Online Supplementary Appendix to Investing in noncommunicable disease risk factor control among adolescents worldwide: a modelling study

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Supplementary text

Analytic approach

Projecting changes in risk factor trends and their relationship to health outcomes at a population level is inherently challenging, more so when the health outcomes lag behind the risk factor changes by many years. Our analysis sought to understand the long-term consequences of reducing exposure to noncommunicable disease (NCD) risk factors among today's adolescents, both in terms of their impact on health outcomes and the investments that would be required to realise these impacts.

NCD mortality (including mortality attributable to major risk factors) increases exponentially with age, and risk only substantially begins to mount during middle age. As a result, this analysis required a long time horizon (five decades) in order to provide a balanced view of (mostly up-front) NCD risk reduction investments and their long-run consequences for premature mortality. Inherent to models with long time horizons is the concern that the future may unfold quite differently than modeled. The potential deviations from the model reference case are complex and may include: (i) demographic dimensions (eg, fertility patterns, migration, etc), (ii) environmental, economic, and social dimensions (eg, acceleration of climate change, collapse or unexpected growth in certain countries and regions, etc), and (iii) epidemiological dimensions (eg, new health technologies that dramatically reduce case-fatality from NCDs, emergence of new risk factors or reversal of trends in established risk factors, etc). Current research methods and technologies are unable to incorporate all of these "fundamental" types of uncertainty.

Many economic evaluations make use of established health outcomes modeling frameworks that focus on one or at most a few disease states and endpoints. For example, a Markov model of hypertension treatment may focus on incidence and prevalence of – and mortality from – ischaemic heart disease and cerebrovascular disease. A major challenge to developing a state transition model of multiple NCD risk factors is the large number of potential disease endpoints and interactions between diseases (eg, diabetes and cardiovascular disease). For instance, Kontis and colleagues, drawing on the WHO Global Health Estimates nosology, mapped a number of specific causes of death to tobacco use, heavy episodic drinking, and obesity, respectively.[1] Further, micro-level outcomes modelling, while useful for assessing the cost-effectiveness of health technologies for an average individual, does not provide an appropriate reference point for population-level (especially global-level) modelling.

Taking all these factors into account, we developed a population model of NCD risk factor reduction that sought to track the annual changes in mortality (ie, shift in overall chance of survival) that current (2015-2020) adolescents would experience over the long-term assuming:

- Patterns of alcohol and tobacco use in adolescence are correlated with patterns of use during early adulthood and intervening in adolescence causes a proportional reduction during early adulthood; early adulthood use patterns persist, to a first approximation, for an individual's remaining lifetime.
- In the absence of additional intervention, the current prevalence of monthly smoking and monthly heavy episodic drinking among current 20-29 year-olds is representative of the level of risk exposure that today's adolescents will face in the coming years.
- Current age-specific obesity patterns among adults are representative of the life-course "trajectory" of obesity risk that current adolescents will face. For example, the mean body-mass index among 50-59 year-olds in a given country today is what the mean body-mass index among today's adolescents will be four decades from now, in the absence of additional intervention.
- Current cause-specific mortality patterns, and their association with risk factors to which they can be attributed, are representative of risk-outcome patterns in future cohorts. For example, current mortality rates from ischaemic heart disease among 50-59 year-olds in a given country serve as a measure of risk for today's adolescents four decades from now, in the absence of additional intervention.

In demographic terms, these assumptions mean that we replaced a true "cohort" analysis with a "period" analysis because in the population group of interest (adolescents) the measurable effects of NCD risk reduction will be realised much further into the future than any available (cause-specific mortality) forecasting model can reasonably estimate. (WHO and the Institute for Health Metrics and Evaluation produce forecasts of mortality rates by age and cause for 2030 to 2040, but not beyond.[2,3])

Regarding the cost of interventions (discussed further below), we estimated the cost of scaling up adolescent-specific interventions during the years in which cohort members will fall in the 10-19 age range. We did not carry these costs forward beyond adolescence because we wished to provide costs and health consequences that could be compared for a cohort. It is acknowledged that – from a budget impact analysis perspective – the cost of sustaining adolescent-specific interventions for future cohorts of adolescents will require ongoing investments; however, health impact would be expected to rise in a commensurate manner. On the other hand, for the policy interventions (taxes and regulations), we estimated the full population cost (ie, across all age groups) of scaling up these interventions, since they cannot realistically be targeted to specific age groups. From an implementation standpoint, it is not meaningful to speak of the cost of, for instance, raising tobacco taxes only among adolescents. In this vein, we carried forward the policy intervention costs to the end of the analysis period (2070), in order to take into account that the policy's impact remains in place throughout individuals' life course.

Model overview

Because there are no standard approaches to conducting an analysis wherein multiple risk factors are reduced in order to target scores of disease endpoints, we developed a model that drew on several principles of descriptive epidemiology and demography. A diagram describing the model is provided in Figure A1.

In brief, this is a static, population-level model that looks at how shifts in the distribution of risk factors relate to shifts in long-term risk of dying from a variety of NCDs. We first estimate the fraction of the mortality rate from each NCD that can be attributed to a shift in the distribution of the risk factor. This is estimated for each age group, sex, and country in the study for each risk factor (changes in mortality from each NCD are added to arrive at all-cause mortality reductions).

We then apply this shift in the mortality rate by age, sex, and country to the baseline population mortality profile, which we derive from projections developed by the United Nations Population Division (UNPD). The shift in population survival is then converted to estimates of the number of deaths averted and life-years saved. Our approach to estimating intervention impact follows largely on the potential impact fraction approach as described by Kontis and colleagues.[1]

Parameters used in the model are depicted graphically in Figure A1 and described in detail in Table A3. The impact model was largely developed and carried out in a series of linked Excel spreadsheets; however, calculation of reductions in cause-specific mortality (see below) were carried out in R (version 3.5.0).

Baseline cohort data

To simplify our analysis, we identified a list of 70 countries that would be representative of the global and (World Bank) country income group environment in terms of demography, epidemiology, costs, and current level of intervention implementation. These countries were largely chosen to align with the WHO's 2017 health SDG price tag report,[4] though we added Germany, Japan, Russia, and the United States to this list to ensure that high-income settings were represented in this analysis. We drew on UN Population Division data on population counts by age and sex in these countries in the year 2015; for the purpose of this report, we identified individuals age 5-9 and 10-14 given that these two cohorts represent those who will be "adolescents" (defined for the purpose of this report as individuals aged 10-19) in the year 2020. Tables A1-A2 provides basic demographic information for countries included in this analysis.

We then extracted estimates of exposure to each of our three risk factors. The exposure measures were chosen to correspond with the effectiveness literature. For tobacco, we used the current prevalence of daily smoking among individuals aged 20-29. For alcohol, we used the current prevalence of heavy episodic drinking within the past 30 days among individuals aged 20-29. For obesity, we used mean population body-mass index (BMI) among individuals aged 20+, assuming that current age-specific patterns represent a risk "trajectory" for today's adolescents in the absence of additional intervention. All data were taken from the most recent papers and online datasets from the NCD Risk Factor Collaboration (NCD-RisC) and related Global Burden of Disease 2016 publications.[5,6]

Identifying interventions to prevent NCDs among adolescents

We conducted structured literature searches during June-December 2017 to identify relevant tobacco, alcohol, and obesity interventions for adolescents. PubMed, Cochrane, Embase, Web of Science, CAB abstracts, IndMED, Directory of Open Access Journals, Google Scholar, and the New York Academy of Medicine Grey Literature databases were searched using specific strings:

Adolescent/Adolescence/young adult/youth/teenage AND Intervention/program/policy AND Tobacco/Smoking/Smokeless tobacco/cigarettes AND 30 days/month/monthly AND cost*

Adolescent/Adolescence/young adult/youth/teenage AND Intervention/program/policy AND Alcohol/drinking/beer/wine/spirits AND binge/heavy episodic/grams AND cost*

Adolescent/Adolescence/young adult/youth/teenage AND Intervention/program/policy AND Prevention AND obesity/overweight AND BMI/diet/physical activity AND cost*

WHO policy documents were also searched, and their relevant citations and recommendations were reviewed. Finally, similar keywords searches were used on Google Scholar to close gaps in the literature.

Titles and abstracts were screened to identify relevant literature. We considered any study that (i) reported a health program or policy dedicated to reducing one or more of these risk factors among adolescents and (ii) contained an economic evaluation (cost or cost-effectiveness data) with outcomes reported in the units described in Table A3.

We found few original studies originating in low- and middle-income country settings. In total, we retrieved 216 full-text research studies but only used data from eight in our analysis (specific literature cited below where relevant). We identified several policy documents from WHO that were useful in guiding our modeling assumptions.

In the end, our literature search led us to six interventions that were based on adolescent-specific effectiveness data and appeared to be supported by evidence of cost-effectiveness and feasibility of implementation in a low- or middle-income country context. These interventions were also supported by recommendations from *Disease Control Priorities*, *Third Edition* (*DCP3*).[7]

Tobacco use

We identified excise tax increases and point-of-sale (POS) advertising bans as having the highest likelihood impact on tobacco use among adolescents. (For the purpose of this analysis, the tobacco use outcome variable we used was the prevalence of using at least one cigarette over the past month.) Although many countries have a tobacco excise tax, rates remain low relative to WHO's recommendation that 75% of the final sale price of tobacco products be taxes.[8] POS advertising bans reduce youth exposure to tobacco industry messages, and thereby reduce smoking initiation and prevalence among youth. POS advertising bans are often missing from country tobacco control efforts.[8]

We defined maximum implementation of the two tobacco policies as (i) rapid achievement of an excise tax hike to the target level of 75% of the final sale price and (ii) full implementation and enforcement of the POS ban in all countries. For tobacco taxes, we estimated the price increase required for each country to reach WHO recommended tax levels based on estimates of the price of the most-sold brand in each country.[9] We then calculated the reduction in adolescent smoking prevalence that would result from the tax hike, based on reviews of adolescent-specific price elasticity data.[10] For the POS advertising ban, we assessed the presence of bans and overall levels of compliance (as currently legislated) by country.[9] We then used estimates of intervention effectiveness from Shang and colleagues to calculate the reduction in smoking prevalence that would result from scaling up the ban to full compliance.[11]

Of note, the effect size for the POS advertising ban was presented in the literature as an odds ratio. Odds ratios are known to over-estimate effect sizes when health outcomes are common, which poses problems in countries where adolescent smoking prevalence is high (the median male smoking prevalence in our dataset was 20%). To address this issue, we simulated relationships between odds ratios and relative risks (the preferred measure of intervention impact) for the mean, lower, and upper (95% confidence interval) estimates of POS ban odds ratios reported by Shang and colleagues.[11] This was done by using a sequence of prevalence values, calculated odds, and known odds ratios to back-calculate pre-intervention odds and thus pre-intervention prevalence values, the latter of which allowed us to then calculate relative risks. Figure A2 shows the results of these simulations for our base case, best case, and worst case values for intervention effect (blue, green, and red tracings, respectively).

Alcohol use

We identified excise tax increases and advertising bans on alcohol as being most likely to reduce the harmful use of alcohol among adolescents. (For the purpose of this analysis, the alcohol use outcome variable we used was the prevalence of heavy episodic drinking, defined as having five or more drinks in a row on at least occasion during the past month.) While a definitive target for an alcohol tax does not exist to the same extent as it does for tobacco, the WHO modelled a 50% increase over current tax rates in the Updated Appendix 3 (Global Action Plan for NCDs)[12] and in the 2017 resource tool on alcohol taxation and pricing policies.[13] WHO's NCD Progress Monitor 2017 report also assesses each country's current level of alcohol advertising bans.[8]

We defined maximum implementation of the two alcohol policies as (i) rapid achievement of an excise tax hike and (ii) full implementation and enforcement of the alcohol advertising ban in all countries. For alcohol taxes, we used the 50% tax increase over the country's current level of alcohol tax implementation as per the WHO's NCD progress monitor report[8] and multiplied it with estimates of effectiveness from literature the effect size to calculate the reduction in heavy episodic drinking prevalence.[14] For the advertising ban, we assessed the presence of bans by country, then we used literature estimates of effectiveness to calculate the reduction in heavy episodic drinking that would result from scaling up the ban to full compliance.[15]

Obesity

We identified excise taxes on sugar-sweetened beverages (SSBs) and school-based physical and nutrition programs as having the highest likelihood of reducing obesity among adolescents. (For the purpose of this analysis, the "obesity" outcome variable we used was mean BMI.) Evidence in support of SSBs taxes is accumulating quickly. Several countries are experimenting with SSB taxes and are beginning to find favourable effects on reducing consumption. School-based programs that encourage physical activity and teach children about nutrition have also shown promise, although most studies have been conducted in high-income countries. In most countries, schools are a logical entry-point for engaging children and adolescents and embedding healthy diet and lifestyle habits.

We defined maximum implementation of the two obesity interventions as (i) uniform execution of an SSB tax and (ii) scale-up of the nutrition and physical activity programs to every adolescent currently attending school. For SSB taxes, we collected SSB consumption data by country,[16] estimates of tax effectiveness,[17] and information on the relationship between SSB consumption and BMI[18] to calculate reductions in population mean BMI. Review of reports from existing SSB tax initiatives suggested that the range of tax hikes being considered was 20-50% of the current price. We chose a more conservative 20% target. We scaled the effect size reported by Malik and colleagues[18] (change in units of BMI per change in 12-ounce serving of SSB) to an effect per 8-ounce serving under the assumption that relationship between change in serving size and change in BMI was proportional.

For the school-based education intervention, we drew on a large trial that quantified the impact of such programs on mean BMI in Chinese schools.[19] We multiplied the average effect size per student by each country's net secondary school enrolment rate to account for the fact that some adolescents do not attend school.[20]

Table 1 in the main paper lists the final interventions included in our analysis and the literature that informed our choice of effect size parameters.

Country-by-country adjustments for partially-implemented interventions

In many countries, some of the interventions analysed in this paper have been at least partially implemented, which means that the literature effect sizes cannot simply be applied to the entire population exposed to the intervention(s). To deal with this issue, in some cases we adjusted effect sizes according to the magnitude of the intervention's implementation gap. For the price interventions, this adjustment was not necessary because the effect sizes were reported in standardised units – e.g., a 10% increase in price leads to a 5·6% reduction in smoking prevalence. For the tobacco and alcohol regulations, the effect sizes were reported as changes in individual probabilities of smoking or heavy episodic use, so the individual effect size Eff_i was adjusted to remove the effect on the proportion of the population already exposed $Impl_{i,baseline}$ already exposed to the intervention:[21]

$$Eff_{i,final} = \frac{Eff_i \times \left(Impl_{i,target} - Impl_{i,baseline}\right)}{1 - \left(Eff_i \times Impl_{i,baseline}\right)}$$

Where $Eff_{i,final}$ can be interpreted as the population-level, weighted-average effect of scaling up the intervention to the target level of implementation $Impl_{i,target}$. For the tobacco and alcohol regulations, $Impl_{i,target}$ was assumed to be 100%, but for the school-based obesity programme it was assumed to equal to the school attendance ratio (and $Impl_{i,baseline}$ was assumed to be equal to zero).

Scenario analyses

Due to the known level of uncertainty in many of our model inputs, we conducted two scenario analyses to illustrate the potential range of health and economic outcomes from implementing the NCD interventions separately or in combination. Beyond the "base case" analysis, we identified extreme values of model parameters that would lead to more optimistic conclusions (eg, higher health impact, lower costs), termed the "best case" scenario, and also to more pessimistic conclusions (eg, lower health impact, higher costs), termed the "worst case" scenario.

Ranges of model inputs across these three scenarios are provided in Table A3. Notably, we did not attempt to incorporate uncertainty in the demographic and epidemiological inputs, since this sort of uncertainty were not presented consistently in the original datasets.

We calculated the overall best- and worst-case scenario as the combination of all best- and worst-case values of parameters (respectively). Admittedly, this approach overestimates uncertainty relative to, eg, Monte Carlo methods based on assumed parameter distributions. However, the objective of this analysis was not to quantify statistical uncertainty (eg, using 95% credible intervals) but rather to illustrate the potential range of costs and health consequences in a small number of computationally less-intensive scenarios.

We note that for some parameters the best- and worst-case values are not "symmetric" around the base case value, leading to asymmetric values for best- and worst-case estimated costs and economic benefits. In large part this is driven by the uncertainty in the level of implementation of the tobacco and alcohol regulatory policies. As described in Table A3, the estimates of implementation level for these interventions were discrete rather than continuous (scale of 0-10 for tobacco regulation and values of 0% [not implemented], 50% [partially implemented], and 100% [fully implemented] for alcohol regulation). For many countries, the base case parameter value for implementation level was near 0 or 10 (for tobacco) or not implemented or fully implemented (for alcohol), meaning that the worst- or best-case estimates of costs and intervention impact (constructed as described in Table A3) would be very similar to the base case. At a global level, this granularity in country-specific values generally averages out so that the aggregate estimates are more symmetric.

Because this analysis was done in two separate environments (Excel and R), it was impractical to conduct a formal one-way sensitivity analysis. However, we explored the potential drivers of differences in economic benefits by looking at input parameters that varied across countries of similar size. Table A4 illustrates how tobacco control policies in Kenya, Turkey, and Vietnam generate divergent economic benefits for roughly the same size target populations.

Country case studies

Supplementing our search for interventions in the global-level analysis, we also did a literature search for data that would guide us tailor the analysis to the real-world policy context in three specific countries, India, Kenya, and Indonesia. We chose these three countries because RTI International had scientific and public health expert collaborators in these settings, including Monika Arora (India), Dorcas Kiptui (Kenya), and Tara Singh Bam (Indonesia).

During June and July 2018, we conducted additional literature searches on PubMed, Cochrane, Embase, Web of Science, CAB abstracts, IndMED, Directory of Open Access Journals, Google Scholar, and the New York Academy of Medicine Grey Literature databases using country specific search terms. In addition, WHO and Ministry of Health policy documents were also searched and their relevant citations and recommendations were reviewed.

India:

Adolescent/Adolescence/young adult/youth/teenage AND India AND Intervention/program/policy AND Prevention AND obesity/overweight AND BMI/diet/physical activity AND cost*_

Adolescent/Adolescence/young adult/youth/teenage AND India AND Intervention/program/policy AND Tobacco/Smoking/Smokeless tobacco/cigarettes/bidi/guthka/khaini/pan/pan masala/betel quid AND 30 days/month/monthly AND cost*_

Adolescent/Adolescence/young adult/youth/teenage AND India AND Intervention/program/policy AND Alcohol/drinking/beer/wine/spirits AND binge/heavy episodic/grams AND cost*

Kenya:

Adolescent/Adolescence/young adult/youth/teenage AND Kenya AND Intervention/program/policy AND Prevention AND obesity/overweight AND BMI/diet/physical activity AND cost*

Adolescent/Adolescence/young adult/youth/teenage AND Kenya AND Intervention/program/policy AND Tobacco/Smoking/Smokeless tobacco/cigarettes/kiko/cigar/shisha/snuff/kuber/betel quid AND 30 days/month/monthly AND cost*

Adolescent/Adolescence/young adult/youth/teenage AND Kenya AND Intervention/program/policy AND Alcohol/drinking/beer/wine/spirits AND binge/heavy episodic/grams AND cost*

Indonesia:

Adolescent/Adolescence/young adult/youth/teenage AND Indonesia AND Intervention/program/policy AND Prevention AND obesity/overweight AND BMI/diet/physical activity AND cost*

Adolescent/Adolescence/young adult/youth/teenage AND Indonesia AND Intervention/program/policy AND Tobacco/Smoking/Smokeless tobacco/cigarettes/pipes/cigar/snuff/betel AND 30 days/month/monthly AND cost*

Adolescent/Adolescence/young adult/youth/teenage AND Indonesia AND Intervention/program/policy AND Alcohol/drinking/beer/wine/spirits AND binge/heavy episodic/grams AND cost*

We identified 233 additional records, out of which 11 studies were used in our final analysis to update interventions and model parameters. Based on these findings and discussion with the experts listed above, we made modifications to the analysis for each of these countries as described in Boxes 1 and 2 in the main text. (For the global numbers presented in the main analysis, we used the default model inputs for these three countries rather than these more-tailored inputs.) The modifications made to our analysis for these country case studies are outlined in Tables A5-A7.

Estimating the health consequences of NCD interventions

Our approach to modelling the health consequences of the interventions relied on estimated changes in cause-specific mortality for causes of death associated with each risk factor. In order to provide a baseline level of all-cause mortality against which to compare reductions in risk factor-attributable mortality, we constructed survival curves for female and male individuals aged 5-9 and 10-14 in the year 2015, looking at the period 2020-2070. This cohort of individuals would have an average age of 15 (range, 10-19) in the year 2020 and 65 (range, 60-69) in the year 2070. The number of individuals in a cohort surviving to year *t* + 1 is a function of the population in year *t* and the mortality rate in year *t*.

Projected all-cause mortality rates for 2020-2070 by age, sex, and country are provided by the UNPD, and we used these to construct "baseline" (i.e., no additional policy intervention) annual mortality rates based on the mathematical principle above. We took medium projections of all-cause mortality rates by age, sex, and country from the World Population Prospects, 2017 Revision. Because the UN's projection models rely largely on historical trends rather than counterfactual scenarios for accelerated uptake of health interventions, the adolescent survival curves developed from these projections can be assumed to reflect a "business as usual" scenario. Future age-specific mortality rates were mapped to the two five-year age groups separately. For example, in 2031, the average age of 10-14-year olds in 2015 will be 28.5 years, so the projected all-cause mortality for age group 20-24 over the period 2030-2035 (per UNPD) will apply to these individuals. Again, demographic estimates were disaggregated by sex and by country as well as by these two UN age groups.

Whereas our model used annual changes in cohort mortality rates, the UN Population Division only provides estimates of mortality over five-year periods. We interpolated annual mortality rates for each year over 2020-2070 using a modification of the Gompertz functional form for adult mortality:

$$\ln(m_t) = \alpha + \beta_1 t + \beta_2 t^2 + \varepsilon$$

Where m_t is the mortality rate in year t. (A time-squared term was added to produce a better fit.) For regression purposes, we assigned the average projected mortality over each five-year period to the midpoint in that period; eg, mortality rates for the periods 2020-2025 and 2025-2030 were assigned to the years 2022.5 and 2027.5, respectively. Predicted values from this regression were generated for each year over 2020-2069, and regressions were done separately by age group (10-14, 15-19), sex, and country. Annual mortality rates were then applied to the starting population size in 2015 (by age group, sex, and country) to calculate the surviving population and life-years experienced during each year over 2020-2069. Figure A2 provides a few representative survival curves.

Next, we estimated the change in attributable mortality rates by age, sex, and country that would occur following proportional (relative) reductions in each of the three risk factors arising from implementation of the six interventions. For each risk factor we estimated the effect sizes Eff_i for the policies separately and then in combination:

$$Eff_{total} = 1 - \prod_{i=1}^{n} (1 - Eff_i)$$

Effect sizes were then applied to cause-specific mortality rates using the potential impact fraction approach:[1]

$$PIF = \frac{\sum_j P_j RR_j - \sum_j \hat{P}_j RR_j}{\sum_j P_j RR_j}$$

Where P_j is the exposure level of the risk factor (see Table A2), $\hat{P}_j$ is the counterfactual exposure level in 2030 following full implementation of the policy or policies (calculated as the product of projected exposure and effect size(s) above), and RR_j are relative risks of mortality for risk factor exposure categories *j* (continuous in the case of BMI, which is a continuous risk factor).

Relative risks of the three risk factors on mortality from specific NCDs were taken from Kontis and colleagues and from Pearson-Stuttard and colleagues.[1 22] Table A8 shows the mortality endpoints modelled for each risk factor. PIFs by cause of death were then applied to cause-specific mortality rates by age, sex, and country as reported by WHO.[23] Importantly, we used current (2016) age-, sex-, and cause-specific death rates for each country as inputs to this model; we did not attempt to forecast cohort-specific death rates by cause for the adolescent cohort. Age-specific mortality rates were mapped to different future ages of this cohort, eg., changes in mortality rates for the age group 50-54 were applied to the cohort years 2057-2061 (for the 10-14 subgroup of the cohort) and 2052-2056 (for the 15-19 subgroup of the cohort) during which the average cohort ages were 49.5 to 53.5.

Finally, for each risk factor, the sum of changes in cause-specific mortality rates (by age, sex, and country) was then subtracted from the projected all-cause mortality rate described previously to generate new survival curves for each of the various risk factor intervention scenarios (including the best- and worst-case variations). Based on the number of person-years lived and the annual mortality rates in the baseline and intervention survival curves, we calculated "statistical" deaths and life-years over 2020-2070, then deaths averted and life-years gained by the intervention(s). As an illustration of the magnitude of improvements in premature mortality, we present business-as-usual and intervention survival curves in Figure A3.

Estimating the financial costs of interventions

We used the WHO's NCD Costing Tool to estimate the financial costs associated with scale-up of the five policy interventions (taxes and regulations).[24] The tool uses a bottom-up costing approach to estimate the cost to plan, develop, and implement policy measures that target NCD risk factors. Policy measures that are assessed within the tool include: (i) bans on tobacco advertising; (ii) bans on alcohol advertising; (iii) increasing tobacco taxes, and (iv) increasing alcohol taxes.

The cost to implement and enforce a sugar-sweetened beverage tax is not included in the tool, and we thus use the tool's assessment of the administrative costs of tobacco and alcohol taxes as a proxy. Moreover, we assume that bans on tobacco advertising stand-in for the more specific tobacco advertising policy measure that we include in our study: bans on advertising at the point of sale.

We generated per-capita costs for each intervention (using the costing tool), updated them to current US dollars using each country's local consumer price index and official 2016 exchange rates, and then applied these unit costs to the total number of cases (cohort size) in each year. We assumed that the policy interventions would be scaled up from current to full implementation over the first five years then be maintained at full implementation until 2070.

For the school-based physical activity intervention, we drew on estimates of the unit cost of the intervention as reported by Meng and colleagues in China.[19] This intervention was reported to cost RMB 180 (US$ 27) per student in 2010 currency. We update to 2016 RMB using China's local consumer price index and then converted the figure to USD using official 2016 exchange rates. To extrapolate these costs to other country settings, we used the method of *DCP3* wherein the final estimate of $cost_i$ (the unit cost of the intervention in country i) would be expressed as:[25]

$$cost_i = \left[a \times (cost_{China}) \times \frac{\bar{y}_i}{\bar{y}_{China}}\right] + [(1-a) \times (cost_i)]$$

Where a is the proportion of healthcare costs that are nontraded, $cost_{China}$ is the "raw" unit cost estimate for the intervention in China (per Ming and colleagues), y_i is the GDP per capita in country y, and y_{China} is the GDP per capita in China. We estimated a as 0.87 on the basis of detailed cost data from the original study.

As noted above, we assumed this intervention would only be applicable during the years when the current cohort is attending school. (This assumption was also taken for the school-based smoking programme in India that we analysed in the country case study [see Table A5].) Again, we mapped the cohort ages to various years (2015-2070) and multiplied the unit cost of the school-based interventions by the number of individuals aged 5-14 in the year 2015 who were expected to be attending school in that year.

Table A9 provides estimates of cumulative incremental costs by intervention and by country. We report costs discounted at 3% annually.

Estimation of economic benefits and return on investment

We calculated economic benefits from the intervention(s) using the human capital approach – i.e., each life-year gained is equivalent to current GDP per capita for each country in the analysis. GDP per capita data were taken from the most recent World Development Indicators along with the country income classifications.[26] Table A10 provides estimates of cumulative benefits by intervention and by country. We report economic benefits discounted at 3% annually.

The range of "per-capita" cumulative economic benefits across the 67 low- and middle-income countries included in this study is illustrated in Figure A4. As noted in Table A4, the main factors that influenced the benefits in each country were (i) the relative size of the intervention effect (a function of baseline vs. target implementation level), (ii) patterns of cause-specific mortality, which lead to variations in the estimates of deaths averted, and (iii) country income levels, which influence the valuation of mortality improvements.

In the main text and appendix, we present estimates of "return on investment," defined as the ratio of economic benefits to the financial costs required for governments to bring the interventions to scale. Figure A5 illustrates "overall" estimates of return on investment for the entire package of six interventions in the largest countries in each income group. Total costs, economic benefits, and return on investment by intervention and by country for the three country case studies are presented in Table A10 (alternative model inputs described above and in Tables A3-A5).

There are at least two potential cost factors that might result in more- or less favourable return-on-investment figures than those presented in this analysis. The first is the potential cost savings resulting from reduced disease incidence. In principle, lower incidence would, over time, lead to lower healthcare consumption, at least for the disease outcomes modelled in this analysis. (It is not clear whether healthcare consumption related to diseases besides NCDs would increase). Including healthcare expenditures averted in our analysis would lead to lower cost estimates. The second factor is the potential increase in consumption due to increased life expectancy. Ideally, increased non-health consumption should be factored into estimates of future costs so as not to overstate the productivity gains associated with improved health. Including future non-health consumption in our analysis would lead to higher cost estimates.

The incorporation of these two cost factors into our analysis poses several challenges. Reviews of costing studies conducted for *DCP3* illustrate the limited range of estimates for NCD-related healthcare in low- and middle-income countries.[27 28] In addition, to our knowledge there are no high-quality estimates of disaggregated expenditure in low- and middle-income countries. (The World Bank does produce estimates of household final consumption expenditure, but (i) this dataset does not distinguish between healthcare expenditure and non-healthcare expenditure, and (ii) even if this could be accomplished, the challenge of disentangling healthcare costs averted and additional healthcare costs incurred, raised previously, would still not be resolved.)

Despite these limitations in the analysis of costs, we maintain that it is still instructive from the perspective of a public decision-maker to compare the magnitude of costs incurred by government to the magnitude of the health gains (valued in economic terms). We acknowledge that this approach to modelling the costs and economic benefits of these interventions is not strictly consistent with a societal benefit-cost analysis, nor do we claim that our "return on investment" figures represent societal benefit-cost ratios. This study focuses more narrowly on the case for greater government investment in NCD risk reduction and follows largely on the "investment case" approach that has been developed by WHO and others. This study is not, in our view, an "economic evaluation" of alternative health technologies and thus does not require strict adherence to the Consolidated Health Economic Evaluation Reporting Statement (CHEERS).

The choice to value life-years gained using the human capital approach (gain in national income) and present these "benefits" relative to costs is meant to speak to one of the main goals of finance ministries, promoting economic growth. Because of the complex, multi-sectoral nature of these interventions and their consequences (eg, on international trade), a full societal benefit-cost analysis would require novel and highly complex approaches (eg, computable general equilibrium models) that would not be practical given data limitations and would not add substantially to the main purpose of this analysis – to assist in planning and "informed advocacy."

Supplementary tables

Table A1. Baseline demographic data for the 70 countries used in this analysis

Setting	Population aged 5-14, both sexes, 2015	Country share of global 5-14 population, both sexes, 2015
Low income	**157,338,878**	**12.52%**
Afghanistan	9,784,129	0.78%
Benin	2,812,541	0.22%
Burkina Faso	5,092,488	0.41%
Burundi	2,711,186	0.22%
Central African Republic	1,259,169	0.10%
Chad	4,064,993	0.32%
Comoros	194,815	0.02%
Democratic Republic of the Congo	21,213,794	1.69%
Eritrea	1,305,691	0.10%
Ethiopia	26,656,850	2.12%
Gambia, The	551,181	0.04%
Guinea	3,207,644	0.26%
Guinea-Bissau	452,704	0.04%
Haiti	2,376,515	0.19%
Liberia	1,202,542	0.10%
Madagascar	6,392,292	0.51%
Malawi	4,959,187	0.39%
Mali	5,098,153	0.41%
Mozambique	7,816,538	0.62%
Nepal	6,524,055	0.52%
Niger	5,922,611	0.47%
Rwanda	3,010,385	0.24%
Sierra Leone	1,957,397	0.16%
Tanzania	14,930,720	1.19%
Togo	1,954,964	0.16%
Uganda	11,848,821	0.94%
Zimbabwe	4,037,513	0.32%
Lower middle income	**568,267,456**	**45.21%**
Angola	7,957,871	0.63%
Bangladesh	32,174,293	2.56%
Cambodia	3,139,307	0.25%
Cameroon	6,085,659	0.48%
Cote d'Ivoire	6,103,234	0.49%
Egypt	18,700,701	1.49%
Ghana	6,678,229	0.53%
India	253,729,589	20.19%
Indonesia	47,328,151	3.77%
Kenya	12,532,527	1.00%
Morocco	6,169,628	0.49%
Myanmar	10,055,842	0.80%
Nigeria	48,819,109	3.88%
Pakistan	41,607,750	3.31%
Philippines	21,347,905	1.70%
Sri Lanka	3,447,475	0.27%
Sudan	10,175,085	0.81%
Tunisia	1,647,246	0.13%
Ukraine	4,315,011	0.34%
Uzbekistan	5,493,033	0.44%
Vietnam	13,856,295	1.10%
Yemen, Rep.	6,903,516	0.55%
Upper middle income	**320,811,801**	**25.52%**

Algeria	6,760,782	0.54%
Azerbaijan	1,337,011	0.11%
Brazil	31,487,618	2.51%
China	161,188,094	12.82%
Colombia	7,974,916	0.63%
Dominican Republic	2,091,961	0.17%
Ecuador	3,074,645	0.24%
Iran, Islamic Rep.	11,855,062	0.94%
Iraq	9,082,137	0.72%
Kazakhstan	2,761,568	0.22%
Malaysia	5,100,331	0.41%
Mexico	23,052,189	1.83%
Peru	5,732,686	0.46%
Romania	2,093,071	0.17%
Russia	14,864,943	1.18%
South Africa	10,561,597	0.84%
Thailand	8,509,000	0.68%
Turkey	13,284,190	1.06%
High income	**60,048,112**	**4.78%**
Germany	7,201,251	0.57%
Japan	11,229,972	0.89%
United States of America	41,616,889	3.31%
Grand Total	**1,106,466,247**	**88.03%**

Notes: Data taken from the World Population Prospects (Medium Variant), 2017 Revision. Grand total for 70 countries. "Share of global 5-14 population" presented as a percentage of the total global 2015 population of 5-14 year olds: 1,256,882,652.

Table A2. Baseline demographic and epidemiological data by country income group

Country income group	Population aged 5-14, millions	Baseline risk factor levels: Monthly tobacco smoking prevalence		Prevalence of heavy episodic drinking		Mean body-mass index (kg/m^2)	
		males	*females*	*males*	*females*	*males*	*females*
Low-income	160	12%	1.7%	23%	5.3%	21	22
Lower-middle-income	570	21%	2.3%	26%	5.8%	21	22
Upper-middle-income	320	30%	4.4%	38%	9.9%	24	23
High-income	60	26%	18%	55%	20%	25	24
Global	1300	23%	4.6%	32%	8.5%	22	22

Notes: Population data are for all 201 countries and territories tracked by the UN population division. Population data are from UN Population Division estimates for the year 2015 (2017 Revision of World Population Prospects). As noted in the text, in this analysis we estimate intervention costs and consequences for 70 countries that comprise 88% of the global population, then extrapolate to the total global population. Baseline risk factor data are calculated as weighted averages of the 70 countries included in this study (see Table A1). Countries are grouped according to gross national income per capita estimates as provided in the 2019 World Development Indicators (World Bank Analytical Classifications, data for the 2017 calendar year). Risk factor level data are from Ezzati and colleagues (Global Burden of Disease 2015 Study, 2017; NCD-RisC, 2017) and reflect current levels among individuals aged 20-29 (ie, probable levels that today's adolescents will experience in the absence of intervention).

Table A3. List of model input parameters, data sources, and ranges of parameter values in scenario analyses.

Parameter name	Data source	Base case value	Best case value	Worst case value
Demographic and epidemiologic inputs				
Population estimates (by age, sex, and country)	World Population Prospects, 2017 Revision (UNPD, 2017)	As per data source	Not varied	Not varied
Baseline projected all-cause mortality rates (by age, sex, and country)	World Population Prospects, 2017 Revision (UNPD, 2017)	As per data source	Not varied	Not varied
Current risk exposure (smoking prevalence; heavy episodic drinking prevalence; mean body-mass index)	Global Burden of Disease study 2016 (IHME, 2017); NCD Risk Factor Collaborators 2018	As per data source	Not varied	Not varied
Baseline cause-specific mortality rates for 2016 (by age, sex, and country)	Global Health Estimates 2016 (WHO, 2018)	As per data source	Not varied	Not varied
Baseline levels of policy implementation				
Tobacco tax implementation	WHO tobacco country profiles*	Varies by country; reported as total taxes as a percentage of final retail price**	Not varied	Not varied
Tobacco point-of-sale ban	WHO tobacco country profiles*	Varies by country; reported as compliance score out of 10**	Assumed to be 3/10 points higher, bounded by 10/10	Assumed to be 3/10 points lower, bounded by 0/10
Alcohol tax	WHO NCD progress monitor*	Varies by country; reported as “fully achieved,” “partially achieved,” or “not achieved”**	Subtract 25% from current tax rate (assumed to be 50% if fully, 25% if partially, and 0% if not achieved)	Add 25% to current tax rate (assumed to be 50% if fully, 25% if partially, and 0% if not achieved)
Alcohol advertising ban	WHO NCD progress monitor 2017*	Varies by country; reported as “fully achieved,” “partially achieved,” or “not achieved”**	Subtract 50% from current level of implementation (assumed to be 100% if fully, 50% if partially, and 0% if not achieved)	Add 50% to current level of implementation (assumed to be 100% if fully, 50% if partially, and 0% if not achieved)
Sugar-sweetened beverage tax	Assumption	Assumed to be not implemented in any country	Not varied	Not varied
School-based obesity programme	UNESCO Institute for Statistics (via World Bank)*	Assumed to not be implemented in any country. Base case assumed to reach the percent of adolescents who complete primary school.	Not varied	Not varied
Intervention effect sizes				
Tobacco price elasticity (price vs. monthly prevalence of smoking)	Nikaj and Chaloupka*	-0.56	Assumed to be 33% more negative	Assumed to be 33% more positive

Odds ratio for monthly smoking following exposure to point-of-sale tobacco advertising ban	Shang and colleagues*	0.73	0.54	0.98
Alcohol price elasticity (price vs. monthly prevalence of heavy episodic drinking)	Saffer and Dave (2006)*	-0.73	-0.97	-0.49
Relative reduction in prevalence of heavy episodic drinking following exposure to advertising bans	Saffer and Dave (2003)*	0.42	0.56	0.28
Sugar-sweetened beverage price elasticity (price vs. consumption)	WHO (2016)*	-1.0	Not varied	Not varied
Relationship between sugar-sweetened beverage consumption and body-mass index	Malik and colleagues*	-0.053 kg/m^2 per 8oz. serving	-0.087 kg/m^2 per 8oz. serving	-0.020 kg/m^2 per 8oz. serving
Mean change in body-mass index resulting from of physical activity and nutrition programme	Meng and colleagues*	-0.29 kg/m^2	-0.48 kg/m^2	-0.12 kg/m^2
Economic parameters				
Unit cost of policy interventions	WHO NCD Costing Tool*	Varies by intervention; calculated as per-capita cost which is then multiplied by the total projected population (all ages) in each year	Assumed to be 33% lower than base case	Assumed to be 33% higher than base case
Discount rate	Assumption	3%	Not varied	Not varied

*Notes: *See text and References section for full citation. **If a country did not report this measure to WHO, it was assumed to be zero or not implemented.*

Table A4. The influence of parameter values on differences in health benefits in three countries

Country	**Baseline smoking prevalence**	**Relative size of tax hike**	**Deaths averted from raising tobacco tax (thousands)**	**Life years gained from raising tobacco tax (thousands)**	**GDP per capita (USD)**	**Discounted economic benefits from raising tobacco tax (USD, millions)**
Kenya	5.8%	44%	41	460	1,500	220
Viet Nam	16%	110%	220	2,290	2,200	1,500
Turkey	28%	0%	0	0	11,000	0

Notes: All three countries had an estimated 13-14 million individuals aged 5-14 in the year 2015 (World Population Prospects, 2017 Revision). Risk factor level data are from Ezzati and colleagues (Global Burden of Disease 2015 Study, 2017; NCD-RisC, 2017) and reflect current levels among individuals aged 20-29 (ie, probable levels that today's adolescents will experience in the absence of intervention). The "relative size of tax hike" shows the increase in the magnitude of the tobacco tax (vs. its current level as a share of the final retail price) required to reach the 75% level recommended by WHO. Data on the current share of taxes vs. final retail price of tobacco (most sold brand) is derived from the 2017 WHO Tobacco Report. Because Turkey already has a tobacco tax in place equal to 82% of the final retail price (ie, exceeding the WHO recommendation), no health gains from raising the tobacco tax are calculated for Turkey. GDP per capita data are from the World Bank. Economic benefits are discounted at a rate of three percent.

Table A5. Adaptation of the global adolescent NCD risk factor intervention package to the Indian context

Risk factor	Outcome of interest	Intervention	Effect size	Source
Tobacco use	Reduction in prevalence of cigarette use within the past month among adolescents	Increase in excise tax to 75% of final retail price of tobacco products	**For every 10% increase in price, smoking prevalence declines by 2.8% among male and 6.0% among female adolescents**	Joseph and Chaloupka[29]
		School-based intervention (Mobilizing Youth for Tobacco-Related Initiatives in India - MYTRI)	**Full implementation leads to a 17% reduction in the chance of smoking**	Perry and colleagues[30]
Harmful use of alcohol	Reduction in heavy episodic drinking (having five or more drinks in a row on any occasion during past 30 days) among adolescents	Increase in 50% excise tax compared to current levels	**For every 10% increase in price, heavy episodic drinking declines by 10%**	Mahal[31]
		Complete ban on alcohol advertising (print, TV, radio or outdoor)	**Alcohol advertising is already banned by the government, so an incremental analysis is not relevant in this context.**	
High body mass index	Reduction in mean body-mass index among adolescents	Addition of 20% excise taxes on sugar-sweetened beverages	**A 10% increase in price will lead to a 9.4% decrease in consumption, considering an elasticity of -0.94.**	Basu and colleagues[32]
		School-based nutrition and physical activity programs to reduce obesity or overweight	Same as global analysis	

Notes: Interventions or effect sizes in boldface vary from the country assumptions used in the global-level analysis.

Table A6. Adaptation of the global adolescent NCD risk factor intervention package to the Kenyan context

Risk factor	Outcome of interest	Intervention	Effect size	Source
Tobacco use	Reduction in prevalence of cigarette use within the past month among adolescents	Increase in excise tax to 75% of final retail price of tobacco products	**For every 10% increase in price, smoking prevalence declines by 3.5% adolescents**	Okello[33]
		Point of sale advertising bans	Same as global analysis	
Harmful use of alcohol	Reduction in heavy episodic drinking (having five or more drinks in a row on any occasion during past 30 days) among adolescents	Increase in 50% excise tax compared to current levels	Same as global analysis	
		Complete ban on alcohol advertising (print, TV, radio or outdoor)	Same as global analysis	
High body mass index	Reduction in mean body-mass index among adolescents	Addition of 20% excise taxes on sugar-sweetened beverages	**A 10% increase in price will lead to a 11.8% decrease in consumption, considering an elasticity of -1.18. (Having found no Kenya-specific data, we used a study from South Africa)**	Stacey and colleagues[34]
		School-based nutrition and physical activity programs to reduce obesity or overweight	Same as global analysis	

Notes: Interventions or effect sizes in boldface vary from the country assumptions used in the global-level analysis.

Table A7. Adaptation of the global adolescent NCD risk factor intervention package to the Indonesian context

Risk factor	Outcome of interest	Intervention	Effect size	Source
Tobacco use	Reduction in prevalence of cigarette use within the past month among adolescents	Increase in excise tax to 75% of final retail price of tobacco products	**For every 10% increase in price, smoking prevalence declines by 7.4% among adolescents**	Kostova and colleagues[35]
		Point of sale advertising bans	Same as global analysis	
Harmful use of alcohol	**Per expert recommendation, we did not conduct an analysis of alcohol reduction in Indonesia. Since 90% of the population is Muslim, the vast majority of the population do not consume alcohol. In addition, there already a value-added tax on alcohol as well as restrictions on advertising and sponsorship nationwide, and consumption is punishable by law in several provinces.**			
High body mass index	Reduction in mean body-mass index among adolescents	Addition of 20% excise taxes on sugar-sweetened beverages	Same as global analysis	
		School-based nutrition and physical activity programs to reduce obesity or overweight	Same as global analysis	

Notes: Interventions or effect sizes in boldface vary from the country assumptions used in the global-level analysis.

Table A8. Specific causes of death modelled for each risk factor included in this analysis

Cause of death	Tobacco smoking	Heavy episodic drinking	Raised BMI
Mouth and oropharynx cancers	x	x	
Oesophagus cancer	x	x	x
Stomach cancer	x		x
Colon and rectum cancers	x	x	x
Liver cancer	x	x	x
Pancreas cancer	x	x	x
Trachea, bronchus and lung cancers	x		
Breast cancer		x	x
Cervix uteri cancer	x		
Corpus uteri cancer			x
Ovary cancer			
Kidney cancer	x		x
Bladder cancer	x		
Gallbladder cancer			x
Larynx cancer		x	
Multiple myeloma			x
Leukaemia	x		
Diabetes mellitus	x	x	x
Alcohol use disorders		x	
Epilepsy		x	
Rheumatic heart disease	x		
Hypertensive heart disease	x	x	x
Ischaemic heart disease	x	x	x
Ischaemic stroke	x	x	x
Haemorrhagic and other non-ischaemic stroke	x	x	x
Cardiomyopathy, myocarditis, endocarditis	x		
Atrial fibrillation and flutter	x	x	
Chronic obstructive pulmonary disease	x		
Asthma	x		
Other respiratory diseases	x		
Liver cirrhosis		x	
Pancreatitis		x	
Chronic kidney disease			x

Notes: causes of death follow the WHO Global Health Estimates 2016 nosology.

Table A9. Estimates of implementation costs by intervention and country

Country	Increase in tobacco tax	Ban tobacco advertising	Increase in alcohol tax	Ban alcohol advertising	Addition of SSB tax	School programmes
Afghanistan	4.9	3.3	0.0	0.0	4.9	151.2
Algeria	11.6	17.6	0.0	0.0	11.6	295.3
Angola	26.4	36.7	26.4	36.2	26.4	112.5
Azerbaijan	3.6	1.7	3.6	1.7	3.6	65.4
Bangladesh	0.0	20.8	0.0	0.0	17.1	626.2
Benin	4.2	3.8	4.2	3.8	4.2	27.5
Brazil	52.3	40.5	52.3	81.2	52.3	2,482.6
Burkina Faso	5.5	5.7	5.5	5.7	5.5	28.4
Burundi	5.2	4.7	5.2	4.6	5.2	14.8
Cambodia	2.9	2.0	2.9	2.8	2.9	41.9
Cameroon	7.7	9.1	7.7	9.1	7.7	80.3
Central African Republic	4.9	3.1	4.9	3.2	4.9	2.9
Chad	7.3	3.3	7.3	6.8	7.3	15.0
China	192.7	273.7	192.7	0.0	192.7	16,536.5
Colombia	10.0	8.9	0.0	14.7	10.0	484.5
Comoros	2.1	1.0	2.1	0.0	2.1	2.1
Côte d'Ivoire	7.6	8.7	7.6	8.6	7.6	90.5
Democratic Republic of the Congo	17.4	15.5	0.0	16.9	17.4	135.0
Dominican Republic	5.4	5.3	0.0	5.2	5.4	140.2
Ecuador	8.8	10.1	8.8	5.0	8.8	251.7
Egypt	22.9	32.7	22.9	0.0	22.9	813.3
Eritrea	5.6	0.0	5.6	3.7	0.0	9.2
Ethiopia	17.5	11.4	17.5	11.5	0.0	170.3
Gambia	2.7	1.5	2.7	1.6	2.7	6.6
Germany	60.6	127.4	60.6	123.5	60.6	2,000.6
Ghana	5.7	0.7	0.0	0.0	5.7	157.9
Guinea	6.4	3.0	6.4	6.0	6.4	23.6
Guinea-Bissau	1.8	0.9	1.8	0.9	1.8	3.3
Haiti	2.8	2.3	2.8	2.3	2.8	43.0

India	193.8	263.9	193.8	270.0	193.8	7,091.3
Indonesia	27.3	42.3	27.3	21.0	27.3	2,303.7
Iran (Islamic Republic of)	23.4	22.9	0.0	0.0	23.4	804.3
Iraq	22.6	36.7	22.6	17.9	22.6	433.0
Japan	98.4	221.5	98.4	214.8	98.4	4,601.3
Kazakhstan	6.5	3.9	6.5	0.0	6.5	296.7
Kenya	16.8	11.5	16.8	11.5	16.8	315.8
Liberia	3.1	2.0	3.1	2.0	3.1	8.4
Madagascar	0.0	3.6	6.9	3.6	6.9	43.8
Malawi	3.8	4.1	3.8	4.1	3.8	17.7
Malaysia	7.1	8.0	7.1	4.9	7.1	528.5
Mali	7.5	7.2	7.5	7.4	7.5	34.7
Mexico	29.7	55.1	29.7	54.1	29.7	1,949.6
Morocco	8.2	12.0	8.2	11.8	8.2	193.4
Mozambique	5.7	6.0	5.7	6.1	5.7	31.0
Myanmar	5.2	6.4	5.2	0.0	5.2	132.0
Nepal	4.0	2.2	4.0	4.4	4.0	119.8
Niger	8.0	5.9	8.0	3.9	8.0	16.9
Nigeria	51.9	48.0	51.9	94.6	51.9	862.6
Pakistan	29.6	54.7	29.6	0.0	29.6	644.2
Peru	10.6	14.2	10.6	14.0	10.6	398.4
Philippines	15.0	24.1	15.0	23.8	15.0	815.6
Romania	5.4	6.8	5.4	0.0	5.4	222.4
Russian Federation	29.7	0.0	29.7	26.7	29.7	1,627.8
Rwanda	4.5	4.4	4.5	4.3	4.5	21.7
Sierra Leone	2.5	1.9	0.0	1.9	2.5	19.4
South Africa	15.3	25.0	15.3	24.6	15.3	296.4
Sri Lanka	2.9	1.3	2.9	1.6	2.9	190.1
Sudan	13.9	8.7	0.0	0.0	13.9	207.6
United Republic of Tanzania	16.4	20.9	16.4	21.3	16.4	122.9
Thailand	7.2	5.1	7.2	0.0	7.2	567.4
Togo	2.7	0.4	2.7	2.1	2.7	16.1

Tunisia	4.0	4.0	4.0	4.0	4.0	62.8
Turkey	0.0	10.3	0.0	0.0	14.6	1,704.0
Uganda	10.5	7.2	10.5	14.2	10.5	61.6
Ukraine	0.0	1.2	0.0	1.2	2.3	156.8
United States of America	306.9	767.9	306.9	744.3	306.9	25,479.8
Uzbekistan	2.7	0.4	2.7	0.0	2.7	190.9
Viet Nam	8.5	7.7	8.5	11.0	8.5	521.5
Yemen	7.5	6.0	0.0	0.0	7.5	82.5
Zimbabwe	0.6	0.6	0.6	0.6	0.6	66.4

Notes: costs are in millions of 2016 US dollars, discounted at 3% annually. Costs of policy measures are summed over 2015-2070. Costs of the school-based obesity intervention are summed over 2015-2024; the intervention does not continue beyond 2024 because none of the cohort members would be attending school after that year. Only "base case" costs are presented here.

Table A10. Estimates of economic benefits by intervention and country

Country	Increase in tobacco tax	Ban tobacco advertising	Increase in alcohol tax	Ban alcohol advertising	Addition of SSB tax	School programmes
Afghanistan	592.0	142.2	0.0	0.0	1.0	52.3
Algeria	558.4	349.1	0.0	0.0	2.2	109.0
Angola	559.1	384.9	418.6	481.8	2.8	24.4
Azerbaijan	342.8	71.5	6.0	8.7	0.1	34.4
Bangladesh	0.0	974.4	0.0	0.0	0.4	44.6
Benin	52.6	25.9	13.7	31.5	0.1	7.3
Brazil	2,649.7	2,857.6	1,768.0	4,072.9	30.8	1,290.5
Burkina Faso	105.8	62.2	57.9	66.7	0.1	4.7
Burundi	16.6	11.3	8.1	18.6	0.0	0.6
Cambodia	159.5	60.9	60.4	139.2	0.1	9.7
Cameroon	273.1	147.3	141.7	326.7	1.3	34.1
Central African Republic	13.5	9.5	1.8	4.2	0.0	0.4
Chad	86.0	30.2	9.2	21.3	0.2	2.8
China	38,894.5	23,290.3	4,050.9	0.0	8.8	4,478.1
Colombia	1,020.4	486.3	0.0	249.4	18.8	199.7
Comoros	5.0	3.0	0.3	0.0	0.0	0.6
Côte d'Ivoire	563.6	296.5	192.2	443.2	1.6	45.2
Democratic Republic of the Congo	136.9	135.5	0.0	57.9	0.2	13.5
Dominican Republic	306.5	219.6	0.0	191.1	12.2	112.8
Ecuador	13.3	132.2	50.5	73.5	3.6	125.5
Egypt	278.7	1,321.5	104.0	0.0	9.9	661.8
Eritrea	32.9	0.0	4.5	5.2	0.0	0.0
Ethiopia	235.8	73.8	91.4	133.2	0.0	0.0
Gambia	7.0	5.5	1.5	3.5	0.1	1.2
Germany	2,390.9	5,342.3	3,229.7	3,717.0	11.2	435.5
Ghana	57.5	4.5	0.0	0.0	1.0	61.7
Guinea	54.8	16.4	3.1	3.6	0.2	5.2
Guinea-Bissau	8.8	4.5	3.1	3.6	0.0	0.6
Haiti	58.5	34.9	24.9	28.7	1.6	20.2

India	16,047.2	10,627.7	7,211.4	8,300.1	28.5	2,138.5
Indonesia	8,819.4	5,162.1	36.9	26.9	15.6	1,472.3
Iran (Islamic Republic of)	1,070.0	314.0	0.0	0.0	1.7	256.6
Iraq	935.3	687.3	8.3	12.1	5.0	261.8
Japan	4,674.7	5,004.7	896.2	2,063.2	6.3	542.5
Kazakhstan	1,501.1	421.5	271.6	0.0	2.6	204.7
Kenya	218.6	102.1	39.9	58.2	0.9	33.2
Liberia	6.1	3.4	7.3	8.4	0.0	1.1
Madagascar	0.0	40.7	4.6	6.8	0.0	0.2
Malawi	19.3	13.6	9.4	10.8	0.1	0.9
Malaysia	1,423.7	763.4	1.6	2.3	6.0	240.9
Mali	107.0	59.9	8.5	9.8	0.5	8.0
Mexico	1,275.1	2,223.4	1,330.2	3,064.7	97.5	1,494.1
Morocco	51.4	166.5	11.2	12.9	1.3	47.9
Mozambique	66.5	37.7	8.4	9.7	0.1	1.9
Myanmar	491.3	277.2	334.9	0.0	0.7	35.0
Nepal	251.1	71.7	23.1	26.6	0.1	24.4
Niger	50.4	25.7	0.1	0.1	0.1	1.1
Nigeria	1,482.6	470.1	2,206.3	5,089.2	6.7	292.0
Pakistan	1,729.1	1,787.2	44.2	0.0	9.9	282.0
Peru	729.6	550.4	189.7	437.0	6.6	185.6
Philippines	3,061.7	2,920.4	423.9	976.5	11.5	559.1
Romania	236.0	712.4	231.4	0.0	0.9	106.2
Russian Federation	10,040.1	0.0	1,817.1	2,648.3	15.7	993.1
Rwanda	24.6	22.0	17.2	39.7	0.0	1.0
Sierra Leone	70.2	34.1	0.0	30.3	0.1	4.6
South Africa	1,753.8	1,341.1	337.3	777.1	10.9	231.4
Sri Lanka	211.7	111.4	101.1	147.3	1.6	79.7
Sudan	26.9	208.3	0.0	0.0	9.6	185.1
United Republic of Tanzania	309.1	182.0	101.9	234.7	0.7	21.1
Thailand	203.2	702.5	439.8	0.0	6.4	224.7
Togo	17.2	2.2	5.7	13.2	0.1	3.6

Tunisia	4.4	102.5	12.1	13.9	0.5	25.4
Turkey	0.0	2,892.6	0.0	0.0	18.3	1,037.3
Uganda	150.7	68.8	73.0	168.2	0.2	4.7
Ukraine	0.0	206.0	0.0	184.7	1.3	76.5
United States of America	77,662.6	49,866.1	12,764.2	29,395.9	597.5	12,889.7
Uzbekistan	439.8	64.1	51.7	0.0	0.6	118.2
Viet Nam	1,448.6	526.0	253.5	584.2	0.9	91.1
Yemen	343.2	184.3	0.0	0.0	1.8	47.8
Zimbabwe	95.0	54.8	14.3	32.9	0.7	18.1

Notes: benefits are in millions of 2016 US dollars, discounted at 3% annually. Benefits are summed over 2015-2070. Only "base case" benefits are presented here.

Table A11. Costs, benefits, and return-on-investment figures for the three country case studies

Country	Measure	Increase in tobacco excise tax	Other tobacco intervention	Increase in alcohol excise tax	Alcohol advertising ban	Addition of sugar-sweetened beverage excise tax	School-based obesity intervention
India	Incremental costs	194	15,550	194	N/A	194	7,091
	Economic benefits	4,624	6,303	9,884	N/A	37	2,117
	Return on investment	23.8	0.4	50.9	N/A	0.2	0.3
Kenya	Incremental costs	17	12	17	12	17	333
	Economic benefits	146	102	33	58	1	33
	Return on investment	8.6	8.5	1.9	4.8	0.1	0.1
Indonesia	Incremental costs	27	42	N/A	N/A	27	2,304
	Economic benefits	11,161	5,162	N/A	N/A	16	1,472
	Return on investment	413.4	122.9	N/A	N/A	0.6	0.6

Notes: costs and benefits are in millions of 2016 US dollars, discounted at 3% annually. These numbers differ from the numbers in Tables A9-A10 due to the use of alternative model inputs described in the Supplementary Text. Other tobacco intervention refers to a school-based intervention in India, and tobacco point of sale bans in Kenya and Indonesia.

Supplementary figures

Figure A1. Flow diagram of modelling approach

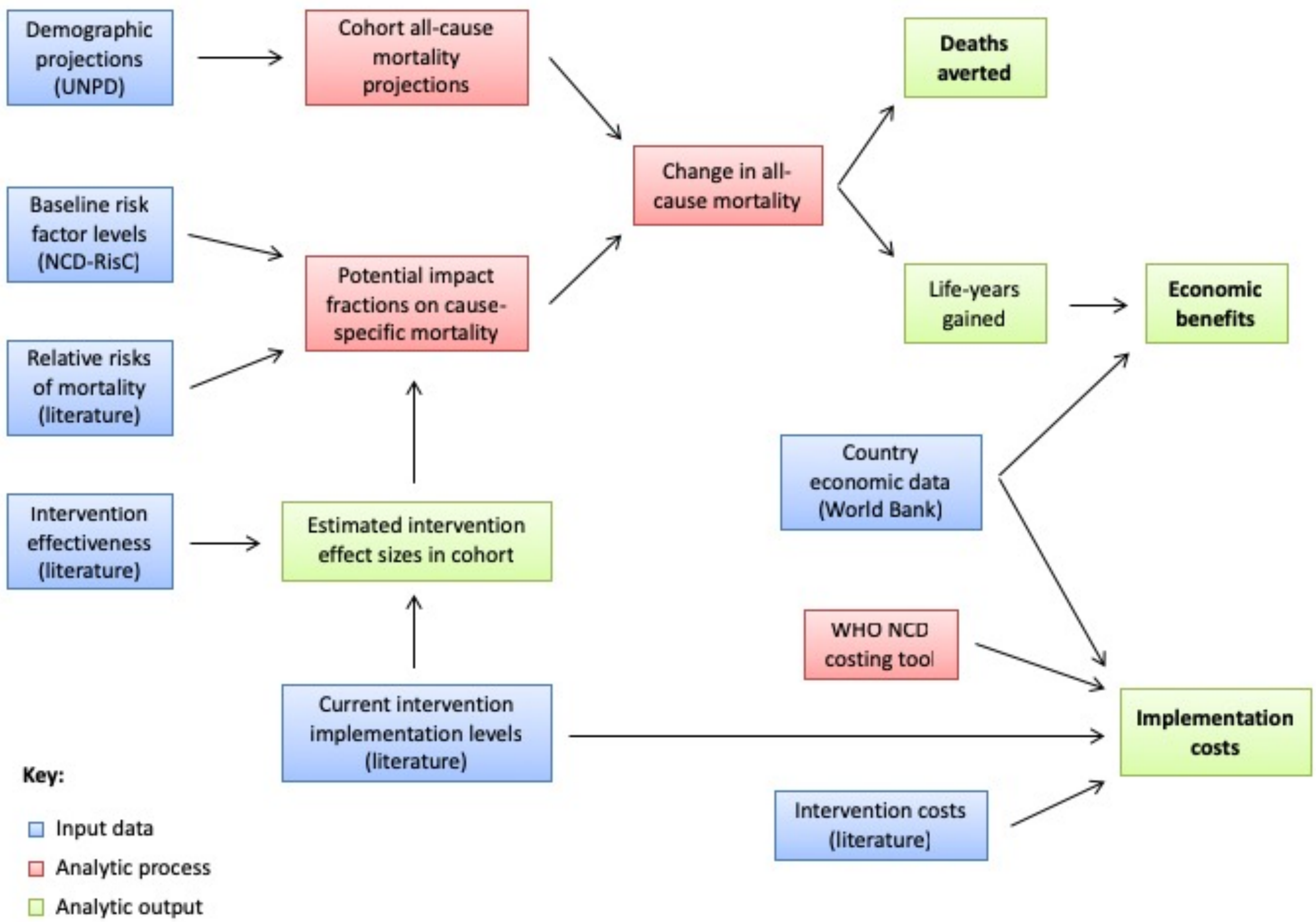
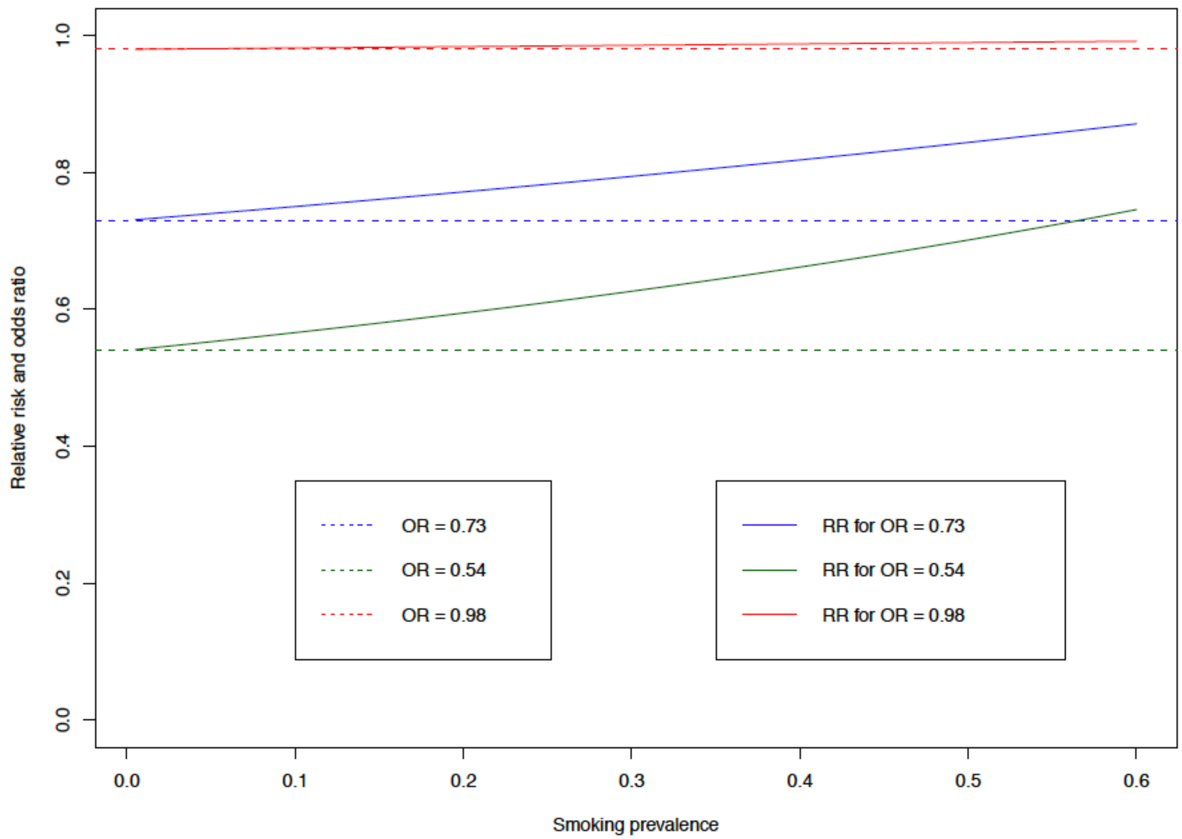
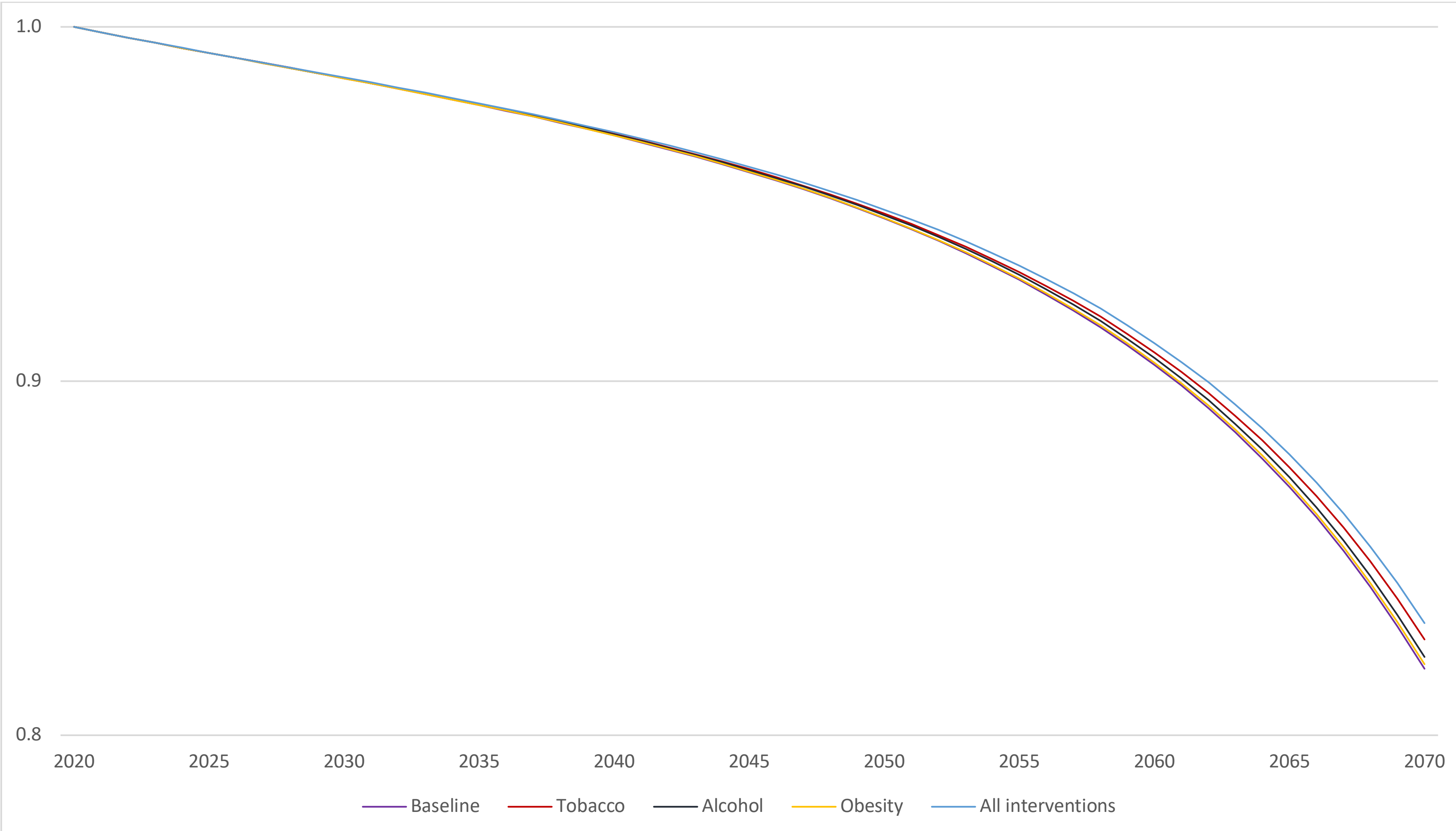


Figure A2. Relationship between odds ratios and simulated relative risks



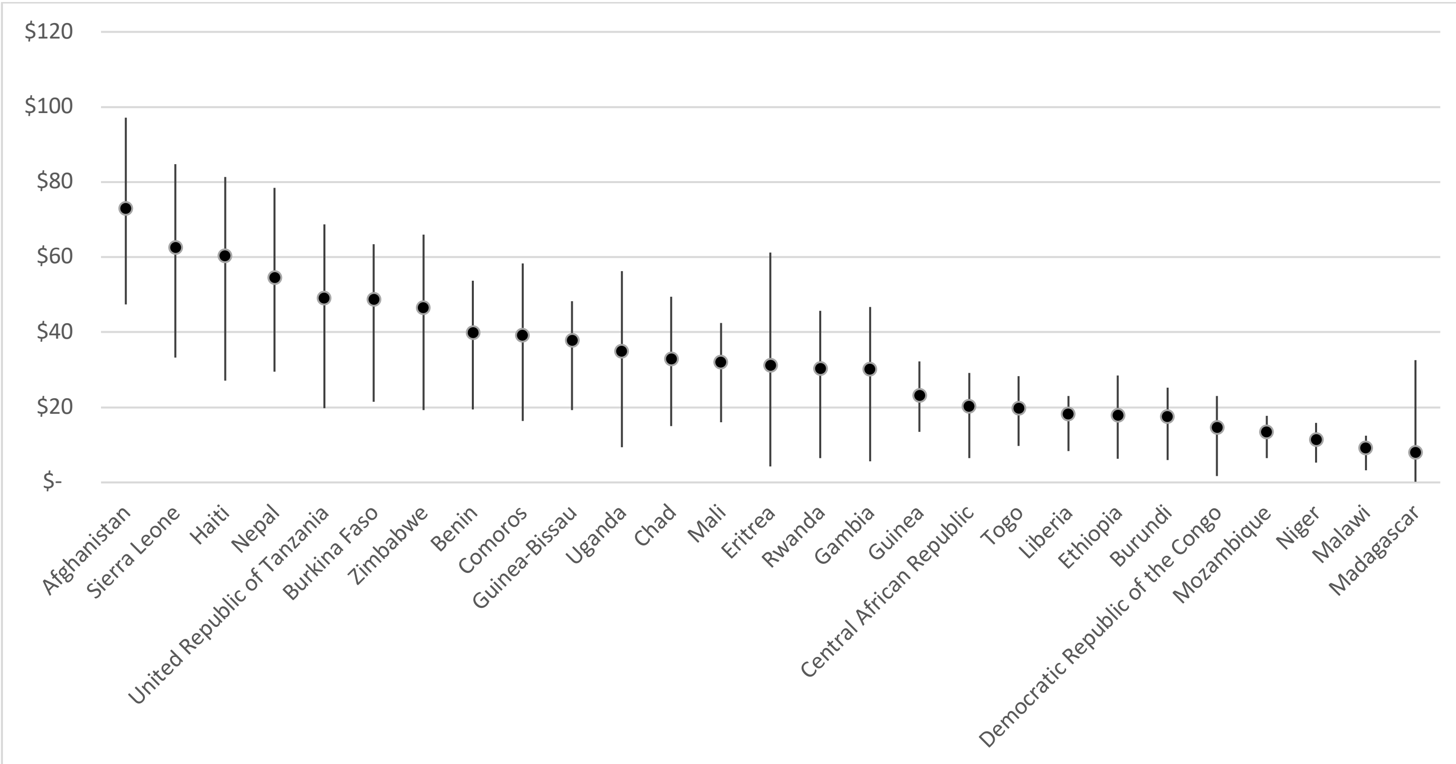
This figure shows the results of simulations to determine relative risks of smoking at different levels of odds ratios (the metric used in the literature to estimate point-of-sale tobacco advertising ban effectiveness). Odds ratios are assumed to be constant over all ranges of prevalence but they over-estimate relative risk and hence health impact when a health outcome is common.

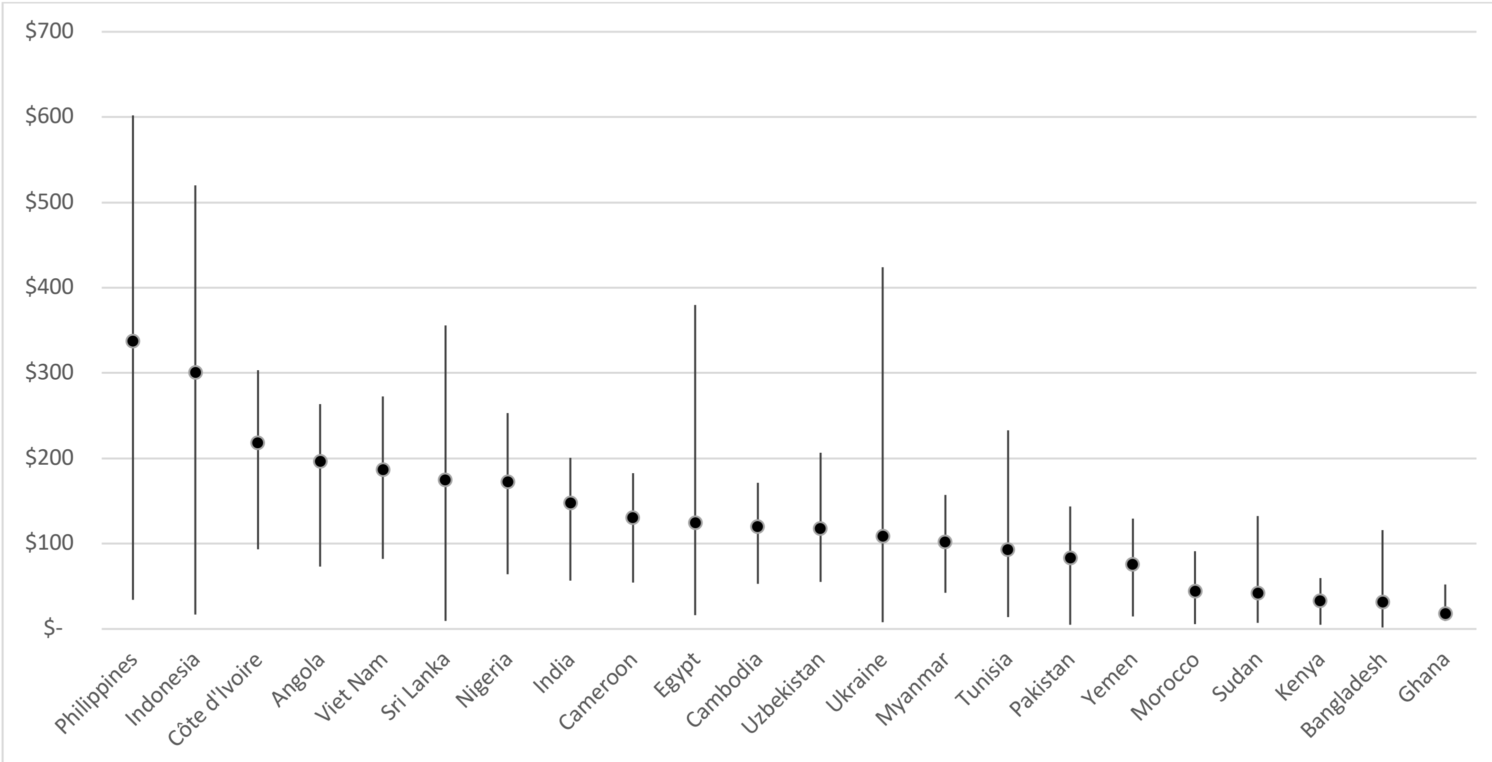
Figure A3. Modeled cohort survival curves by intervention scenario



This figure traces the annual survival of the cohort of 1.1 billion individuals aged 5-14 in the year 2015. In the baseline scenario, survival is based on projections of all-cause mortality by age, sex, country, and location from the World Population Prospects, 2017 revision. In the intervention scenarios, survival is based on a reduction in mortality that results from implementing interventions that reduce tobacco use, hazardous/harmful use of alcohol, and obesity.

Figure A4. Country variation in cumulative per-capita economic benefits, 2020-2070

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Philippines
Indonesia
Côte d'Ivoire
Angola
Viet Nam
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Nigeria
India
Cameroon
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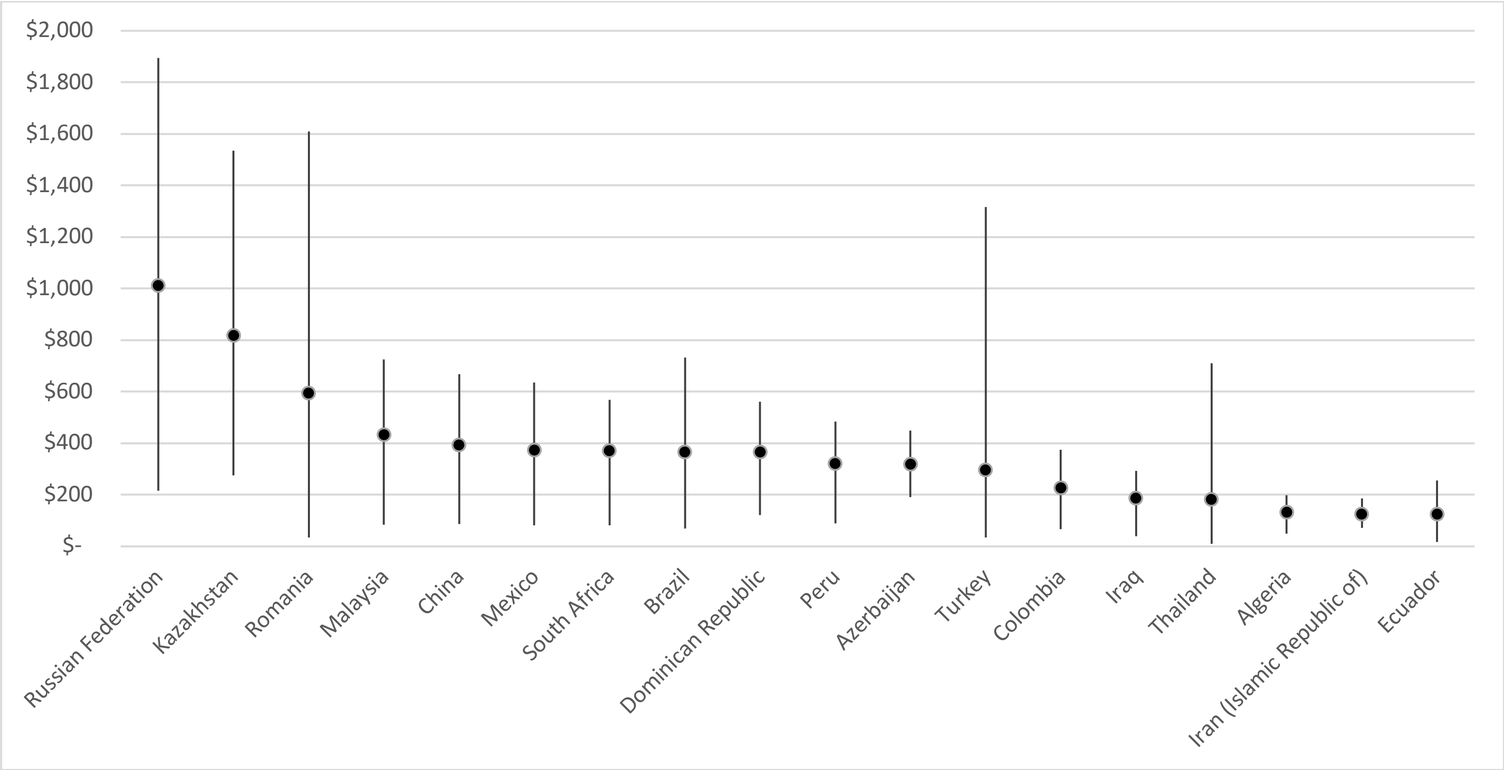
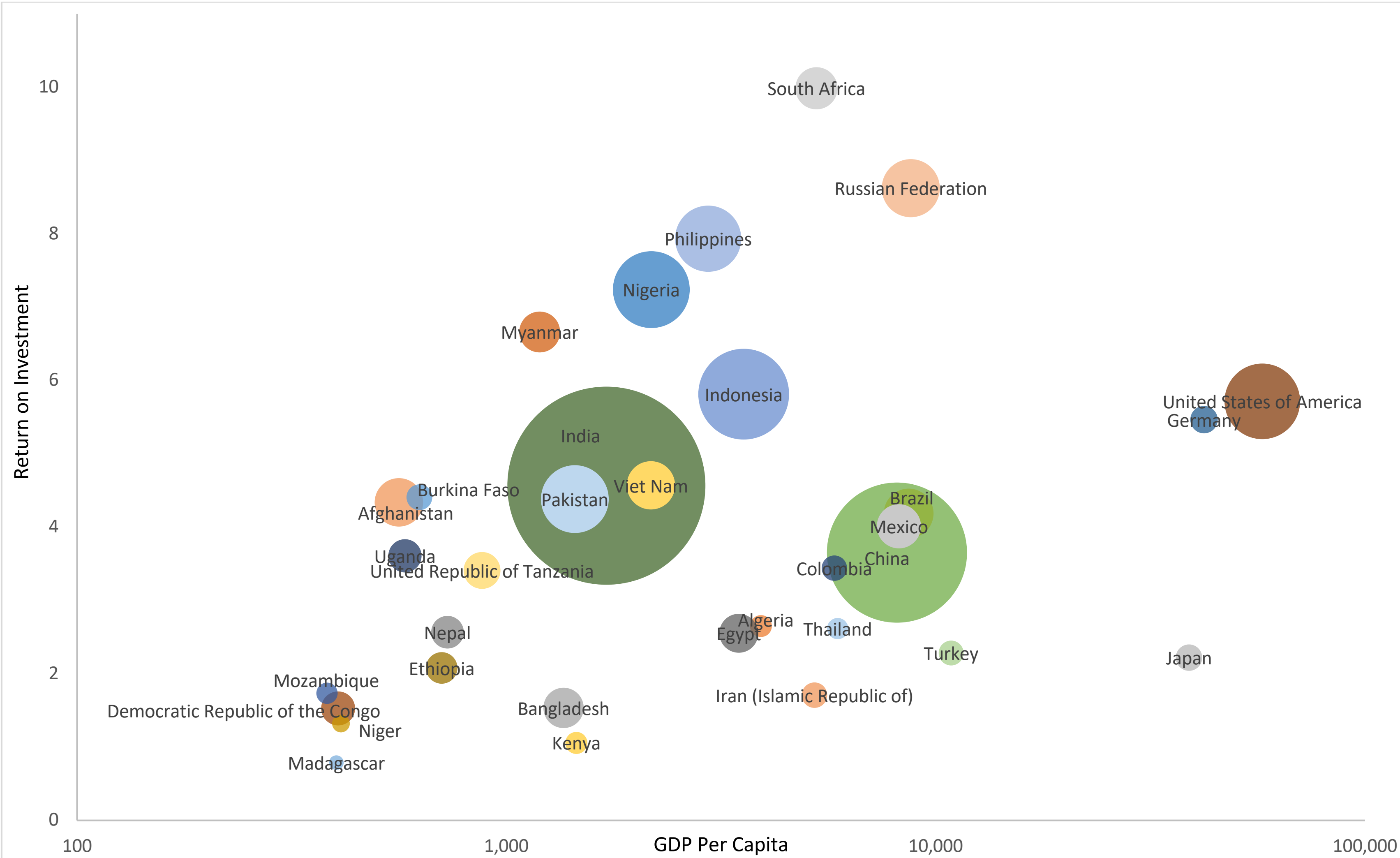
Ukraine
Myanmar
Tunisia
Pakistan
Yemen
Morocco
Sudan
Kenya
Bangladesh
Ghana



Top panel: low-income countries; middle panel: lower-middle-income countries; bottom panel: upper-middle-income countries. The range of values shown for each country come from the worst- and best-case scenario analyses; the point reflects the base case scenario. "Cumulative per-capita economic benefits" are calculated as the cumulative aggregate benefits in each country divided by the number of cohort members in each country (based on population estimates for ages 5-14 in each country in the year 2015). Benefits are represented in 2016 US dollars and are discounted at 3% annually.

Figure A5. Country-specific return on investment for the NCD risk factor package



This figure presents the overall return on investment – sum of the cumulative discounted economic benefits vs. cumulative discounted costs – of the package of six NCD risk factor reduction interventions in the most populous nations that were included in the study for each World Bank income group. The size of each bubble is proportional to the number of cumulative deaths averted.

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