The Economic Costs of Tobacco Use in Bangladesh: An updated estimate including health and environmental damages

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Abstract

Tobacco use remains a leading preventable cause of morbidity, premature mortality, and economic loss in Bangladesh. While earlier studies of the costs of tobacco use in Bangladesh have focused on direct medical and productivity losses, this study presents an expanded analysis that includes environmental externalities such as waste, land degradation, and pollution.

This study estimates the total annual economic costs of smoked and smokeless tobacco consumption and production in Bangladesh at BDT 875.44 billion in 2024 (1.58% of the GDP). Using a prevalence-based cost-of-illness framework, updated with the latest available data, the estimated health-related costs are BDT 730.63 billion (83.5 percent of total costs). Additionally, this is the first study to our knowledge to integrate comprehensive costs of the environmental damages (estimated at BDT 144.81 billion, or 16.5 percent of the total costs) associated with tobacco consumption and production. A probabilistic sensitivity analysis confirms the overall estimate's robustness, yielding a 95-percent confidence interval of BDT 716 billion to 1.056 trillion total. Morbidity and private health care expenditures are the most sensitive cost components.

The substantial and under-recognized economic burden revealed by this study underscores the urgent need for stronger tobacco control measures, including significant tax reforms, to achieve Bangladesh's 2040 tobacco-free goal.

Introduction

Tobacco use continues to pose a significant challenge to public health in South Asia, including Bangladesh. Despite some progress in reducing prevalence rates over the past decade, tobacco consumption remains high, with more than one-third of Bangladeshi adults using some form of tobacco (WHO, 2021). The burden is particularly severe among low-income households, where the health impacts of tobacco-attributable diseases are exacerbated by limited access to health care. The economic consequences of tobacco use extend well beyond health status, however, encompassing increased health care costs and productivity losses as well as broader social and environmental harms.

The World Health Organization (WHO) estimates that tobacco use causes more than eight million deaths annually. In addition, tobacco-related health expenditures and productivity losses impose more than USD 1.4 trillion in costs on the global economy (*Tobacco Scorecard 2nd Edition - Policy Note: Tax Structure*, 2025). These costs disproportionately affect low- and middle-income countries with under-resourced health systems, and Bangladesh is no exception. A 2018 study estimated the economic cost of tobacco use in the country to be BDT 305.6 billion (USD 3.6 billion), or around 1.4 percent of gross domestic product (GDP), based on direct medical costs and productivity losses. However, by excluding environmental costs such as deforestation, waste generation, and pollution, those costs were vastly underestimated.

Global research has highlighted how tobacco production and consumption contribute to land degradation, air and water pollution, and nonbiodegradable waste. For instance, discarded cigarette butts are among the most common forms of litter globally. These externalities remain largely unaccounted for in traditional economic analyses of the costs of tobacco use.

In Bangladesh, specifically, tobacco farming contributes to soil depletion, pesticide runoff, and water contamination. For example, a study using laboratory analyses of soil and water samples from tobacco and non-tobacco farming areas found significant environmental damage from tobacco cultivation. Factoring in unpaid labor and opportunity costs, the study concluded that tobacco farming in fact yields a net social loss in the country (Hussain et al., 2020).

This study aims to update and expand upon previous estimates of the costs of tobacco in Bangladesh by incorporating environmental costs into a comprehensive cost-of-illness (COI) framework. It integrates new data sources, updated disease burden metrics, and probabilistic

sensitivity analysis (PSA) to better capture uncertainty in cost estimates. The findings are intended to inform robust fiscal and regulatory policy, especially adopting optimal tobacco tax policy to support Bangladesh's goal of becoming tobacco-free by 2040.

Data & Methodology

This study estimates three categories of economic costs associated with tobacco consumption and production: 1) direct health costs resulting from tobacco use and second-hand smoking; 2) productivity loss due to tobacco use and second-hand smoking and 3) environmental costs attributed to tobacco production and consumption. To estimate the direct health costs and productivity loss, we follow a prevalence-based cost-of-illness (COI) approach. Costs to the environment include land use and degradation, waste and pollution, fire hazards and climate impact. Data sources and estimation methods of these components are detailed in the following sections.

Estimating tobacco use and associated epidemiological measures

Using data from the 2018 WHO STEPwise approach to NCD risk factor surveillance (STEPS) survey, we estimate the prevalence rate of tobacco use among adults of 30 years and older, including both smoked and smokeless tobacco. The relative risk (RR) estimate is imputed from a previous study from 2018 (Faruque, 2020). Without a strong reason to assume an epidemiological transition in the population, we can reasonably assume the RR would not change significantly from 2018 to 2024.

With these prevalence and RR values, we calculate the population-attributable risk (PAR) for tobacco consumption in 2024. Population data for the 30-years-or-older age group are taken from the United Nations World Population Prospect 2024. Building upon the previous estimate in Nargis et al. (2020), we extend the list of diseases by adding pneumonia, tuberculosis, kidney and liver disease as numerous studies report their association with tobacco use (Jayes et al., 2016; Jiang et al., 2020; Marti-Aguado et al., 2022; Yacoub et al., 2010).

From the nationally representative Household Income and Expenditure Survey (HIES) 2022, we compute the proportion of individuals (30 years or older) who reported being affected with the selected tobacco-related diseases (blood pressure, respiratory disease/bronchial asthma, chronic heart disease, cancer, pneumonia, tuberculosis, kidney disease, and liver disease).

Taking this value as the prevalence rate and multiplying it by the total population in 2024 and the PAR we estimate the total number of patients affected by tobacco-attributable disease in 2024, assuming the prevalence rate is unchanged from 2022 to 2024. More detailed methodology and a list of the variables used in estimating health-related costs are provided in the appendix.

Estimating health-related economic burden

We use the cost-of-illness (COI) framework to estimate the health-related economic burden of tobacco use in Bangladesh, encompassing direct health care costs and indirect health-related productivity losses. This prevalence-based, disease-specific approach follows standard COI methods.

The analysis covers seven major tobacco-attributable diseases—ischemic heart disease, stroke, chronic obstructive pulmonary disease (COPD), pulmonary tuberculosis, and cancers (lung, laryngeal, oral)—that have well established links to tobacco use (Faruque, 2020). In addition, to capture the impacts of second-hand smoke exposure, we include health conditions among non-smokers (especially children and infants)—such as asthma, lower respiratory infections, low birth weight, and sudden infant death syndrome (SIDS)—that are associated with living in households with smokers (WHO, 2017).

For each of these conditions, we determine the proportion of cases (and deaths) attributable to tobacco use, utilizing the standard population-attributable risk (PAR) formula based on tobacco exposure prevalence and relative risk (RR) of the outcome in exposed versus unexposed groups (*Economics of Tobacco Toolkit: Assessment of the Economic Costs of Smoking*, 2011).

Health care cost estimation (direct costs)

Bangladesh has a pluralistic health system with public, private, and informal providers. Public hospitals are primarily financed by the government, but patients may still incur small user fees and medication costs out of pocket. Private providers include privately owned clinics/hospitals and individual practitioners. These are relatively more expensive than public facilities, operate on either a for-profit or not-for-profit basis, and are financed mainly through out-of-pocket payments from the patients. Informal providers are non-qualified providers, such as traditional healers and pharmacy shopkeepers, offering low-cost and accessible outpatient services, also paid for out of pocket.

In our analysis, we define public health system cost as government spending on health care in public facilities, excluding any payments by patients. Private cost refers to out-of-pocket payments made by patients seeking care in both public and private facilities, including informal providers.

To estimate direct health care costs, we separately estimate expenditures for outpatient care, inpatient care, and medications for chronic patients, distinguishing between private out-of-pocket (OOP) costs and public health system costs.

- **Outpatient care costs:** Private OOP spending on outpatient care is derived from the Household Income and Expenditure Survey (HIES 2022). It includes consultation fees, diagnostic costs, medication costs, and transportation costs incurred in the past three months from the day of the survey.

  Per-patient public spending on outpatient services provided in public facilities is estimated using administrative data from the Directorate General of Health Services (DGHS) and the Ministry of Health and Family Welfare (MOHFW). In the absence of reliable estimates of the costs incurred by the government for each disease, Nargis et al. (2020) reported that around half of private OOP spending was due to outpatient care while the other half was for inpatient care; we assume a similar distribution for public expenditure.
- **Inpatient care costs:** OOP spending on inpatient care is estimated from HIES 2022, which includes cost of surgery, bed charges, consultation fees, medication costs, diagnostic costs, transportation costs, informal fees, and other costs incurred in the last 12 months from the day of the survey. Similar to outpatient care cost, per-patient public expenditure for inpatient services is estimated using DGHS and MOHFW data. We took the annual budget of the Directorate General of Health Services (DGHS) under the Ministry of Health and Family Welfare and assume that half of the budget is spent on inpatient services while the other half is spent for outpatient services (Nargis et al., 2022).
- **Medication costs:** Monthly OOP cost of routine medicine for chronically ill patients is computed from HIES 2022.

All costs using data from previous years are adjusted for inflation using World Bank data (World Bank Group, n.d.). For each disease, total direct cost per patient is the sum of outpatient, inpatient, and medication costs, adjusted using the PAR.

Indirect cost estimation (productivity losses)

Indirect health costs capture the productivity losses associated with morbidity and premature mortality attributable to tobacco-related diseases.

Costs due to morbidity include the value of time lost by patients while seeking inpatient and outpatient care (estimated from HIES 2022), reflecting foregone productive activities during treatment episodes. Annual productivity losses were estimated separately for employed patients, based on reduced market productivity, and for unemployed patients, based on lost household productivity; estimated using HIES 2022 and Labor Force Survey 2022. The time spent by caregivers providing care to sick individuals was also included, valued as forgone productive time.

Mortality-related indirect costs were estimated using the human capital approach, accounting for productivity losses due to premature deaths from tobacco-related illnesses. We measured the present value of future earnings lost over the remaining expected working life. Costs of mortality are estimated from the tobacco-attributable mortality data from the Bangladesh country profile in the Global Burden of Disease (GBD) 2021 study. For each tobacco-attributable death of an individual aged 30–64 years, we measure the lost productive years and multiply that by the patient's expected annual income and probability of surviving that year (from WHO life tables) to get the foregone income due to death.

The sum of morbidity- and mortality-related productivity losses constitutes the total indirect cost.

Second-hand smoke impacts

We estimate the economic cost of diseases from second-hand smoke exposure among non-smokers, applying PARs derived from second-hand smoking prevalence and published RRs (*Preliminary Report on GATS Bangladesh 2017*, 2025). Direct and indirect costs for these conditions are estimated using the same costing structure as above. Where country-specific data are not available, data from similar countries or regions are considered.

Environmental cost estimation

To comprehensively capture the externalities of tobacco use in Bangladesh, we extend the cost-of-illness framework to include yearly environmental costs attributable to tobacco cultivation, manufacturing, consumption, and waste disposal.

Total environmental cost comprises the following categories: 1) land use and opportunity costs of tobacco production, 2) waste and pollution from tobacco products, 3) damage due to fire hazards, and 4) emissions and climate impact. To estimate these components, we draw upon diverse national and international data sources, using conservative and transparent estimation techniques aligned with global environmental valuation practices as detailed below.

Land use and degradation

The environmental cost of land use for tobacco farming is estimated based on land area under cultivation, the opportunity cost of alternative high-yield crops such as rice production in Bangladesh, and costs associated with soil degradation and reforestation. Data from the Yearbook of Agricultural Statistics 2023 by the Bangladesh Bureau of Statistics and relevant literature are used to estimate costs. Reforestation and land rehabilitation costs are estimated using local/foreign forestry benchmarks, while opportunity costs are assessed by comparing the net returns per acre of tobacco with those of staple or cash crops. To provide a range of costs, biodiversity restoration costs are also considered.

Waste and pollution from tobacco products

Tobacco product cleanup costs: Tobacco product waste (TPW)—particularly cigarette butts – is one of the most collected waste items globally. A significant environmental concern arises from the cellulose acetate filter that is a nonbiodegradable plastic component of most commercially manufactured cigarettes. This material persists in the environment for years, releasing toxic substances into ecosystems. TPW also imposes societal costs related to proper disposal and cleanup, all of which place economic burdens on governments and municipalities. The economic impact of TPW is likely to be substantial across all income levels, affecting low- and middle-income countries (LMICs) as well as high-income countries (HICs), due to the widespread nature of tobacco consumption and littering (Lam et al., 2022).

The basic cost estimation model is expressed as:

$$c(TPW) = \lambda\, c(all)$$

where $c(TPW)$ denotes the cost of tobacco product waste (TPW) prevention and reduction, λ represents the proportion of total litter attributable to TPW, and $c(all)$ refers to the estimated costs of preventing and reducing all forms of litter.

The TPW percentage is calculated using the following formula:

$$TPW = weight \times mean\ global\ TPW\ percent$$

where

$$weight = smoking\ prevalence\ of\ Bangladesh \,/\, mean\ global\ smoking\ prevalence$$

Tobacco product cleanup costs are estimated by multiplying the average per capita cleanup cost for low- and middle-income countries (LMICs) of USD 7.85 by the proportion of wastes attributable to tobacco products.

Marine ecosystem loss

Single-use plastics, most notably discarded cigarette butts or filters, have been associated with detrimental ecological impacts, particularly on microorganisms, aquatic species, and terrestrial wildlife, as they can be transported from urban environments into rivers, streams, and ultimately oceans. This pathway connects tobacco-related plastic waste to marine ecosystem losses, compounding its negative impacts beyond immediate environmental degradation (Sy, 2024).

For estimating marine ecosystem loss (MEL) associated with tobacco product waste, we quantify the corresponding loss for Bangladesh using the following formula:

$$MEL\ (annual) = estimated\ plastic\ waste\ (EPW) \times leakage\ rate \times MEL\ from\ plastic\ pollution\ (per\ ton\ per\ year)$$

where:

$$EPW\ (tons) = [number\ of\ cigarettes\ consumed \times filter\ weight\ (g/stick)] + \{number\ of\ cigarette\ packs \times [plastic\ per\ pack\ (g) + (sleeve\ length\ (m) \times plastic\ density\ (g/m))]\}$$

Leakage rate of plastics refers to the small proportion (typically 1–14 percent, varying by country) of plastic waste that leaks into oceans. In the case of Bangladesh, this study applies a conservative assumption of a 1.5-percent leakage rate, representing the fraction of aquatic plastics that ultimately reach the ocean (Sy, 2024).

According to the World Wildlife Fund (WWF), each ton of plastic waste can cause marine ecosystem losses valued between USD 204,270 and USD 408,541 per year. To maintain a conservative and balanced approach, the median value of USD 306,405.50 from this range was used as the standard estimate for calculating the marine ecosystem impact per ton of tobacco-related plastic waste (Sy, 2024).

Fire hazards and associated damages

Discarded cigarette butts and embers from bidis or hand-rolled cigarettes are known causes of fire, especially in densely populated areas or rural ones with thatched structures. To estimate this cost, we reviewed data from the Fire Service and Civil Defense Annual Report 2024 identifying the reported value of property damages linked to tobacco-related fires in the year 2024.

Emissions and climate impact

Greenhouse gas emissions from tobacco-related activities are estimated using the values reported in Hussain et al. (2020). To assess the impacts of tobacco cultivation and processing in Bangladesh, we apply a methodology that estimates the amount of firewood required for tobacco curing and converts it into cubic meters of solid wood, while adjusting for gaps and air spaces to ensure more accurate biomass measurement. The equivalent area of woody biomass is then estimated using two approaches: the mean annual increment (MAI) method, representing a sustainable harvest, and the growing stock (GS) method, representing potential deforestation.

Carbon emissions are calculated both from burning firewood and emitted from soil due to deforestation, capturing direct and indirect sources of greenhouse gas emissions. Finally, the total carbon emissions are converted to equivalent environmental cost (USD 36 per ton of carbon-dioxide) (Hussain et al., 2020), to translate the environmental impact into dollar value (Hussain et al., 2020).

This approach provides a comprehensive assessment of the climate and ecological effects of tobacco cultivation and production, with the estimation derived on a per-acre basis. By multiplying these estimates to the total area under tobacco cultivation, the total emissions- and climate-impact-related costs are obtained.

Total cost estimation

The total economic burden of tobacco use in Bangladesh is estimated by aggregating the components described above. Each component is computed separately then summed to generate the national-level estimate. For each disease or impact domain, we apply a population-attributable risk (PAR) to isolate the proportion of the burden specifically caused by tobacco exposure. Cost estimates are expressed in 2024 Bangladeshi taka (BDT) adjusted for inflation. Table 1 provides a summary of the cost components with their associated data sources.

Probabilistic sensitivity analysis (PSA)

To account for parameter uncertainty and enhance the robustness of our cost estimates, we implement a probabilistic sensitivity analysis (PSA) using the Monte Carlo simulation with 10,000 iterations. This approach allows for a comprehensive assessment of how variability in key inputs—such as tobacco use prevalence, disease-specific relative risks, and health care or productivity costs—impacts the overall estimate of the economic burden of tobacco use in Bangladesh. Each input parameter is assigned a probability distribution based on its empirical characteristics. Examples include beta distribution for prevalence rates, as it effectively models proportions, log-normal distribution for relative risk estimates to capture their skewed and strictly positive nature, and log-normal distribution for cost parameters to reflect the nature of costs.

For each simulation run, values are randomly drawn from these distributions, and the total cost is recalculated. This process generates a distribution of outcomes from which we are able to extract key summary statistics, including the mean, median, and 95-percent confidence intervals. These outputs provide a more realistic range of potential economic impacts, rather than relying solely on point estimates. In addition, we generate tornado diagrams to identify the variables with the greatest influence on model uncertainty, thereby highlighting priority areas for data refinement and future research.

Table 1. Data sources

Component	Sources used	Descriptive indicators
Tobacco use prevalence	STEPwise approach to NCD risk factor surveillance (STEPS) 2018	Current/former use of cigarettes, bidis, smokeless tobacco by age, sex, income group
Household tobacco spending	Household Income and Expenditure Survey (HIES) 2022, Global Adult Tobacco Survey (GATS) 2017	Monthly expenditure on tobacco products
Disease prevalence & mortality	HIES 2022	Prevalence of tobacco-attributable diseases, age-specific mortality rates
Direct health costs	HIES 2022, DGHS Health Bulletin 2023, Bangladesh National Health Accounts (2020)	Out-of-pocket and public health spending by disease, type of care
Indirect costs	Labor Force Survey 2022, HIES 2022	Age-specific employment rates, average wage, household income
Environmental costs - land use	Yearbook of Agricultural Statistics 2023 by Bangladesh Bureau of Statistics; Hussain et al., 2020	Land under tobacco cultivation, opportunity cost of land, crop yields, reforestation cost
Environmental costs - waste	WHO Tobacco and Environment Report (2022), Local waste reports	Plastic waste per cigarette, cleanup cost, proportion of waste from tobacco, marine ecosystem loss
Fire hazards & pollution	Fire Service and Civil Defense Annual Reports (2024)	Number of fire incidents attributed to tobacco use, damage valuation
Emissions & climate impact	Hussain et al., 2020	GHG emissions from cultivation, curing, burning of tobacco and deforestation

Note: All costs are adjusted for inflation and converted into 2024 values.

The PSA offers several advantages. It allows policy makers to make informed decisions under uncertainty by presenting plausible bounds for the estimated economic burden. It also improves the transparency and reproducibility of the analysis, as it explicitly incorporates empirical variability in input parameters. Moreover, PSA can guide resource allocation by identifying which variables have the most substantial impact on total costs.

Results

Tobacco use and associated disease-related measures

From the 2018 STEPS survey, we found the prevalence rate of tobacco use (smoked and smokeless) among adults aged 30 years or older to be 53.87 percent. The relative risk (RR) was estimated to be 1.57 in 2018 (Faruque, 2020). We calculated the population-attributable risk (PAR) for tobacco consumption to be 0.23. The total population of adults 30 years and older was 76.7 million in 2024. According to HIES 2022, 24.65 percent of individuals aged 30 years or older reported being affected with tobacco-related diseases. From these statistics, we estimate the total number of patients affected by tobacco-attributable disease at 4.44 million in 2024.

$$\begin{aligned} &No.of\ patients\ (aged\ 30\ years\ and\ above)\ affected\ by\ tobacco\ attributable\ diseases \\ &\quad = Population \times Prevalence\ of\ tobacco\ use \\ &\quad \times Prevalence\ of\ tobacco\ related\ diseases \times PAR \\ &= 76{,}703{,}209 \times 0.5387 \times 0.2465 \times 0.23 = 4{,}441{,}781\ (approx.\ 4.44\ million) \end{aligned}$$

Health-related economic burden for tobacco consumption

We estimate direct and indirect health-related costs attributable to tobacco-related diseases, detailed in Table 2. Previously in 2018, the health-related total economic cost was estimated at BDT 305.6 billion (in 2018 prices) using primary data (Nargis et al., 2022). We used the latest available secondary sources to update the health care costs and productivity (income) loss estimates. In the following sections we describe findings of each of the subcomponents of health-related economic burden. All monetary values are adjusted for inflation and reported in 2024 values, unless stated otherwise.

Table 2. Health-related cost of illness attributable to tobacco use in 2024

Cost categories	Annual cost (in billion BDT)
Private expenditure	**255.23**
Routine medicine cost	88.15
Inpatient cost - adults	100.03

Outpatient cost - adults	57.66
Inpatient expenditure for second-hand smoke	1.39
Outpatient expenditure for second-hand smoke	0.92
Treatment received abroad	7.08
Public expenditure	**52.48**
Inpatient services	32.05
Outpatient services	20.43
Total direct cost	**307.71**
Cost of morbidity	**261.54**
Lost time for attending inpatient services	7.94
Lost time for attending outpatient services	0.72
Annual market productivity loss (employed patients)	152.42
Annual household productivity loss (unemployed patients)	96.11
Caregivers' time	4.34
Cost of mortality	**161.37**
Lost productivity due to premature deaths from tobacco-related illness	100.91
Lost productivity due to premature deaths from second-hand smoke	60.47
Total indirect cost	**422.92**
Health-related annual economic burden	**730.63**

Source: Authors' calculations

Direct costs

Private out-of-pocket expenditure

From HIES 2022, we calculate the average routine medicine expenditure per month to be BDT 1,801 per patient for those who chronically suffer from tobacco-related illness. Combining the proportion of patients who take medicine regularly (92.28 percent) and the 4,441,781 patients

suffering from diseases attributable to tobacco use, it amounts to BDT 88.15 billion worth of annual spending on routine medicines.

$$\begin{aligned}&Annual\ expenditure\ on\ routine\ medicine\\&\quad= no.of\ patients\ with\ disease\ attributable\ to\ tobacco\ use\\&\quad\times proportion\ of\ patients\ who\ take\ medicine\ regularly\\&\quad\times average\ routine\ medicine\ expenditure\ per\ month\ (BDT)\ \times\ 12\\&= 444{,}178 \times 0.92 \times 1{,}801.51 \times 12 =\ \ 88{,}149{,}200{,}377.19\ (\sim 88.15\ billion)\ \backslash\end{aligned}$$

Average expenditure for inpatient services is estimated to be BDT 9,732 (HIES 2022) per patient, for patients aged 30 years or older. Average length of stay for inpatient admissions is 8.4 days (HIES 2022). We assume the previously estimated inpatient service utilization rate to be 0.5 and that 55 percent of the patients with diseases attributable to tobacco use sought care (Nargis et al., 2022). In combination, this results in an annual cost of BDT 100.03 billion for inpatient services.

$$\begin{aligned}&Annual\ private\ expenditure\ on\ inpatient\ services\\&\quad= Average\ expenditure\ per\ patient\ per\ day \times average\ length\ of\ stay\\&\quad\times inpatient\ service\ utlization\ rate\\&\quad\times proportion\ of\ patients\ who\ sought\ care\\&\quad\times no.of\ patients\ with\ tobacco\ attributable\ diseases\\&= 9{,}732 \times 8.4 \times 0.5 \times 0.55 \times 444{,}178 =\ \ 100{,}033{,}259{,}798\ (\sim 100.03\ billion)\ \backslash\end{aligned}$$

We find the average cost of an outpatient visit is BDT 5,885 (HIES 2022). HIES has a one-month recall period for collecting data on outpatient services, which overlooks the possibility of multiple outpatient visits over a one-year period. Thus, we obtain the average number of visits per patient per year (4.01) from a previous study and assume 55 percent of the patients with tobacco-attributable diseases sought care (Nargis et al., 2022). We estimate outpatient costs to be BDT 57.66 billion.

$$\begin{aligned}&Annual\ private\ expenditure\ on\ outpatient\ services =\\&\quad= Average\ cost\ per\ outpatient\ visit \times average\ no.of\ visits\ per\ year\\&\quad\times proportion\ of\ patients\ who\ sought\ care\\&\quad\times no.of\ patients\ with\ tobacco\ attributable\ diseases\\&= 5{,}885.79 \times 4.01 \times 0.55 \times 444{,}178 =\ \ 57{,}659{,}270{,}122.13\ (\sim 57.66\ billion)\end{aligned}$$

In terms of costs associated with second-hand smoking for non-adults, we do not have updated data on indoor smoking status and associated illness among non-adults. Thus, we take the estimated cost from an earlier study (Nargis et al., 2022) and adjust for inflation using World Bank data (World Bank Group, n.d.). This gives us annual inpatient and outpatient costs for second-hand smoking of BDT 1.39 billion and BDT 0.92 billion, respectively.

Similarly, we adjust a previously estimated cost of treatment received abroad, due to the lack of reliable secondary data sources specifying the amount of medical spending abroad for tobacco-related diseases. The adjusted annual figure totals BDT 7.08 billion for treatment received abroad.

These components add up to BDT 255.23 billion in annual private spending on health care caused by diseases attributable to tobacco use.

Public expenditure

To estimate public expenditure for inpatient services we use the annual number of inpatient admissions from the Health Bulletin 2023 (Directorate General of Health Services, 2023). A total of 8.79 million admissions into government hospitals were reported in 2023. The average length of stay was reported to be 5.9 days in 2023 in public health care facilities (Directorate General of Health Services, 2023). We multiply the average length of stay by the number of admissions to get the total number of inpatient days in 2023. Then we divide the budget for inpatient services by the total number of inpatient days. This gives us the average cost per inpatient day per patient at BDT 3,117.

We multiply this cost with the number of patients who sought health care, inpatient service-utilization rate (0.5), average length of stay from HIES 2022 (5.9 days), and PAR to calculate the total public inpatient expenditure attributable to tobacco-related diseases (Nargis et al., 2022). After adjusting for inflation, the public expenditure for inpatient services attributed to tobacco use stands at BDT 32.05 billion in 2024.

$$
\begin{aligned}
&Annual\ public\ expenditure\ for\ inpatient\ services \\
&\quad = Average\ cost\ per\ inpatient\ day\ per\ patient \\
&\quad \times proportion\ of\ patients\ who\ sought\ care \\
&\quad \times inpatient\ service\ utilization\ rate \times average\ length\ of\ stay \\
&\quad \times no.of\ patients\ with\ tobacco\ attributable\ diseases
\end{aligned}
$$

$$= 3{,}117 \times 0.55 \times 0.5 \times 8.415 \times 4{,}441{,}781 = \ 32{,}046{,}892{,}021.53\ (\sim 32.05\ billion\ BDT)$$

In terms of public expenditure for outpatient services, 77.5 million outpatient visits were recorded in 2023 in public health care facilities (Directorate General of Health Services, 2023). Similar to inpatient services, assuming half of the budget was spent for outpatient services, we calculate the cost per outpatient visit to be BDT 2,086 in 2024. Assuming 55 percent of patients sought health care and average no. of visit is 4.01 per year, we estimate the tobacco-attributable costs for public outpatient services for adults at BDT 20.43 billion in 2024.

$$\begin{aligned} &Annual\ public\ expenditure\ for\ outpatient\ services \\ &\quad = Average\ cost\ per\ outpatient\ visit \\ &\quad \times average\ no.of\ visits\ per\ year\ per\ patient \\ &\quad \times proportion\ of\ patients\ who\ sought\ care \\ &\quad \times no.of\ patients\ with\ tobacco\ attributable\ diseases \\ &= 2{,}086 \times 4.01 \times 0.55 \times 4{,}441{,}781 = \ \ 20{,}433{,}235{,}477.86\ \ (\sim 20.4\ billion\ BDT) \end{aligned}$$

In summation, a total of BDT 52.48 billion of public expenditure in 2024 is attributed to tobacco use.

By combining private and public health expenditure, we estimate the health-related total direct cost in 2024 at around BDT 307.71 billion attributable to tobacco consumption.

Costs of morbidity

Loss of productive time for attending health care services

From HIES 2022, we calculate the average time spent for inpatient and outpatient services to be 7.6 days and 0.08 days, respectively. From HIES 2022, we also calculate the average daily wage/salary at BDT 846.85 in 2024. HIES 2022 collects data on individual income. We considered the monthly income of salaried individuals who had tobacco-related diseases and were aged 30 years or older to match with our study population, which we divided by 30 to get an estimate of daily income. Combining this with the annual inpatient and outpatient utilization rate from a previous study (Nargis et al., 2022), we can attribute BDT 7.94 billion and BDT 0.72 billion worth of productive time lost due to attending inpatient and outpatient services, respectively.

$$\begin{aligned}&Lost\ productivity\ due\ to\ attending\ inpatient\ care\\&= average\ time\ spent \times average\ daily\ wage \times\\&\times proportion\ of\ patients\ who\ sought\ care\\&\times inpatient\ service\ utilization\ rate\\&\times no.of\ patients\ with\ tobacco\ attributable\ diseases\\&= 7.6 \times 846.85 \times 0.55 \times 0.5 \times 4{,}441{,}781 = \ 7{,}943{,}698{,}730.65\ (\sim 7.94\ billion\ BDT)\end{aligned}$$

$$\begin{aligned}&Lost\ productivity\ due\ to\ attending\ outpatient\ care\\&= average\ time\ spent \times average\ daily\ wage \times\\&\times average\ no.of\ visits\ per\ year\ per\ patient\\&\times proportion\ of\ patients\ who\ sought\ care\\&\times no.of\ patients\ with\ tobacco\ attributable\ diseases\\&= 0.08 \times 846.85 \times 4.01 \times 0.55 \times 4{,}441{,}781 = \ \ 723{,}901{,}429.94\ \ (\sim 0.72\ billion\ BDT)\end{aligned}$$

Annual loss of market productivity

According to HIES 2022, patients with tobacco-related illness had an employment rate of 55.32 percent and average annual earnings of BDT 156,272 (in 2022 prices). Using the national employment rate and national average annual income from the Labor Force Survey 2022, we calculate the employment rate and annual income for non-patient adults at 68.32 percent and BDT 166,565 (2022 prices), respectively. The expected loss of annual income for the employed patients is BDT 28,270, which becomes BDT 34,315 after adjusting for inflation. This leads to an annual loss of potential income worth BDT 152.42 billion in 2024.

$$\begin{aligned}&Annual\ loss\ of\ income\ due\ to\ morbidity\ for\ employed\ patients\\&= Expected\ annual\ productivity\ loss \times\\&\times no.of\ patients\ with\ tobacco\ attributable\ diseases\\&= 34{,}315 \times 4{,}441{,}781 = \ 152{,}421{,}293{,}873.79\ (\sim 152.42\ billion\ BDT)\end{aligned}$$

For non-employed patients, we assume their potential earning capacity to be the same as employed patients and impute non-employed household productivity with the average income of the employed patients (Nargis et al., 2022). This results in around BDT 96.11 billion worth of lost household productivity in 2024.

We are unable to update caregivers' time cost from more recent sources due to the unavailability of data. Thus, we report the inflation-adjusted cost of caregivers' time spent on attending patients with tobacco-attributable diseases from a previous study (Nargis et al.,

2022). An estimated BDT 4.34 billion is lost through caregivers' time attributable to tobacco consumption in 2024.

In total, BDT 261.54 billion is attributed to the cost of morbidity due to tobacco consumption in 2024.

Costs of mortality

For each tobacco-attributable death of an individual aged 30–64 years, we calculate the present value for the foregone income assuming a three-percent discount rate and four-percent annual growth in income (Nargis et al., 2022). We estimate a total BDT 100.91 billion in foregone income due to premature deaths attributable to tobacco consumption.

Lost productivity in non-adults for morbidity due to second-hand smoking could not be updated using more recent sources due to lack of data on indoor smoking in the sources we used. However, an earlier study used a household survey to collect primary data on indoor smoking and associated disease prevalence and costs for the under-15 population. The study reported direct costs and indirect costs (cost of caregiver time and productivity loss due to premature mortality) to be around BDT 41 billion. Derived from this study and adjusted for inflation, we find the cost of second-hand smoking to be around BDT 60.47 billion in 2024 (Nargis et al., 2022).

Total direct and indirect costs

In total, BDT 261.54 billion is attributed to the cost of morbidity due to tobacco consumption in 2024.

In terms of tobacco-attributable health-related indirect costs, we arrive at an estimated BDT 422.92 billion in the year 2024.

Combining direct costs and indirect costs, we estimate the annual health-related cost of tobacco-attributable disease to be BDT 730.63 billion in the year 2024.

Environmental costs for tobacco consumption and cultivation

In this study, we quantify four previously unrecognized environmental cost components attributable to tobacco cultivation and consumption in Bangladesh. They are a significant

addition to the overall social and economic burden associated with tobacco use. The four components assessed include: (1) land use and soil degradation, (2) tobacco-related waste generation and cleanup, (3) fire-related damage caused by cigarette use, and (4) greenhouse gas (GHG) emissions. The following sections provide a detailed estimation of each component.

Land use and soil degradation

According to the Food and Agricultural Organization, Bangladesh is considered the 12th-klargest tobacco-producing country in the world. In fiscal year 2022/2023, approximately 93,000 acres of land were used for tobacco cultivation, producing 87,000 metric tons of tobacco, according to the Bangladesh Bureau of Statistics. Tobacco cultivation reduces the arable land for cultivation of food grains, which creates an opportunity cost. Hussain et al. (2020) estimated that, per season, the opportunity cost of cultivating alternative crops in Bangladesh is BDT 15,514 per one-third acre. Based on that estimate and adjusting for inflation, we find that the total opportunity costs attributed to cultivating tobacco amount to BDT 5.41 billion (Table 3).

$$\begin{aligned} &Opportunity\ cost\ of\ land\ area\ under\ tobacco\ cultivation \\ &\quad = Land\ area\ under\ tobacco\ cultivation\ (acres) \\ &\quad \times\ opportunity\ cost\ of\ cultivating\ alternative\ crops \end{aligned}$$

$$= 93{,}000 \times 58{,}163 = 5{,}409{,}200{,}992\ (\sim 5.41\ billion)$$

Tobacco cultivation also degrades soil quality, making it difficult to switch to different crops. To revert the aldicarb level to that of other crops, Hussain et al. (2020) reported the cost of treating soil at BDT 19,362 per acre (inflation adjusted). Using this figure, we compute a total estimated cost of approximately BDT 1.8 billion (Table 3) for soil restoration in 2024.

$$\begin{aligned} &Cost\ of\ soil\ treatment\ for\ degradation \\ &\quad = Land\ area\ under\ tobacco\ cultivation\ (acres) \\ &\quad \times\ Cost\ of\ treatment\ for\ soil\ degradation\ (per\ acre) \end{aligned}$$

$$= 93{,}000 \times 19{,}362\ =\ 1{,}800{,}742{,}559\ (\sim 1.8\ billion)$$

There are also larger ecosystem-level costs. Land degraded by tobacco cultivation – primarily due to deforestation – requires reforestation for ecological restoration. One well regarded approach to restore the ecosystem is establishing tree plantations. The cost of active tree

plantation is estimated at USD 400 per acre (Hawken, 2017). Using this value, the total reforestation cost for the tobacco cultivation area is estimated at BDT 5.14 billion (Table 3).

$$\begin{aligned} &Cost\ of\ reforestation \\ &= Land\ area\ under\ tobacco\ cultivation\ (acres) \\ &\times Cost\ of\ reforestation\ (per\ acre) \\ &= 93{,}000\ \text{X}\ 48{,}400\ =\ 5{,}145{,}795{,}369.19\ (\sim 5.14\ \text{billion}) \end{aligned}$$

Table 3. Land use, degradation, and reforestation costs

Components	Amount (BDT)
Total opportunity cost of land area under tobacco cultivation (A)	5.41 billion
Total cost of treatment for soil degradation (B)	1.8 billion
Total reforestation costs (C)	5.14 billion
Total land use, degradation, and reforestation costs (A+B+C)	**BDT 12.35 billion**

Source: Authors' calculations

Tobacco waste pollution and cleanup costs

Tobacco product waste cleanup cost: We quantify this cost using a proportional allocation method recommended by WHO. According to WHO, global smoking prevalence is 22.30% and global tobacco product waste (TPW) share is 23.40% (WHO, 2017). The Tobacco Atlas reported smoking prevalence in Bangladesh to be 17%. Based on the following formula, the estimated proportion of tobacco product waste in Bangladesh is 17.63% percent.

$$TPW\ = \frac{smoking\ prevalence\ of\ Bangladesh}{mean\ global\ smoking\ prevalence} \times\ mean\ global\ TPW\ percent$$

$$= \frac{17}{22.30} \times 23.40\%\ =\ 17.63\%$$

Based on an average of other middle-income countries, the all-product waste per capita is USD 7.85 (BDT 938). Using the following formula – described in detail in the earlier section – we get the per capita tobacco product waste of BDT 165 (Lam et al., 2022).

$$\begin{aligned} &c(TPW) = \lambda\ \times c(all) \\ &= 17.63\% \times 938\ BDT = 165\ BDT \end{aligned}$$

Considering total population in Bangladesh - 175,686,899, total cost of tobacco product waste becomes BDT 34,870,910,211 (~ 35 billion inflation adjusted).

Marine ecosystem loss from leakage of tobacco plastic: The burden of the direct and secondary environmental costs of tobacco product waste, especially plastic cigarette filters, is reflected in marine ecosystem losses (MEL). About 98 percent of all cigarettes sold are filtered. A set of 20 plastic filters weighs approximately 3.4 grams, and the packaging with sleeve for a standard 20-cigarette pack weighs around 19 grams (Sy, 2024). Total number of sticks consumed per year are 153,864,180,080. Using the following formula, estimated plastic waste (EPW) is calculated as 171,804 tons per year.

$$EPW(tons) = [numberofcigarettesconsumed \times filterweight(g/stick)] + numberofcigarettepacks \times [plasticperpack(g) + (sleevelength(m) \times plasticdensity(g/m))]$$

$$EPW(tons) = [153,864,180,080 \times (3.4/20)] + \{(153,864,180,080/20) \times [19]\} \div 1,000,000$$

$$= 171,804 \text{ tons per year (approximately)}$$

Based on this cost, and applying a 1.5 percent leakage rate, the total MEL was calculated at BDT 94.36 billion per year in Bangladesh , using the following formula.

$$Annual\ marine\ ecosystem\ losses\ (MEL) = estimated\ plastic\ waste\ (EPW) \times leakage\ rate \times Median\ MEL\ from\ plastic\ pollution\ (per\ ton\ per\ year)$$

$$= 171,804 \times 1.5 \times 36,615,457.25 = 94,360,638,602\ (\sim 94\ billion\ BDT)$$

Fire hazards and damage costs by cigarette use

Cigarette smoking represents a significant source of fire hazards. According to Bangladesh Fire Service and Civil Defense statistics, 4,139 fires – about 15.52 percent of all 26,659 fire incidents – were caused by burning fragments of a bidi or cigarette in 2024. Total property losses from fires in 2024 amounted to BDT 0.17 billion.

Greenhouse gas emissions and climate impact

To estimate the greenhouse gas emissions and related costs associated with tobacco cultivation in Bangladesh, we reference the methodology and estimates outlined in Hussain et al. (2020).

Total carbon emission per acre of tobacco cultivation includes emissions from fuelwood burning, which contributes 1.26 metric tons of carbon, and deforestation, which contributes 1.09 metric tons. Nearly half (48 percent) of all tobacco leaves are cured using wood or bamboo as fuel in Bangladesh. Based on the use of fuelwood to cure tobacco leaves and the amount of carbon emitted due to deforestation, the total carbon emission and its consequent cost on the environment is reported to be BDT 26,199.87 (equivalent to USD 310.06) per acre of land used for tobacco cultivation (Hussain et al., 2020). Based on the per-acre estimation, the total costs for greenhouse gas emissions and climate-related impacts amount to BDT 3.05 billion.

Total environmental costs

Table 4. Environmental costs of tobacco consumption and cultivation

Cost categories	Annual cost (in billion BDT)
Land use and degradation	**12.36**
Opportunity cost of land area under tobacco cultivation	5.41
Treatment of soil degradation costs for tobacco cultivation	1.8
Reforestation/land rehabilitation costs	5.14
Waste and pollution / TPW cleanup cost	**35.31**
Annual marine ecosystem loss	**94.36**
Property loss value associated with tobacco-related fire hazard	**0.17**
Costs for greenhouse gas emission	**3.05**
Total environmental costs	**144.81**

The total environmental costs, based on all contributing components, are estimated at BDT 144.81 billion. (Table 4). Among the components, more than 50 percent of the total environmental burden arises from marine ecosystem loss, and the lowest burden (though still high), arises from fire hazard and associated damages.

Total economic costs

If we combine the health-related costs (Table 2) with the environmental costs (Table 4), the total estimated annual economic cost of tobacco use in 2024 amounts to BDT 875.44 billion (Table 5).

Table 5. Total economic burden of tobacco in Bangladesh

Cost categories	Annual cost (2024)	
	(in billion BDT)	% of total
Health-related costs		
Private expenditure (H1)	*255.23*	*29.15%*
Public expenditure (H2)	*52.48*	*5.99%*
= Total direct cost (H3=H1+H2)	**307.71**	**35.15%**
Cost of morbidity (H4)	*261.54*	*29.88%*
Cost of mortality (H5)	*161.37*	*18.43%*
= Total indirect cost (H6=H4+H5)	**422.92**	**48.31%**
Total health costs (H): H3 +H6	**730.63**	**83.46%**
Environment related		
Land use and degradation (E1)	*12.36*	*1.41%*
Waste and pollution / TPW cleanup cost (E2)	*35.31*	*4.03%*
Annual marine ecosystem loss (E3)	*94.36*	*10.78%*
Property loss value associated with tobacco-related fire hazard (E4)	*0.17*	*0.02%*
Costs for greenhouse gas emission (E5)	*3.05*	*0.35%*
Total environmental costs (E): E1+E2+E3+E4+E5	**144.81**	**16.54%**
TOTAL ECONOMIC COSTS (H+E)	**875.44**	**100.00%**

In contrast, tobacco tax revenue in the same year was approximately BDT 400 billion. This means the economic burden is more than twice the revenue government receives from tobacco taxes. Health-related costs account for 83 percent of the total, while the remaining 17 percent is attributed to environmental damage. Among the health-related costs, a significant portion arises from indirect losses—such as productivity loss due to illness and premature death—which are often overlooked in conventional estimates. Similarly, the ecological damage caused by tobacco-related plastic waste remains substantial yet frequently ignored in policy discussions.

Sensitivity analysis of cost estimates with PSA

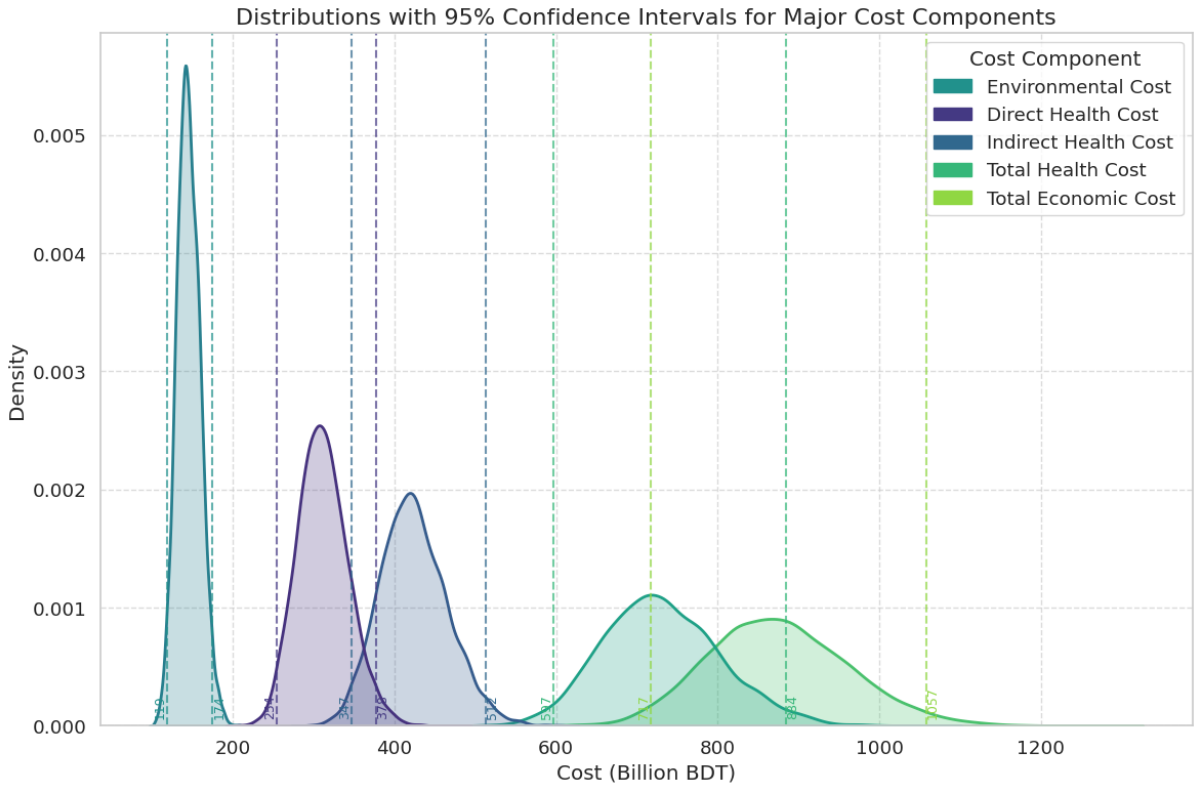
To assess the impact of parameter uncertainty on the estimated costs of tobacco use, we conducted a probabilistic sensitivity analysis (PSA) using 10,000 Monte Carlo simulations. Each parameter was modeled with a probability distribution derived from the best available data. Base parameters were obtained from existing studies in the literature as mentioned in the methodology. See Figure 1 and tables A3 and A4 in the appendix for related information.

The analysis revealed significant uncertainty across several cost categories, with the 95-percent confidence intervals (CI) highlighting the model's sensitivity to key epidemiological and financial inputs. Morbidity (BDT 149.5 billion to 390.3 billion) and private health expenditure (BDT 146.3 billion to 377.2 billion) were the most sensitive components, reflecting high variability in factors like disease prevalence, productivity loss, and out-of-pocket payments. Mortality cost also showed considerable variation (BDT 93.0 billion to 239.4 billion), as did public health expenditure (BDT 29.9 billion to 78.6 billion).

Among environmental impacts, uncertainty was highest for marine ecosystem loss (BDT 76.8 billion to 112.3 billion) and waste & pollution (BDT 28.7 billion to 42.6 billion), primarily due to varied ecological valuation methodologies. In contrast, uncertainty was more constrained for land use & degradation (BDT 10.0 billion to 14.7 billion), greenhouse gas emissions (BDT 2.47 billion to 3.67 billion), and fire hazards (BDT 0.14 billion to 0.21 billion).

As illustrated in Figure 1, indirect costs such as morbidity and mortality demonstrated greater sensitivity to parameter changes than direct health and environmental costs. Despite this variability, the overall economic burden of tobacco use remains substantial. The 95-percent CI for the total economic cost ranges from BDT 716 billion to BDT 1,056 billion. Since even the lower bound of this range represents a significant economic impact, we conclude that our primary estimates are robust.

Figure 1. Distribution of major cost components with 95% confidence interval



In addition, an analysis was conducted to examine the relationship between key epidemiological inputs—prevalence, relative risk (RR), and population-attributable risk (PAR)—and the simulated cost of mortality (see Figure A1 in Appendix 3).

The analysis revealed that the PAR, which integrates both prevalence and RR, exhibited the strongest and most direct linear correlation with mortality costs, establishing it as the model's primary determinant. RR also showed a strong positive correlation, confirming it as a key driver of cost variation. In contrast, the relationship for prevalence was positive but more diffuse, indicating a less direct influence on the final cost estimates.

These findings confirm that uncertainty in cost projections is primarily driven by the variability in RR and prevalence estimates, which are synthesized within the PAR. Therefore, enhancing the precision of RR estimates and prioritizing PAR as a central calibration parameter is critical for improving the robustness of tobacco cost-attribution models.

Conclusion

This study provides a comprehensive estimate of the economic burden of tobacco use in Bangladesh, integrating both health and environmental costs into a single framework. We estimate the total annual cost in 2024 at BDT 875.44 billion, an amount equivalent to 1.58% of the GDP and more than double the revenue generated from tobacco taxes in the same year (approximately BDT 400 billion). A novel contribution of this work is the quantification of environmental damages, which account for 16.5 percent of the total burden, while direct health-related costs and productivity losses constitute the remaining 83.5 percent. By quantifying environmental externalities—including marine degradation, waste cleanup, and GHG emissions—this study fills a critical gap and demonstrates how these harms erode public resources and long-term sustainability.

The robustness of our findings is confirmed by a probabilistic sensitivity analysis, which places the total economic cost within a 95-percent confidence interval of BDT 716 billion to 1,056 billion. The primary drivers of this uncertainty are morbidity-related productivity losses and private health expenditures, underscoring the need for enhanced national surveillance and data systems.

There are several limitations to this study intrinsic to the nature of the data used in our analysis. The data in this study are from secondary sources, in contrast to an earlier 2020 study which used primary sources. There is also an element of time inconsistency in the data since different sets of data were from somewhat different points in time. The data are generally self-reported costs, and the data for diagnosis of disease may introduce some uncertainty. Also because of gaps in recent data, some estimates of inpatient and outpatient costs in government health expenditures were adapted from earlier studies (Nargis et al., 2018). The study focuses on adults who are aged 30 and older, so it likely underestimates costs because it does not consider younger smokers and/or victims of second-hand smoke. Lastly, changes in the parameters we assumed from other studies (such as, relative risk, health service utilization rate etc.) may affect the magnitude of the health costs.

It is important to note that this study estimates health costs associated solely with tobacco consumption. However, tobacco cultivation and curing also impose additional health burdens that are not captured in our analysis. Residents living in tobacco-growing areas are frequently exposed to harmful conditions that contribute to a range of health problems related to green

tobacco sickness (GTS), a form of acute nicotine poisoning. While these health-related costs are not quantified within the scope of this study, previous research shows that GTS causes health harms and lost productivity among those suffering from the illness. There is also evidence that children in low-income countries are employed in tobacco cultivation, and the deleterious effects on their health, schooling, and future productivity are not captured in this study either.

Finally, the estimate of marine ecosystem loss presented in this study is likely conservative and underestimates the true impact. Our calculation does not account for additional waste generated from tobacco manufacturing, the disposal of non-cigarette products such as bidis and smokeless tobacco, or other toxic residues linked to tobacco use. As a result, the actual environmental burden on marine ecosystems is probably higher than the amount reported here.

The magnitude of this economic burden signals an urgent need for stronger tobacco control policies. Fiscal tools, such as significantly higher and simplified tobacco taxes, alongside stricter regulation of environmental externalities, can yield substantial health, economic, and ecological benefits by substantially driving down consumption. As Bangladesh pursues its goal of becoming tobacco-free by 2040, this evidence provides a compelling foundation for decisive policy action and cross-sectoral collaboration.

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Appendix

A1. Health Cost Estimations

Direct costs

Direct costs involve the combination of out-of-pocket costs incurred by patients (private health expenditure) and the costs incurred by the government for delivering health care in public hospitals (public health expenditure). These costs are directly attributed to treating tobacco related diseases.

$$\text{Direct cost} = \text{Private health expenditure} + \text{Public health expenditure}$$

Private health expenditure

Out-of-pocket costs for inpatient care, outpatient visits, cost of regularly taken medicine, and overseas health care expenses constitute private health expenditures.

Population-level **inpatient expenditure** can be estimated as:

$$\text{Inpatient expenditure} = (C_{ip} \times H_{days} \times H_n) \times P_{treatIP} \times N \times \text{PAR}$$

Here, C_{ip} is average inpatient cost per day, which includes items such as bed fee, diagnostic costs, and medicines. H_{days} is average hospital stay in days, H_n is average number of hospitalizations in the past 12 months for a patient, $P_{treatIP}$ is the proportion of patients who sought inpatient treatment in the past 12 months, N is the total population, and PAR is the population-attributable risk of tobacco for the specific diseases.

The term inside the parentheses denotes the average cost of inpatient treatment for one patient. Estimates from published literature are used to compute these figures and then adjusted for inflation. The latest data on the age-specific total population N will be collected from the United Nations Population Division database.

PAR denotes the proportion of disease burden or cost that can be attributed to tobacco use, since tobacco-related diseases can also be caused by non-tobacco-related factors. PAR is a function of relative risk (RR) for tobacco use and prevalence of tobacco use (P).

$$\text{PAR} = \frac{(RR-1)P}{1+(RR-1)P}$$

We used the latest estimates of RR reported in published literature to compute the PAR for tobacco-related diseases in Bangladesh. The latest GATS is used for computing tobacco use prevalence (P) for the specific age group in consideration.

For **outpatient care**, we follow a similar method to estimate private health expenses.

$$\text{Outpatient expenditure} = (C_{op} \times V_n) \times P_{treatOP} \times N \times \text{PAR}$$

C_{op} is the average outpatient cost per visit, V_n is the average number of outpatient visits per patient in the last 12 months, $P_{treatOP}$ is the proportion of patients who sought outpatient care in the last 12 months.

For chronic conditions, patients may have to take medicine on a regular basis, which can constitute a substantial OOP cost over time. Taking C_{med} as the average cost per month for regularly taken medicines and P_{med} being the proportion of patients who take medicine regularly, we estimate:

$$\text{Medicine cost} = (C_{med} \times 12) \times P_{med} \times N \times \text{PAR}$$

Public health expenditure

Public health expenditure is the cost incurred by the government for treating tobacco-related illness in public hospitals. To estimate this, we take the annual health sector budget, which includes operating and development expenses for inpatient, outpatient, and emergency medical services in public health care facilities. Then, adopting a top-down approach, we disaggregate the budget into outpatient and inpatient services. Publicly available documents from the Ministry of Health and Family Welfare are reviewed to identify the proportion of spending corresponding to inpatient/outpatient care. Alternatively, we also utilize nationally representative household expenditure survey data (HIES 2016, HIES 2022) to determine the

proportion of the costs incurred among the households to get an approximation of inpatient/outpatient cost proportion. Next, we obtain the national-level annual utilization rate of inpatient and outpatient care in public health facilities from the latest Health Bulletin. The budget allocation for each type of care is divided by the annual utilization rate to get an approximation of average spending per patient. We can express the estimation process as follows:

$$\text{Public inpatient expenditure} = \frac{IP_b}{IP_n} \times P_{treatIP} \times N \times \text{PAR}$$

$$\text{Public outpatient expenditure} = \frac{OP_b}{OP_n} \times V_n \times P_{treatOP} \times N \times \text{PAR}$$

Here, IP_b, IP_n, OP_b, and OP_n represent annual public spending for inpatient services, annual inpatient admissions, annual public spending for outpatient services, and annual utilization of outpatient services in public facilities, respectively. The rest of the terms remain as defined previously.

Indirect cost

In estimating indirect costs caused by tobacco-related diseases we adopt the human capital approach for measuring lost productivity, which mainly includes loss of productivity due to mortality and morbidity. Additionally, we try to estimate the environmental costs of tobacco (including cigarette butt pollution and agricultural opportunity costs) and second-hand smoking. We can write:

$$\text{Indirect cost} = Time + Prod_{morb} + Prod_{mort} + Env + SH_{smoke}$$

Loss of income due to morbidity contains $Time$ (loss of productive time for attending health services) and $Prod_{morb}$ (loss of income due to lower productivity of affected patients).

$$Time = (T \times Emp \times P \times N \times \text{PAR} \times Y_{emp}) + (T \times Unemp \times P \times N \times \text{PAR} \times Y_{unemp})$$

Here, T is the average number of days spent for attending health care services (outpatient and inpatient) in the last 12 months, Emp is the proportion of employed patients, and $Unemp$ is

the proportion of unemployed patients with Y_{emp} and Y_{unemp} being their respective average income per day.

Loss of household productivity is approximated by the gap between expected annual income of a patient and a non-patient.

$$Prod_{morb} = [(W \times Z) - (W^* \times Z^*)] \times Emp \times P \times N \times PAR$$

The term inside the parentheses represents the gap in expected annual income, where W and Z are the national average annual income and employment rate, respectively. The terms with asterisks denote the same but for a patient with a tobacco-related illness. We get an estimate for these parameters from the latest Labor Force Survey (LFS).

Loss of potential income due to mortality/premature death, $Prod_{mort}$, is computed as:

$$Prod_{mort} = \sum_{x} \left(\sum_{x}^{m} Prob(m) \times W \times \frac{(1+g)^{m-x}}{(1+r)^{m-x}} \right) \times Deaths_x$$

For each age group x, we calculate the foregone income up to 64 years of age with an annual income growth rate of $g = 6$ percent and discount rate $r = 3$ percent. The probability of death at age m, $Prob(m)$, is obtained from life tables. Age-specific tobacco-attributable deaths, $Deaths_x$ (obtained from literature) are then multiplied with the foregone income and summed up for each of the age groups.

A2. Variables Used for Health Cost Estimation

Table A1. Variables used for health cost estimation (with updated values)

Variables	Inflation-adjusted (in 2024 prices BDT)	Values	Year	Source
Tobacco prevalence rate		0.54	2018	STEPS 2018
Relative risk (RR)		1.57	2018	Nargis et al., 2020
Population-attributable risk (PAR)		0.23		Authors' calculations
Total population (age 30+)		76,703,209	2024	https://www.populationpyramid.net/bangladesh/2024/
Disease prevalence		0.25	2022	HIES 2022
Estimated total patients with tobacco-attributable diseases		4,441,781	2024	Authors' calculations
Direct costs (inpatient)				
Average inpatient cost per admission - adults (BDT)	81,894	67,467.48	2022	HIES 2022
Average hospital stays (days)		8.41	2022	HIES 2022
Average inpatient cost per day - adults (BDT)	9,732	8,017.79	2022	HIES 2022
Average number of hospitalizations in the past 12 months per patient		0.50	2018	Nargis et al., 2020

Proportion of patients who sought inpatient care in the past 12 months		0.55	2018	Nargis et al., 2020
Direct costs (outpatient)				
Average outpatient cost (BDT)	5,885	4,848.92	2022	HIES 2022
Average number of visits per year per patient		4.01	2018	Nargis et al., 2020
Proportion of patients who sought outpatient care in the past 12 months		0.55	2018	Nargis et al., 2020
Direct costs (medicine)				
Average cost of regularly taken medicine (BDT) per month	1,801	1,484.15	2022	HIES 2020
Proportion of patients who take medicine regularly		0.92	2022	HIES 2020
DGHS budget		292,820,000,000	2023	Health Bulletin 2023
Public inpatient expenditure				
Annual public spending for inpatient service		146,410,000,000	2023	Health Bulletin 2023
Annual number of inpatient admissions		8,792,051	2023	Health Bulletin 2023

Average length of stay at government facilities (days)		5.90	2023	Health Bulletin 2023
Number of total inpatient days		51,873,100	2023	Health Bulletin 2023
Average spending per admission	18,395	16,652.54	2023	
Average spending per day per patient	3,117	2,822.46	2023	
Public outpatient expenditure				
Annual public spending for outpatient service		146,410,000,000	2023	Health Bulletin 2023
Annual number of outpatient admissions		77,539,925	2023	Health Bulletin 2023
Average spending per outpatient visit	2,085	1,888.19	2023	Health Bulletin 2023
Average number of visits per patient in a year		4.01	2018	Nargis et al., 2020
Average annual outpatient spending per patient	8,364	7,571.64	2023	
Time attending health services				
Average number of days spent per patient attending inpatient services		8.41	2022	HIES 2022
Average number of days spent per patient		0.08	2022	HIES 2022

attending outpatient services				
Loss of productivity				
Proportion of patients who are working		0.55	2022	HIES 2022
Proportion of patients who are not working		0.45	2022	HIES 2022
Average income per day (employed patients)	846.85	697.66	2022	HIES 2022
Average income per day (unemployed patients - imputed)	846.85	697.66	2022	HIES 2022
Average annual income (non-patient)	242,231	199,558.80	2022	HIES 2022
Employment rate (non-patient)		0.69	2022	HIES 2022
Average annual income (patient)	189,689.36	156,272.60	2022	HIES 2022
Employment rate (patient)		0.55	2022	HIES 2022
Difference in expected annual income	43,286.20	43,286.20	2022	HIES 2022
Average annual national monthly income (LFS 2022)	199,103	13,669	2022	LFS 2022
Expected productivity loss	34,315.36	28,270.17	2022	LFS 2022 and HIES 2022
Reported days ill (sick days)	12.68		2018	Nargis et al., 2020
Other costs (inflation-adjusted from previous study)				

Treatment received abroad	7,083,225,923	4,600,000,000	2018	Nargis et al., 2020
Caregivers' time	4,342,325,457	2,820,000,000	2018	Nargis et al., 2020
Lost productivity due to second-hand smoking	60,469,191,743	39,270,000,000	2018	Nargis et al., 2020
Inpatient expenditure for second-hand smoking	1,385,848,550	900,000,000	2018	Nargis et al., 2020
Outpatient expenditure for second-hand smoking	923,899,033	600,000,000	2018	Nargis et al., 2020

A3. Variables Used for Environmental Cost Estimation

Table A2. Variables used for environmental cost estimation (with updated values)

Variables	Inflation-adjusted (in 2024 prices (BDT)	Values	Year	Source
Land use and degradation costs				
Land area under tobacco cultivation (acres)		93,000	2022–2023	Yearbook of Agricultural Statistics 2023
Opportunity cost of cultivating alternative crops (per 1/3 acre)	19,388	15,514	2020	Hussain et al., 2020
The cost of treatment for soil degradation (per acre)	19,363	15,494	2020	Hussain et al., 2020
Reforestation cost (per acre)	55,331	48400	2017	Hawkens et al., 2017
Waste and pollution from tobacco products				
Adult smoking rate		16.8%	2022	https://gsthr.org/countries/profile/bgd/1/
Mean global tobacco product waste (TPW) percentage		23.40%	2021	Lam et al., 2022

Global smoking prevalence		22.30%	2021	Lam et al., 2022
Per capita waste costs for LMICs (BDT)	1,126	938	2021	Lam et al., 2022
Total population		175,686,899	Mid 2025	Worldometer
Marine ecosystem loss				
Adult smokers		20,395,570	2022	https://gsthr.org/countries/profile/bgd/1/
Number of cigarettes per smoker per year (sticks)		7,544	2017	GATS
Share of filtered cigarettes sold		98%		Sy, 2024
Average weight of 20 plastic filters (grams)		3.40		Sy, 2024
Weight of the package and sleeve for a pack (grams)		19		Sy, 2024
Median marine ecosystem loss (MEL) per leaked ton of plastic		36,615,457		Sy, 2024
Fire hazards and associated damages				
Property loss value associated with tobacco-related fire hazard		173,516,161	2024	Fire Service and Civil Defense Report 2024

Emissions and climate impact				
Carbon emission cost resulting from the amount of wood burned for curing tobacco leaves and from deforestation (per acre)	32,742	26,200	2020	Hussain et al., 2020

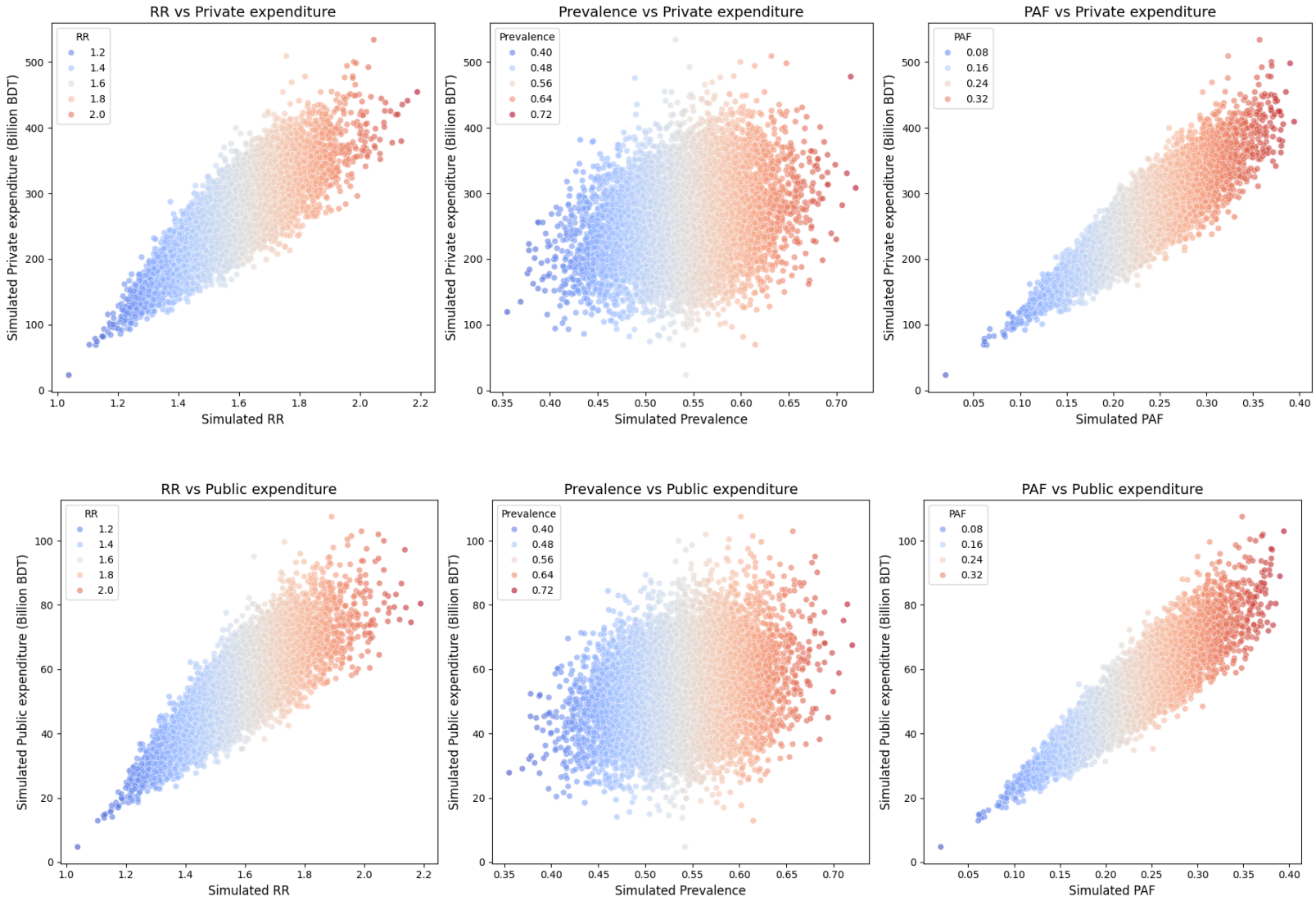
Table A3. Mean costs with 95% CI (in billion BDT)

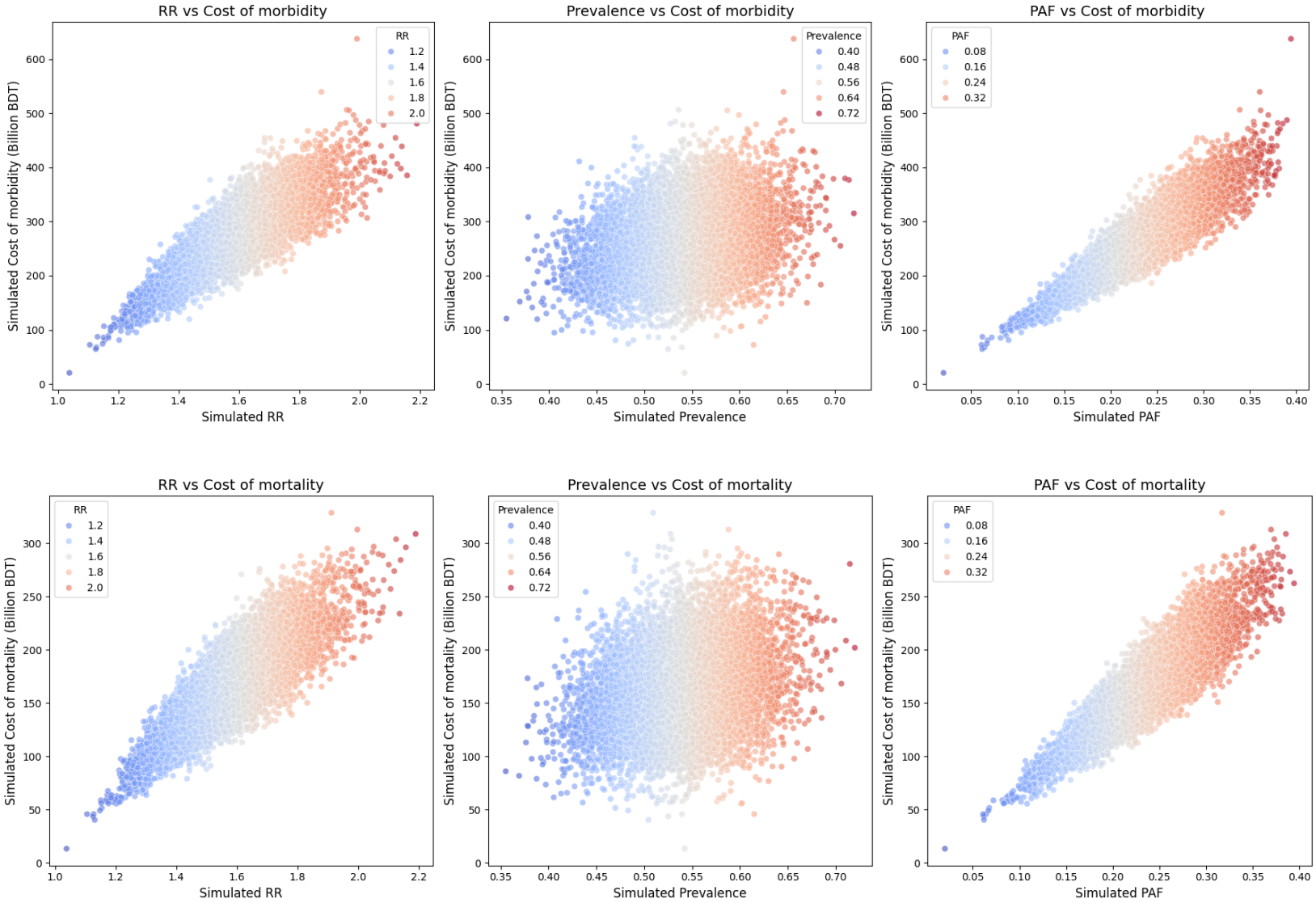
Cost component	Mean	95% CI (2.5% – 97.5%)
Private health expenditure	258.3	146.3 – 377.2
Public health expenditure	53.1	29.9 – 78.6
Morbidity cost	264.7	149.5 – 390.3
Mortality cost	163.5	93.0 – 239.4
Land use & degradation	12.4	10.0 – 14.7
Waste & pollution	35.3	28.7 – 42.6
Marine ecosystem loss	94.2	76.8 – 112.3
Fire hazard losses	0.17	0.14 – 0.21
Greenhouse gas emissions	3.05	2.47 – 3.67

Table A4. 95% CI from PSA (in billion BDT)

Environmental costs	**118.85**	**175.20**
Total health costs	596.35	889.23
Total economic costs	**716.05**	**1056.17**

Figure A1. Sensitivity of costs with varying RR, prevalence, and PAR values




RR vs Cost of morbidity
Simulated Cost of morbidity (Billion BDT)
Simulated RR
RR
1.2
1.4
1.6
1.8
2.0
Prevalence vs Cost of morbidity
Simulated Cost of morbidity (Billion BDT)
Simulated Prevalence
Prevalence
0.40
0.48
0.56
0.64
0.72
PAF vs Cost of morbidity
Simulated Cost of morbidity (Billion BDT)
Simulated PAF
PAF
0.08
0.16
0.24
0.32
RR vs Cost of mortality
Simulated Cost of mortality (Billion BDT)
Simulated RR
RR
1.2
1.4
1.6
1.8
2.0
Prevalence vs Cost of mortality
Simulated Cost of mortality (Billion BDT)
Simulated Prevalence
Prevalence
0.40
0.48
0.56
0.64
0.72
PAF vs Cost of mortality
Simulated Cost of mortality (Billion BDT)
Simulated PAF
PAF
0.08
0.16
0.24
0.32