Technical Document: Cost Recovery and Revenue Estimator – *CoRRE*

Introduction

CoRRE is designed for public health community, health policy advocates, and policy makers to assess the economic costs of smoking in their countries, as well as potential economic gains to be expected from reductions in smoking. The estimator is based on country-level data from UN agencies, other international organizations, government agencies, and proprietary sources. It translates the adverse effects of smoking on nations—and the opportunities to reverse those effects—into monetary values, the universal language of policy makers. *CoRRE* offers the following five sets of estimates:

(i) national economic cost due to smoking;
(ii) potential national economic cost recovery from reduction in smoking prevalence;
(iii) recommended cigarette total tax and price to achieve the desired reduction in smoking prevalence;
(iv) expected tax revenue gain from raising cigarette tax and price to the recommended levels; and
(v) cost-of-illness broken down into excess health expenditures and loss of productivity from smoking-related morbidities and premature mortality.

The estimates are provided in equivalent local currency units, U.S. dollars, and International Purchasing Power Parity dollars (Int$PPP).

This technical note provides a detailed guide for users to understand each step in the estimation presented in the tool including data sources, variable definitions, and references. There are three sections in the technical document. Section 1 elaborates the estimation of smoking-attributable national economic cost. Section 2 discusses the method of calculation of national economic cost recovery from reduction in smoking prevalence induced by an increase in cigarette tax and price. Section 3 explains how the tool estimates the cost-of-illness attributable to smoking.

Section 1. Smoking-attributable national economic cost

Smoking-attributable national economic cost is a measure of the cumulative, aggregate economic loss that accounts for the negative impact of smoking on population health and the economy, including by lowering income trajectories. The country level economic loss has been estimated using the difference between observed gross domestic product (GDP) and potential GDP under the counterfactual scenario of smoke-free state. It represents a more comprehensive and improved method of assessing costs and gains compared to the cost-of-illness approach. The estimator calculates the cumulative loss over a 15-year period from 2010 to 2025 in light of two considerations, drawn from the study conducted by Nargis and colleagues (2022) using U.S. data, and extrapolates those considerations to other countries with adequate data availability.

First, the adverse impacts of smoking on population health and the economy become tangible with some lag between the cause/intervention and the effects. The same is true with the reversal of adverse impacts, as observed in studies of reduced excess risk of smoking-related deaths after cessation of smoking. Nargis et al. (2022) estimated this lag to be five years on average, which implies that the population-level impact of smoking in 2020 will be reflected in the projected income values in 2025. However, the projected income values in 2025 are on a trajectory that has already been lowered by the smoking status of the population in previous years. In the present case of the five-year-lag scenario, the lowering of the income path in 2025 is traced back to the year 2020, which then goes back to 2015, and further on to 2010, with the carryover effect diminishing the further one goes into the past.

Second, the parameters used in this tool—such as the elasticity of per capita GDP (PGDP), with respect to the smoking status of the population, and the coefficient of lagged PGDP—are estimated based on state-level data from the U.S. Even though the scenarios of the tobacco epidemic and its health and economic consequences may vary widely across countries, the parameter estimates are generalizable in view of the method of estimation in Nargis et al. (2022), using relative values of all the variables as opposed to absolute values. We encourage readers who are interested in the details of the derivation of the estimation model to read the technical appendix to this article.

Variables and parameters	Data sources
Ratio of potential to observed PGDP (2015, 2020 and 2025) The ratio of potential PGDP under the counterfactual scenario of smoke-free state to the observed PGDP under the status quo is calculated using the following variable and parameter: (i) percentage of non-smokers in the population, termed non-smoking prevalence (NSP) in a given year, calculated as the difference of smoking prevalence from 95%; NSP in the smoke-free state assumed the value of 95% to allow for 5% non-commercial smoking prevalence; and (ii) elasticity of PGDP with respect to NSP (EPN). The formula used for this calculation is given by: $Ratio\ of\ potential\ to\ observed\ PGDP = \frac{\left(1 + EPN \times \frac{0.95 - NSP}{0.95 + NSP}\right)}{\left(1 - EPN \times \frac{0.95 - NSP}{0.95 + NSP}\right)}$	1. Smoking prevalence estimates for reference years were obtained from World Health Organization. (2023). Global Health Observatory database. Available from https://www.who.int/data/gho 2. The EPN estimate was obtained from Nargis, N., Hussain, A. K. M. G., Asare, S., Xue, Z.,

where: NSP = Non-smoking prevalence, derived as 100% less percentage of smokers in a population; the NSPs for 2010, 2015, and 2020 were used for calculating the ratios of potential to observed PGDP for 2015, 2020, and 2025 respectively. EPN = Elasticity of per capita income with respect to NSP, estimated at 0.143 (Nargis et al., 2022) which indicates that for every 1% increase in the percentage of nonsmokers in the population due to reduction in smoking in a given year *t*, per capita income is expected to increase by 0.143% in 5 years in *t+5*.	Majmundar, A., Bandi, P., Islami, F., Yabroff, K. R., & Jemal, A. (2022). Economic loss attributable to cigarette smoking in the USA: An economic modelling study. *The Lancet Public Health*, *7*(10), e834–e843.
<u>Potential PGDP (2015, 2020, and 2025)</u> The potential PGDP represents the level of GDP per person that could be achieved at the desired smoke-free state. This potential PGDP is calculated by adjusting the observed PGDP in 2025 prices of each year with their ratios of potential to observed PGDP: $Potential\ PGDP = Ratio\ of\ potential\ to\ observed\ PGDP \times Observed\ PGDP$	Observed PGDP (2015, 2020) and projected PGDP (2025) were retrieved from International Monetary Fund (IMF) (April 2024). *World Economic Outlook Database*. Washington, D.C., United States of America: International Monetary Fund (IMF). Available from https://www.imf.org/external/datamapper/datasets/WEO
<u>PGDP gap (2015, 2020, and 2025)</u> The PGDPs for 2020 and 2015 are converted to 2025 constant prices by multiplying with the ratio of the GDP deflator for 2025 to the GDP deflators for 2020 and 2015, respectively: $PGDP\ in\ reference\ year\ in\ 2025\ constant\ prices = PGDP\ in\ reference\ year \times \frac{GDP\ deflator\ (2025)}{GDP\ deflator\ (reference\ year)}$ The PGDP gap for each reference year is then given by:$PGDP\ gap\ in\ 2025\ constant\ prices = Potential\ PGDP\ in\ 2025\ constant\ prices - Observed\ PGDP\ in\ 2025\ constant\ prices$ PGDP gaps for 2015 and 2020 (in 2025 constant prices) are then multiplied with a coefficient of lagged income, estimated at 0.531 (Nargis et al., 2022): $PGDP\ gap\ (2015)\ in\ 2025\ constant\ prices = (0.531)^2 \times PGDP\ gap, 2015$ $PGDP\ (2020) in\ 2025\ constant\ prices = (0.531) \times PGDP\ gap, 2020$	1. PGDP (2015, 2020, and 2025) and GDP deflator (2015 and 2020) retrieved from International Monetary Fund (IMF). *World Economic Outlook Database*. Washington, D.C., United States of America: International Monetary Fund (IMF). https://www.imf.org/external/datamapper/datasets/WEO 2. The estimate of the coefficient of lagged income was obtained from Nargis, N., Hussain, A. K. M. G., Asare, S., Xue, Z., Majmundar, A., Bandi, P., Islami, F., Yabroff, K. R., & Jemal, A. (2022). Economic loss attributable to cigarette smoking in the USA: An economic modelling

	study. *The Lancet Public Health*, *7*(10), e834–e843.
National economic cost *Smoking-attributable national economic cost in 2025 constant prices = [PGDP gap (2025) + PGDP gap (2020) + PGDP gap (2015)] X Population (2025)*	The country-level total population data were obtained from U.S. Census Bureau. International Database (IDB). Available from https://www.census.gov/data-tools/demo/idb/#/pop?COUNTRY_YEAR=2022&COUNTRY_YR_ANIM=2022&menu=popViz&POP_YEARS=2020&popPages=BYAGE&ageGroup=BR

Note: The PGDP gap (2025) is linked to the smoking status of the population in 2020, while the PGDP gap (2020) and PGDP gap (2015) are linked to the income-propagation mechanism in the previous decade. The estimates from further back in the past become negligible and are omitted for simplification of the estimation procedure. The current estimate of the cumulative economic loss can be taken as a close approximation to the true estimate.

Section 2. National economic cost recovery from reduction in smoking

This section provides users with the option to select a desired absolute reduction in smoking prevalence ranging from -1% point to -5% points. Based on the selected percentage-point reduction, the tool will estimate the expected economic gain from the reduction in smoking and the recommended cigarette price and tax per pack needed to achieve that reduction.

2.1. Expected national economic cost recovery from desired smoking reduction

The expected national economic cost recovery is estimated as a gain in projected GDP in five years from the year of reduction in smoking prevalence to the desired level.

Variables and Parameters	Data Sources
Ratio of potential to projected PGDP (2028) The ratio of potential PGDP under the counterfactual scenario with a reduced smoking prevalence to the projected PGDP under the status quo is calculated using non-smoking prevalence (NSP1) (100% less smoking prevalence) in the base year, desired non-smoking prevalence (NSP2) (100% less desired smoking prevalence) , and elasticity of per capita income with respect to NSP (EPN). The base year for the desired reduction in smoking prevalence and corresponding increase in non-smoking prevalence is 2023, and the expected economic gain is projected for 2028 (i.e., five years after the intervention). The formula used for this calculation is as follows: $$Ratio\ of\ potential\ to\ projected\ PGDP = \frac{\left(1 + EPN \times \frac{NSP2 - NSP1}{NSP2 + NSP1}\right)}{\left(1 - EPN \times \frac{NSP2 - NSP1}{NSP2 + NSP1}\right)}$$ where: NSP1 = non-smoking prevalence, derived as 100% less percentage of smokers in a country's population; the NSPs for 2010, 2015, and 2020 were used for calculating the ratios of potential to projected PGDP for 2015, 2020, and 2025, respectively; NSP2 = desired non-smoking prevalence, derived as 100% less desired smoking prevalence; and EPN = elasticity of per capita income with respect to NSP, estimated at 0.143 (Nargis et al., 2022), which indicates that for every 1% increase in the percentage of non-smokers in the population due to reduction in smoking in a given year t, PGDP is expected to increase by 0.143% in five years in t+5.	1. Smoking prevalence (2022) data were retrieved from World Health Organization. (2023). *Global Health Observatory database*. https://www.who.int/data/gho 2. The EPN estimate was obtained from Nargis, N., Hussain, A. K. M. G., Asare, S., Xue, Z., Majmundar, A., Bandi, P., Islami, F., Yabroff, K. R., & Jemal, A. (2022). Economic loss attributable to cigarette smoking in the USA: An economic modelling study. *The Lancet Public Health*, *7*(10), e834–e843.

Potential PGDP (2028) The potential PGDP (2028) in 2028 constant prices under the scenario of the desired reduction in smoking prevalence is calculated by adjusting the projected PGDP (2028) in 2028 constant prices under the status quo with the ratio of potential to projected PGDP (2028): $Potential\ PGDP = Ratio\ of\ potential\ to\ \ projected\ PGDP \times Projected\ PGDP$	Projected PGDP (2028) in 2028 prices were retrieved from International Monetary Fund (IMF) (April 2024). *World Economic Outlook Database*. Washington, D.C., United States of America: International Monetary Fund (IMF). https://www.imf.org/external/datamapper/datasets/WEO
Expected PGDP gain (2028) Expected PGDP gain (2028) is given by the difference between potential PGDP (2028) and projected PGDP (2028) in 2028 constant prices: $PGDP\ gain = Potential\ PGDP - Projected\ PGDP$	
National economic cost recovery $National\ economic\ cost\ recovery$ $= Expected\ PGDP\ gain\ (2028) \times Projected\ population\ (2028)$	The country-level projected total population data were obtained from U.S. Census Bureau. International Database (IDB). Available from https://www.census.gov/data-tools/demo/idb/#/pop?COUNTRY_YEAR=2022&COUNTRY_YR_ANIM=2022&menu=popViz&POP_YEARS=2020&popPages=BYAGE&ageGroup=BR

2.2. Recommended cigarette price per pack

The tool calculates the recommended price of a 20-cigarette pack to attain the desired smoking prevalence. This is based on the desired percentage decrease in smoking prevalence and the price elasticity of smoking prevalence.

Variables and parameters	Data sources
Desired percentage decrease in smoking prevalence The desired percentage decrease in smoking prevalence is a measure used to quantify the reduction in smoking rates between the baseline and the desired level. The formula used for this calculation is as follows: $$Desired\ percentage\ decrease\ in\ smoking\ prevalence = \frac{(Baseline\ smoking\ prevalence - Desired\ smoking\ prevalence)}{Baseline\ smoking\ prevalence}$$	Baseline cigarette smoking prevalence (2022) data were retrieved from World Health Organization. (2023). *Global Health Observatory database*. https://www.who.int/data/gho
Required percentage increase in cigarette price The required percentage increase in cigarette price is determined based on the desired percentage decrease in smoking prevalence. This calculation leverages the concept of price elasticity of smoking prevalence, which measures the responsiveness of smoking prevalence to changes in cigarette price. The formula used for this calculation is as follows: $$Required\ percentage\ increase\ in\ cigarette\ price = \frac{Desired\ percentage\ decrease\ in\ smoking\ prevalence}{Price\ elasticity\ of\ smoking\ prevalence}$$ Note: The value of the price elasticity of smoking prevalence used in this tool is -0.20, based on the midpoint of the range of estimates in previous studies (U.S. National Cancer Institute and World Health Organization, 2016).	The price elasticity of smoking prevalence estimates was obtained from U.S. National Cancer Institute and World Health Organization. (2016). *The Economics of Tobacco and Tobacco Control*. National Cancer Institute Tobacco Control Monograph 21. NIH Publication No. 16-CA-8029A. Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute; and Geneva, CH: World Health Organization.
Recommended cigarette price per pack $$Recommended\ cigarette\ price\ per\ pack = Baseline\ cigarette\ price\ per\ pack \times (1 + Required\ percentage\ increase\ in\ cigarette\ price)$$	Baseline cigarette price per pack (2022) data were retrieved from World Health Organization. (2023). *WHO Report on the Global Tobacco Epidemic, 2023*.

2.3. Recommended total tax per pack of cigarettes

Recommended total tax per pack of cigarettes is the recommended tax per 20-cigarette pack to attain the recommended cigarette price level that would lead to the desired reduction in smoking prevalence.

Variables and parameters	Data sources
Baseline total tax per pack of cigarettes (2022) The baseline total tax per pack of cigarettes is determined by using the baseline cigarette price per pack and the total cigarette tax share: $Baseline\ total\ tax\ per\ pack\ of\ cigarettes$ $= Baseline\ cigarette\ price\ per\ pack \times Total\ cigarette\ tax\ share$	Baseline cigarette price per pack of 20 pieces of the most-sold cigarette brand (2022) and total cigarette tax share (excise, sales, and other taxes combined) for the most-sold brand (2022) were retrieved from World Health Organization. (2023). *WHO Report on the Global Tobacco Epidemic, 2023*.
Recommended increase in total tax per pack of cigarettes The desired increase in total tax per pack of cigarettes is determined by the difference between the recommended cigarette price per pack and the baseline cigarette price per pack, under the assumption that the tax increase is fully passed on to retail price increase: $Recommended\ increase\ in\ total\ tax\ per\ pack\ of\ cigarettes$ $= Recommended\ cigarette\ price\ per\ pack$ $-Baseline\ cigarette\ price\ per\ pack$ The details of the calculation of the recommended cigarette price per pack are available in Section 2.2 above.	Baseline cigarette price per pack (2022) data were retrieved from World Health Organization. (2023). *WHO Report on the Global Tobacco Epidemic, 2023*.
Recommended total tax per pack of cigarettes $Recommended\ total\ tax\ per\ pack\ of\ cigarettes$ $= Baseline\ total\ tax\ per\ pack\ of\ cigarettes$ $+Recommended\ increase\ in\ total\ tax\ per\ pack\ of\ cigarettes$	

2.4. Expected cigarette tax revenue

Expected cigarette tax revenue is the revenue expected to be generated through cigarette sales at the desired smoking prevalence. It is calculated based on the recommended cigarette tax and projected cigarette sales and smoking intensity at the desired smoking prevalence. These are annual estimates

referring to a one-year window after the implementation of the recommended increases in cigarette tax and price.

Variables and parameters	Data sources
Baseline number of adult smokers (2020) The baseline number of adult smokers is estimated by multiplying the baseline smoking prevalence by total population in 2020. Baseline smoking intensity (2020) Smoking intensity is a measure that quantifies the average number of cigarettes consumed by each smoker over a one-year period. The baseline smoking intensity is calculated by dividing the annual total number of cigarettes sold by the total number of adult smokers: $$Baseline\ smoking\ intensity = \frac{Baseline\ total\ cigarette\ sales\ (million\ pieces)}{Baseline\ number\ of\ adult\ smokers}$$	1. Number of cigarettes sold per country in 2022 were retrieved from Euromonitor International. (2024). *Market sizes: Cigarettes* [Dataset]. Passport. https://www.portal.euromonitor.com/ 2. Smoking prevalence data were retrieved from World Health Organization. (2023). *Global Health Observatory data repository*. https://www.who.int/data/gho 3. Total population data were retrieved from U.S. Census Bureau. International Database (IDB). Available from https://www.census.gov/data-tools/demo/idb/#/pop?COUNTRY_YEAR=2022&COUNTRY_YR_ANIM=2022&menu=popViz&POP_YEARS=2020&popPages=BYAGE&ageGroup=BR
Expected percentage reduction in smoking intensity The expected percentage reduction in smoking intensity quantifies the expected decrease in the average number of cigarettes consumed per smoker due to an increase in cigarette prices. This calculation leverages the concept of price elasticity of smoking intensity, which measures the responsiveness of smoking intensity to changes in cigarette prices. The formula used for this calculation is as follows: $$Expected\ percentage\ reduction\ in\ smoking\ intensity = Price\ elasticity\ of\ smoking\ intensity \times Recommended\ percentage\ increase\ in\ cigarette\ price$$	Price elasticity of smoking intensity estimate was obtained from U.S. National Cancer Institute and World Health Organization. (2016). *The Economics of Tobacco and Tobacco Control*. National Cancer Institute Tobacco Control Monograph 21. NIH Publication No. 16-CA-8029A. Bethesda, MD:

The value of the price elasticity of smoking intensity used in the tool is -0.20, based on the midpoint of the range of estimates in previous studies (U.S. National Cancer Institute and World Health Organization, 2016). The details of the calculation of the recommended percentage increase in cigarette price are available in Section 2.2 above.	U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute; and Geneva, CH: World Health Organization.
Expected reduced smoking intensity The expected reduced smoking intensity quantifies the average number of cigarettes consumed per smoker after increasing cigarette tax and price to the recommended levels. It is calculated by applying the expected percentage reduction in smoking intensity to the baseline smoking intensity. The formula used for this calculation is as follows: $Expected\ reduced\ smoking\ intensity$ $= Baseline\ smoking\ intensity$ $\times (1 + Expected\ percentage\ reduction\ in\ smoking\ intensity)$	
Expected reduced number of smokers The expected reduced number of smokers is determined by applying the desired smoking prevalence to the adult population in 2023. The formula used for this calculation is as follows: $Expected\ reduced\ number\ of\ smokers$ $= Desired\ smoking\ prevalence \times Adult\ population\ in\ 2023$	Adult population (15+) data for 2023 were retrieved from U.S. Census Bureau. International Database (IDB). Available from https://www.census.gov/data-tools/demo/idb/#/pop?COUNTRY_YEAR=2022&COUNTRY_YR_ANIM=2022&menu=popViz&POP_YEARS=2020&popPages=BYAGE&ageGroup=BR
Expected reduced annual total cigarette sales (million pieces) The expected reduced annual total cigarette sales are determined by multiplying the expected reduced smoking intensity by the expected reduced number of adult smokers. This calculation helps estimate the expected reduced total number of cigarettes that will be sold at the desired smoking prevalence and expected smoking intensity at the recommended cigarette price and tax. The formula used for this calculation is as follows: $Expected\ reduced\ annual\ total\ cigarette\ sale$ $= Expected\ reduced\ smoking\ intensity$ $\times Expected\ reduced\ number\ of\ smokers$	

Expected cigarette tax revenue $Expected\ annual\ cigarette\ tax\ revenue$ $= \left(\frac{Expected\ reduced\ annual\ cigarette\ sales\ in\ million\ pieces}{20}\right)$ $\times\ Recommended\ cigarette\ tax\ per\ pack$	

Note: The expected cigarette tax revenue is determined by multiplying the expected reduced cigarette sales (converted to 20-cigarette packs in millions) by the recommended cigarette tax per pack. This calculation helps estimate the expected annual total tax revenue generated from cigarette sales after the implementation of cigarette tax and price increases.

2.5. Expected cigarette tax revenue gain

Expected cigarette tax revenue gain illustrates how much additional revenue can be generated through recommended increases in cigarette price and tax to attain the desired reduction in smoking prevalence.

Variables and parameters	Data sources
Baseline cigarette tax revenue (2023) The baseline cigarette tax revenue is determined by multiplying the baseline total cigarette sales (converted to 20-cigarette packs in millions) by the baseline cigarette tax per pack. This calculation helps to estimate the total tax revenue generated from cigarette sales before applying recommended cigarette price and tax. The formula used for this calculation is as follows: $Baseline\ cigarette\ tax\ revenue$ $= \left(\frac{Baseline\ total\ cigarette\ sales\ in\ million\ pieces}{20}\right)$ $\times\ Baseline\ cigarette\ tax\ per\ pack$ The details of the calculation of baseline cigarette tax per pack are provided in Section 2.3 above.	Data on the number of cigarettes sold in individual countries in 2023 were obtained from Euromonitor International. (2024). *Market sizes: Cigarettes* [Dataset]. Passport. https://www.portal.euromonitor.com/
Expected cigarette tax revenue gain $Expected\ tax\ revenue\ gain$ $= Expected\ cigarette\ tax\ revenue - Baseline\ cigarette\ tax\ revenue$	

Section 3. Cost-of-illness attributable to smoking

3.1. Smoking-attributable direct cost-of-illness: Health expenditure

The smoking-attributable direct cost or health expenditure is the aggregate health expenditure to treat illnesses caused by smoking and exposure to second-hand smoke. This calculation provides an estimate of the smoking-related financial burden on a nation's public and private health care systems funded by taxpayers' money, donors' aid, and/or out-of-pocket expenses of the patients and their families.

Variables and parameters	Data sources
Smoking- and second-hand-smoke-exposure–attributable fraction (SAF) of total health expenditure (%) (2021) The SAF estimates the percentage of health care costs that can be attributed to smoking-related illnesses and deaths. The country-specific SAF is drawn from the studies that estimated SAF for individual countries. As this type of study is limited to only a few countries, country-specific SAF for the remaining countries is calculated with a generalized formula as follows: *SAF of total health expenditure = Smoking-attributable death rate (SAD) per 100,000 population aged 25 years and above × 0.024643* The coefficient 0.024643 relates SAD to SAF of total health expenditure, as estimated in Goodchild et al. (2018), based on prior country-specific SAF estimates.	1. The age-specific smoking-attributable death rate (SAD) for 25 years and older age group for both smoking and second-hand smoke exposure were obtained from the Global Burden of Disease Collaborative Network. (2022). *Global Burden of Disease Study 2021 (GBD 2021) results*. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). https://vizhub.healthdata.org/gbd-results/ 2.Goodchild, M., Nargis, N., & Tursan d'Espaignet, E. (2018). Global economic cost of smoking-attributable diseases. *Tobacco Control, 27*(1), 58-64.
Total health expenditure (2021) The total health expenditure, which includes both public and private spending, is calculated by multiplying the per capita health expenditure in 2021 by the total population. This calculation provides an estimate of the overall financial resources dedicated to health care in a country or region.	1. Per capita health expenditure (2021) data were retrieved from the WHO Global Health Observatory Database. 2. Total population 2021 data were retrieved from U.S. Census Bureau. International Database. Available from

	https://www.census.gov/data-tools/demo/idb/#/pop?COUNTRY_YEAR=2022&COUNTRY_YR_ANIM=2022&menu=popViz&POP_YEARS=2020&popPages=BYAGE&ageGroup=BR
Smoking-attributable direct cost or health expenditure (2021) $Smoking\text{-}attributable\ direct\ cost = SAF \times Total\ health\ expenditure$	

3.2. Smoking-attributable indirect cost-of-illness: Productivity loss

The smoking-attributable cost due to productivity loss represents the economic burden caused indirectly by reduced productivity related to illnesses from smoking and second-hand smoke exposure. This includes both the morbidity cost (productivity losses due to illness and disability) and the mortality cost (productivity losses due to premature deaths). The total productivity loss is calculated by summing up these costs.

Variables and parameters	Data sources
Morbidity cost (2021) The indirect cost due to smoking-related morbidity is calculated by considering the years lived with disability (YLD) due to illnesses attributable to smoking and exposure to secondhand smoke, PGDP (2021), and the employment rate, which reflects the proportion of the working-age population engaged in employment in 2021. The formula used for this calculation is as follows: $Smoking\text{-}attributable\ morbidity\ cost = Smoking\text{-}attributable\ YLD \times PGDP \times Employment\ rate$	1. YLD 2021 data were obtained from Global Burden of Disease Collaborative Network. (2022). *Global Burden of Disease Study 2021 (GBD 2021) Results*. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). https://vizhub.healthdata.org/gbd-results/ 2. PGDP (2021) and employment rate (2021) data were retrieved from International Monetary Fund (IMF). *World Economic Outlook Database*. Washington, D.C., United States of America: International Monetary Fund (IMF). https://www.imf.org/external/datamapper/datasets/WEO

Mortality cost (2021) The indirect cost due to smoking-related mortality is calculated by considering the years of life lost (YLL) attributable to premature mortality from illnesses caused by smoking and exposure to secondhand smoke, PGDP (2021), and the employment rate, which reflects the proportion of the working-age population engaged in employment in 2021. The formula used for this calculation is as follows: *Smoking-attributable mortality cost = Smoking-attributable YLL × PGDP × Employment rate* This estimate is simplified from the human capital approach in the cost-of-illness studies that estimates discounted future productivity losses from the year after death to the expected life years of individuals stratified by age and sex at death. The estimates from the two approaches would be the same under the assumption that the growth rate in future productivity and the discount rate for future income are equal.	1. YLL 2021 data were obtained from Global Burden of Disease Collaborative Network. (2022). *Global Burden of Disease Study 2021 (GBD 2021) Results*. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2022. https://vizhub.healthdata.org/gbd-results/ 2. PGDP 2021 and employment rate 2021 data were retrieved from International Monetary Fund (IMF). *World Economic Outlook Database*. Washington, D.C., United States of America: International Monetary Fund (IMF). https://www.imf.org/external/datamapper/datasets/WEO
Smoking-attributable indirect cost or productivity loss (2021) *Smoking-attributable indirect cost = Smoking-attributable morbidity cost + Smoking-attributable mortality cost*	

3.3. Annual smoking-attributable cost-of-illness

The annual smoking-attributable cost-of-illness represents the total economic burden of smoking-related diseases on society. This includes both the direct health care costs and the indirect costs associated with lost productivity due to smoking-related illnesses and premature deaths from those illnesses. The total cost of illness is calculated by summing these two components.

Annual smoking-attributable cost-of-illness = Smoking-attributable direct cost + Smoking-attributable indirect cost