June 11, 2013

Disease Control Priorities in Developing Countries, 3rd Edition
Working Paper #2

Copenhagen Consensus 2012 Challenge Paper Diseases
Chronic Disease Prevention and Control[1]

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[1] This paper was prepared with support from the Copenhagen Consensus Center and from the Bill & Melinda Gates Foundation through the Disease Control Priorities Network Grant to the University of Washington. We are indebted to Dean T. Jamison for his advice and guidance. We also thank David Watkins for helpful input.

Contents

INTRODUCTION

Eighty percent of global deaths from heart disease, stroke, cancer, and other chronic diseases occur in low- and middle-income countries. This paper identifies priorities for control of these chronic diseases as an input into the Copenhagen Consensus effort for 2012 (CC12). The paper and the accompanying CC12 paper on infectious disease control build on the results of the CCO8 paper on disease control (Jamison et al, 2008), and is best read as an extension of the CC08 paper on disease control.

This paper draws on the framework and findings of the Disease Control Priorities Project (DCP2).[2] The DCP2 engaged over 350 authors and among its outputs were estimates of the cost-effectiveness of 315 interventions including about 100 interventions for chronic diseases. These estimates vary a good deal in their thoroughness and in the extent to which they provide regionally specific estimates of both cost and effectiveness. Taken as a whole, however, they represent a comprehensive canvas of chronic disease control opportunities. This paper identifies 5 key priority interventions for chronic disease in developing countries which chiefly address heart attacks, strokes, cancer, and tobacco-related respiratory disease. These interventions are chosen from among many because of their cost-effectiveness, the size of the disease burden they address, their implementation ease and other criteria. Separate but related papers for CC08 deal with other major determinants of chronic diseases such as nutrition, (Behrman, Alderman and Hoddinott, 2008), air pollution (Larsen, Hutton, Khanna,

[2] The DCP2 was a joint effort, extending over 4 years, of the Fogarty International Center of the U.S. National Institutes of Health, the World Bank, and the World Health Organization with financial support from the Bill & Melinda Gates Foundation. While the views and conclusions expressed in this paper draw principally on the DCP2, others might draw different broad conclusions. In particular views expressed in this paper are not necessarily those of any of the sponsoring organizations.
The DCP2 resulted in two main volumes, both of which Oxford University Press published in 2006. One book deals with the *Global Burden of Disease and Risk Factors* (Lopez et al., 2006). The other book, *Disease Control Priorities in Developing Countries, 2nd edition* (Jamison et al., 2006) discusses interventions to address diseases and risk factors and the health systems to deliver those interventions. A first edition was published by Oxford University Press for the World Bank in 1993. This paper will refer to these two volumes as *DCP1* and *DCP2*.

2008) and education (Orazem, 2008). The health related papers for CC12 are focusing on infectious diseases (Jamison et al, 2012), sanitation and water (Rijsberman and Zwane, 2012), education (Orazem, 2012), hunger and under nutrition (Hoddinott et al) and population growth (Kohler, 2012).

The main conclusions of this paper are several. First, chronic diseases already pose a substantial economic burden, and this burden will evolve into a staggering one over the next two decades. Second, although high-income countries currently bear the biggest economic burden of chronic diseases, countries in the developing world, especially middle-income, are expected to assume an increasing share as their economies and populations grow. Third, the marginal costs for governments of achieving maximal adult survival are rising, in contrast to declines in marginal costs of achieving child survival. This divergence is a consequence chiefly of the lack of tobacco control in most low- and middle-income countries, the lack of sustained investments in new drugs, and gaps in the strategies and in the program implementation for chronic diseases. This leads to the fourth conclusion, which is that addressing chronic disease in poor countries requires a concomitant rethinking of developmental assistance and possibly new delivery approaches. Finally, selected options available to prevent and control chronic diseases appear to justify themselves in economic terms in the sense that the welfare gains and the economic losses that could be averted by investments that would reduce chronic diseases are considerably larger than the financial costs to implement them.

After some brief definitions, Section 1 of the paper first describes and contrasts the declines in childhood and adult mortality and presents current burden. Section 1 also summarizes recent work for the World Economic Forum on the cost of illness from selected chronic diseases and the resulting economic costs. Section 2 describes the DCP2 framework for choosing interventions, including issues of poverty, implementation costs and the demands of the intervention on health system. Section 3 summarizes the cost-benefit methodology. Section 4

presents specific interventions for tobacco control, prevention and treatment of vascular disease, and immunization against liver cancer as opportunities in chronic disease control, and includes very approximate cost-benefit analyses for these interventions. This paper concludes with the implications for developmental assistance. As in CC08, the paper emphasizes, although not exclusively, opportunities relevant to low-income countries in South Asia and Sub-Saharan Africa.

1. PROGRESS AND CHALLENGES

1.1 Definitions

***Epidemiological Transition*.** The next few decades will see continuation of rising trends resulting from dramatic fertility declines (and consequent population aging) that is occurring variously in countries over the last few decades. The combination of an aging population paired with increases in smoking and other lifestyle changes mean that the major chronic diseases (sometimes called non-communicable diseases or chronic non-communicable diseases)—circulatory system diseases, cancers, respiratory diseases and major psychiatric disorders—are fast replacing (or adding to) the traditional scourges—particularly infectious diseases and under nutrition in children. Additionally, injuries resulting from road traffic are adding to or replacing some of the more traditional forms of injury (although these will not be dealt with in this paper). Responding to this epidemiological transition within sharply constrained resources is a key challenge.

Table 1 provides cause-specific estimates of the number of deaths over age 5 due to major causes in low- and middle-income countries. This summary indicates that chronic disease already accounts for two thirds of all deaths over age 5 in these countries.

Table 3.1 Causes of Chronic (NCD) Death in Low- and Middle-Income Countries, Age 5 and Older, Estimates from the GBD, 2010

Disease	Deaths (in millions)	% of total
Cancers	5.6	15.0
Chronic obstructive pulmonary disease	2.5	6.7
Diabetes	1.1	2.8
Ischemic and hypertensive heart disease	6.2	16.5
Stroke	5.0	13.4
Other	5.9	15.8
Subtotal	**26.3**	**70.2**

Source: Global Burden of Disease Study 2010. Global Burden of Disease Study 2010 (GBD 2010) Results by Cause 1990-2010. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2012.

At the same time that most low- and middle-income countries need to address traditional health problems that are now effectively controlled in high-income countries, they are increasingly sharing the high-income countries' heavy burdens of cardiovascular system disease, diabetes, cancers, respiratory diseases, psychiatric disorders, and automobile-related injuries. *DCP2* has chapters addressing each of these chronic diseases and others. Until recently, the public health research and policy communities have been surprisingly silent about these epidemics even though, for example, cardiovascular disease (CVD) in low- and middle-income countries killed over twice as many people in 2001 as did AIDS, malaria, and TB combined.

Avoidable mortality: A central conclusion from nearly 200 years of epidemiology and demography is that while death in old age (after age 70 years) is inevitable, death at young ages (below age 30 years) could become a rare occurrence, and death in middle age (age 30 to 69 years) need not be common (Doll and Peto, 1981). Currently, about 60 million deaths occur worldwide per year of which 50 million are in low- and middle-income countries (as defined by the World Bank). Taking into account some expected increase in HIV deaths, then about 20 million deaths occur before age 30 (mostly in the first 5 years of life), about 20 million deaths occur during age 30-69 years, and another 20 million occur at older ages (Peto, 2006). The years of life lost are greatest for

those at young ages; even in middle age, a premature death incurs 20 to 25 years of productive life lost, often as the head of a household. Rapid reductions in child mortality over the last few decades have meant that the vast majority of the 130 million children born worldwide in 2010 can expect to reach middle age.

Today, there are an estimated 2.9 billion (United Nations, 2009) adults aged 30-69 in low and middle-income countries, and currently there are about 40 million deaths over age 30 in these countries. As of 2001, nearly 70% of deaths during these ages were from the “non-communicable diseases”, shown in Table 1. Thus as much as possible, we emphasize the avoidable premature deaths before age 70. This is not to argue that many deaths and much disability can be avoided at older ages. Indeed, Fred Paccaud (Rousson and Paccaud, 2010) points out the ideal pattern of mortality involves low death rates in young age and middle age, paired with sharply compressed time before death lived in any disability state.

Finally, although we focus chiefly here on changes in mortality, it is worth noting that the chronic diseases also carry considerable disability. Our calculations for cost-benefit take this into account, but for the purposes of tracking changes over time, use of mortality is preferred -- simply because it is far less likely to be misclassified than are the more subjective measures of disability.

1.2 Trends and Burdens

Global life expectancy has increased by about 3 months per calendar year for the last four decades, with much of this gain from sharp declines in childhood mortality (see accompanying paper on infectious disease control by Jamison et al, and the Copenhagen Century Challenge Review also by Jamison et al, 2012). Notably, adult mortality has also declined overall. Table 2 shows progress in the probability of death between age 15 and 60 for selected countries from 1970 to 2010 (Rajaratnam et al, 2010). The large increases in adult male and female (not shown) mortality in South Africa and Russia, reflect the specific effects of the 1980 onward increases in HIV/AIDS and in binge drinking of alcohol in these

countries, respectively. On the whole, the declines aside from these countries have been impressive and have been greater in the high-income countries than in low- or middle-income countries. Even within high-income countries, sharp differences in declines have been noted among the G-7 countries, with the United States doing much worse in its decline of adult male mortality, than Canada.

Table 3.2. Trends in the risk of death between ages 15-59 for males from 1970-2010, in selected countries.

	% of 15 year old males dead by age 60				
Country	**1970**	**1990**	**2010**	**Change %**	**Rank 2010**
Russia	31	32	41	34	155
South Africa	42	38	53	28	172
Brazil	27	24	19	-29	82
India	33	27	23	-31	103
China	24	20	15	-35	58
France	20	16	12	-42	33
US	23	17	13	-43	44
Germany	19	16	10	-47	24
UK	18	13	9	-48	17
Japan	17	11	8	-51	13
Canada	19	13	8	-55	11
Italy	18	13	8	-55	8
Low income	34	37	32	-5	
Middle income	26	23	22	-15	
High income	23	16	20	-13	
Global average	28	25	25	-10	

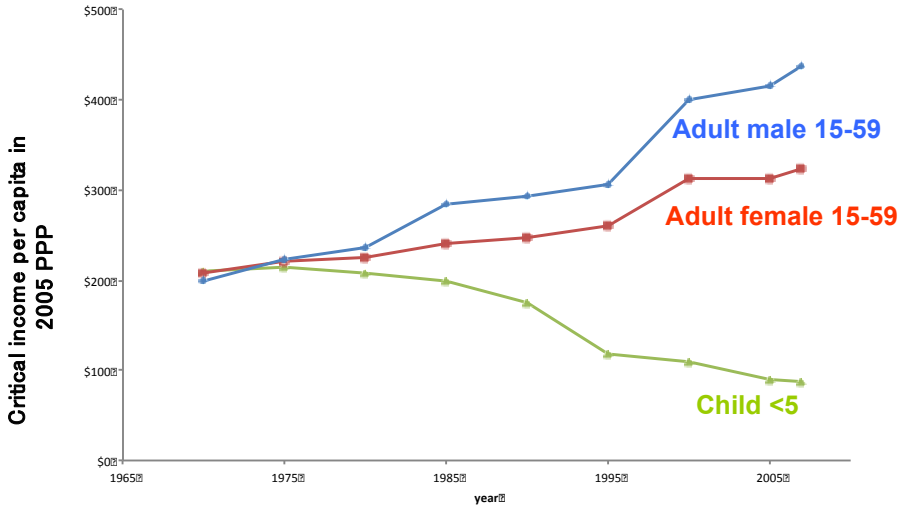
Source: Authors from IHME Data, 2010

Much of the variation in country outcomes appears to result from the very substantial cross-country variation in the rate of diffusion of appropriate health technologies (or ‘technical progress’). Comparatively, in the case of child mortality, countries range from having essentially no decline in infant mortality rate caused by technical progress to reductions of up to 5 percent per year (Jamison, Sandbu and Wang, 2004). Measham et al (2003) reached a similar conclusion concerning variation in IMR decline across the states of India. Cutler, Deaton and Lleras-Muney (2006) provide a complementary and extended

discussion of the importance of technological diffusion for improvements in health. Differing rates of technical progress are the principal source of the cross-country variation in rate of under-5 mortality decline (Jamison et al, 2012). Controlling for socioeconomic and geographic factors, under-5 mortality in low- and middle-income countries has been declining at about 3 percent per year, a high rate of technical progress.

With justification, investment in cost-effective interventions have been disproportionately devoted to child and maternal health (Daar et al, 2007) and more recently to control of HIV/AIDS, malaria and tuberculosis. In a novel analysis, Hum et al. (2013) explain that increasing coverage of inexpensive health interventions has not only reduced child mortality, but have also reduced the national income per capita required to achieve one half of the maximal survival seen in a year across countries. They define this as “critical income” which represents efficiency of mortality gains in relation to available resources, given the maximum that other countries have achieved (Figure 1). Critical income has fallen for child survival gains, with the majority of declines occurring since 1990 – coinciding with global efforts to improve child health. For adult survival, however, there is a reversal of fortune. While global adult survival has improved, Hum et al find that higher income is needed to achieve these improvements. This may explain the lower rate of decline in adult mortality in countries with low income seen in table 2, compared to the more widespread decline in child mortality (Rajaratnam et al, 2010b). High-income countries, where overall income well exceeds the critical income needed, have benefited from the rise in maximum survival among adults. The key explanation for greater disparity appears to be the lack of widespread use of treatments for chronic diseases, and sharp reductions in tobacco-attributable deaths that are occurring mostly in high-income countries. This has implications for developmental assistance for health, to which we return at the end of this paper. More disturbingly, the trend in adult critical income level continues to rise each year. This suggests that delaying concerted effort now would escalate costs in the future.

Figure 3.1. Divergence of "critical income" for child and adult mortality.



"Critical" incomes is real $ needed to achieve ½ of maximal survival (in that year) from 1970 to 2007; note higher adult costs due in part to HIV and tobacco; Source Hum et al, in press

Of course, the importance of technical progress and diffusion should be viewed in a larger context. Factors from outside the health sector also affect the pace of health improvement: education levels of populations appear quite important although the level and growth rate of income appear much less so. Expanded education improves the coverage and efficiency of disease control, as in the case of maternal education improving child health. Indeed, rapid economic growth in many parts of the world, especially in China and India, might well mean that some can buy their way into better health, but this paper argues far more benefit will occur from using public coffers on a relatively limited set of highly effective public health and clinical interventions. This point bears reiterating in a slightly different way: income growth is neither necessary nor sufficient for sustained improvements in health (Preston, 1975). The experiences of Costa Rica, Cuba, Sri Lanka, and Kerala state in India, among others, conclusively show that dramatic improvements in health can occur without high or rapidly growing incomes. Publicly-financed health care or insurance can dramatically reduce the social costs of chronic conditions, just as they have with communicable diseases

(Jeemon and Reddy, 2010). Today's tools for improving health are so powerful and inexpensive that health conditions can be reasonably good even in countries with low incomes.

1.3 Rising costs of chronic diseases

Recent analysis underscores the very large economic costs imposed on society, broadly-defined, by chronic diseases and gives rise to a compelling need for public response. Bloom, et al. (2011) estimate the economic burden of five major categories of NCDs (cardiovascular disease, cancer, chronic respiratory diseases, and diabetes) and mental health conditions) for 2010 and 2030. They do this by applying three distinct approaches to conceptualizing and measuring that burden.[3]

The *cost-of-illness (COI) approach* views the cost of NCDs as the sum of several categories of direct costs (meaning actual expenditures) and indirect costs (meaning lost output and the implicit cost of pain and suffering). The direct costs typically considered in this approach are personal medical care costs for diagnosis, procedures, drugs, and inpatient and outpatient care; personal non-medical costs, such as the costs of transportation for treatment and care; and non-personal costs like those associated with information, education, communication, and research. The indirect costs are the income losses that arise because of NCDs (with no attempt made in this report to monetize the burden of pain and suffering).[4] Due to the nature of data available on the prevalence and cost of the various conditions covered, the COI method was implemented in different ways for each condition. For example, the time frame to which the medical care cost and foregone productivity data apply differ by diseases; in addition, personal non-medical care costs are available for some diseases and not others. Therefore, cost-of-illness results presented for any one of the

[3] The data sources for this study include information on demographics, income per capita, mortality rates by disease, DALYs by disease, treatment costs per case by disease, and measures of the value of statistical life.

[4] A key assumption made in this calculation is that if someone stops working because of an NCD, there will not be another worker to take that person's place.

conditions are not directly comparable to the results presented for another. In the case of diabetes, prevalence estimates for 2030 are taken from International Diabetes Federation (2010). For all other conditions, prevalence is assumed to be constant over time. The number of cases in 2010 and 2030 is derived by multiplying incidence by the population in the respective year.

The *value of lost output approach* estimates the projected impact of NCDs on aggregate economic output (GDP) by using WHO's EPIC model to simulate the macroeconomic consequences of NCDs for the factors of production (labor and capital) that determine economic output and growth. The basic premise is that if there were no NCDs, there would be more labor and capital and hence more output.[5] EPIC calculates the output that is lost because of NCDs on a disease- and country-specific basis in 1997 international (PPP-adjusted) dollars. The EPIC results are then adjusted so they are (a) expressed in 2010 US$ (not PPP adjusted); (b) scaled up so they refer to all countries;[6] (c) scaled up using WHO data on DALYs to reflect five NCDs; [7] and (d) scaled up further, using WHO data on mental illness DALYs, to include estimates of economic losses from mental health conditions. Estimates for both 2010 and 2030 are based on WHO projections of the mortality trajectory associated with these five conditions.

The *value of statistical life (VSL) approach* reflects a population's willingness to pay to reduce the risk of disability or death associated with NCDs. By placing an economic value on morbidity and mortality, this approach goes beyond the impact of NCDs on GDP alone. Separate analyses are conducted for the five sets of health conditions, as well as for all NCDs taken as a whole. The VSL approach can be carried out in three different ways. The first method requires

[5] The model also assumes that if there were no NCDs in a given time frame, there would be no rise in deaths from other causes.
[6] The EPIC model is only calibrated for 101 countries. For the purposes of the exercises reported in Bloom, Cafiero, et al. (2011), further calibration was done for 68 countries.
[7] The original EPIC model accommodates diabetes, ischemic heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, and breast cancer. This study uses EPIC to generate results for these five conditions, and then scales up to derive figures for the larger NCD categories.

regression-based projection – for all countries in 2010 and 2030 – of (a) GDP per capita, (b) VSL, and (c) DALYs. GDP per capita is projected by extrapolation using the annual average growth rate of GDP per capita during 2004 through 2009 (drawn from the World Bank's *World Development Indicators*). VSL estimates are constructed by regressing VSL (in US$ 2000) for 12 countries reported in Viscusi and Aldy (Viscusi & Aldy, 2003) on GDP per capita (in US$ 2000) and life expectancy at birth (from the UN Population Division).[8] The parameter estimates are then applied to estimates of GDP per capita in 2010 (2030) and life expectancy data/projections in 2010 (2030) for all countries to impute VSL estimates for countries where no studies existed in Viscusi and Aldy (Viscusi & Aldy, 2003). DALYs are projected by regressing the most recent estimates of DALYs (in 2004) on GDP per capita, total population, and the share of population over age 65, and using projected GDP per capita and population projections published by the UN Population Division.[9] The second method builds on a rule-of-thumb proposed by the WHO Commission on Macroeconomics and Health. It values DALYs at one times GDP per capita (CMH1). The third method is the same as the second, except that it values DALYs at three times GDP per capita (CMH3).

Caveats

Some important caveats apply to the results presented. First, the estimates refer to the dollar impact of all future NCDs, *not* the cost of inaction, nor the cost of preventable disease burden only. Expressing the cost of NCD prevalence in dollar terms is meant to garner the attention of economic policymakers, and perhaps to spur them to action. Second, all of the methods used by these studies are sub-optimal: they all rely on assumptions that are less than ideal and on data

[8] The VSL estimates that appear here are used as primary data.

[9] The VSL data are taken to be the value of life of a representative median-aged member of the corresponding national population. For example, consider a population in which life expectancy at birth is 75, median age is 25, and VSL is US$ 1 million. Suppose further that a 50 year-old dies unexpectedly and suddenly. This death contributes 25 DALYs, and an economic loss of US$ 500,000 (= [25/(75-25)] * US$ 1 million). The CMH1, CMH3 and VSL figures reported herein may be interpreted as the total future cost of incident NCD cases in 2010 (2030). The implicit assumption is that the value of a life-year is not a function of age.

that are far from perfect. Third, the set of NCDs studied is not comprehensive; not included, for example are vision and hearing disorders, digestive diseases, and musculoskeletal diseases. And fourth, the various methods used in the report (COI, value of lost output, and VSL) are sufficiently disparate that their results cannot be compared with each other. The VSL estimates are drawn from only 10 countries, of which only one (India) is a low- and middle-income country (Viscusi and Aldy, 2003). Finally, there is uncertainty in the causes of death given low levels of medical certification of adult deaths worldwide (RGI/CGHR, 2009). However, the magnitude of the major causes of death is such that it exceeds greatly the uncertainty in the point estimates. Indeed, the major uncertainty is in the size and shape of the future tobacco hazards which make several of the chronic diseases more common (Jha, 2009). The estimates are simply intended to provide a ballpark idea of the economic cost at the macro level of NCDs, to complement estimates of their impact on morbidity and mortality. Estimates of cost at the micro level (on households and individuals) for specific populations have been published elsewhere (Suhrcke et al, 2006, IOM, 2010). Better data and further refinement of analytical techniques will yield more accurate estimates.

1.3.1. Cost-of-illness (COI) estimates

- Cancer: *The 13.3 million new cases of cancer worldwide in 2010 are estimated to cost US$ 290 billion.* Medical costs accounted for the greatest share at US$ 154 billion (53% of the total), while non-medical costs and income losses accounted for US$ 67 billion, and US$ 69 billion, respectively. *The total costs are expected to rise to US$ 458 billion in the year 2030.*
- Cardiovascular disease (CVD): *In 2010, the global cost of CVD is estimated at US$ 863 billion (an average per capita cost of US$ 125), and it is estimated to rise to US$ 1,044 billion in 2030 – an increase of 22%.* Overall, the cost for CVD could be as high as US$ 20 trillion over the 20-year period (an average per capita cost of nearly US$ 3,000). Currently

about US$ 474 billion (55%) is due to direct healthcare costs and the remaining 45% to productivity loss from disability or premature death, or time lost from work because of illness or the need to seek care.

- Chronic Obstructive Pulmonary Disease: *The global cost of illness for COPD is projected to rise from US$ 2.1 trillion in 2010 to US$ 4.8 trillion in 2030*. Approximately half of all global costs for COPD arise in developing countries.
- Diabetes: *Diabetes cost the global economy nearly US$ 500 billion in 2010. That figure is projected to rise to at least US$ 745 billion in 2030,* with developing countries increasingly taking on a much greater share of the outlays.
- Mental health conditions: *The global cost of mental health conditions in 2010 was estimated at US$ 2.5 trillion, with the cost projected to surge to US$ 6.0 trillion by 2030.* About two-thirds of the total cost comes from indirect costs and the remainder from direct costs. Currently, high-income countries shoulder about 65% of the burden, which is not expected to change over the next 20 years.

1.3.2 Value of lost output

Over the period 2011-2030, the total lost output from the five NCD conditions (including mental health) is projected to be nearly US$ 47 trillion (see Table 3). On a per-year basis, this loss is equivalent to about 5% of global GDP in 2010. For every country income group, cardiovascular diseases and mental illnesses each account for approximately one-third of the total loss. High-income countries, which currently account for only 16% of world population, are slated to absorb 55% of the loss, largely because their economic output per capita is high. That is, when a high-income worker stops working because of an NCD, the lost economic output is much greater than in a country where economically-measured output is lower. Conversely, lower- and middle-income countries, which together currently account for only 25% of world income, are projected to experience 45% of the losses. Upper-middle-income countries will experience nearly one-third of the

cost of NCDs over the period 2011-2030, even though their share of world mortality is currently only 10%.

Table 3.3: Economic burden of NCDs, 2011-2030 (trillions of US$ 2010), based on EPIC model

Country income group	Share of world economic losses from NCDs	Share of world population, 2010	Share of world mortality, 2008	Share of world income, 2010 (constant 2000 US$)	Total loss	CVD	Can-cers	CRD	Dia-betes	Mental illness
Low (L)	0.02	0.12	0.43	0.01	0.9	0.3	0.1	0.1	0.0	0.3
Lower-middle (LM)	0.12	0.37	0.32	0.05	5.4	2.0	0.5	0.9	0.2	1.9
Upper-middle (UM)	0.32	0.36	0.10	0.19	14.9	4.8	2.3	2.2	0.6	5.1
High	0.55	0.16	0.14	0.75	25.5	8.5	5.4	1.6	1.0	9.0
L + LM + UM	*0.45*	*0.84*	*0.85*	*0.25*	*21.2*	*7.1*	*2.9*	*3.2*	*0.8*	*7.3*
World					**46.7**	**15.6**	**8.3**	**4.8**	**1.7**	**16.3**

Notes: CVD = cardiovascular disease; CRD - chronic respiratory disease

Tobacco use is unique in its scale of contribution to these costs as it makes more common deaths from vascular disease, cancers and chronic respiratory disease, which together account for about 28.7 trillion dollars (or about 60% of the total loss for all chronic diseases). Conservatively estimating that tobacco is a cause of about 1/3 of the vascular disease, half the cancers and 60% of chronic respiratory diseases (Peto et al, 2006; Jha, 2009), we estimate a total economic loss from tobacco of about 12.7 trillion dollars (Table 4). This corresponds approximately to about 1.3% of GDP on annual basis, or roughly $0.9 trillion in 2010 terms. Section 4.2 further discusses the economic costs/benefits of tobacco use.

Table 3.4: Economic burden of tobacco, 2011-2030 (trillions of US$ 2010), based on EPIC model

Country income group	Total due to vascular disease, cancers and chronic respiratory	Tobacco attributable loss
High	15.5	6.6
Lower and middle	13.2	6.0
World	28.7	12.7

Source: Author calculations

1.3.3 Value of statistical life (VSL) approach

The VSL approach leads to economic burden estimates that vary widely, which valuation depending on assumption is used, by a factor of more than 6 – from 2010 US$ 3.6 to 22.8 trillion in 2010, and from 2010 US$ 6.7 to 43.4 trillion in 2030 (see Table 5). The upper end of these estimates looms exceedingly large, representing a notable and growing fraction of GDP, but even at the lower end, these estimates for 2010 and 2030 are sizable. All three methods used in this approach show that high-income countries currently bear the greatest burden. But all three methods also show that in 2030 upper-middle-income countries will approach high-income countries in burden borne.

Table 3.5: Value of life lost due to NCDs, by estimation method and income group (trillions of 2010 US$)

Country Income Group	2010 Total (CMH1)	2030 Total (CMH1)	2010 Total (CMH3)	2030 Total (CMH3)	2010 Total (VSL)	2030 Total (VSL)
Low (L)	0.0	0.1	0.1	0.2	0.5	1.0
Lower-middle (LM)	0.2	0.6	0.6	1.9	2.4	5.3
Upper-middle (UM)	0.7	2.6	.2.1	7.8	5.1	17.4
High	2.7	3.4	8.0	10.3	14.8	19.7
L + LM + UM						
World	**3.6**	**6.7**	**10.7**	**20.2**	**22.8**	**43.4**

Notes: Table incorporates losses from all five categories of NCDs; CMH1 = DALYs valued at one times GDP/capita; CMH3 = DALYs valued at three times GDP/capita

Conclusions of costing studies

Three main messages from the economic analyses are summarized herein. First, NCDs already pose a substantial economic burden, and this burden will evolve into a staggering one over the next two decades, particularly from tobacco use. Second, although high-income countries currently bear the biggest economic burden of NCDs, the developing world, especially middle-income countries, is expected to assume an ever larger share as its economies and populations grow and third, cardiovascular disease and mental health conditions are the dominant contributors to the global economic burden of NCDs.

The above estimates on the economic costs of chronic diseases are consistent with earlier studies of economic losses due to medical costs and productivity losses of poor health (CMH, 2002) including from more extreme changes in adult mortality arising from advanced HIV/AIDS epidemics (CMH, 2002). Moreover, earlier work by Jamison et al (2002) examined the contribution of improvements in adult survival to economic growth in the former socialist economies. Among 52 countries, adult male survival between ages 15 to 60 (45p15) rose from 70% to 80% between 1965 and 1990. This better survival raised income growth by 0.23% per year between 1965 and 1990, after adjustment for changes in physical capital, education, fertility, economic openness, and technical progress. Between 1960 and 1990 there was a sharp divergence in the survival probability of males between the former socialist economies (FSE) in Eastern and Central Europe and those in the OECD. Much, but not all of this 1960-1990 difference was attributable to the markedly higher rates of tobacco attributable mortality in FSE (Peto et al, 1996; Zatonski and Jha, 2002). However the 1990 onward dramatic worsening of adult mortality in many FSE countries, particularly Russia, is due to binge alcohol drinking (Zaridze et al, 2009). Jamison et al (2002), estimated that were adult male survival in FSE at levels in OECD countries, annual growth rates over the last three decades would have been about 1.4% vs. 1%. This would have meant that the 1990 per capita income would have been $3000 versus the actual of $2700, or about 12% higher or $140 billion greater.

Murphy and Topol (2006) have estimated that in the United States gains in longevity between 1970 and 1990 (using willingness to pay to avoid death) amount to: $57 trillion or over 50% of the average of GDP per year during the period. About half of the gain was from reduction in heart disease alone. They further estimate that elimination of heart disease and cancer would generate about $47 and $48 trillion in economic value respectively. They further find, consistent with Hum et al (2011) analysis, that there are increasing returns in health improvements.

Given the enormous health and economic burden of chronic diseases, we next turn to the criteria to assess which of the numerous interventions might be used to reduce disease.

2. MAJOR CRITERIA TO ASSESS PRIORITY INTERVENTIONS

2.1. Chronic disease and poverty

A starting point for cost-effectiveness analysis is to observe that health systems have two objectives: (a) to improve the level and distribution of health outcomes in the population and (b) to protect individuals from financial risks that are often very substantial and that are frequent causes of poverty (WHO, 2000). Financial risk results from illness-related loss of income as well as expenditures on care; the loss can be ameliorated by preventing illness or its progression and by using appropriate financial architecture for the system.

The distribution of chronic diseases has often been assumed to be one that falls mostly on affluent, more educated and urban adults in low and middle-income countries. A variety of recent epidemiological data, including from the ongoing Indian “Million Death Study” finds that the highest burdens of cancer, stroke, and heart attacks are in the least educated and in the rural areas (RGI/CGHR, 2009). For example, the age-standardized cancer mortality rates were surprisingly similar in rural and urban areas, and were 2-fold higher in the least educated compared to the most educated adults (Dikshit et al, 2012). While this pattern is not universally true in LMICs, a growing body of literature points toward NCDs becoming associated with lower socioeconomic status (SES). For example, in high-income countries, risk factors such as smoking and high intake of saturated animal fat were first introduced in higher income groups, but transformed over time to become more common in lower SES groups (Popkin et al, 1996).

Most low- and middle-income countries lack universal health coverage and safety nets to prevent large expenditures on out of pocket spending during illness. In many of these settings, chronic disease thus can cause households to fall into poverty. Recent work by Reddy et al (2007), finds that risk factors for heart attacks and acute heart attacks and their associated treatment costs are a major source of distressed selling of household assets or severe debt. Similar work by

John et al (2011) finds that tobacco use is a major source of households falling below the poverty line in India. Conversely, new evidence by Xavier et al (2008) finds that the risk of death after a heart attack was notably higher in the lowest socioeconomic group (Table 6). However, upon adjustment for the access to treatments, including heart attack “clot” busting drugs and adjustment for the higher levels of smoking and other risk factors in the poor, these marked differences in death rates disappeared.

Table 3.6: Post heart-attack mortality by income, Indian males

	Rich	Upper mid	Lower mid	Poor	P for trend
Death rate (unadjusted)	*5.5*	*5.9*	*6.5*	*8.2*	<0.0001
Death rate (adjusted for RFs)	*5.1* 1.0	*5.9* 1.16 (0.83,1.63)	*6.7* 1.32 (0.96, 1.82)	*7.8* 1.57 (1.12, 2.20)	0.0093
Death rate (adjusted for RF+Trt)	*6.9* 1.0	*7.0* 1.01 (0.50, 2.02)	*6.5* 0.94 (0.48, 1.84)	*6.7* 0.96 (0.46, 2.01)	0.9487

RF=Risk factors such as age, sex, previous heart attack, diabetes, hypertension, smoking, heart rate, body mass and stage of heart attack. **Treatment=Trtm:** type of hospital, time to hospital, use of in-hospital drugs, interventions. Source Xavier et al, 2010. Risk ratios of the highest socioeconomic group are taken as the baseline and plotted as a value of 1.0.

2.2. Demands of intervention on health systems

The literature on economic evaluation of health projects typically reports the cost per unit of achieving some measure of health outcome—quality-adjusted life years (QALYs) or DALYs or deaths averted—and at times addresses how that cost varies with the level of intervention and other factors. Cost-effectiveness calculations provide important insights into the economic attractiveness of an

intervention, but other considerations—such as consequences for financial protection and demands on health system capacity—need to be borne in mind.

We can consider two classes of resources to be available: financial resources and health system capacity. To implement an intervention in a population, the system uses some of each resource. Just as some interventions have higher dollar costs than others, some interventions are more demanding of system capacity than others. In countries with limited health system capacity, it is clearly important to select interventions that require relatively little of such capacity. Human resource capacity constitutes a particularly important aspect of system capacity, discussed in a report of the Joint Learning Initiative (Gostin et al, 2011). Jamison et al (2008) provides a more extended discussion.

Although in the very short run little tradeoff may exist between dollars and human resources or system capacity more generally, investing in the development of such capacity can help make more of that resource available in the future. Mills, et al. (2006) discuss different types of health system capacity and intervention complexity and point to the potential for responding to low capacity by selecting interventions that are less demanding of capacity and by simplifying interventions. Mills, et al. also explore the extent to which financial resources can substitute for different aspects of system capacity (see also Gericke et al, 2003). An important mechanism for strengthening capacity, inherent in highly outcome-oriented programs, may simply be to use it successfully—learning by doing. Re-orientation of system capacity might also hold the potential to deliver interventions for chronic conditions in a more cost-effective manner than currently implied. Health system capacity in low- and middle-income countries may be ill-suited to respond to chronic conditions in particular, which demand long-term, sustained care, close monitoring, and specialized knowledge following the care model used in high-income countries. Even in some high-income countries, current chronic disease management schemes are perceived to be

unsustainable due to increasing caseload, cost, and suboptimal outcomes related to low quality of care.

Increased costs of chronic disease in developing countries are fueling experimentation in the field of chronic care delivery models. This conversation is taking place in the context of efforts to strengthen developing country health systems to manage a broader array of health conditions and achieve better outcomes. It is conceivable that experimentation in low- and middle-income countries to identify and scale-up affordable prevention and treatment of chronic conditions may fuel reverse technology transfer that could slow the rise of health costs in developed countries.

In the traditional (Western) healthcare model, the primary care provider (usually a physician) manages chronic illness, with input from specialist physicians and ancillary services such as pharmacists. More recently, there has been a turn towards more collaborative models that shift tasks and give patients more responsibility over their own care. The following types of programs have recently been promoted, particularly in the U.S. and U.K: the “Chronic Care Model or CCM” (Pearson et al, 2005), peer support programs, self-management interventions, and “full self-management” (van Olmen, 2011). Aside from full self-management, these strategies have been trialed and their cost-effectiveness estimated in limited settings, as discussed below.

Collaborative care strategies have been recognized for over a decade, and the best-known example is the CCM, which expands team-based primary care disease management. Several studies from the U.S. and other countries show immediate improvement in process outcomes, e.g., percent of diabetics screened, as well as delayed improvements in intermediate outcomes, e.g., changes in average plasma glucose concentration (Coleman, 2009). More recently, evidence has emerged of cost-effective reductions in adverse events and mortality from a societal perspective (Huang et al., 2007). The CCM is a

complex intervention, however, and its cost-effectiveness as a whole model has not been established (Coleman, 2009), therefore, it is perhaps more salient for developing regions to examine individual components, since the CCM is highly resource-intensive and would be difficult to scale to less developed health systems (van Olmen, 2011). The World Health Organization has developed the Innovative Care for Chronic Conditions (ICCC) model, which is meant to scale CCM-based principles to resource-limited settings (WHO, 2002). Unfortunately, rigorous trials of this program have not yet been conducted in developing countries.

Some of the components of the CCM and ICCC have undergone economic assessment. These include case management, peer support, and self-care. Shifting to lower-level providers and caregivers for on-going patient support shows promise for achieving good outcomes at lower cost in developed country settings. Protocols of nurse-led diabetes case management are cost-effective in low-income American populations, with ICERs approximately US $10,000 per QALY (Gilmer et al., 2007). Similarly, multidisciplinary home-based care for chronic heart failure is cost-saving in South Australia and markedly improves survival (Inglis et al., 2006). Peer support, or “lay-led” programs make use of highly knowledgeable patients with chronic diseases to be community spokespersons for behavior change or self-management. Peer support for diabetes (Lujan et al., 2007) and tobacco addiction (Woodruff, 2002) were highly cost-effective with results driven by the size of the potential gain from the healthy behavior that is being promoted – whether changing diet, quitting tobacco, or adhering to a complicated regimen of medications (Carr et al., 2011). These findings were echoed by an earlier meta-analysis demonstrating that behavior change (in the context of a self-management program) can lead to clinically meaningful reductions in blood pressure and glycemic control (Chodosh et al., 2005). One study of peer programs in Cambodia combined individual clinic counseling and peer support for patients with diabetes, hypertension, and HIV (Janssens et al., 2007). Cost-effectiveness was not assessed.

A final component of “collaborative care” relates to tools for self-care and self-management without explicit peer assistance. Many of these programs use internet- or mobile phone-based technology to educate patients and improve adherence. Overall, the literature on self-management interventions shows mixed results, depending on the condition and type of intervention. Examples of effective interventions include SMS-based diabetes self-care (Liang et al., 2011) and interactive health education software developed for various chronic diseases (Murray, 2005). Worldwide cell phone usage is expected to reach about 5 billion in the 2010s, and as such offers a novel platform for information and delivery of services. In the near term, limits on technology and connectivity beyond simple mobile phone and SMS technology are likely to deter broader applications for disease management.

3. COST-BENEFIT METHODOLOGY

This section explicitly builds on the cost-benefit analysis framework in the CCO8 paper on disease control (Jamison et al, 2008). The basic approach to cost-benefit analysis used in this paper is to start with the cost-effectiveness (CE) results from the extensive comparative analyses reported in *DCP2* (Jamison et al, 2006; Laxminarayan et al, 2006). These results are expressed as the cost of buying a DALY, a summary measure involving mortality change and a valuation of disability change that can be considered to have been generated by calibration against mortality change.

Section 3.1 describes an idealized version of our approach to CE – idealized in the sense that it seeks to explicitly call attention to the value of financial protection and nonfinancial costs (e.g. use of limited system capacity). The point is to serve as a reminder in drawing conclusions of some important considerations that go beyond the CE ratios reported. Section 3.2 discusses DALYs. Section 3.3 draws on Section 2 to assign, very conservatively, dollar values to DALYs for the subsequent cost-benefit assessment. Section 3.4 summarizes this paper's approach to costing.

3.1 Cost-effectiveness analysis broadly and narrowly construed

As mentioned in Sections 2.1 and 2.2, a starting point for cost-effectiveness analysis broadly construed is to observe that health systems have two objectives: (a) to improve the level and distribution of health outcomes in the population and (b) to protect individuals from financial risks that are often very substantial and that are frequent causes of poverty (WHO, 2000). Financial risk results from illness-related loss of income as well as expenditures on care; the loss can be ameliorated by preventing illness or its progression and by using appropriate financial architecture for the system.

The literature on economic evaluation of health projects typically reports the cost per unit of achieving some measure of health outcome—quality-adjusted life

years (QALYs) or DALYs or deaths averted—and at times addresses how that cost varies with the level of intervention and other factors. Pritchard (2004) provides a valuable introduction to this literature. *DCP1* reported such cost-effectiveness findings for about 70 interventions; *DCP2* does so as well, in the end providing evidence on about 315 interventions. *DCP2* authors were asked to use methods described in Jamison et al., (2006).

3.2 Defining and redefining DALYs

The DALY family of indicators measures the disease burden from the age of onset of a condition by summing an indicator of years of life lost (YLL) due to the condition and an indicator of years of life lost due to disability (YLD) resulting from the condition. Disability-adjusted life years (DALYs) due to a condition are the sum of the relevant YLLs and YLDs.

DALYs generate a measure of the disease burden resulting from premature mortality by integrating a discounted, potentially age-weighted, disability-adjusted stream of life years from the age of incidence of the condition to infinity using a survival curve based on the otherwise expected age of death. The formulation within the family of DALYs previously used to empirically assess the global burden of disease specifies a constant discount rate of 3 percent per year and an age-weighting function that gives low weight to a year lived in early childhood and older ages and greater weight to middle ages. The current global burden of disease estimates are generated with the 3% discount rate but uniform age weights (Lopez et al., 2006a). Mathers et al. (2006) provide an extensive exploration of the uncertainty and sensitivity inherent in disease burden assessment, including the results of differing assumptions about age weighting and discount rates.

To be clear about the particular form of DALY being used, the terminology from Mathers et al. (2006) is employed. DALYs(r,K) are DALYs constructed using a discount rate of r percent per year and an amount of age weighting indexed by a

parameter *K*. DALYs(3,1) are DALYs generated with a discount rate of 3 percent per year and with full age weighting, that is, *K* = 1. DALYs(3,0) are DALYs generated with a discount rate of 3 percent per year and with no age weighting, that is, *K* = 0. Mathers, Lopez and Murray (2006) present results concerning the burden of disease based on DALYs(3,0); Ezzati, et al. (2006) present estimates of the burden of major risk factors. Ezzati, et al. (2006) is based on DALYs (3,0).

3.3 The Value of a DALY

The VSL estimates discussed in Section 1.2 yield a range of values for a statistical life— from around 100 to almost 200 times per capita income. Very approximately this can be translated to a value for a statistical life year in the range of 2 to 4 times per capita income. Tolley, Kenkel and Fabian (1994) provide a valuable overview of relevant estimates, including estimates of the value of preventing disability. The emphasis in Tolley et al. (1994) is on low-income countries defined by the World Bank for 2001 as countries with per capita incomes of less than $745. The World Bank's estimate of the average income of people living in low-income countries is $430 per year (World Bank, 2003, Table 1.1). Choosing a value for a statistical life year near the low end of the range (a little above 2) would give a convenient value of $1,000, which is what this paper uses in its main calculations as the value of a DALY. We explore the sensitivity of our results to these assumptions by using a DALY value of $5000.

3.4 The cost of a DALY

The cost of buying a DALY with different interventions was calculated, in *DCP2*, by combining 'typical' prices for a geographical region (Mulligan et al. 2003) with input quantities estimated from clinical and public health experience and case studies in the literature. For internationally traded inputs prices were the same for all regions. (Because of tiered pricing, off-patent drugs were *not* considered to be internationally- traded.) For local costs regional estimates were used. Intervention costs, therefore, are *not* expressed in PPP dollars. The reason for this is that local costs present decision-makers with the appropriate numbers for

budgeting and for comparing interventions in the context where they are working. The estimates of DALY benefits from various interventions were provided by each DCP2 author team, and do vary across disease groupings.

4. OPPORTUNITIES FOR CONTROLLING CHRONIC DISEASES

This section provides a specific overview of the most cost-beneficial interventions, including considerations of their system demands, risk protection and other metrics described above. It then goes on to discuss briefly examples of prevention and treatment of chronic diseases.

4.1. Cost benefits of selected interventions

The DCP2 experience shows that there is a broad range of reasonable estimates of the cost-effectiveness of most interventions. This results partly from (often highly) incomplete information and uncertainty. It results also, and even more importantly, from the responsiveness of the cost-effectiveness function to variations in prices, in the scale of the intervention (and of its substitutes and complements), and in the epidemiological environment.

Given these often broad ranges in CE ratios, and hence in BC ratios, it makes little sense to conclude with precise estimates or with attempts to quantify statistical uncertainty around the point estimates. Rather we have identified major opportunities for investment in interventions that address a large disease burden highly cost effectively (Table 7). Even valuing DALYs at a conservative $1,000 the benefit to cost ratios associated with investing in these opportunities is enormously high. Appendix A provides a brief assessment of the sensitivity of our findings to key assumptions. Overall this suggests that the conclusions in our Table 7 are conservative.

Table 7 lists the main health outcomes influenced by the five interventions that were selected for their high benefit-cost ratios. Calculations were derived from reliable estimates of the adult mortality (age 30-69) for the world arising from those health conditions. Benefits were valued at $1,000 per death following the value of statistical life discussed above. Costs of each intervention were taken from experience or published estimates to depict as closely as possible the full

social costs of intervening but, absent social values in most instances, the costs reflect financial estimates. An indicative benefit-cost ratio is calculated.

Table 3.7. CHRONIC DISEASE CONTROL: KEY INVESTMENT PRIORITIES

Priority Area	Indicative Benefit-Cost Ratio	Level of Capacity Required[a]	Financial Risk Protection Provided[a]	Relevance for Development Assistance[a]	Annual Costs ($ billions)	Annual Benefits[b]
1. Cancer, heart disease, other:tobacco taxation	40:1	L	H	H	0.5	1 million deaths averted or 20 million DALYs
2. Heart attacks (AMI): acute management with low-cost drugs	25:1	H	H	H	0.2	300,000 heart attack deaths averted each year or 4.5 million DALYs
3. Heart disease, strokes: salt reduction	20:1	M	H	H	1	1.3 million deaths averted or 20 million DALYs
4. Hepatitis B immunization	10:1	H	H	H	0.1	150,000 deaths averted or 3 million DALYs
5. Heart attacks and strokes: secondary prevention with 3-4 drugs in a “generic risk pill”	4:1	H	H	H	32	1.6 million deaths averted or 118 million DALYs averted

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

Table 7 orders opportunities by benefit cost-ratio—from 40:1 for tobacco taxation to 3:1 for the “generic risk pill". Every opportunity in the table has not only a high estimated B:C ratio but also addresses major disease burden. For example, despite considerable cost of $32 billion a year, secondary management with the “generic risk pill” would treat over 320 million adults, and avoid annually about 16

million heart attacks and strokes a year (of which a significant number would be fatal).

Table 7 also provides a “dashboard” of indicators that can be used as selection criteria for interventions provided by a public health system and/or development assistance. These include the demands placed on health system capacity, the degree of financial protection afforded, and the relevance to donors of each of the interventions selected for this analysis. The ratings of level of capacity required are, admittedly, speculative, and are drawn mostly from the author experience and feedback from the DCP2 authors (Laxminarayan et al, 2006). Thus, they use only a qualitative ranking of high capacity (meaning substantial transaction and organizational costs) to low capacity (meaning much less administrative and organizational effort to implement the intervention). Experience with implementation of heart attack treatment and, to a lesser extent, tobacco taxation and salt reduction, is much more limited in low-income countries. There is a strong case for early, large-scale implementation trials in each of these 3 areas, and correspondingly strong arguments for international development assistance to finance these trials and learn from their results.

The opportunities identified don’t explicitly address the strengthening of health system capacity. It will be important to ensure that implementation includes related investments in human resources and institutions, with ‘related’ broadly defined. In the cases of tobacco taxation and salt reduction, this could include public sector capacity to impose change on the private sector. One might consider there to be two broad approaches to strengthening health systems. One involves relatively non-specific investments in capacity and reforms of process. The second involves creating specific capacity to deliver priority services in volume and with high quality. In the second model capacity strengthening spreads out from high-performing initial nodes. The approach that this paper implicitly advocates is very much in the spirit of the latter.

These analyses are consistent with a recent World Health Organization (2012) report that examined both population-wide and individual-focused measures that low- and middle-income countries can take to reduce the burden of chronic diseases. The study finds that “best buy” interventions are relatively inexpensive, and further, evaluates interventions on the basis of other criteria including system capacity. For US$ 2 billion per year (less than US$ 0.40 per person) low- and middle-income countries can adopt a set of feasible population-based measures that can reduce the burdens imposed including those by tobacco, unhealthy diet, and lack of physical activity. Adding interventions that focus on individuals would result in a total cost of US$ 11.4 billion, implying an annual per capita investment of less than US$ 1 in low-income countries and approximately US$ 3 in upper-middle-income countries.

Reducing tobacco use

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

Smoking is already more common among poor (uneducated) males than among richer (educated) males, and smoking mortality accounts for about half of the difference in mortality risk between rich and poor men in Western countries (Jha et al, 2006b).

Per adult consumption of cigarettes (cigarettes smoked, divided by the population of smokers and non-smokers) has more than halved in the last 2-3 decades in the US, United Kingdom (UK), Canada, France and other high-income countries (Forey et. al, 2009). In contrast, male smoking has risen sharply in many low- and middle-income countries such as China and Indonesia (Jha, 2009) (Figure 2). Indian smoking is mostly in the form of bidis, which are smaller than cigarettes and typically contain only about a quarter as much tobacco, wrapped in the leaf of another plant. Bidis account for approximately 85% of total smoked tobacco consumption in India, although cigarettes appear to be displacing bidis among younger males over the last 12 years (Joseph et.al, 2011). Brazil, exceptionally, has recorded decreases in the prevalence of adult smoking (Monteiro et al., 2007).

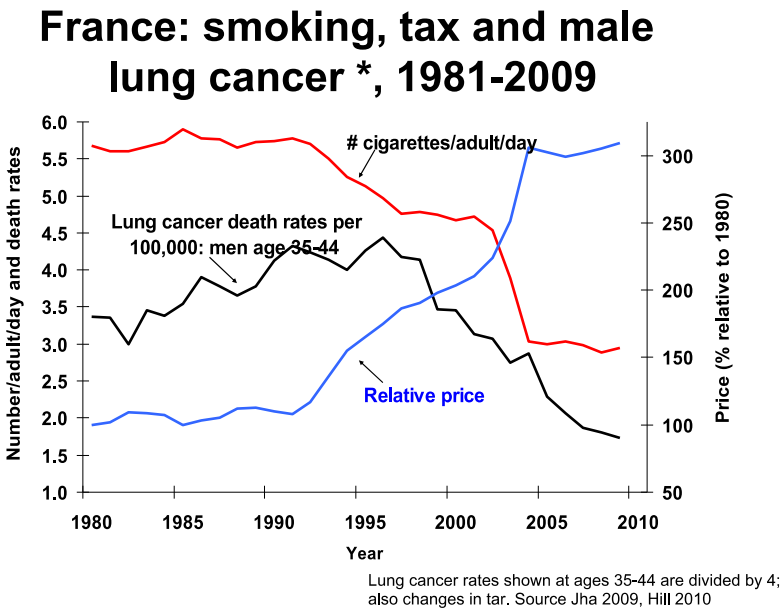
Preventing the initiation of smoking is important because addiction to tobacco makes smoking cessation very difficult, even for the numerous individuals who would like to do so. However, helping people quit smoking is at least as important as preventing initiation. Far more lives could be saved between now and 2050 with successful efforts to help people stop smoking than with efforts to keep them from starting. Reducing smoking levels is demonstrated to be well within the control of public policy. Indeed, many OECD countries have seen substantial declines in smoking deaths over the past 2 decades; for example, lung cancer deaths among young men 30–44 years of age have fallen by nearly 80% in the United Kingdom (Peto et al, 2006) a change attributable chiefly to marked increases in cessation. Also, in OECD countries more than 30% of the adult population are ex-smokers, in contrast to only 2-5% in India, 9% in China and 15% in Thailand (Jha et al, 2006a). Tobacco tax increases, dissemination of

information about the health risks of smoking, restrictions on smoking in public and work places, comprehensive bans on advertising and promotion, and increased access to cessation therapies are effective in reducing tobacco use and its consequences (Jha et al, 2006a). Of these, tobacco taxation is particularly effective--with a 10% increase in price leading to a 4 to 8% drop in consumption (roughly equally split between cessation and power initiation). Young people and the poor are particularly more responsive to price (Jha and Chaloupka, 2000a). Because the poor in many countries are more responsive to price than higher income groups, tax increases might not be as regressive financially as would be believed. Analyses of the US federal excise tax increase of $0.53 in 2009 suggests that Americans below the poverty line bore 12% of the marginal higher tax, with Americans twice above the poverty line bearing 67% of the increase. In contrast, the health benefits were very progressive- with nearly half of the reduced deaths arising in those below the poverty line (Chaloupka et al, 2012). Indeed, in Canada, aggressive tobacco control and use of higher taxes has led to greater absolute declines in tobacco deaths among the lowest income group of men than in the highest income group of men (Singhal et al, 2012).

Powerful policy interventions to tax and regulate consumption and to inform consumers have reduced consumption in most high-income countries (Forey et. al, 2009; Molarius, et. al, 2001; Jha and Chaloupka, 1999). The US and UK each took about 35 years and Canada about 25 years to halve per adult cigarette consumption (from about 10 per adult per day to about 5) (Forey et. al, 2009). However, France took only 15 years (Hill and Laplanche, 2003). France's uptake of smoking was chiefly after the Second World War and its prevalence rose until the mid-1980s. From 1990 to 2005, cigarette consumption fell from about six cigarettes per adult per day (which is comparable to the per capita adult male consumption in India today) to three cigarettes (Figure 2). This decline was mostly due to a sharp increase in tobacco taxation starting in 1990 under the then president Jacques Chirac. These price increases raised the inflation-adjusted price by threefold. Among men, the corresponding lung cancer rates at

ages 35-44 fell sharply from 1997 onward. During this period, revenues in real terms rose from about 6 billion euros to 12 billion euros (Hill, 2010). Of note, the stagnation in tax levels from 2004 onward when Nicolas Sarkozy became finance minister has also led to stagnation in per capita cigarette consumption. The decline in lung cancer was also due, more controversially, to replacement of high-tar with lower-tar cigarettes (Jha and Chaloupka, 1999).

Figure 3.2.



Source: Jha 2009, Hill, 2010

High specific excise duties are far more likely to discourage switching between different types of tobacco products, are much easier to administer, and produce a much steadier stream of revenue (WHO, 2010). The exact impact of this excise duty structure would depend, of course, on the market conditions, industry efforts to counter the tax hike, and on large-scale tax avoidance. The use of excise duty also would decrease the difference between higher and lower priced cigarettes, effectively increasing the public health impact. In India, higher taxes on all length of cigarettes would slow growth of lower length cigarettes that appear to be displacing bidi sales (Joseph et. al, 2011). The main weakness is that such excise duties need to adjust periodically for inflation, which is much higher in

developing than in developed countries. Thus a complementary strategy is to raise the excise duty every year, in line with overall inflation and preferably in excess of inflation, such that the number of ex-smokers increases every year. Australia and New Zealand have opted to raise tax rates above inflation automatically, rather than necessitating annual increases through the usual channels (WHO, 2010). France pursued such an objective starting in 1991, and increased cigarette prices by 5% or more in excess of inflation (Recours 1999; see above). In high inflation settings, it might make sense to focus on affordability, in which case tobacco taxes would be increased by enough to raise prices above income growth so as to reduce affordability (Blecher and van Walbeek, 2004).

An increase in cigarette taxes of 10% globally would raise cigarette tax revenues by nearly 7% as the fall in demand is less than proportional to the price increase in most countries (Jha and Chaloupka, 1999). However, taxes are underused in most developing countries (Guindon and Bettcher, 2001; Blecher and van Walbeek, 2004). Taxes tend to be absolutely higher and account for a greater share of the retail price (71% as of 2006) in high-income countries. In low- and middle-income countries, taxes account for 54% of the final price of cigarettes (Jha and Chaloupka, 1999). In South Africa, tax as a percentage of retail price fell to about 20% around 1990, but has subsequently risen to nearly 40% (Jha and Chaloupka, 1999). As a result, consumption fell from about 4 cigarettes per adult per day to 2 over a decade (van Walbeek, 2005). Poland's recent tax increases have doubled the real price of cigarettes and dropped consumption (Ciecierski, 2003). Mauritius and Mexico recently raised taxes by about 30%, which has already reduced consumption.

A tax increase needed to raise the street prices of cigarettes by 70% would involve a 2 to 2.8 fold increase across countries (Jha, 2009). The increase would raise the street price from about $0.7 to $1.3 in low-income countries, from about $1.3 to $2.3 in middle-income countries and from $3.7 to $6.3 in high-income

countries. Such increases, while large, have been achieved in numerous countries, including Canada, France, Poland and South Africa and within the various states of the US. Indeed, price elasticity studies (Tauras and Chaloupka, 2004) suggest that the 2.5 fold increase in the US federal cigarette tax as of 2009 (rising by 62 cents to $1.01/pack) might get about 1 million Americans to quit smoking and deter another 2 million youth from starting, thus saving over 1 million lives.

Tobacco use is substantially different than other health challenges as it involves a consumer good, with presumed economic benefits from that consumption. This has led to criticisms that tobacco control ignores the welfare benefits of smoking (Wolf 2006). Given that smoking is addictive and that most smoking starts early in life when youths are short sighted, the calculation of welfare benefits is tricky (meaning that these benefits are simply the costs of withdrawal from smoking). In countries with good information, the vast majority of smokers themselves support much higher taxation on tobacco products (WHO 2010). Moreover, the nature of the tobacco industry's manufacturing process of cigarettes is to spike cigarettes with nicotine in ways that increase the addictive power of tobacco (USDHSS, 2001). This is not to argue that cessation is not possible, as large numbers of adults in the US and other high-income countries have quit smoking in recent decades (Jha 2009). But the presence of information gaps, the strong addictive properties of consumption, and the considerable costs of quitting smoking on physical and mental health mean that defining the welfare benefits which would normally be calculated against the costs of illnesses (shown above to be quite sizeable at about 1.3% of global GDP) might well be zero. Hu and colleagues (Hu, Xu and Keeler, 1999) examined deadweight losses in China and noted these varied greatly from quite small to actual deadweight gains from reduced smoking- depending on the assumptions.

The biggest cost of smoking is the value of life foregone among smokers who wish to quit, but struggle against the strongly addictive properties of tobacco.

Putting addiction into a cost-benefit framework is equally tricky. Peck et al (2000) built on an earlier framework by Barnum (1994) by comparing the consumer and producer surplus of tobacco (based on price and supply elasticities) to the value of statistical life (conservatively valued as 1 times per capita GDP) weighted by tobacco-related mortality and the degree to which health smoking risks are known. They conclude that if a typical smoker underestimates his or her own health costs by 3% to 23%, then the net benefits of consumption are zero. Similarly, the marginal costs of a 10% higher price due to taxation have net welfare gains as long as 3% of smokers or more underestimate their health risks of smoking. Gruber and Mullainathan (2002) have conducted recent economic work that incorporates addiction into consumption choices and conclude higher taxes increase welfare because the health costs to smokers are huge (even though the external costs to others might be small). The same work finds that higher cigarette taxes do not hurt the poor (since the self-control value of higher taxes helps the poor more).

In sum, it might suffice to say that the tobacco market suffers from three major market failures, thus justifying a public response. Two market failures relate to lack of sufficient information for consumers to make a rational decision about tobacco use: i) most consumers do not have full knowledge of risks associated with the consumption of tobacco, and ii) consumers, especially young smokers, underestimate the risk of addiction to tobacco. In India, few smokers know that 70% of smoking deaths occur during productive middle age or that the average years of life lost from smoking is as great as 10 years, and less than 50% know that smoking is a cause of stroke (Government of India-IIPS, 2011). In China fully 61% of smokers thought tobacco did them no or little harm (Chinese Academy of Preventative Medicine, 1997). The lack of information on the full risks of smoking paired with the strongly addictive nature of manufactured smoked tobacco results in smokers facing high costs (withdrawal symptoms and physical distress) if they try to quit. In high-income countries with good information on smoking hazards, over 80% of adult smokers wish they had never started. Thus, there is no

comparable consumer product that carries such severe health risks from continued use, causes regret among informed consumers, and has high costs from the withdrawal of its use. Moreover, the tobacco industry specifically engineers cigarettes to be addictive, and designs reinforcing media messages and consumer signals to maintain this addiction (US DHHS, 2001).

The third market failure arises from health externalities from exposure to tobacco smoke and some financial externalities due to public spending to treat diseases caused by smoking. The costs of exposure to second hand smoke have not been well studied in developing countries. However, 6-15% of health spending estimated to go toward tobacco-related diseases in other developing countries (Lightwood et. al, 2000). The direct cost of treating four major tobacco-related diseases in India amounted to United States dollars (USD) 1.2 billion, or 4.7% of India's national health care expenditure in 2004 (John et. al, 2004). Of course, the adage that the cheapest patient is a dead patient also applies to smoking-related deaths, and indeed some have argued that the death of smoker saves money for others in pension schemes (Raynauld, 1992). However, this argument relies on the false assumption that smokers are fully informed about their consumption choices. Moreover, the costs to households who lack formal insurance schemes or pensions and in whom smoking-related diseases leads to poverty or borrowing to treat the sick and loss of intergenerational wealth transfers is likely to be large. A recent study finds that after accounting for direct expenditure on tobacco by Indian households in 2004, tobacco consumption in India impoverishes roughly 15 million people (John et. al, 2004). Households with a smoker have worse child health outcomes, including lower immunization rates in children (Rani et. al, 2003).

While acknowledging the importance of attempts to estimate welfare losses associated with tobacco use and cessation, our approach in this paper is simpler. We use published estimates of the costs of mounting a comprehensive tobacco control program (analogous to the "combination prevention" approach to HIV

transmission). CDC has recommended expenditures of $1-4 per capita but some US states have done well with less. Estimates for India from *DCP2* are for about $80 million per year. This figure includes costs of mobilizing public support, anti-smoking advertising and promotion, support for cessation programs and tax administration costs. (Proposed levels of taxation are revenue-enhancing for governments relative to the overall cost of comprehensive anti-smoking program, but our B:C analysis is based on social costs). In light of the range of published program cost we use $0.5 billion per year as a reasonable estimate of the cost of comprehensive programs in the low- and middle-income countries. Indeed, this is the amount of tobacco control funding pledged from the philanthropic foundations of Bill and Melinda Gates and Michael Bloomberg. Our specific estimates of mortality reduction are based on the effect of a 33% price (about a 50% increase in tax) on demand with a price elasticity of 0.4% (i.e. a 10% increase leads to about a 4% reduction in demand, of which about half is on current consumption), and assume a total of 1 million deaths (or 20 million DALYs) averted annually. Jha et al. (2006) reported that, over 50 years, worldwide, among smokers alive today, a 33 percent price increase would yield to a reduction of 22 to 66 million deaths. This B:C ratio of 40:1 is reported in Table 7.

4.2. Management of acute and chronic vascular diseases

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

proportion of these diseases in high-income countries, where they are concentrated at older ages.

The main risk factors for CVD account for very large fractions of the deaths (and even more of the burden) from those diseases. For ischemic heart disease, they collectively account for 78 percent of deaths in low- and middle-income countries; for stroke, they account for 61 percent (Ezzati et al, 2006). Measures to reduce the levels of those risk factors—high blood pressure, high intake of saturated animal fat, smoking, obesity, binge drinking of alcohol, physical inactivity, and low fruit and vegetable consumption—are the goals for prevention. Unlike experience with controlling tobacco use, there have been far fewer attempts to change the behaviors leading to obesity, hypertension, adverse lipid profiles, or physical activity and there are few examples of success at a population level. Notable exceptions are the remarkable decline of 25% in vascular mortality in the 1990s in Poland, which appears due to macroeconomic reforms that effectively removed the government subsidy for butter overnight, and simultaneously opened up markets from Western Europe of fresh fruits and vegetables as well as products with lower amounts of saturated fat (Zatosnki and Jha, 2002), and the Finnish experience of reducing vascular mortality first in North Karelia, and then country-wide, with an aggressive population-based program of interventions. Common sense suggests that they should be initiated even while more systematic efforts to develop and evaluate behavior-change packages are ramped up.

4.3.1. Low-cost generic risk pills for vascular disease

Despite the uncertainty in effective interventions to prevent elevated blood pressure, blood lipids, and diabetes, there is considerable evidence that simple combination of cheap drugs can be highly effective at reducing mortality among the millions of adults in South and East Asia who have some existing vascular disease or diabetes (Rodgers, et al, 2006; Gaziano, et al, 2006; Peto, 2006). Consider the following: in the absence of any drug therapy, adults with previous

stroke, heart attack, diabetes or any other evidence of some serious vascular disease have about a 7% annual risk of either dying or being re-hospitalized with a recurrence. If they take an aspirin a day, that risk drops to 5%; if they add two more drugs to reduce blood pressure and blood lipids, it drops to 2%. The exact sequence of drugs matters little, but being on 3 or 4 drugs (aspirin, a blood pressure pill or two, and a statin drug to lower cholesterol) daily versus none means a 10-year risk of death or re-hospitalization of about 50% untreated versus 16% on treatment. All these drugs are low-cost, and thus could be easily packaged into “polypills” or generic risk pills for widespread use (Peto, 2006). Indeed, China’s success in widely accessible tuberculosis therapy with several drugs serves (Dye and Floyd, 2006) as a model on which simple drug therapy for vascular disease could be introduced in the region.

Provision of a generic risk pill to adults could be cost-effective. We consider a cohort of about 400 million adults to have some indication of existing vascular disease (typically by a physician diagnosis or earlier clinical event). Of these, using Indian registry data, about 20% of them will already be on treatment (80 million adults; Xavier et al, 2008) therefore 80% (320 million adults) would see the benefits of the pill. Without treatment, about 5% would have a stroke or heart attack (16 million events) and 10% of these events will be fatal, as acute management of these is uncommon in most developing countries (a total of 1.6 million deaths or 24 million DALYs if one assumes 15 DALYs per death averted). The rest (90% or 14.4 million adults) will have disability (disability weight of 0.437 (Lopez et al. 2006a)), which leads to about 94 million DALYs. Hence, the intervention would avert a total of 1.6 million deaths (or 118 million DALYs) annually. If the cost per adult patient were $100, the total cost would then be $32 billion per year. Hence a B:C ratio of 118/32 ~ 4:1 (Table 7).

Pharmaceutical interventions to manage two major components of cardiovascular risk—hypertension and high cholesterol levels—are well established and are highly cost-effective for individuals at high risk of a stroke or

heart attack. Adding aspirin to the list of pharmaceutical interventions can reduce risk significantly further. From at least the time of publication of *Disease Control Priorities in Developing Countries,* 1st edition (*DCP1*), researchers have recognized that the low cost and high effectiveness of drugs to prevent the reoccurrence of a cardiovascular event made their long-term use potentially cost-effective in low-income environments. Even if sustained behavior change proves difficult to achieve, medications have the potential to reduce CVD risks by 50 percent or more. Gaziano et al. (2006) and Rodgers et al. (2006) develop the current evidence on that point. A key problem, however, concerns the health care personnel and systems requirements associated with the need for lifelong medication, a problem also facing antiretroviral therapy for AIDS and the use of medications to target several major psychiatric disorders. Adherence to drugs is a key issue, but unlike the challenge with AIDS drugs, resistance to the polypill drugs are unlikely, and their costs are quite low. Uncertainty about adherence is one of the prompts for exploration of alternative chronic care, discussed in section 2.2 above.

Aside from the lifelong requirement for drug use associated with CVD risk reduction in high-risk individuals, treatment of acute heart attacks with inexpensive drugs is slightly less demanding of system resources and also cost-effective (Gaziano et al., 2006). Given the high incidence of these problems, system-wide efforts to achieve high rates of appropriate drug use in response to acute heart disease are a high priority. As identified by Jamison, Jha and Bloom (2008) and reported in Table 7, acute management of heart attacks with low cost drugs is highly cost-effective with a B:C ratio of 25:1 and the prevention of 300,000 heart attack deaths (4.5 million DALYs) at a cost of $200 million, annually (Jamison, Jha and Bloom 2008).

4.3.2 Prevention of obesity and diabetes

Obesity and lack of physical activity are clear risk factors for development of diabetes, which can be further compounded by raising blood pressure and

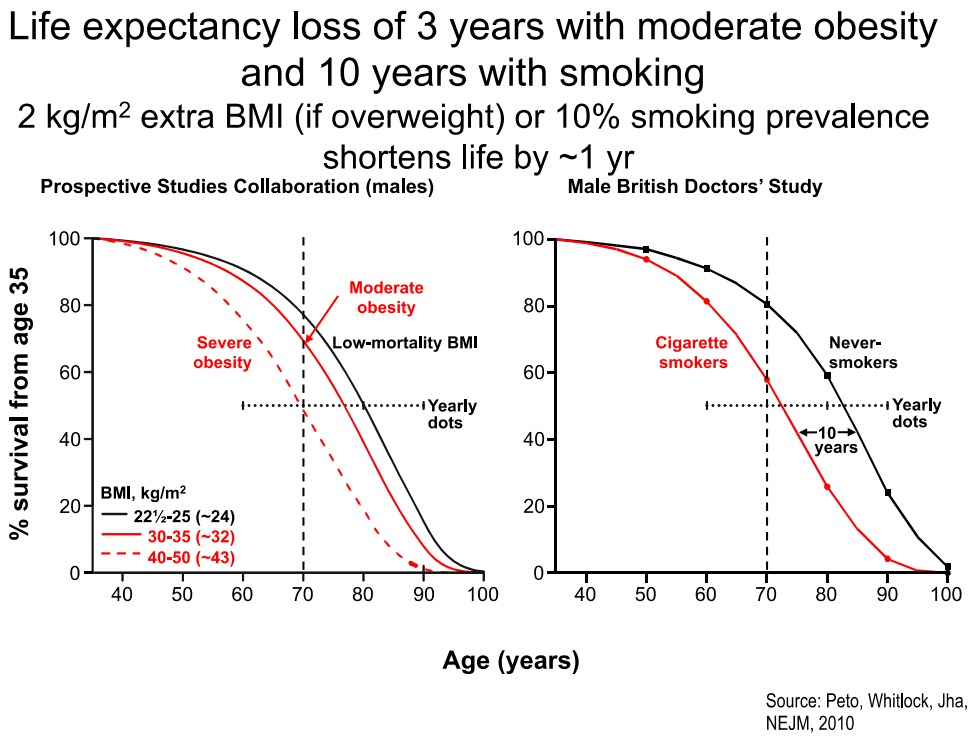
contributing to lipid imbalances, such as elevated “bad” cholesterol (PSC Collaborators, 1995). These factors work together, so only careful epidemiological studies can tease out which contribute to eventual mortality from vascular disease, and to a less clear extent from selected cancers. It is clear that diabetes rates are markedly increasing with urbanization: in China and India, diabetes prevalence among urban adults is nearly 10 times that of their rural counterparts (Jha and Anderson, 2007). However, the contribution of body mass to premature mortality in developing countries such as India and China may well be different, for reasons that are not well understood. A 10-year prospective study of 220,000 men in urban China found higher risks of vascular deaths among those with elevated body mass index (BMI), but also excess risk at low BMI levels. Indeed, the excess risk at lower BMI persisted after restricting analysis to never smokers or excluding the first 3 years of follow-up, and became about twice as great after allowing for blood pressure (Chen, et. al, 2006). In Mumbai (formerly Bombay), India elevated as well as low BMI were noted; thinness was more common among illiterate men, and was associated with smoking and chewing tobacco, whereas higher education was associated with raised BMI (Gupta and Metha, 2000; Shukla, et al, 2002). Interventions to reduce obesity, aside from the general recommendations to increase physical activity are not yet widely practicable. Better public information on risks, including more widespread communication of emerging scientific findings for large, reliable studies, is likely to influence both individual behaviour by adults, and lead to further public demand for control of risk factors.

4.3.3. Comparison of smoking and obesity risks

Studies of tens of thousands of deaths have reliably assessed mortality from adult obesity and from persistent smoking in developed countries (Peto et al, 2010). In the Prospective Studies Collaboration study (1995) of 70,000 deaths in 900,000 adults, an increase of two units in the body-mass index (BMI; the weight in kilograms divided by the square of the height in meters) among men who were overweight, reduced life span by one year (mostly from an increase in vascular

disease death rates). This loss of one year of life was comparable to the reduction in life span with an increase of 10% in the prevalence of smoking seen among UK doctors (Doll et al, 2004; Figure 3). Moderate obesity (overweight, defined as BMI range 30-35, mean 32) shortens life expectancy by approximately three years. Only among the small minority of adults with severe obesity (BMI range 40-50, mean 43) was the loss of life comparable to the ten years lost for being a life long smoker. Thus, stopping smoking (which is widely practicable) can lead to a gain of about ten years in life expectancy; far more than smokers could expect from weight control (which is currently far less practicable).

Figure 3.3: Mortality risks from smoking and obesity



Source: Peto, Whitlock, Jha, NEJM, 2010

Male survival, ages 35-100: severe obesity and cigarette smoking each shorten life expectancy by ~10 years, and moderate obesity shortens it by ~3 years; so, 2 kg/m2 extra BMI (if overweight) or a 10% prevalence of smoking shortens it by ~1 year. Left: Prospective Studies Collaboration analyses of BMI among males; effects among females are not greater (PSC Collaborators, 1995). Right: Analyses of persistent cigarette smoking among male British doctors (Doll, et al, 2004).

4.4. Salt reduction

High blood pressure is a significant chronic disease risk factor, responsible for at least 50 percent of cardiovascular disease, particularly stroke and ischemic heart disease. Reduction in salt intake is a key factor in reducing hypertension. Moderate salt reduction can lower systolic blood pressure by small (1.7 to 3.4 mm Hg) but meaningful amounts (He, MacGregor 2004, Hooper et al, 2004).

Salt reduction was identified by WHO as a "best buy" for NCD prevention and control (WHO, 2011) and attention is turning to finding the most effective methods to achieve it. Depending on the diet composition in a population, greater effect may occur through interventions to reduce salt in food processing or at the

cooking or eating stages. The former approach is being tried in Latin America where Brazil, Argentina and Chile are among the countries with industry agreements to reduce salt in processing. The main limitation in salt reduction strategies is the unproven impact on changing behaviour when salt is mostly added at the table often as a sole condiment to food. This is the dietary pattern in much of India and Asia for example.

Increasing numbers of countries are implementing national policies to reduce salt consumption. Population-based interventions to achieve salt reduction include information and behavior change to reduce use at the point of cooking and eating and changes by manufacturers in processed product formulation and food preservation through regulatory or voluntary steps. Studies of consumer acceptance of reduced salt from developing countries have not yet been done, but experience in the US and other developed countries suggest that substantial reduction from current levels is feasible with little or no consumer resistance. Selecting the appropriate level of intervention to achieve the greatest possible reduction in salt intake requires understanding local consumption habits and food systems. For instance, Argentina and South Africa are focusing on salt reduction in bread (Rubinstein et al, 2010, Bertram et al, 2012). Reducing salt in bread has been found to be very cost effective in Argentina with an ICER of (2007) I$1407 or a savings of US$703 per DALY gained. The cost-effectiveness of 15 to 30 percent reduction in salt intake in Mexico through the two channels of voluntary and legislated manufacturing changes and labeling was modeled. The average cost-effectiveness across the population is US$286 (in 2005 US$) per DALY gained (Salomon et al, 2012).

Asaria et al (2007) estimated the cost-effectiveness of interventions to achieve lower systolic blood pressure for age groups and sex across 23 low- and middle-income countries, which account for 65 percent of global population. They describe a combined population-level intervention to reduce salt intake through voluntary manufacturing changes, behavior change using mass media and other

awareness raising campaigns. As pointed out in DCP2, the cost-effectiveness of public information efforts through mass media or other campaigns varies widely depending on the population reached and assumptions about their responsiveness to information. Large reductions in salt intake – up to 30 percent of average daily intake – are achievable through changed table and cooking behavior, but depend on context. Population-level manufacturing changes have become a favored intervention in recent years because they appear to reduce this uncertainty.

Over a 10-year period (2006-15), Asaria et al estimate that a 15 percent reduction in salt consumption in 23 low- and middle-income countries would avert 8.5 million deaths. This is achieved through lowering blood pressure by 1.24 to 3.46 mm Hg (depending on age) at an average cost of US$0.14 per capita. Our analysis uses this figure as the basis for per capita program costs. The salt reduction intervention is most cost-effective in countries with high average salt intake, such as China and Philippines.

The 23 countries from the list of Asaria et al. (2007) count 2.1 billion adults over age 30; the total world population counts about 3.3 billion people (United Nations 2009). If one were to scale the intervention presented by Asaria et al. (2007) to the global level, potentially, this intervention would save 13 million deaths over 10 years (~ 200 million DALYs assuming 1 death averted corresponds to 15 DALYs). At a tentative cost of $0.3 per adult per year, the total costs of the intervention would be $10 billions over 10 years. Hence, the B:C ratio would be 20:1.

4.5 Hepatitis B vaccination

Hepatitis B is a viral infection that attacks the liver and can cause acute and chronic disease (WHO, 2012). It is transmitted through contact with body fluids, especially blood, of a person infected (WHO, 2012). In high-income countries, hepatitis B transmission occurs mostly during adolescence or at the early

adulthood, with the onset of sexual activity and drug abuse involving unsafe reuse of needles (Brenzel et al, 2006). In low- and middle-income countries, such as in sub-Saharan Africa and South Asia, hepatitis B transmission occurs mostly at early childhood through contact with infectious body fluids and unsafe injections, and through mother to infant transmission (Brenzel et al, 2006).

About 2 billion people worldwide have been infected with hepatitis B and about 350 million live with chronic infection (WHO, 2012). An estimated 600,000 persons die each year due to the consequences of hepatitis B (WHO, 2012). For those who are already infected, strategies to reduce co-factors, such as exposure to alflatoxins and alcohol, are required.

Hepatitis B is preventable with a safe and very effective vaccine of 75 to 95% efficacy (Brenzel et al, 2006). Current global immunization coverage with hepatitis B vaccine is high, at 75% (WHO, 2011). The cost per child vaccinated with hepatitis B monovalent vaccine (birth dose) is of to 2-4 US dollars (Brenzel et al, 2006). The cost of India's hepatitis B immunization program, vaccinating about a 37% of the Indian birth cohort (about 10 million children) is of 1.8 billion Indian Rupees (US$ 36 million) (Jha and Laxminarayan, 2009), leading to a cost per vaccinated child of about US$ 3.6 in India.

Most vaccine-preventable diseases result in deaths occurring at an early age, shortly after vaccination usually. On the contrary, deaths from hepatitis B happen many years into the future. Therefore, countries and immunization programs that introduce hepatitis B vaccination today will not see most of the health benefits for many years. A 1-, 5- or 10-year time period into the future is to short to accumulate the total health benefits (deaths averted) resulting from universal hepatitis B immunization today, as deaths from liver cancer or liver cirrhosis occur at older ages (Brenzel et al, 2006).

Universal immunization with hepatitis B vaccine is highly cost-effective. Consider aiming for universal immunization of the world birth cohort (~ about 136 million children (United Nations 2009)), which corresponds to raising the immunization coverage from 75% to 100%. Take a cost of $3.6 per child vaccinated. The total annual cost would be of $122 million (or about US$ 0.1 billion (Table 7)). If we assume that this 25% incremental coverage raise would avert 25% of the 600,000 annual deaths 40 years into the future (about 150,000 deaths or 3 million DALYs (assuming 1 death averted corresponds to 20 DALYs averted) (Table 7)), then the undiscounted B:C ratio would be 30:1. Discounting health benefits to present value at a 3% discount rate would yield a B:C ratio of about 10:1.

This calculation evidently presents limitations in terms of the dynamic modeling of transmission including herd immunity as well as a potential exogenously-driven decline of hepatitis B-related mortality and morbidity because of other behavioral or dietary interventions in the future.

5. Implications for development assistance for health

The spreading awareness of changing health needs in developing countries to include chronic disease has not translated into major shifts in resources from international donors or governments in affected countries. The donor role in addressing specific global health conditions is important for several reasons. First, poor countries face severe resource constraints and have little to no latitude to add services, especially for seemingly less urgent needs. Second, donors provide global public goods in the form of research. Third, donor priorities influence their own resource allocations for health conditions, as well as provide a signaling effect to middle- and low-income governments.

According to a recent review of donor health funding, chronic disease receives the smallest amount of donor assistance of all health conditions, having lost ground since 1990 relative to infectious diseases (IHME 2010) Donor assistance for health (DAH) was estimated at almost $26 billion in 2009. The amount allocated to chronic disease (chronic diseases) was $270 million, or about 1% of the total (IHME 2010). An earlier, more comprehensive, measure of global health funding for chronic diseases that includes corporate philanthropic contributions and research funding shows $750 million dedicated to chronic diseases in 2008, or less than 3 percent of the total (Nugent and Feigl 2010). In relation to the burden of disease, donors and other funders provided about $0.76/DALY lost due to chronic diseases in developing countries, compared to $12.5/DALY lost due to all infectious diseases (Nugent and Feigl 2010).

The costs of chronic diseases on a global basis have been estimated for specific diseases and regions of the world as consuming significant GDP shares (these estimates were discussed in section 1.2 of this paper).

The picture of donor involvement in chronic diseases is not entirely bleak. Narrowly-defined NCD donor funding rose from $30 million in 1990 to $270 million in 2009 (IHME, 2011). This translates into a nine-fold rise over the period.

The largest share of the increase in NCD funds for developing countries comes from private, non-profit donors, and there is evidence of accelerating interest from public donors (Nugent and Feigl 2010).

The above findings on large and growing costs of chronic diseases, escalating costs to achieve maximal survival, and the growing tobacco and obesity epidemics all suggest that a more fundamental re-alignment of developmental assistance is required. While such major changes may not be politically feasible in the short or even medium term, we pose them nonetheless. The main requirement might well be to substantially re-engineer developmental assistance, particularly from bilateral agencies, to solve the intervention, delivery and implementation challenges of chronic disease control. Specifically, households in low- and middle-income countries already spend considerable sums on adult clinical services (such as those for acute or chronic management of heart attacks). Thus, the key issue is to ensure that the spending is as effective and cost-effective as possible. Borrowing from the success in reducing childhood mortality, the requirement for adults would see a considerable scale up and change in traditional development assistance to focus on research of new interventions as well as operational research and modules to deliver these at low cost.

While such as substantial shift in the nature of developmental assistance may be feasible even without substantial increases in overall funding if cost-saving or low-cost interventions are prioritized, the longer-term prospect is that health services will need to shift substantially toward chronic care and disease management. Hum et al (2012) suggests that the marginal costs of increasing longevity are rising. The logic is that chronic diseases consume a substantial amount of adult disposable income, pose considerable risk to economic growth prospects of low- and middle-income countries, and governments in low and middle-income countries require more know-how and intervention strategies and tools, including operational tools, to tackle chronic diseases. Thus, the

requirement is less to finance directly these services, but rather to conduct research which makes the marginal costs of these affordable. As with the development of cheaper and widely available technologies for the prevention and treatment of under nutrition and infectious diseases, this implies the need for greater R&D for technology, but also investment in both implementation science and in closing the “know-do” gap. Specific examples might well be to permit more rapid licensing and approval of generic drug risk combinations, and perhaps even to think of global subsidies to alter risk behaviors, along the lines of the AmFM. Also needed is a substantial scale up of mortality statistics and risk factor information on chronic diseases, perhaps based out of WHO (WHO Ad Hoc Committee, 1997).

Over the past few decades, the development of new technologies (drugs, vaccines, policies) has focused mostly on childhood and infectious disease, with fewer worldwide investments in research and development for adult chronic diseases. Thus the longer-term trajectory of critical incomes for adult survival might well depend on the development of newer interventions, as well as more widespread application of interventions already proven to be cost-effective.

Appendix A: Sensitivity Analysis

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

1. The discount rate is 3% per year and the version of the DALY that was used was based on this 3% and *no age weighting*. These are the assumptions used in the most recent presentation of methods, data sources and results on the global burden of disease (Lopez et al, 2006a, 2006b).

2. In an attempt to include relevant health systems costs and to take a long-run view, cost estimates in this chapter are based on long-run average costs (at least in principle as there is some variation in actual costing methods).

3. The chapter assumes the value of a DALY to be $1,000.

4. The chapter assumes zero deadweight loss from taxation.

We proceeded in a sensitivity analysis of our findings while examining three dimensions of sensitivity:

i) A change in the discount rate from 3% to 5% per year.

We then moved from the use of DALYs (3,0) to the use of DALYs (5,0). Therefore, 30 years of life lost discounted at 3% (~ 20 DALYs), when discounted at 5%, amounted to 15 DALYs: in this case, all health benefits and B:C ratios were divided by 4/3. In the same way, 20 years of life lost discounted at 3% (~ 15

DALYs), when discounted at 5%, amounted to 12 DALYs: in this case, all health benefits and B:C ratios were divided by 5/4.

The ensuing B:C ratios become: 30:1 (tobacco taxation), 20:1 (acute management with low cost drugs), 16:1 (salt reduction); 3:1 (hepatitis B immunization), 3:1 (generic risk pill).

ii) Inclusion of the underestimation of ex ante costs.

Since *ex ante* costs are often substantially underestimated, we multiplied all costs by 3 consistently with Jamison, Jha and Bloom, (2008). Therefore, all B:C ratios are divided by 3.

iii) A change in the value of a DALY to $5,000 rather than $1,000.

All health benefits are multiplied by 5, and therefore all the B:C ratios become multiplied by 5.

The most optimistic alternative assumption of (i)-(iii) increases all B:C ratios by a factor of 5. The most pessimistic alternative assumption of (i)-(iii) decreases all B:C ratios by 4, and the B:C for hepatitis B immunization becomes about 1:1 (when both (i) and (ii) are applied).

Without discounting its future health benefits, the B:C ratio for hepatitis B immunization would rise to 30:1.

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