who are underweight relative to GDP per capita. Contrast India and Honduras. In 2005, both had GDP per capita of just over \$3,000 at purchasing power parity. Yet the most recent WHO estimates of childhood undernutrition differ strikingly for the two countries—43.5 percent in India (2006) compared to 8.6 percent in Honduras in the same year. The reasons for unexpectedly high or low undernutrition rates in relation to per capita income in particular regions or countries often remain unclear; historically South Asia has been a particular outlier.

One way to quickly summarize the extent of cross-country variation for a risk factor is the standard error relative to the regression line (the equivalent of the standard deviation relative to a mean) in a relationship such as that of Figure 5.2. The standard error of 8.50 compared to a mean underweight percentage of 16.1 suggests that values for undernutrition frequently vary by about 50 percent above or below the values we would expect based on GDP per capita. In contrast, relative to income-based expectations, the variation around female smoking, where the relationship with income is extremely weak, is nearly 80 percent.

High and low proximate-driver scenarios in Chapters 5 and 6 draw on analyses of cross-national variation in the individual risk factors, such as that shown here for childhood underweight. Specifically, the high and low scenarios for undernutrition are 50 percent (or roughly one standard deviation) above and below the base case, and the range of variation for other interventions is similarly linked to the magnitude of the standard errors of those risk factors.

Figure 5.2 Underweight children (percent) as a function of GDP per capita at PPP



Note: Equation:  $y = 86.2833 - 8.8428 * \ln(x)$ ; R-squared = 0.5075; standard error = 8.4

Source: IFs version 6.32 using WDI data (most recent by country).

a sufficient amount of food but fail to absorb the nutrients due to diarrheal disease or other disorders (Fogel 2004b). As recently as the late 1960s and early 1970s, people in many regions of the world had, on average, fewer than 2200 calories available per day and experienced severe nutritional shortfalls. In sub-Saharan Africa and South Asia, available calories remained fairly low through the 1990s, and calorie availability actually fell for the transition countries of Europe during the 1990s (FAO 2006). Still, people in developing countries had an average of over 500 more calories available in 2006 than they did in the mid-1970s, moving on average from 2110 to 2650 (FAO 2006: 3).

The problem of global malnutrition is, however, very far from solved, as we can see from cross-national data on body size. Generally defined, malnutrition describes a condition in which dietary energy or nutrient supply to the body is insufficient, excessive, or imbalanced (resulting from food insecurity, food excess, and/or vitamin and mineral deficiency). Here we use the term undernutrition to describe a physiological state of inadequate nutrition. For children under five years of age, the rate of undernutrition in a population is measured through weight, and underweight is defined as two or more standard deviations below the international reference weight.<sup>5</sup> Recent WHO figures report the percentage of children classified as underweight to be more than 30 percent for 18 countries and more than 20 percent for 40 countries (WHO Statistical Information System, accessed August 2009).<sup>6</sup> Sharply rising prices from 2005 through 2008 (FAO 2008: 6) exacerbated food insecurity in many parts of the world, as did the subsequent economic crisis.

Childhood undernutrition is a major contributor to the overall global burden of disease—in fact, the GBD project has determined childhood underweight to be the single leading global cause of disability-adjusted life years (Ezzati et al. 2006). Although undernutrition is rarely listed as a direct cause of death, analysis suggests that it is an underlying determinant in between 22 and 35 percent of all deaths for children younger than five years of age worldwide (Black et al. 2003).<sup>7, 8</sup>

A study by Pelletier, Frongillo, and Habicht (1993) greatly advanced understanding of the role of childhood malnutrition in disease. The authors reanalyzed data from

six population-based studies of childhood malnutrition and demonstrated a number of significant points. First, their analysis confirmed that the risk of mortality is inversely related to weight-for-age (Pelletier 1994). In other words, the analysis showed conclusively that the more malnourished children are, the higher their risk of early death. Importantly, Pelletier, Frongillo, and Habicht demonstrated that mortality risk among children is not limited to those affected by the most severe malnutrition; instead, there is a spectrum of risk associated with all grades of malnourishment, and even mild and moderate forms are associated with an elevated risk of mortality. In fact, because of the high proportion of children falling into the mild-to-moderate range of malnourishment, the number of associated deaths in that population was much higher than the number of child deaths resulting from severe malnutrition (Pelletier, Frongillo, and Habicht 1993: 1132). The results of their study also confirmed that undernutrition has a multiplicative rather than an additive effect on mortality, a finding that has far-reaching implications for child survival strategies at policy and programmatic levels:

If these associations are causal, an increase or decrease in the prevalence of malnutrition will have a bigger impact on mortality in populations with already high mortality levels than in those populations with low mortality levels. Efforts to lower child mortality would therefore be most effective if attention is given to improving health and nutritional status simultaneously and if such efforts are targeted towards populations with the highest mortality levels. (Pelletier 1994: 2058S)

### ***Drivers and forecasts of undernutrition in children***

The determinants of childhood undernutrition are highly complex, multidimensional, and difficult to encapsulate in a single theory. Undernutrition is most directly a result of dietary inadequacy, the effect of an infectious disease on energy absorption, or an interaction between the two. The interaction with infectious

■ *In this chapter we explore high and low scenarios around four risk factors: childhood undernutrition, overweight and obesity, smoking, and road traffic accidents.* ■

■ *Childhood underweight has been identified as the single leading global cause of disability-adjusted life years.* ■

diseases, including diarrheal diseases, links undernutrition strongly to the availability of safe water and sanitation systems, and those are key driving variables in the IFs formulation (we discuss this link in Chapter 6).

Clearly, however, calorie availability is fundamentally important. The number of available calories depends strongly on the interaction of two factors: income (including its distribution) and food price. Long-term trends in calorie availability reflect fairly rapidly rising incomes in most parts of the world and slowly falling real food prices. Both of those trends have seen periods of significant interruption. Famines in 1974 (especially in Bangladesh and Ethiopia) arose in periods of sharply higher-than-normal world food prices in interaction with more localized natural disasters. The “lost decade” of the 1980s in Latin America, with debt crises giving rise to economic stagnation, led to a long flattening of calorie availability levels, just as the fall of incomes in the former communist countries (and the elimination of safety nets) more recently led to a decline in calories available there.<sup>9</sup> Similarly, the sharp rises in world food prices from 2005 through 2009, with a doubling from early 2006 to early 2008 (FAO 2008: 6; FAO Food Price Index data, accessed August 2009)<sup>10</sup> resulted in reports of rapid and significant rises in undernutrition. On average, however, incomes swing much less widely than do food prices. Therefore, the long-term rise in incomes has been a foundational force for dietary

improvement, while food prices have been especially important in the shorter term.

The interaction of supply and demand substantially determines the course of food prices. On the supply side, increased production around the world—as a function primarily of technological advance since the 1950s and primarily of cultivation expansion before that—has been critical. On the demand side, rising incomes translate quite directly into food demand. In fact, the earliest definitions of extreme poverty (living on less than \$1 per day) relate quite directly to undernutrition (the Ahluwalia, Carter, and Chenery 1979 poverty level was associated with roughly 2,250 calories per day), and the global numbers of those who are extremely poor and those who are severely malnourished are very comparable. As incomes advance, of course, food demand continues to grow and to change in character, and it has in part been the rapid rise of the global middle class and its demand for improved diets, especially in China and India, that has driven the pressure on food prices since 2000. Another critical factor has been the increased demand on agricultural production for biofuels as an alternative energy source. This pressure depends significantly on the price of energy, as well as on subsidies and policy mandates, and the future course of it is uncertain.

IFs represents the demand and supply interaction in its forecast of calorie availability and nutrition levels. Even taking into account

■ In the IFs base case, childhood undernutrition falls by 2060 to 5 percent or less in all but South Asia and sub-Saharan Africa, where it remains at 7–8 percent. ■

**Table 5.1** FAO and IFs forecasts of available calories per capita by region

	2015		2030		2050	
	FAO	IFs	FAO	IFs	FAO	IFs
Developing countries	2860	2782	2960	2944	3070	3098
East Asia	3110	3028	3190	3232	3230	3410
Latin America and Caribbean	2990	2961	3120	3084	3200	3217
Near East and North Africa	3080	3062	3130	3153	3190	3245
South Asia	2660	2577	2790	2806	2980	3057
Sub-Saharan Africa	2420	2311	2600	2477	2830	2674
Industrial countries	3480	3505	3520	3545	3540	3603
Transition countries	3030	3116	3150	3227	3270	3265
World	2950	2897	3040	3030	3130	3161

Notes: While the table displays regional categories used by the FAO, the IFs forecasts are for descriptively comparable World Bank regions; there may be small differences in the regionalization of the FAO and IFs forecasts. Calorie estimates from the FAO are based on national Food Balance Sheets rather than food consumption surveys. Thus, they refer to average available calories rather than consumed calories, and are reasonably assumed to be greater than consumed calories.

Source: FAO 2006: 8 and IFs Version 6.32 base case forecast.



the global disruption of income growth resulting from the economic crisis that began in 2008, the analysis with IFs suggests that the longer-term trend in available calories per capita (and thus reduction in undernutrition) continues to appear positive. Forecasts of available calories per capita in IFs are largely very similar to those that the UN Food and Agricultural Organization (FAO) projected in 2006 (see Table 5.1).

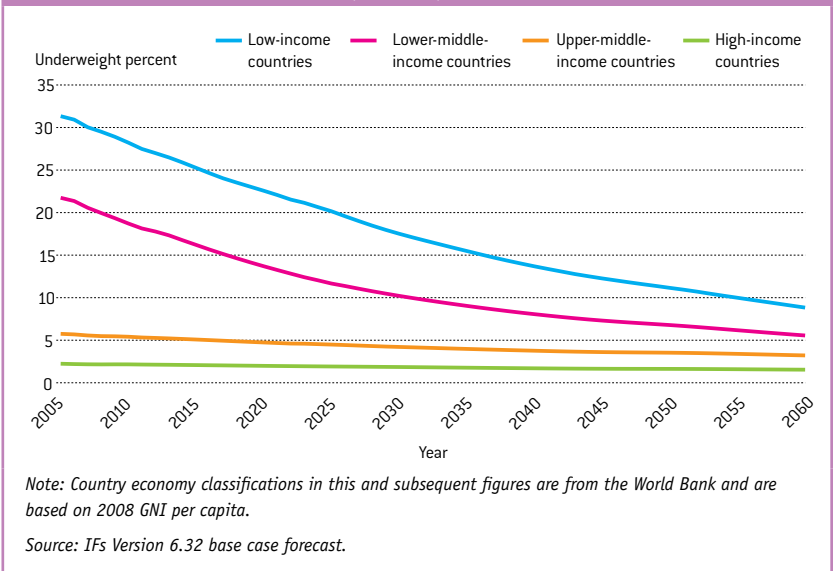
Given expectations of increasing calories per capita, IFs forecasts that childhood undernutrition will continue to fall around the world in the base case scenario (Figure 5.3 shows the pattern across country economy categories). At a regional level, the most acute reduction appears in South Asia, where the historical prevalence of undernutrition stands in marked contrast to its expected future of quite rapid economic development (especially in India). By mid-century, projected childhood undernutrition falls to 5 percent or less in all but two regions (South Asia and sub-Saharan Africa), where it remains at 7–8 percent.

### Childhood undernutrition and mortality: Alternative scenarios

How might an expansion of policies and programs focused on reducing childhood undernutrition decrease child mortality relative to our base case forecast? Alternatively, how might rising hunger, perhaps in conjunction with unexpected conflict or political turmoil, increase child deaths? To explore these questions, we created high and low scenarios within IFs in which the rate of childhood undernutrition either increases or decreases by 50 percent of its base case expected value by 2030 (see again Box 5.1 for discussion of the foundation for potential variation in undernutrition rates).<sup>11</sup>

On a global basis, the forecast difference between the two scenarios in under-five deaths totals as much as 1.82 million in peak year 2026 (see Figure 5.4). We project the greatest impact in sub-Saharan Africa, where the child mortality rate across our forecast horizon varies by five deaths per 1,000 (e.g., 11.2 versus 16.2 in 2030), and almost 500,000 fewer child deaths occur in the low-undernutrition scenario (as compared to the high scenario) every year from 2020 to 2060. Significant differences also occur in South Asia, where we forecast nearly 600,000 fewer child deaths in peak years (late-

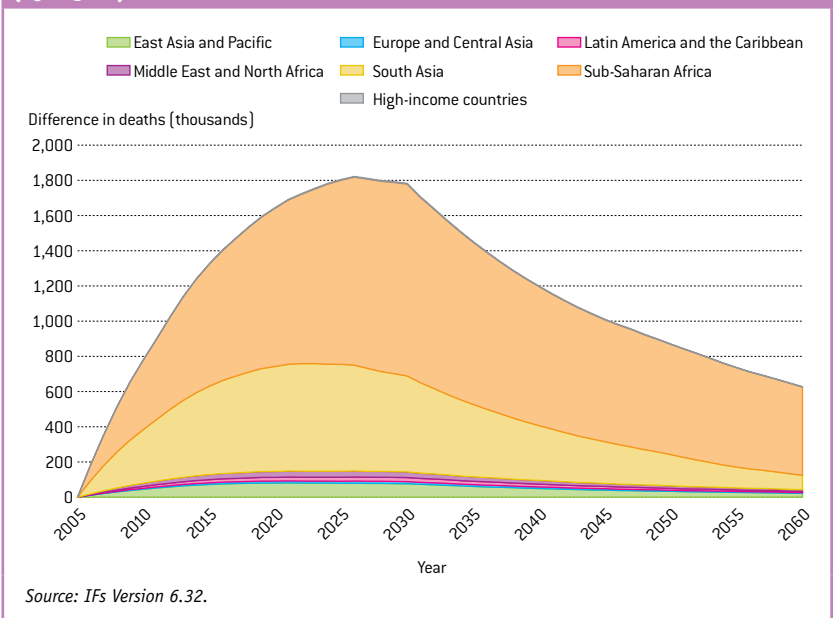
Figure 5.3 Underweight children (percent) by country economy classification



2020s). In short, alternative undernutrition rates result in tremendous differences in forecasts of child mortality.

While differences between scenarios peak in the late 2020s, we forecast that child mortality will generally fall across all regions over time. Because child mortality steadily decreases in the base case, the impact of alternative undernutrition scenarios gradually

Figure 5.4 Difference in forecasts of child deaths (thousands) between scenarios with slower and faster improvements in access to adequate nutrition (by region)



■ In our low undernutrition scenario, we forecast as many as 1.8 million fewer deaths of children under five in 2026 (the year of peak difference) than in our high scenario. ■

■ The global number of adults considered overweight surpassed those who were underweight for the first time in 2000. ■

erodes. The impact of alternative futures for undernutrition would be even somewhat greater but for the fact that the low undernutrition scenario is responsible for a substantial increase in global population by 2060 (about 21 million) compared to the high undernutrition scenario, increasing the population at risk and placing some pressure on food systems (a topic that we explore in our forward linkages in Chapter 7).

### **Overweight and Obesity**

Historically, those concerned about nutrition, and especially about nutrition in the developing world, focused on undernutrition. More recently, there has been increasing awareness of a spectrum of malnutrition extending across insufficiency, excess, and poor or incomplete nutritional quality. Unfortunately, simply being able to eat more and gain weight does not necessarily translate into good health.

Increased body mass can mask serious deficiencies in vitamins, minerals, and other important nutrients. More directly, however, numerous studies relate the growing burden of many noncommunicable diseases to a worldwide escalation of overweight and obesity. As body weight rises, so does the risk of cardiovascular diseases, type 2 diabetes, osteoarthritis, and some cancers.

Overweight and obesity are generally measured in terms of body mass index (see endnote for a description of how BMI is calculated).<sup>12</sup> WHO defines 21–22 as the optimum universal BMI. A BMI equal to or greater than 25 describes overweight, while a BMI equal to or greater than 30 classifies an individual as obese (James et al. 2004).

In 2000, for the first time the global number of adults considered overweight surpassed those who were underweight (Caballero 2007: 1). The prevalence of obesity began rising in high-income countries in the 1930s; the explosion in overweight and obesity appeared more recently and is occurring much more rapidly in low- and middle-income countries (Popkin and Gordon-Larsen 2004). In some Latin American countries, the annual increase in overweight and obesity prevalence rates throughout the 1990s was more than 1 percent—a growth rate four times that of the United States during the same period (Popkin 2002). While data on prevalence and trends in

much of the world remain scarce, studies suggest similarly large increases throughout the 1990s in overweight and obesity for parts of the Middle East, Asia, and even sub-Saharan Africa (Popkin 2002). Many of these countries may bear a double nutritional burden, with excess calorie intake among some population segments even as others remain undernourished.

### **Drivers and forecasts of obesity**

Fundamentally, weight gain results when an individual consumes more energy than the body is using. Yet behind this fairly simple insight lies a more complex web of causality, as suggested by the recognition that interventions aimed at changing eating and/or physical activity patterns often fail to produce sustained results (Hill 2006). Rather, a combination of genetic, nutritional, environmental, and economic factors must converge to produce the rapid increases in population overweight and obesity observed over the past few decades.

Evidence suggests (Peters et al. 2002) that humans evolved to contend with an environment in which food was often unavailable and survival required extensive physical activity (and hence high calorie intake). The environment has changed much more quickly than human physiology; as described in the section on undernutrition, available calories have risen quickly throughout most of the world. Moreover, the composition of available calories has changed over time. Paradoxically, today the (over)production of the cheapest foods, such as vegetable oils and sugar, contribute to a world marked both by oversupply and undernutrition, as individuals consume energy-dense rather than nutrient-dense foods (Elinder 2005; Swinburn et al. 2004). In both high- and some middle-income countries, obesity impacts especially the poorest socioeconomic classes, in part because nutrient-dense foods (such as whole fruits and vegetables) tend to cost more than energy-dense fast foods (Tanumihardjo et al. 2007).<sup>13</sup>

Popkin and Doak (1998) describe a *nutrition transition*, analogous to the demographic and epidemiologic transitions, in which populations abandon traditional ethnic foods and eating practices in favor of a “Western” diet filled with animal products, refined grains, sugar, and fat. Multiple factors drive the nutrition transition, including rising incomes; food prices (themselves

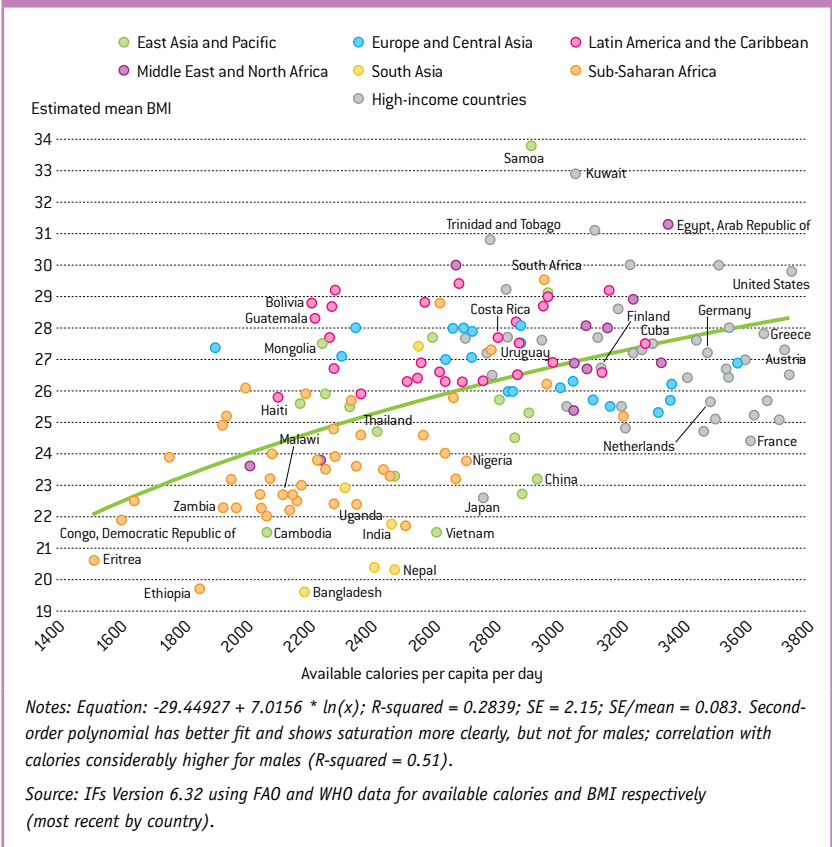
influenced by government agricultural policies and agricultural technology); urbanization; and food marketing (Elinder 2005; Popkin and Doak 1998; Swinburn et al. 2004).<sup>14</sup> The factors influencing the nutrition transition also tend to change a population's physical activity patterns, reducing needed calorie intake. Economic development often leads to more sedentary employment, to automobiles replacing bicycles as a primary mode of transportation, and to increased opportunity for sedentary leisure time.

Published forecasts of body mass index often extrapolate from historical trends, due in large part to a paucity of analytical foundations on which to base forecasts (James et al. 2004). However, given the very large increases in both mean BMI and obesity in the recent past, extrapolative methods tend to produce extremely alarming estimates. For example, a recent study estimates that in the United States, where the prevalence of individuals with BMIs over 25 jumped from 47 percent in 1960 to 66 percent in 2003 (Wang, Colditz, and Kuntz 2007), 78 percent of men and 71 percent of women will be overweight in 2020, and over 40 percent of both sexes will be classified as obese (Ruhm 2007). Similarly, WHO forecasts obesity rates of more than 40 percent for many countries by 2015 (<https://apps.who.int/infobase/index.aspx>).

For a long-range forecast in which body weight modifies health outcomes, such trend forecasting makes little sense as a baseline trajectory. As populations recognize the health effects of poor diet and limited physical activity, they will likely respond in ways that halt or at least slow further weight gain, even if long-term interventions demonstrate mixed results with respect to weight loss. In fact, we currently see some evidence of both government- and consumer-initiated changes, including health promotion campaigns and regulations on food, in both high- and middle-income countries (Popkin 2002).

Of course, exactly how such efforts may ultimately impact body-weight trends remains highly speculative. We are aware of no long-term forecasts of BMI (at least on a global scale) that attempt to model the impact of potential interventions. Instead, projections often vary trend assumptions exogenously. For example, the GBD project's mortality forecast for diabetes (which incorporates BMI) uses time-trend

**Figure 5.5 Body mass index as a function of calorie availability for females age 30 and older**



projections from the WHO's Surf2 report (WHO Global Infobase Team 2005) but modifies them somewhat—after 2010, the GBD project models BMI flattening to 2015 and then remaining constant to 2030.<sup>15</sup>

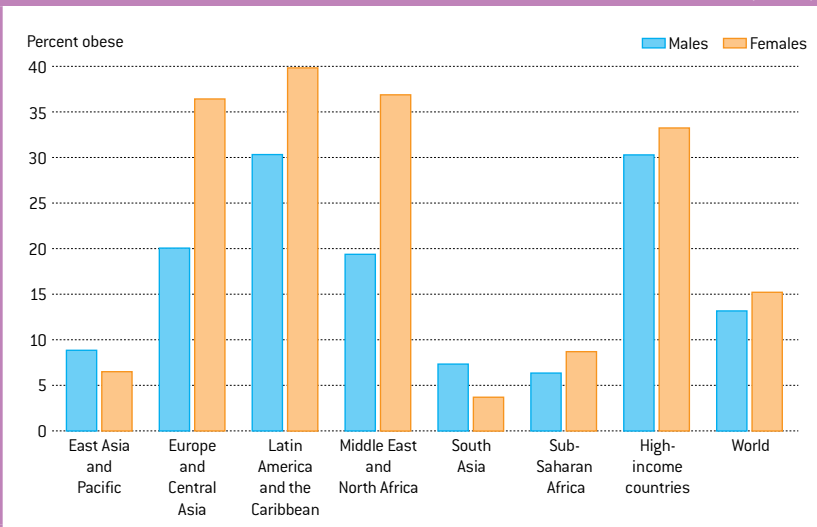
Rather than extrapolation or exogenous specification of future patterns, IFs uses a driver-based approach, relating adult mean BMI to projections of available calories per capita, the demand for which responds to a function estimated cross-sectionally with income. From forecasts of mean BMI we calculate the population percentage of obesity, using sex-specific linear equations published by CRA authors.<sup>16</sup> Cross-sectional analysis indicates an apparent saturation of calorie availability near 3500 calories per capita per day at higher levels of income. Albeit less clearly, Figure 5.5 also suggests a beginning of saturation of BMI rise with increased calorie availability (especially in Europe).

As a result of saturating calorie availability, and to a lesser degree saturating BMI in high-calorie countries, our base case forecasts of

■ Our base case forecasts that average BMI and obesity will rise fairly slowly but steadily across all regions through 2060. ■



**Figure 5.6 Percent of obese male and female adults age 15–59 by region (2060)**



Note: Obesity is defined as a BMI of 30 or more.

Source: IFs Version 6.32 base case forecast.

average BMI and obesity rise fairly slowly but steadily across all regions through 2060 (see Figure 5.6). Regionally, IFs projects the fastest rise in Latin America, where an estimated 26 percent obesity rate in 2005 may increase to over 35 percent by 2060. At the other extreme, the obesity rate in sub-Saharan Africa is forecast to rise only from 5.2 percent in 2005 to 7.6 percent in 2060. In fact, in coming decades the biggest news with respect to health implications of the global obesity epidemic will likely be in

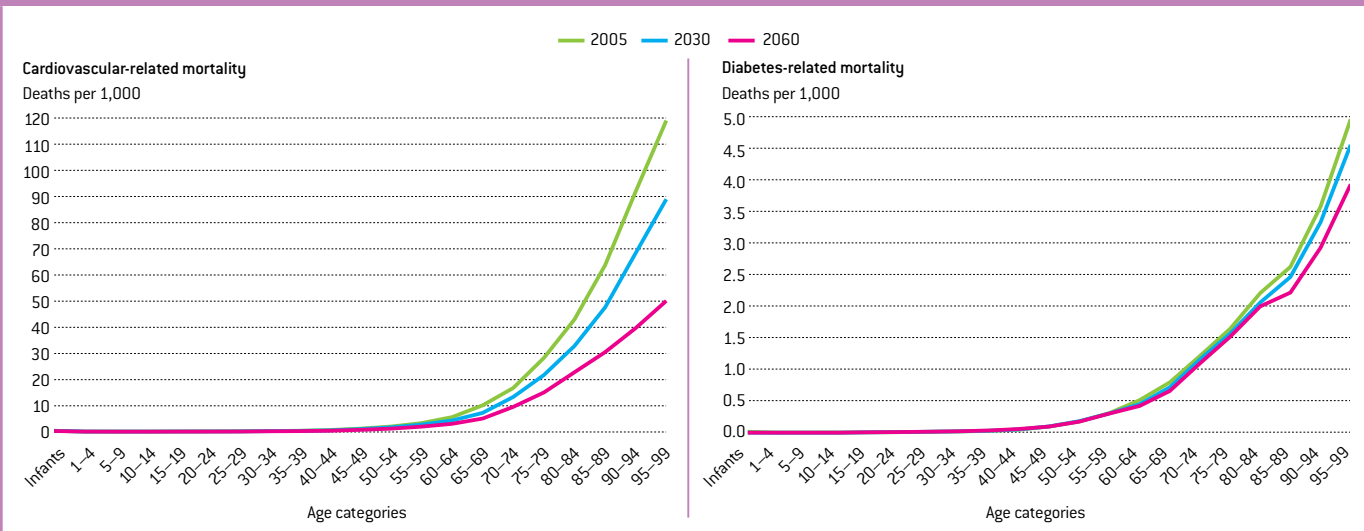
the lower-middle- and upper-middle-income countries, where there is a combination of significant existing and rising levels of obesity.

There are clear sex differences in population BMI, with contemporary female obesity rates far exceeding those of males across all regions (WHO Global Infobase Team 2005). This trend generally continues throughout our forecasts, though our somewhat slower forecast increase in female (compared to male) average BMI results in slightly higher male obesity rates for the East Asia and Pacific and South Asia regions by 2060. However, for the majority of regions projected to experience a high burden of obesity, female rates will remain between 10 and 20 percent higher than male obesity rates. These observations and forecasts suggest that women could suffer disproportionately from the major ill-health outcomes related to overweight and obesity.

**Adult BMI and related mortality: Alternative scenarios**

Associations exist between elevated BMI and a host of disease outcomes, including ischaemic heart disease, type 2 diabetes, hypertensive disease, breast cancer, colon and rectal cancers, endometrial cancer, osteoarthritis, and cerebrovascular disease (James et al. 2004). However, quantifying the relationship between BMI and cause-specific mortality becomes complicated by the long lag, typical with chronic diseases, between risk factor, disease

**Figure 5.7 Global mortality rates related to cardiovascular diseases and diabetes across age categories and time**



Source: IFs Version 6.32 base case forecast.

incidence, and eventual death. Still, in the case of two main cause-groups, cardiovascular diseases and type 2 diabetes, significant research exists to allow us to use BMI to modify mortality using published relative-risk estimates (Danaei et al. 2009; McGee and DPC 2005). For cardiovascular-related mortality we use the relative-risk estimates of Danaei et al. (2009: 13), increasing relative risk by 1.02 to 1.14 (depending on age) for every unit of BMI over 21. Our approach to diabetes-related mortality was described earlier in Chapter 3.

In the base case, IFs forecasts that age- and sex-specific cardiovascular mortality rates will generally fall, through mid-century, across regions.<sup>17</sup> Diabetes-related mortality rates also generally decrease over time, though the trend is somewhat less clear for specific age/sex groups in the high-income countries and in the Europe and Central Asia region. At a global level, the decline in our base case mortality rates over time is decidedly more dramatic for cardiovascular-related mortality as compared to diabetes (see Figure 5.7). This reflects the negative impact of rising population BMI on diabetes, which moderates improvements in other distal drivers even in the base case.

As with undernutrition, the prevalence of overweight and obesity varies significantly across countries independent of per capita income and calorie availability. A number of factors might explain the positive cases, including favorable genetics and behavioral interventions that encourage people to make healthy choices around diet and exercise. In addition, technological advances, such as successful pharmaceutical intervention (already being pursued by private industry driven by lucrative market potential), could conceivably alter the obesity landscape dramatically. Obesity could surprise us negatively as well. The spread of processed foods and rapid urbanization of populations are among the factors that could cause it to rise at even faster than historical rates.

Therefore, we consider again high and low scenarios, in which average BMI rises or falls by 10 percent relative to the base case between 2005 and 2030 and remains at that relative level (Box 5.1 discusses the foundation for such rates of intervention). Even the low BMI scenario results in a population average well above international recommendations; for

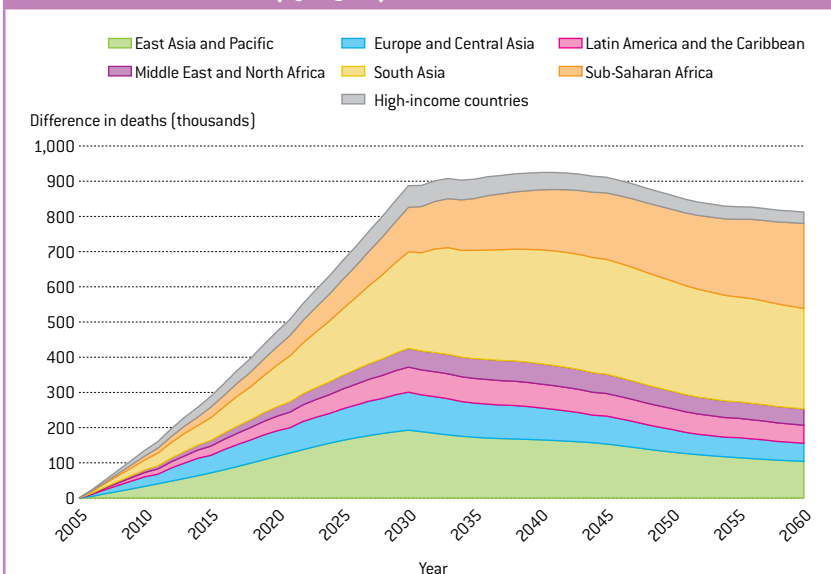
example, in three regions (Europe and Central Asia, Latin America and the Caribbean, and high-income countries) average BMI in the IFs “low” scenario hovers around 27, just between overweight and obese.

Yet even this modest change in BMI, which in our model impacts only adults over 30 years of age, results in dramatic differences in total mortality. Figure 5.8 shows the differences between the high and low scenarios for cardiovascular- and diabetes-related mortality combined. Globally, the low BMI scenario results in a forecast of nearly 2.8 million fewer annual deaths (compared to the high BMI scenario) throughout the 2030s. Mortality differences are spread across all regions, though we might note especially the impact on low- and middle-income regions. In sub-Saharan Africa, for example, limiting the spread of overweight and obesity becomes increasingly important over our forecast horizon.

In fact, while we often associate overweight and obesity with high-income countries, our scenario forecasts suggest that moderating or reversing BMI trends may particularly benefit low- and middle-income countries. As shown in Figure 5.9, life expectancy differences

■ In the 2030s, adults over 30 have nearly 2.8 million fewer annual cardiovascular and diabetes-related deaths between the favorable and unfavorable BMI scenarios. ■

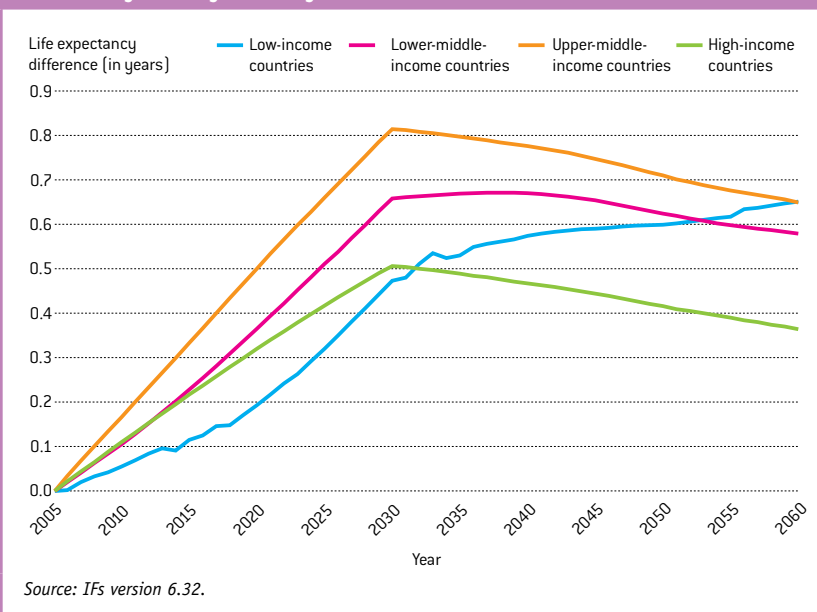
**Figure 5.8 Difference in forecasts of deaths (thousands) of adults 30 years of age and older related to cardiovascular diseases and diabetes under high versus low BMI scenarios (by region)**



Note: Cardiovascular-related mortality far outstrips diabetes-related mortality in both total and difference comparisons. However, the general shape of their patterns is similar.

Source: IFs Version 6.32.

**Figure 5.9 Difference in forecasts of life expectancy between high and low BMI scenarios by country economy classification**



between the two scenarios are initially largest in upper-middle-income countries, but by mid-century even people in low-income countries gain somewhat more than one-half year of life expectancy due to reduced BMI.

### Tobacco Use

As a recent WHO report on the global tobacco epidemic noted, since its popularization and rapid rise in consumption at the start of the 20th century, tobacco has become one of the world's most significant risk factors for premature death and disability and the single leading preventable cause of death worldwide (WHO 2008c). Cigarette smoking, more than any other form of tobacco use, causes the majority of adverse health effects of tobacco, including cardiovascular disease, chronic obstructive lung disease, and lung cancer (Doll 2004; WHO 2002). Despite increasing global awareness of these adverse effects, the number of deaths attributable to tobacco continues to rise. If current smoking patterns persist, annual tobacco-related deaths are projected to exceed 8 million by the year 2030, still exceeding any other single cause (Jha and Chaloupka 2000; Mathers and Loncar 2006; WHO 2008c).

By the end of World War II, manufactured cigarettes had surpassed all other means of tobacco consumption (Doll 1998: 88; Goodman

1993: 92). In Great Britain, 80 percent of men were regular cigarette smokers (Doll 1998: 88), and in the United States it is estimated that over 50 percent of men were smokers; this number increased to 70 percent in some urban areas by 1950 (Harris 1980). It was also during the war years that tobacco consumption among women in the United States and Great Britain began its trend upward, as cigarettes came to symbolize female independence and emancipation. By the mid-20th century, an estimated 40 percent of adult British women and 28 percent of women in the United States smoked cigarettes (Thun and Henley 2004: 19).

Following an earlier expansion of tobacco use, the decades after World War I saw a marked acceleration in incidence of lung cancer, as well as heart attacks.<sup>18</sup> Lung cancer, formerly an extremely rare disease representing only 1 percent of all cancers in the late 19th century, had by 1940 become a major cause of death (Doll et al. 2004: 1). By the 1950s, it had become the most common form of cancer in the United States and Britain, and by 1990 it had replaced stomach cancer as the most common form of cancer in the world (Cantor and Timmermann 2005: 320).

Evidence of the deleterious effects of tobacco continued to accumulate throughout the 1950s, contributing to a growing scientific consensus that smoking was causally related to lung cancer as well as responsible for a number of other diseases (Doll 1998: 102–103; Thun and Henley 2004: 23–25). This consensus was further strengthened in the 1960s with the release of numerous other case control and cohort studies from various health ministries and research institutes, all of which explicitly concluded that cigarette smoking is causally related to lung cancer. Ultimately, as Doll (1998: 102–103) and Thun and Henley (2004: 24) noted, it was the widely publicized reports of the World Health Organization in 1960, the Royal College of Physicians of London in 1962, and the Advisory Committee to the United States Surgeon General in 1964 that effectively ended any serious counter-arguments, outside of the tobacco industry itself, regarding the causal implications of cigarette smoking.

### Drivers and forecasts of tobacco use

Several factors led to the 20th-century popularization of the cigarette. Not inconsequential was the tobacco industry's

■ *The World Health Organization has described tobacco use as the single leading preventable cause of death worldwide.* ■

ability to capitalize on the prevailing sentiments of the time in associating the cigarette with powerful images of patriotism, courage, and heroism during World War I and modernity, sophistication, and autonomy in the 1920s (Rudy 2005: 148). Innovations in technology, including the mechanization of cigarette rolling by machine (invented in 1881), allowed for mass production of a more versatile and affordable mode of tobacco use. Furthermore, milder forms of tobacco had been developed that allowed tobacco smoke to be more easily inhaled (Proctor 2001: 31). These new industrial developments, combined with new marketing strategies (packaging, advertising, and branding) and the power of the images that had come to be associated with the cigarette, created mass demand in markets that had historically preferred tobacco in the form of snuff or chew (Goodman 1993).

In step with rising incomes, much of the worldwide increase in tobacco use now comes from the developing world—especially China. Studies suggest that the income elasticity of demand for tobacco products ranges from between 0.2 and 0.8, with the higher elasticities found in developing countries (FAO 2003). The retail price of tobacco also matters greatly, especially in low-income countries. Given that taxation can heavily influence price, public policy emerges as a further driver of tobacco use.

Still, while the prevalence of smoking in high-income countries could perhaps once be blamed on ignorance of ill-health effects, clearly most users worldwide are now at least somewhat aware of the dangers. What, then, accounts for growing consumer demand among individuals in middle- and low-income countries? A clue may lie in the observation that teenagers make up the bulk of new tobacco users. In fact, many studies suggest that most individuals who avoid smoking in early adulthood never become smokers (Jha and Chaloupka 2000). Young people may underestimate the addictiveness of tobacco, later finding it very difficult to give up. Thus, increased consumer demand in the developing world may result from a mix of habit formation, lax public policy that does not adequately discourage initial use, and growing populations overall. Overcoming that mix of factors leads to falling demand in high-income countries.

In the mid-1990s, Lopez, Collishaw, and Pihl (1994) described four stages that characterize

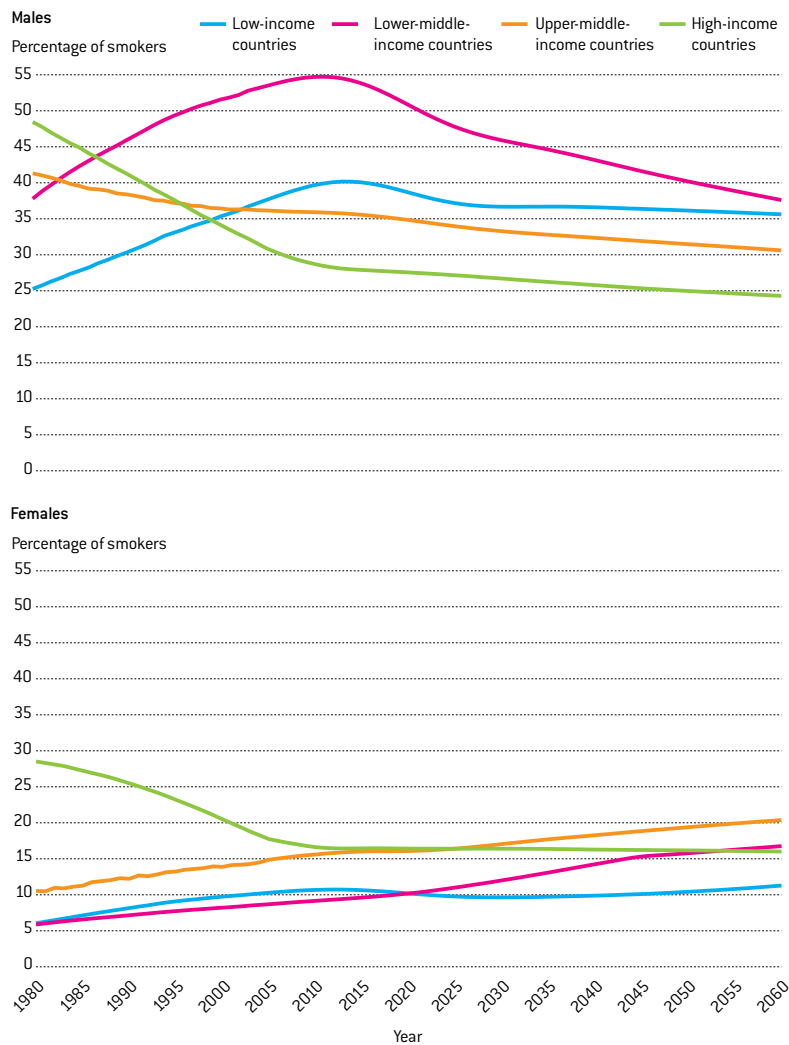
adult smoking prevalence and associated mortality, by sex, over time in industrialized countries; smoking rises slowly in stage one and rapidly in stage two, peaks in stage three, and falls through stage four. Ploeg, Aben, and Kiemeny (2009) adopted this stylized model to represent historical smoking patterns and to project future tobacco use for various countries and regions. They placed sub-Saharan Africa in stage one, much of Asia (including China and Japan) in stage two, Eastern and Southern Europe in stage three, and Western Europe and the United States in stage four, with a nearly 100-year period separating the beginning of stage one from the downturn of male smoking deaths in stage four (at which point female smoking deaths are still rising).

Most observers agree with this stylized representation of tobacco use over time. Indeed, a widely cited analysis (Shibuya, Inoue, and Lopez 2005: 481) of four high-income economies (Australia, Canada, the United Kingdom, and the United States) described the historical progression in these countries past stage three (peak use) to the continually diminishing use of stage four, anticipating that the smoking rates in these four countries will decline to around 5 percent by 2035. In spite of these stylized understandings, both the historical and future paths of smoking prevalence around the world, especially for developing economies, remain very unclear. Historical data are very sparse. The IFs project constructed a historical series around the sparse data with “backcasting” based on the smoking impact forecasts of WHO (discussed in Chapter 3). Our constructed historical series and base case forecast appear in Figure 5.10.

The general forecasting approach of IFs is greatly complicated for smoking (in contrast to undernutrition and obesity) by the fact that the relationship of smoking to GDP per capita is very weak. Even the rise and fall of smoking that the four-stage model attempts to capture is not consistently related to income but has been shaped historically by the power of the tobacco industry, transmission of usage patterns internationally, and changing understandings of (and attitudes with respect to) health implications. For males, the R-squared across all countries is effectively zero. Within high-income countries it is 0.15 around a slowing downward slope that

■ *As income increases, smoking tends to increase up to a point and then to begin to decline; males have historically smoked at higher rates than females.* ■

**Figure 5.10 Adult smoking prevalence by sex and country economy classification: History and forecasts**



Note: Smoking prevalence is defined as the percent of the population over a certain age (variable by country, but typically 18 and older or 15 and older) who smoke a tobacco product on a daily or non-daily basis.

Source: IFs Version 6.32 base case forecast using a historical series constructed by combining data from WDI and WHO with Mathers and Loncar's smoking impact series (Mathers and Loncar 2006: see Chapter 3 of this volume for IFs methodology).

would suggest rates in 2035 closer to 20–25 percent than the 5 percent forecast of Shibuya, Inoue, and Lopez (2005: 481). In spite of relatively low income levels, male smoking rates in many other regions of the world, including East Asia and Pacific, where they are currently especially high, may be near their peaks.

For females, the slope of the again weak relationship of smoking to income is actually upward. Female rates are rising almost

everywhere except in high-income countries. It is possible, for example, that rates in East Asia and Pacific could rise especially sharply (in China, current rates for men are over 50 percent and those for women are under 10 percent). In contrast to the health disadvantage that women have with respect to obesity, they have historically had an advantage with respect to smoking. That is now eroding, especially in middle-income countries. Yet, stronger and better publicized evidence exists today to detail the ill-health effects of smoking. Policy initiatives, such as the global tobacco treaty, may slow initial and/or continued use in many areas. In short, any forecast of tobacco use is open to significant modification and human intervention. See the technical documentation of the IFs health model (Hughes et al. 2010) and Chapter 3 of this volume for our approach.

### **Tobacco use and related mortality: Alternative scenarios**

For several reasons, it is not appropriate to use data on the current prevalence of smoking to obtain smoking-attributable mortality estimates. Due to rapidly changing patterns in tobacco consumption, cross-country comparable data on smoking prevalence are often unavailable or inaccurate, and therefore cannot provide a reliable indicator of attributable risk. Furthermore, the health effects of smoking are related to an exposure history that is influenced in many different ways, including the number of cigarettes smoked per day, at what age smoking began, the degree of inhalation, and the characteristic of the cigarette itself (that is, tar and nicotine content, filter type, and amount of tobacco in one cigarette). And importantly, as we noted in Chapter 3, the lag between smoking and its health impacts appears to be about 25 years.

Future smoking rates remain open to human intervention. Policy initiatives can aim to change individual behavior, raise prices, limit production and export, and create environmental conditions less hospitable to smoking, such as the restrictions on public smoking passed in many countries in recent years. Therefore, we explore a “reduced smoking scenario” in which smoking prevalence falls steadily for males to 50 percent of its

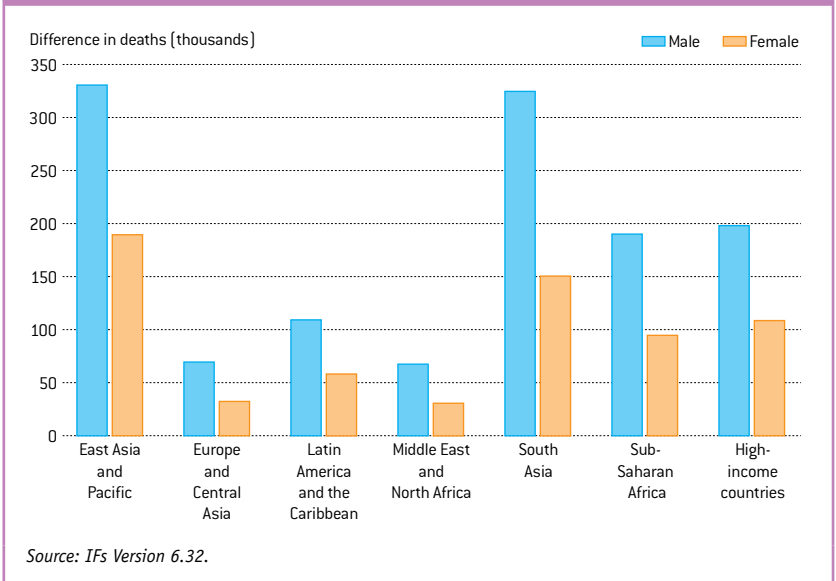


base case rate by 2030 and to 25 percent of the gender-specific base rate for females. The 75 percent reduction for females introduces a greater range of variability for them because, relative to a function with income, female cross-country variability is even greater than it is for males (see again Box 5.1 for discussion of the relationship between cross-country variability and scenario intervention values). In contrast to the more symmetrical high and low interventions that we introduced for malnutrition and obesity, we raise smoking for both sexes by only 25 percent in the high case, in part because our base case forecast already is a bit high relative to Shibuya, Inoue, and Lopez (2005) and because global momentum to reduce smoking has been growing steadily.

Figure 5.11 shows the impact separately for females and males that the high and low smoking scenarios have on mortality related to malignant neoplasms, cardiovascular diseases, and chronic respiratory diseases and conditions. The figure shows regional differences in deaths between the high and low smoking scenarios for the year 2060 only; due to the lagged effect of our smoking interventions, smoking-related deaths in 2030 differ very little between the two scenarios since they are heavily determined by smoking patterns in years already behind us. Interestingly, while our low smoking scenario is more aggressive for females than for males, men still benefit most (in terms of total deaths averted) from reducing smoking. This largely reflects higher current and projected smoking rates for men over women.

Globally, for men and women across the three cause-groups and all age categories, we forecast 1.9 million fewer deaths in 2060 from the low smoking scenario as compared to the high one. Most of the impact (79 percent) results from averted and delayed mortality from malignant neoplasms. The mortality rate reduction is smallest for chronic respiratory diseases and conditions. In combination with the increase in overall population size in the low smoking scenario, the relatively small rate reduction in chronic respiratory conditions results in a marginally greater number of deaths from respiratory diseases, especially among those over 70 years of age, in the low smoking scenario.

**Figure 5.11 Difference in forecasts of deaths (thousands) by region related to malignant neoplasms, cardiovascular diseases, and chronic respiratory conditions and diseases under high versus low smoking scenarios (2060)**



### Vehicle Ownership and Safety

WHO forecasts that by 2030 road traffic accidents will become the fifth-largest cause of mortality, contributing to approximately 2.4 million deaths a year (WHO 2009b). Although road traffic safety is often not included in analyses of major health risks (see the CRA listing in Table 2.2), this large death toll makes patterns of vehicle ownership and safety key risk factors. The discussion around Figure 5.1 identified them as a transitional (rather than traditional or modern) risk factor because they loom largest fairly early in development transitions, and the World Bank projects that fatalities will increase in every region except high-income economies (Kopits and Cropper 2005). Another rather unique characteristic is that the impact of road traffic accidents is concentrated on adults age 15–59 rather than on children or older adults. They therefore merit some of our attention for many reasons.

#### Drivers and forecasts of vehicle ownership

Mortality related to road traffic accidents depends primarily on two factors: vehicle ownership rates (vehicles per capita) and vehicle fatality rates (deaths per vehicle). Vehicle ownership tends to increase with rising GDP per capita; in contrast, fatalities per vehicle tend to decline as income rises past a relatively low level.

■ Globally in 2060, we forecast 1.9 million fewer deaths from malignant neoplasms and cardiovascular and respiratory diseases in the low smoking scenario compared to the high one. ■

WHO has projected that road traffic accidents will become the fifth-largest global cause of death by 2030.

These relationships, in combination, suggest that overall mortality will first increase along with income, before declining as income continues to rise. Consistent with this pattern, since the 1970s vehicle ownership in high-income countries has risen more slowly than the vehicle fatality rate has fallen, and overall mortality rates have decreased. In developing countries, however, traffic-related mortality has increased dramatically (Kopits and Cropper 2005).

Focusing on vehicle ownership, Dargay, Gately, and Sommer (2007: 24, Table 4) report that middle-income countries such as China are experiencing growth in vehicle ownership of as much as two times income growth (an elasticity of 2) or even somewhat more. In contrast, they anticipate that the elasticity for high-income countries will be 0.42 between 2002 and 2030. Overall, demand follows an S-shaped (or Gompertz) curve with ownership rising slowly at low income levels, quickly at middle income levels (between \$3,000 and \$10,000), and then leveling off at the highest income levels (Dargay, Gately, and Sommer 2007). In addition to income, variables that increase or decrease overall vehicle ownership costs (such as fuel prices) may also encourage or discourage ownership. Policy choices and

demographic factors play a role as well. Increased urbanization and population density may encourage the development of alternative transportation. However, if governments choose to build more roads instead, vehicles will come.

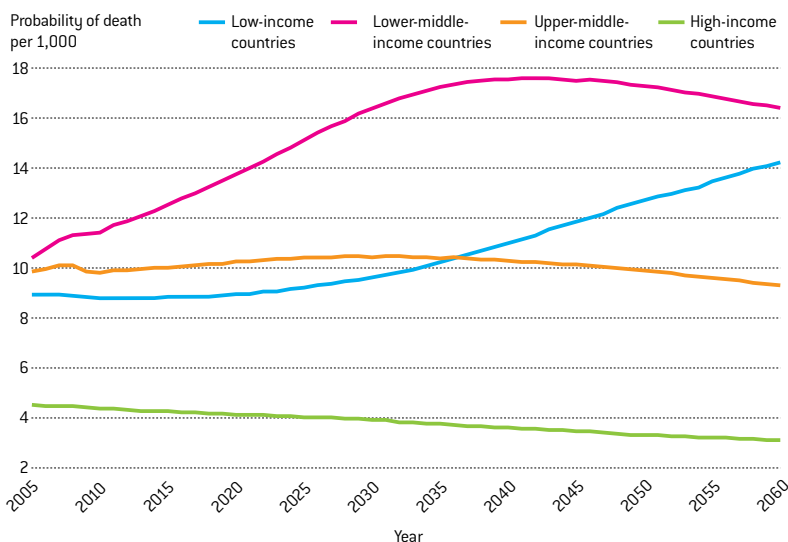
The number of fatalities per vehicle relates to characteristics of vehicles, drivers, and the larger environment. Studies credit advances in vehicle safety (such as the introduction of the three-point seat belt), driven largely through government regulation, with most proximately reducing accident death rates (O'Neill 2009). Others note that having a large proportion of either very young or very old drivers can increase the probability of a fatal accident (Williams and Shabanova 2003). Environmental and policy factors, such as road maintenance and the imposition of speed limits, may also influence mortality outcomes (Kopits and Cropper 2005; Richter et al. 2005).

Estimates of future fatality rates per vehicle depend heavily on both technological advances and policy decisions. In their forecast for the World Bank, Kopits and Cropper (2005) assume that historical cross-sectional relationships between vehicle fatality rates and income will continue to 2020. Specifically, they expect that deaths per vehicle will rise at very low levels of GDP per capita, decline rapidly at middle income levels, and then decline more modestly at high income levels.<sup>19</sup> IFs uses a variation of this relationship based on Smeed's Law (Adams 1987; Smeed 1949) that represents the downward slope only, generally appropriate because almost all the world is already past the point at which the decline begins. Chapter 3 elaborated the approach, and Chapter 4 compared IFs forecasts of fatalities with those of Kopits and Cropper and the GBD project (see Table 4.8).

### Vehicle ownership, fatality rates, and related mortality: Alternative scenarios

Figure 5.12 shows the IFs base case forecast of adult mortality probabilities from road traffic accidents resulting from our interacting forecasts of vehicle numbers and fatalities per vehicle. The mortality probability is substantially lower than that from cardiovascular diseases, but for adults it is still significant. A 15-year-old has 5 to 10 chances per 1,000 of dying from an accident before reaching the age of 60, depending on

Figure 5.12 Adult mortality probability from road traffic accidents by country economy classification



Note: Adults defined as age 15-59; probability is of a 15-year old dying before age 60 from causes related to road traffic accidents.

Source: IFs Version 6.32 base case forecast.

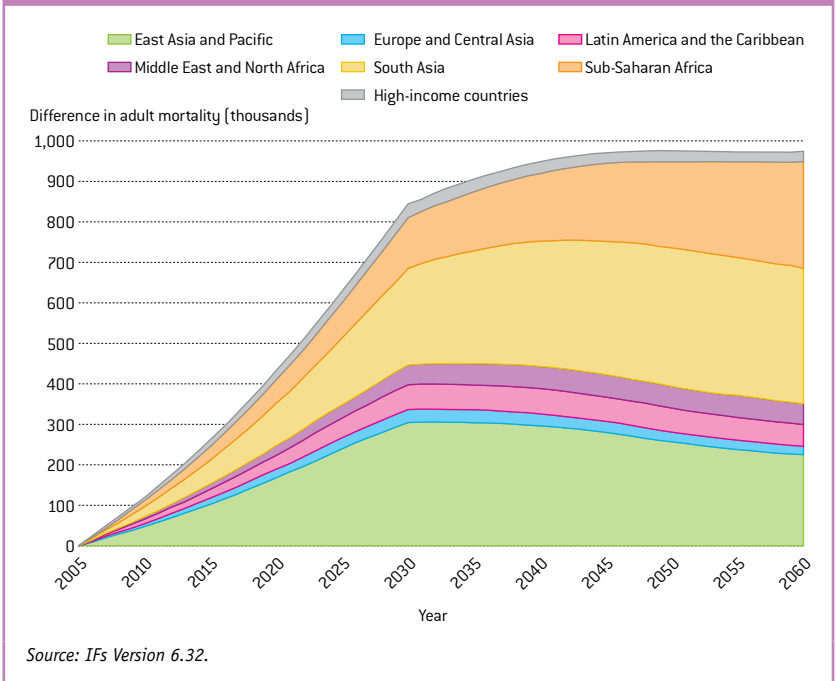
where he or she lives. Those rates are now rising quite sharply in lower-middle-income countries such as China and India, and after 2030 they are likely to do the same in low-income countries. Regionally, IFs forecasts that the biggest increases in probability of mortality will be in East Asia and Pacific, Middle East and North Africa, and South Asia, with some increase also in sub-Saharan Africa. Levels in high-income countries are likely to trend slowly down, followed by those in Europe and Central Asia, then Latin America and the Caribbean.

Government policy choices can significantly change base case forecasts. The promotion of alternative transportation or high fuel taxes would almost certainly lower vehicle ownership. Alternatively, vehicle ownership might increase under policies designed to encourage individuals to buy cars (such as programs in many countries during the global recession following 2007). Similarly, regulations around road and vehicle safety could result (as they have in many high-income countries) in far fewer accidents per vehicle and/or deaths per accident.

Therefore, we explore the potential impact of alternative scenarios concerning vehicle ownership and vehicle fatality rates. Relative to income levels, there is a great deal of cross-country variation in both of those variables. In the “favorable road traffic safety scenario,” vehicle ownership steadily decreases to 50 percent of base case values by 2030 and the fatality rate per vehicle does the same. In the instance of this proximate driver, we compare the favorable scenario with the base case (rather than an unfavorable scenario) because higher values look unlikely in the face of rising energy prices with a concomitant push toward public transport, as well as increasing vehicle safety worldwide.

Figure 5.13 shows the impact of the favorable vehicle accident scenario relative to the base case. In contrast to interventions such as reduction of undernutrition, obesity, or smoking rates, which translate only partially into reductions of death from any single disease or disease cluster (there are always other risk factors), reductions in either vehicle numbers or fatalities per vehicle translate directly into mortality reduction. Thus, while the probability of dying from a traffic accident is generally much less than

**Figure 5.13 Difference in forecasts of adult deaths (thousands) related to road traffic accidents under road traffic safety favorable scenario versus base case forecast (by region)**



the probability of dying from other causes, the total number of deaths that might be averted in a “favorable road traffic safety scenario” is quite substantial. The difference between the base case and the favorable scenario becomes especially important over time in low- and middle-income countries, where we project significant increases in vehicle ownership.

### Conclusion

As detailed throughout this chapter, significant opportunities exist to change health outcomes. We do not pretend to offer solutions for implementing successful interventions, nor can we fully understand how a reduction in one cause of death might ultimately shift the burden of disease to other death causes. However, alternative scenario analysis emerges as a useful tool for thinking about the costs and benefits of policies aimed at specific risk factors affecting population health.

The proximate risk factors highlighted (undernutrition, obesity, smoking, and road traffic safety) represent some of largest sources of avoidable mortality at the beginning of the 21st century. In the base case scenario, on a global basis we forecast a continuing decline

● Road traffic deaths result from two interacting factors that relate to income in opposite ways: vehicle ownership increases with income but fatalities per vehicle decline. ●

*In our favorable scenario, almost 1 million deaths of adults 15–59 (the age group where road traffic deaths are concentrated) are averted annually from 2040 to 2060.*

in the rate of child undernutrition from 17.6 percent in 2005 to 5.6 in 2060. Although undernutrition is resistant to rapid reduction in the near term, even sub-Saharan Africa is making progress. Yet, our scenario analysis of undernutrition suggests that considerably more rapid progress could avert about 1.8 million child deaths annually at its peak impact in 2026 compared to a more pessimistic scenario. Undernutrition will almost certainly remain one of the leading killers globally for at least the next two to three decades.

In contrast to declining rates of undernutrition, adult obesity rates will likely climb globally from 11 to 14 percent, making it a steadily growing health threat. On a regional basis, our base case suggests that middle- and high-income regions could all have rates near or above 30 percent by 2060 (their rates tend to be near 25 percent already). Our base case forecast of obesity is actually lower than other projections based more on trend extrapolation. Scenario analysis clearly suggests making a priority of interventions aimed at limiting overweight and obesity as well as continuing to fight undernutrition. In the year 2060, the IFs model forecasts 2.5 million fewer deaths globally from cardiovascular-related causes alone in the lower obesity scenario compared to the higher one.

We anticipate in the base case that global adult smoking rates will decline from 28 percent to about 25 percent in 2060, in spite of increases in some developing regions, especially sub-Saharan Africa. Reducing such anticipated smoking levels, especially among males in parts of the developing world, might result in much lower chronic disease mortality; the reduced smoking scenario forecasts approximately 1.6 million fewer global deaths (compared to the high smoking forecast) due to noncommunicable diseases in 2060. For females in developing countries, who at the beginning of this century smoke far less than their male counterparts, prevention seems a reasonable goal. Experience

in high-income countries, where smoking prevalence has fallen significantly from historically high levels, can provide some guidance to countries that wish to attenuate or to avoid progressing through all stages of a smoking epidemic.

Road traffic safety offers another area in which low- and middle-income countries will hopefully benefit from the experience of their high-income neighbors. On a global basis, the base case suggests that accidents per vehicle may decline by about 70 percent between 2005 and 2060. Vehicle ownership will almost certainly increase with income, however, and our base forecast is for a global increase in vehicles per capita that pretty closely offsets the decline in deaths per vehicle. Low- and lower-middle-income countries are at special risk as a result of a rapid rise in vehicle ownership and relatively high death rates per vehicle. Because road traffic accidents are a leading cause of death among 15- to 29-year-olds (WHO 2009b: 3), the adoption of stronger vehicle and road safety standards than are implicit in the base case could provide a unique opportunity to reduce mortality in this population and morbidity across a lifetime. In 2060, IFs forecasts more than 275,000 fewer deaths globally in this age group alone when comparing an increased road traffic safety scenario to the base case model.

This chapter has provided an introduction to possible leverage points available to policymakers looking for opportunities to reduce health risks and associated mortality and morbidity (which is closely related to mortality even though the chapter did not discuss it explicitly), across the age, sex, and regional spectrum. Chapter 6 will continue this exploration, looking at environmental links to health and further potential points of intervention. It will conclude with comparative analysis of health implications of all risk factors treated in both Chapters 5 and 6.

- 1 For the most part, we focus on behavioral risks rather than on pathophysiological risks (the mechanical, physical, or biochemical precursors or markers of disease or injury, such as elevated blood pressure and cholesterol levels).
- 2 Earlier CRA studies included 22 risk factors; suboptimal breast feeding and high blood glucose were added to bring the total to 24; occupational risks were combined in one category for a total of 24 risk factors rather than the 28 that would have resulted from looking at each of the five occupational risks separately (WHO 2009a: 5).
- 3 In making our choices, we also considered areas in which WHO and others are currently attempting major initiatives such as the Framework Convention on Tobacco Control and the Global Strategy on Diet, Physical Activity, and Health (Magnusson 2009).
- 4 Chapter 3 explained that our distal-driver formulations already include the impact of tobacco (through the smoking impact variable) on certain diseases. The diabetes forecast also adjusts for BMI, an indicator of overweight and obesity. However, the distal-driver formulations only implicitly capture other risk factors to the extent that they are correlated with changes in the distal drivers.
- 5 WHO adopted new international weight reference standards in 2006. For more detailed information on both the standard and the latest data, see the WHO Global Database on Child Growth and Malnutrition website (<http://www.who.int/nutgrowthdb/en/>).
- 6 Data available at <http://www.who.int/whosis/en/index.html>.
- 7 This estimate also includes the impacts of maternal undernutrition by taking into account the impacts on children of intrauterine growth restriction and suboptimal breast-feeding.
- 8 As Chapter 3 described, in IFs the country levels of childhood undernutrition modify under-five mortality related to all communicable diseases other than HIV/AIDS.
- 9 In some cases, of course, changes of diet under pressure of income reduction can improve health.
- 10 Data publicly available at <http://www.fao.org/worldfoodsituation/FoodPricesIndex/en/>.
- 11 For a region such as sub-Saharan Africa, where the base case forecast projects relatively high levels of childhood undernutrition continuing into mid-century, the scenarios change undernutrition forecasts significantly: from 7.7 percent (low scenario) to 23.2 percent (high scenario) in 2030, and from 4.1 percent (low scenario) to 13.0 percent (high scenario) in 2060.
- 12 Body mass index, defined as weight in kilograms divided by the square of height in meters (kg/m<sup>2</sup>), is the generally accepted index measure for classifying overweight and obesity in adults.
- 13 Weight gain may result from both total calorie overconsumption and macronutrient composition. For example, studies suggest that the proportion of intake derived from dietary fat may influence weight gain even as calories remain constant (Mosca et al. 2004).
- 14 The ways in which globalization interacts with obesity through global food trade policies and practices and developing countries' dependence on foreign aid is the subject of recent research and concern (see Cassels 2006 for the example of the Federated States of Micronesia).
- 15 Mathers and Loncar, Protocol S1 Technical Appendix (n.d.).
- 16 Males (% obese) = 205.1 - 20.4x(mean BMI) + 0.5x(mean BMI)<sup>2</sup>; Females (% obese) = 168.5 - 17.4x(mean BMI) + 0.4x(mean BMI)<sup>2</sup>. See James et al. 2004: 519.
- 17 Both males and females aged 70 and older in sub-Saharan Africa are the exception. For these groups, cardiovascular-related mortality rates peak in the early 2030s.
- 18 Doll (1998: 94) noted the surprising absence in the historical medical literature of reference to a relationship between bronchial disorders and smoking, despite the high prevalence in smokers of a persistent "smoker's cough."
- 19 Kopits and Cropper (2005: 174) estimate that fatalities per vehicle begin to decline above \$1,000 per capita and especially after reaching \$1,200 (1985 dollars), and that total traffic fatalities tend to decline in the range of about \$6,100-\$8,600. IFs currently forecasts decline in fatalities per vehicle at even lower levels.