The health, poverty and financial consequences of a cigarette price increase among 500 million male smokers in 13 low and middle-income countries

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Objective: Higher tobacco excise taxes are required to achieve the Sustainable Development Goal (SDG) targets to reduce non-communicable disease (NCD). We examined the relevance of tobacco taxes to meet the SDG targets on extreme income poverty and financial protection against illness.

Design: Extended cost-effectiveness analysis of the cumulative impact of one-time 50% cigarette price increase on health, poverty and financial protection

Setting: Thirteen low and middle-income countries

Participants: 500 million male smokers

Main outcome measures: Life-years gained, averted treatment costs, catastrophic healthcare expenditures and poverty, and additional tax revenue by income quintile

Results: A 50% increase in cigarette prices would lead to about 450 million years of life gained across the 13 countries from cessation, half of these in China. Across all countries, the bottom income quintile would gain 6.7 times more life-years than the top quintile (155 vs. 23 million). The average life-years gained per smoker from cessation was in the bottom quintile was 5.1 times that of the top quintile (1.46 vs. 0.23 years). Of the USD $157 billion in averted treatment costs, the bottom quintile would avert 4.6 times more costs than the top quintile (46 vs. 10 billion). About 15.5 million men would avoid catastrophic health expenditures in a subset of seven countries without universal health coverage. As result 8.8 million men, half of whom were in the bottom income quintile, would avoid falling below the World Bank's extreme poverty line. These 8.8 million constitute 2.4% of the poor in these countries. By contrast, the top quintile would pay twice as much as the bottom income quintile of the $122 billion additional tax collected. Overall, the bottom income quintile would get 31% of the life-years saved and 29% each of the averted disease costs or averted catastrophic health expenditures but pay only 10% of the additional taxes.

Conclusions: Higher tobacco taxes support SDG targets on NCDs, poverty and financial protection against illness.

INTRODUCTION

On current smoking patterns where large numbers of young adults start smoking but few quit, smoking will kill about 1 billion people this century.[1] Most of these deaths will be in low and middle-income countries (LMICs). At the global level, tobacco control relies on the Framework Convention on Tobacco Control, [2] and increasingly on the United Nations (UN) 2030 Sustainable Development Goals (SDG). The SDGs include goals to eradicate extreme income poverty, reduce by one third the age-standardized death rates from non-communicable diseases (NCD) and achieve universal health coverage (UHC) so as to provide financial risk protection against the impoverishment that arises from illness.[3] These three goals are interrelated. Tobacco use is the leading risk factor of NCDs.[1] In most countries, smoking prevalence and smoking-attributable diseases are highest among those with low income.[4] Smoking accounts for much of the difference in risk of death among men of different social status.[5] The World Health Organization (WHO) estimated 100 million (M) individuals fall into poverty (defined by low food expenditure) every year due to out of pocket (OOP) health expenditures[6] with much of these expenditures arising from treatment of NCDs.

Effective tobacco control could avoid hundreds of millions of premature deaths this century. It is already established that progress towards the NCD goals will depend greatly on progress in substantially raising the low tobacco cessation rates in most LMICs.[1,7,8] Tobacco taxation is the single most-effective intervention to increase cessation rates by current smokers and to decrease initiation by youth, with greatest effects among youth and persons with low income.[9,10] Higher excise taxes increase government revenue, which can be used for pro-poor health and other programs. However, high excise taxes are underused in nearly all LMICs.[2, 11]

The relationship between higher tobacco taxes on poverty levels, impoverishment due to medical treatment costs and financial burden of higher taxes in poor and non-poor groups has been published only for China[12] and Lebanon.[13] Broad representative assessments across LMICs have not yet been done. Here, we quantify the impact of a practicable 50% cigarette price increase on health, poverty and financial outcomes in 13 LMICs with diverse socio-economic demographic characteristics, tobacco use and effective UHC coverage.

METHODS

Extended cost effectiveness analysis (ECEA) is a policy tool to assess health gains, financial protection and tax gains for governments across income groups.[14] It was developed by the Disease Control Priorities Project building on an earlier poverty and tobacco taxation analysis by the Asian Development Bank.[12,15] Among the current cohort of smokers in 13 countries, we calculated the cumulative impact of a one-time 50% increase in cigarette prices on life-years gained, treatment costs averted, number of individuals avoiding catastrophic health expenditures and extreme poverty, and additional tax revenues collected. Appendix (p 3-4, p-13-16) provides the details of the data sources and statistical procedures.

Study population

We focused on 2 billion adult males in 13 LMICs selected from different regions in Latin America and Asia based on the prevalence of smoking, population size, and availability of model parameters. Using the World Bank income definitions,[16] six countries are classified as lower middle-income (India, Indonesia, Bangladesh, the Philippines, Vietnam and Armenia), and seven are classified as upper middle-income (China, Mexico, Turkey, Brazil, Colombia, Thailand and Chile). We focused on male smokers, as they comprised about 90% of all smokers in these 13 LMICs.[17] To estimate the number of baseline smokers by age group and income quintile in each country, we applied to the UN 2015 population estimates[18] (in 5-year age groups) the smoking prevalence by sex and age group and income quintile from the most recent rounds of the Global Adult Tobacco Survey (GATS)[17] or from a similar nationally representative surveys. Because GATS and other similar surveys do not usually report household income, we used asset index or education as a proxy measure to estimate the smoking prevalence by income quintile.[19]

Price effects on smoking

The main analyses involve estimating the number of smokers who would cumulatively quit as a consequence to a one-time 50% increase in cigarette prices. We assumed that quitting is only a function of price elasticity of demand for cigarette, age and income. Studies on cigarette price elasticity (defined by the percentage reduction in cigarette consumption resulting from a specific increase in price) have mostly been done in high-income countries,

but are increasingly available for LMICs.[9,10] Several comprehensive reviews find a price elasticity of -0.4 across most countries[20] so that a 50% price increase will reduce smoking by about 20%. Of the reduction, about half (10%) is attributable to quitting by current smokers and half to fewer cigarettes smoked. Most (but not all) of the published literature demonstrates greater price responsiveness, in the range of twice as much, in the young and among the poor.[9,20] The International Agency for Research on Cancer found all 18 price elasticity studies in LMICs reviewed to show a gradient by income or education.[9] We applied a relative weighted price elasticity matrix by age and income quintile to all estimates. Hence, price elasticity in younger smokers (15-24 years) in the bottom income quintile was -1.27 whereas that in smokers aged 25+ years in the top quintile was -0.24. We applied the higher price elasticity to future smokers <15 years that have not yet started to smoke. Sensitivity analyses examined the key outcomes by excluding China and India (as these have over two-thirds of the male smokers of all 13 countries in the study), including the three countries (Chile, Colombia and Mexico) with notable female smoking, and testing price increases by 25% and 100% with the above elasticities. We also applied country-specific price elasticities from published literature.

Price effects on life-years gained, disease costs, income poverty and taxes paid

We calculated the total life-years gained as a result of quitting by age group and income quintile. First, epidemiological studies in high and middle-income countries have documented that smoking kills at least half of the current and future smokers that begin early in adult life and do not quit. Smokers lose 10 years of life on average compared to otherwise similar non-smokers. [1, 21-26] This risk is a reasonable premise for the 13 countries, as many of the current and future smokers studied are below age 35 years so many began (or would begin) smoking from early adult life. As well, the cessation rates in most LMICs are low.[17,27] Second, various studies in high-income countries document that the life-years gained from cessation varies by age: approximately 10 years gained for cessation before age 30 years and 9 years, 6 years and 3 years gained for cessation during 25-44 years, 45-64 years, and >65 years-old, respectively.[1,21-25] We used spline regression to smooth these estimates into 5-year intervals from 15 to 90 years. We assumed similar risk reductions by age across the five income quintiles. We excluded the marginal health benefit accrues due to of fewer cigarette smoked.

Next, we estimated the treatment costs averted due to reduced tobacco-attributable deaths (All costs and prices were in US dollars adjusted for purchasing power parity or PPP and expressed in inflation-adjusted terms for 2015).[16] We proportioned the reductions in deaths from the above procedure across four main causes of smoking-attributable mortality: chronic obstructive pulmonary disease, stroke, heart disease and cancers (ignoring tuberculosis). We used Global Burden of Disease estimates of the mortality proportions for these four diseases,[28] verified with the local epidemiological evidence if available (appendix p 3-4).

We derived the annual treatment cost for these four conditions for 2015 (PPP-adjusted) [16] from peer-reviewed studies or country reports (appendix p 3-4). The treatment cost averted was a function of the reduced number of cause-specific tobacco-attributable deaths. We quantified the individuals avoiding catastrophic healthcare expenditures using the WHO definition (OOP costs > 10% of an individual's yearly income) [6] and extreme poverty as when OOP costs reduce daily income below the World Bank definition (< USD 1.90/day).[16] Since comparable average individual's yearly income within each income quintile were not readily available for all 13 countries, we created a probability distribution of catastrophic expenditures and extreme poverty from an income distribution function for each country based on the Gini coefficient and average per capita household income (appendix p 3-4).

Finally, to estimate the value of taxes gained from additional tax revenues from cigarette price increase, we used WHO estimates of country-specific data on price per pack of cigarettes (USD PPP), tobacco tax incidence as percentage of final price and average cigarette sticks consumed by smokers per day across income quintiles.[2] All analyses were done in STATA version 13.0. The STATA code is available freely upon written request to the authors.

RESULTS

We studied 490M male smokers in the 13 countries (Table 1); 291M were in China and 199M in the other 12 countries. Smoking prevalence varied considerably across countries, as did the daily cigarettes consumed. Some countries, such as Indonesia, showed sharply lower smoking prevalence in top income quintiles, whereas Bangladesh and India showed

similar cigarette smoking prevalence across income quintiles. The proportion of health expenditure borne by public health systems and the co-payment requirements for the four diseases also varied. The price (all in USD PPP) per pack of the most commonly smoked cigarettes varied from $2.20 in Colombia to $10.30 in Turkey. The absolute increase in the median excise tax needed to achieve a 50% price increase was $1.70, ranging from $1.10 in Colombia and the Philippines to $5.10 in Turkey. The median of $1.70 would correspond to an approximate doubling of the excise tax rate.

The number of male smokers prior to the price increase was greater (106M, or 20%, range 14-27%) in the bottom income quintile than in the top (82M or 17%, range 9-24%) – a ratio of 1.3:1 (Table 2). A 50% price increase would result in about 67M males quitting smoking, with the bottom income quintile having 7.7 times as many quitters as the top (23M vs. 3M). Cessation would result in about 449M years of life gained, about half of which will be in China (241M). Across the 13 countries, the bottom income quintile will gain 6.7 times more life-years than the top (155M vs. 23M). The average life-years gained per smoker from cessation was in the bottom quintile was 5.1 times that of the top quintile (1.46 vs. 0.23 years). The average life-years gained per smoker would be greatest in the young. At ages 25-29 years, the 50% higher price would lead to 1.4 life-years gained per smoker in the bottom income quintile compared to 0.3 in the top quintile. At ages 60-64 years old, the comparable results would be 0.6 life-years gained and 0.2 life years for the bottom and top income quintiles, respectively (appendix p 12).

The disease costs (all in USD PPP) that would be averted to treat the four tobacco-attributable diseases would be about $157 billion. These averted costs in the bottom income quintile ($46 billion, median 29%, range 16-34%) would be 4.6 times those in the top quintile ($10 billion, median 7%, range 2-12%). The excise tax increases needed to achieve a 50% higher price would generate about $122 billion across countries, corresponding to between 0.1 and 1.1% of each current country's gross domestic product in 2015. The extra tax revenue generated from the top income quintile ($29 billion, median 23%, range 19-35%) would be double that of the bottom income quintile ($15 billion, median 10%, range 5-22%).

Table 1: Key study indicators

World Bank classification of countries	Lower middle Income						Upper middle Income						
Indicator	**IND**	**IDN**	**BGD**	**PHL**	**VNM**	**ARM**	**CHN**	**MEX**	**TUR**	**BRA**	**COL**	**THA**	**CHL§**
Population (2015; in millions)	1311	258	161	101	93	2.9	1376	127	79	208	48	68	18
Male population (2015; in millions)	679	130	81	51	46	1	709	63	39	102	24	34	9
No. of poor at $1.90 a day (2011; USD PPP; in millions)	268	21	28	13	3	0	25	4	0.3	8	3	0.03	1
Total health expenditure as % of GDP	5	3	3	5	7	4	6	6	5	8	7	4	8
Public expenditure on health as % of GDP	1	1	1	2	4	2	3	3	4	4	5	3	4
Out of pocket expenditure as % of total health expenditure	62	47	67	54	37	54	32	44	18	25	15	12	32
% of population covered with public financing scheme *	14	55	26	88	60	28	97	89‡	85	100	91	98	90
Proportion of costs paid by public financing	40	70	36	41	60	100	26	82‡	98	81	100	99	90
Male smoking prevalence (15-74 years old) †	10	58	28	39	46	53	52	21	39	23	18	45	48
Average sticks/day per current smoker	4	12	8	9	11	24	14	10	18	11	8	9	13
No. of male cigarette smokers (in millions)	46	53	25	16	15	1	291	10	12	16	3	12	3
Price per pack of cigarettes (2016; in USD PPP)	9.2	5.2	3.4	2.3	2.6	3.1	2.8	5.7	10.3	3.2	2.2	7.1	5.8
Excise tax increase needed for a 50% increase in price (2016; in USD PPP)	4.6	2.6	1.7	1.1	1.3	1.5	1.4	2.9	5.1	1.6	1.1	3.5	2.9
Share of tax to retail price (%)	43.1	57.4	77.0	62.6	35.7	35.0	50.8	67.0	82.1	67.9	49.5	73.5	64.9
% increase in tax rate from baseline tax rate	232	174	130	160	280	286	197	149	122	147	202	136	154
Price per pack after 50% price increase	14	8	5	3	4	5	4	9	15	5	3	11	9

Notes: Country Abbreviation: India: IND; Indonesia: IDN; Bangladesh: BGD; Philippines: PHL; Vietnam: VNM; Armenia: ARM; China: CHN; Mexico: MEX; Turkey: TUR; Brazil: BRA; Colombia: COL; Thailand: THA; Chile: CHL. *We only considered public financing schemes, but included mandatory p4.6rivate schemes (e.g. ISAPREs for Chile). For other countries, we excluded private insurance as they cover only a small portion of the population, and they are not mandatory. † Estimates only include cigarettes but exclude bidis mostly used in India and Bangladesh. ‡ In Mexico, though the UHC coverage rate as well as financial protection provided by the Seguro Popular for Q1 and Q2 is 100%, the policy only covers COPD among tobacco-related conditions. While for Q3-Q5 the coverage rate is 82% and financial protection is 70%, all diseases are covered by health insurance. §The World Bank classifies Chile as a high-income country, but for these analyses we considered Chile as middle-income, given that the average household income for Chileans is more or less similar to that of other upper middle-income countries like Brazil.

Table 2: Cumulative Impact of a 50% cigarette price increase on health and financing outcomes

Quintiles	Lower middle Income						Upper middle Income							Min- Max (%)	Median
	IND	IDN	BGD	PHL	VNM	ARM	CHN	MEX	TUR	BRA	COL	THA	CHL		
Number of male smokers aged 15+ years prior to 50% price increase (in millions)															
Q1 (bottom 20%)	7.3	13.6	3	3	3.7	0.1	63.9	1.6	1.8	4.2	0.6	2.8	0.5	14-27	19
Q2	10.2	12	3.3	2.8	3.3	0.1	68.5	2	2.4	3.6	0.6	3.3	0.6	18-27	22
Q3	9.5	9.8	3.1	2.6	2.6	0.1	63.1	1.8	2.9	2.9	0.7	2.7	0.7	18-25	21
Q4	9.1	9.7	3.8	2.5	2.6	0.1	47.7	2	2.6	3.1	0.6	2.3	0.7	16-23	19
Q5 (top 20%)	10	7.7	3	2.2	2.4	0.1	47.7	2.1	1.9	2	0.6	1	0.8	8-24	17
Total=490	**46.1**	**52.9**	**16.2**	**13.2**	**14.6**	**0.6**	**290.9**	**9.5**	**11.6**	**15.9**	**3.1**	**12**	**3.2**		
Q1/Q5 ratio	**0.7**	**1.8**	**1**	**1.3**	**1.5**	**1.2**	**1.3**	**0.8**	**0.9**	**2.1**	**0.9**	**2.7**	**0.6**		
Total life-years gained (in millions)															
Q1 (bottom 20%)	12.3	22.5	5.4	5.3	5.6	0.1	83.6	3.7	3.3	6.5	0.9	4.5	0.8	26-40	31
Q2	13.7	15.8	4.8	4	4.1	0.1	71.6	3.8	3.4	4.5	0.8	4.2	0.8	26-32	28
Q3	9.4	9.7	3.3	2.8	2.4	0.1	49.2	2.5	3.1	2.7	0.7	2.6	0.7	17-25	20
Q4	6	6.3	2.7	1.8	1.5	0.1	24.6	1.9	1.8	1.8	0.4	1.5	0.5	8-16	12
Q5 (top 20%)	3.2	2.5	1.1	0.8	0.7	0	12	0.9	0.7	0.6	0.2	0.3	0.3	2-8	5
Total=449	44.7	56.8	17.2	14.7	14.3	0.5	241	12.8	12.2	16.1	3	13	3.1		
Q1/Q5 ratio	3.8	9.1	5.1	6.9	7.9	6.1	7	4	4.9	11	4.6	14	3.1		
Disease cost averted (adjusted for PPP in USD; in millions)															
Q1 (bottom 20%)	8 15	4 120	81	647	296	16	33 400	2 170	445	1 850	363	878	457	16-34	29
Q2	1 040	3 220	132	538	233	17	35 500	2 260	566	1 720	357	836	494	24-32	27
Q3	773	2 770	97	405	199	16	24 900	1 980	524	1 170	264	507	436	19-26	22
Q4	547	2 190	136	255	118	10	13 400	1 600	322	874	168	290	373	11-27	15
Q5 (top 20%)	313	1 050	61	119	73	4	6 980	818	132	295	93	64	224	2-12	7
Total=157 002	3 488	13 350	507	1 964	919	63	114 180	8 828	1 989	5 909	1 245	2 575	1 984		
Q1/Q5 ratio	2.6	3.9	1.3	5.4	4	3.7	4.8	2.7	3.4	6.3	3.9	13.7	2		
Additional tax revenues (adjusted for PPP in USD; in billions)															
Q1 (bottom 20%)	0.9	2.1	0.2	0.2	0.5	<0.1	9.5	0.3	0.6	0.2	<0.1	0.4	0.1	5-22	10
Q2	1.6	2.6	0.4	0.2	0.4	0.1	14.2	0.5	1.6	0.5	0.1	0.8	0.2	13-21	17
Q3	1.9	3.4	0.5	0.3	0.4	0.1	14.9	0.4	2.8	0.8	0.1	0.8	0.2	16-26	21
Q4	2.5	4.8	0.8	0.4	0.5	0.1	12.7	0.8	3.2	0.8	0.1	1	0.3	19-30	26
Q5 (top 20%)	3.5	3.4	0.8	0.3	0.5	0.1	15	0.9	2.9	0.7	0.1	0.7	0.4	19-35	26
Total=122	10.4	16.4	2.6	1.5	2.4	0.3	66.3	2.9	11.1	3.1	0.4	3.6	1.3		
Q1/Q5 ratio	0.3	0.6	0.2	0.6	1.1	0.6	0.6	0.3	0.2	0.3	0.2	0.6	0.2		
% additional tax to GDP	**0.1%**	**1.0%**	**0.1%**	**0.2%**	**0.4%**	**1.0%**	**0.2%**	**0.1%**	**0.7%**	**0.1%**	**0.1%**	**0.3%**	**0.3%**	**0.1-1.1%**	

Notes: Country Abbreviation: India: IND; Indonesia: IDN; Bangladesh: BGD; Philippines: PHL; Vietnam: VNM; Armenia: ARM; China: CHN; Mexico: MEX; Turkey: TUR; Brazil: BRA; Colombia: COL; Thailand: THA; Chile: CHL

Figure 1 presents the results for poverty and catastrophic expenditures that would occur in the six countries with low coverage of UHC (India, Indonesia, Bangladesh, the Philippines, Vietnam, and China) and in Mexico, which had high OOP treatment costs for the four smoking-attributable diseases. The 50% higher cigarette price would lead to about 15.5M men avoiding catastrophic health expenditures. Of these, 4.4M would be in the bottom income quintile (median 29%, range 24-34%; appendix p 5). As a consequence, about 8.8M males would avoid extreme poverty across the seven countries. Of these, about 4.2M would be in the bottom income quintile (median 37%, range 16-68%), and another 2.5M would be in the second lowest income quintile. The bottom quintile would avoid 18.2 times more poverty than the top quintile. The 8.8M men represent 2.4% of the baseline number of 360M men and women living in extreme poverty in these seven countries. In most countries, there is an inverse relationship between income quintile and number of individuals will avoid catastrophic healthcare expenditures or poverty. However, in Bangladesh, a sizeable number of men who would avoid poverty and catastrophic healthcare expenditures would be from the fourth income quintile due to the relatively high prevalence of smoking in this income group.

Figure 2 summarizes the differences in the key outcomes for the bottom and top income quintile across the 13 countries. Smoking is 1.3 times as common in the bottom income quintile as the top. However, they would receive a significantly larger share of the health and financial benefits in terms of years of life gained, disease costs averted, and number of individuals avoiding catastrophic health expenditures in comparison to the top quintile. Overall, the bottom income quintile would get 31% of the life-years saved, and 29% each of the averted disease costs or averted catastrophic health expenditures but pay only 10% of the additional taxes.

Sensitivity analyses yielded similar results. The ratio of catastrophic health expenditures avoided by the bottom versus top income quintiles was 4 for all 13 countries and similar (3.5) in the 11 countries after exclusion of China and India. This ratio was similar (3.3) if we included female smokers from three countries where the proportion of female smokers to total smokers is relatively high (Chile at 46%, Colombia at 29% and Mexico at 29%). Use of lower or higher price increases or country-specific elasticities showed slightly greater ratios

for the bottom versus top income quintiles (Figure 3; appendix p 6-10). The additional tax burden from a 100% price increase would be borne mostly by the top quintile.

DISCUSSION

Key findings

Across 13 quite diverse LMICs, we demonstrate that benefits of tobacco taxation through a 50% price increase favour the bottom income quintile of the population more strongly in terms of life-years saved, OOP expenditures from averted tobacco-attributable treatment costs, or catastrophic health expenditures or extreme poverty averted. However, a much greater share of the additional tax burden is borne by the top quintile. Our results were consistent across a range of countries, despite quite marked differences in smoking prevalence, type of UHC system in place, and poverty levels. Our analysis challenges the conventional view that tobacco taxes are anti-poor.[29] which is based on the observation that low-income smokers spend a disproportionately greater share of their income on these taxes than high-income smokers.

Relevance of higher taxes to SDGs

Higher tobacco excise taxes support three of the SDG targets on reduction of NCDs, poverty, and expanded financial protection against illness. First, just in seven countries, practicable tax hikes could avoid about 2.4% of the income poverty by averting OOP treatment costs. The reduction in poverty is heavily concentrated in the bottom income quintile, but is notable also in the second lowest quintile, suggesting that higher tobacco taxes help protect the "near poor" from poverty. Higher tobacco excise taxes appear to be a powerful but generally under-appreciated tool for governments to reduce income poverty. Worldwide, some 20M people could avoid extreme poverty from a 50% higher cigarette price which is a sizeable acceleration of the 30M people who avoid extreme poverty annually in recent years due to economic growth and other reasons.[30] Second, in these 13 countries alone, some 450M life-years would be saved from higher excise taxes, contributing substantially to the SDG target of a one-third reduction in NCD death rates at ages 30-69 years by 2030.[1,8]

The relevance of higher tobacco taxes to UHC is more complex. Tobacco taxes can generate substantial revenues but, in most countries, not enough to meet the financing needs of

UHC. Extra tobacco revenue could finance an average of 4% of the recently-estimated costs of achieving the health system-related SDGs, ranging from 1% in India to 16% in Turkey (appendix p 11).[31] The goals of UHC are not only to improve health, but also to reduce poverty through financial risk protection.[6] Tobacco taxation is an unusually effective way to achieve both. As such, tobacco taxation (within the strategies of the FCTC) should be a prominent and early intervention in most UHC plans.

WHO has observed that between 2012 and 2015, over 100 countries raised their excise taxes on tobacco.[2] However, very few did so at the high levels required to reduce consumption, particularly in many LMICs where rapid income growth has made tobacco relatively more affordable in the last decade. The median tax increase required to achieve a 50% higher price across the countries was $1.70 per pack of cigarettes. While $1.70 is not small, the Philippines, Turkey, France and other countries have adopted comparable or even larger increases.[1, 2, 32] The large increase in excise taxes in some countries mostly reflects the low cost of manufacturing cigarettes. In addition to large tax increases that change consumer behaviour, governments need to pay attention to the structure of tax and many folds of price differentiation that exists, emphasizing taxation of the “cheap, short” cigarette so as to reduce downward brand substitution. In most LMICs, and most notably in China and Indonesia, the cigarette industry manipulates a wide range of cigarette prices to limit the health impact of any tax increases by encouraging smokers to shift to cheaper brands. The structure in some countries can also create financial incentives for those who engage in tax evasion and avoidance. The World Bank has recently endorsed this view, and called on Governments to implement large, simplified taxes that reduce downward substitution and combat tax avoidance.[33]

Smokers, including the poor, who do not quit or significantly reduce smoking will eventually spend more of their income on taxes. Those that quit in particular will free up additional income for other expenditures that could enhance their household welfare. Male addiction to tobacco reduces household spending on health, education or other items.[34,35] While the reductions in smoking deaths from higher taxes are concentrated in men, the benefits of reduced catastrophic health expenditures and poverty benefit children, women and families. Effectively, tobacco taxation enables an income transfer from male smokers to

females and other family members. Moreover, tobacco taxes reduce maternal tobacco use, which is an important risk factor for low birth weight and child mortality [36] the reduction of each also being SDGs.

Study limitations

As with any cross-country comparisons, our analyses face certain limitations. First, while there is variation in estimates of price elasticities across countries, we used a middle value of about -0.4. Sensitivity analysis showed that most of our results were not markedly different with use of country-specific elasticities, most of which had similar poverty effects. Our core premise is of a gradient in price elasticity by age and income group is supported by economic theory and most (but not all) price elasticity studies.[9, 20] Second, ECEA is a static model estimating cumulative benefits of a one-time increase. The ideal would be a dynamic model that incorporates demographic, economic, and healthcare system changes over time, but this is not yet developed. Large, one-time price shocks in several countries or states within the United States have reduced tobacco use.[9] Third, in theory, faster future economic growth among the lower income quintiles would mean that tobacco taxes increases are less pro-poor than we estimate. In reality, much of the rapid economic growth in the 13 countries continues to be greater in upper income quintiles (i.e. fast growing countries like China and Brazil have Gini coefficient of 0.46, and 0.53 respectively).[16] Similarly, a rapid expansion of UHC that reaches the poor would also mean tobacco taxes increases are less pro-poor than we estimate. However, UHC expansion has generally been slow, and high OOP continue to be the norm in many LMICs.[37]

Indeed, we might be underestimating the true benefits of smoking cessation among the poor. Due to lack of sufficient data and comparability between all 13 countries, our analyses did not take account of loss of productivity and family earnings due to tobacco use, and thereby the greater probability of being pushed into impoverishment. Only about 40% of welfare benefits of disease control broadly arise from averted treatment costs,[38] with the rest from productivity gains that we did not include. We did not take into account the consumers' utility or welfare derived from smoking. The welfare benefits of consuming a highly addictive product are complex, in that they represent the willingness to pay both to continue to smoke, but also to avoid the substantial discomfort from withdrawal of

smoking. In the United States, analyses that take into account addiction find that higher taxes increase the welfare of smokers, especially the poorest, by serving as an external force against the addiction of tobacco.[39] We limited our analyses to cigarette smoking. The Indian sub-continent has a sizable number of bidi (small, locally-manufactured cigarettes) users as well as oral tobacco users. In this region, smoking patterns are changing with cigarettes increasingly substituting bidis, particularly in the poor and in the young.[40] Similarly, we also did not account for the modest health benefits of reduced smoking amount.

Finally, our estimates did not take into account the long term signalling effects of higher taxes on individual smoking behaviour. France has halved its daily per capita smoking in only 15 years (the UK took 30 years to halve consumption), in part as its government announced at the outset (in 1992) that excise taxes would rise 5% above inflation every year.[1] Like mortgages, future rational price expectations can have an additional benefit beyond the initial price shock.

Implications

Our analyses suggest that large increases in tobacco excise taxation are not only effective at reducing smoking and its consequences on diseases, but also strongly relevant to the UN SDGs for poverty and UHC. On-going efforts by countries, the World Bank, WHO and the Bloomberg Philanthropies and Gates Foundation to advance tobacco control can use our findings as substantial new arguments to accelerate smoking cessation. Modest action by many governments could yield unprecedented health gains and poverty-reduction in the 21st century.[41]

What is already known on this topic?

- Higher-excise taxes on tobacco are essential to reach the SDGs to reduce NCD death rates by one-third by 2030.
- Low-income groups are more responsive to price increases than high-income groups. However, there are only limited published studies of the distributional impact of higher tobacco taxes on health and financial outcomes.

What this study adds?

- This is the largest study to directly quantify the potential impact of a tobacco price increase across income groups in a diverse range of low and middle-income countries covering 2 billion population and 500 million male smokers. Despite differences in socio-economic condition and health financing arrangements, tobacco taxation through a 50% price increase strongly favours the bottom income quintile of the population in terms of life-years saved, out of pocket expenditures from tobacco-attributable treatment costs averted, and individuals avoiding catastrophic health expenditures or poverty.
- Higher tobacco excise taxes appear to be a powerful but generally under-appreciated tool for governments to reduce income poverty. Worldwide, some 20 million people could avoid poverty from a 50% higher cigarette price, which is a sizeable acceleration of the 30M people who avoid extreme poverty annually due to economic growth and other reasons.
- In these 13 countries alone, some 450M life-years would be saved from higher excise taxes, contributing substantially to the SDG target of a one-third reduction in NCD death rates at ages 30-69 years by 2030.

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S Mishra, V Ulep and P Jha conducted the analyses. P Jha, S Mishra, V Ulep, P Isenman and P Marquez wrote the first draft. P Jha conceived the study and is Principal Investigator of the Global Tobacco Economics Consortium. All co-authors satisfy the recommendations outlined in the ICMJE Recommendations 2013. All co-authors provided substantial contributions to the conception or design of the work or acquisition, analysis, or interpretation of data for the work, and helped with drafting the work or revising it critically for important intellectual content. All co-authors approve this version of the manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. PJ is guarantor for the study, had full access to all of the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

The authors affirm that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Role of the funding source

The sponsors of the study had no role in the study design, data collection, data analysis, data

interpretation, or writing of the manuscript. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Conflict of interest

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethics review

Institutional review board approval was not required. No primary data collection conducted. We attest that we have obtained appropriate permissions and paid any required fees for use of copyright protected materials.

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Data sharing statement

The parameters are included in the supplementary appendix, and the STATA code is available freely upon written request to the authors.

Figure legends:

Figure 1: Number of individuals avoiding catastrophic health expenditures and averting extreme poverty

Catastrophic health expenditure is >10% of individual's annual income and extreme poverty is the World Bank's international poverty line of income of USD $1.90/day in PPP.

Figure 2: Share of health and financial benefits accruing to bottom and top income quintiles of the population

*Expected value if there are no differences across bottom and top

Figure 3: Sensitivity analysis for health and financial outcomes by varying degree of tobacco price increase and using country-specific elasticities

All USD are in PPP

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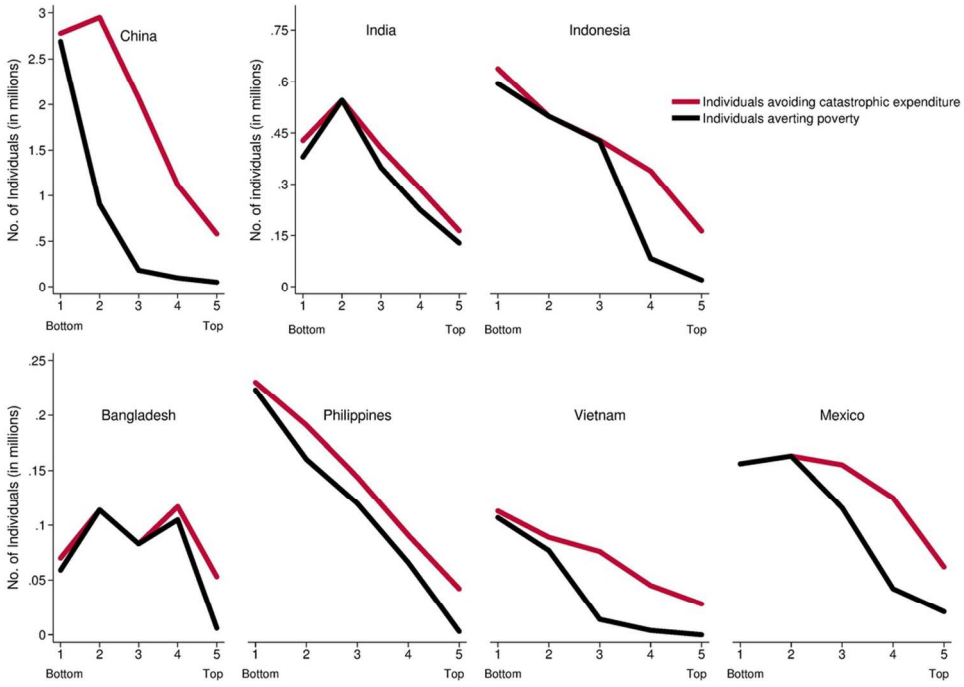

Figure 1: Number of individuals avoiding catastrophic health expenditures and averting poverty

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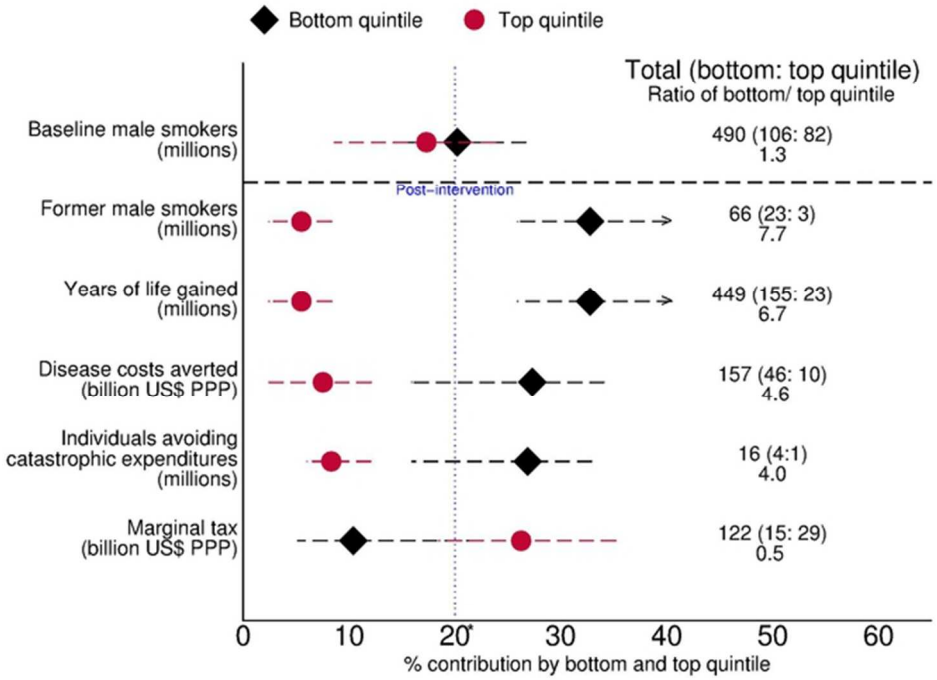


Figure 2: Share of health and financial benefits accruing to bottom and top quintiles of the population

60x44mm (300 x 300 DPI)

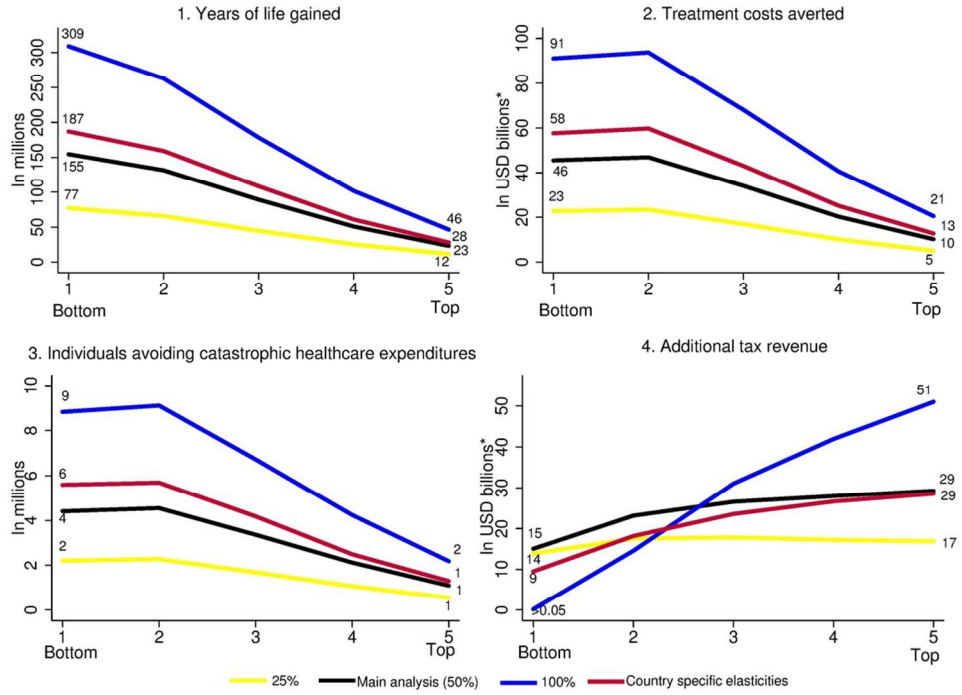


Figure 3: Sensitivity analysis for health and financial outcomes by varying degree of tobacco price increase and using country-specific elasticities

101x73mm (300 x 300 DPI)

Supplementary appendix: The health poverty and financial consequences of a cigarette price increase among 0.5 billion male smokers in 13 low and middle-income countries

Supplementary appendix: The health poverty and financial consequences of a cigarette price increase among 0.5 billion male smokers in 13 low and middle-income countries

Appendix Table 1: Input parameters for 13 countries

			Lower middle Income				Upper middle Income							
Indicators	**IND**	**IDN**	**BGL**	**PHL**	**VNM**	**ARM**	**CHN**	**MEX**	**TUR**	**BRA**	**COL**	**THA**	**CHL**	**Source**
Population (males in millions)														(1)
0-4	65.1	12.7	7.8	5.7	3.8	0.1	44.6	6.0	3.5	7.7	1.9	2.0	0.6	
5-9	66.9	11.8	8.0	5.3	3 4	0.1	42.4	6.2	3.4	7.9	2.0	2.1	0.6	
10-14	66.9	12.1	8.4	5.1	3.6	0.1	40.4	6.2	3.4	8.9	2.1	2.1	0.6	
15-19	64.9	11.8	8.2	5.1	4.5	0.1	42.0	6.2	3.4	8.9	2.1	2.2	0.7	
20-24	62.1	10.7	7.7	4.8	4.4	0.1	55.9	5.6	3.2	8.4	2.1	2.3	0.7	
25-29	58.7	9.9	7.2	4.2	4.0	0.1	67.0	5.0	3.2	8.8	2.0	2.3	0.7	
30-34	54.1	10.7	6.6	3.7	3.6	0.1	51.1	4.8	3.2	8.9	1.9	2.5	0.7	
35-39	47.2	10.0	5.8	3.3	3.3	0.1	48.8	4.7	3.0	8.1	1.7	2.8	0.6	
40-44	41.8	9.3	5.0	3.0	3.0	0.1	61.0	4.0	2.6	7.0	1.5	2.8	0.6	
45-49	36.5	8.3	4.5	2.7	2.7	0.1	62.7	3.4	2.3	6.4	1.5	2.8	0.6	
50-54	31.9	6.9	3.7	2.3	2.2	0.1	50.6	2.9	2.0	5.9	1.3	2.5	0.6	
55-59	26.9	5.6	2.6	1.9	1.5	0.1	40.1	2.2	1.7	4.8	1.1	2.2	0.5	
60-64	21.7	4.0	1.7	1.4	0.8	0.1	39.2	1.8	1.3	3.8	0.9	1.7	0.4	
65-69	14.2	2.5	1.5	1.0	0.5	<0.1	25.4	1.3	0.9	2.7	0.6	1.2	0.3	
70-74	9.6	1.7	1.1	0.6	0.4	<0.1	16.8	1.1	0.7	1.8	0.4	0.8	0.2	
Smoking prevalence, by age														(2–14)
15-19	4%	21%	12%	19%	12%	26%	14%	19%	21%	9%	7%	34%	38%	
20-24	9%	47%	29%	29%	42%	35%	49%	29%	47%	20%	19%	52%	46%	
25-29	9%	54%	34%	39%	45%	43%	53%	27%	54%	18%	26%	48%	51%	
30-34	13%	52%	38%	49%	58%	52%	52%	22%	52%	20%	25%	49%	55%	
35-39	12%	51%	36%	49%	62%	60%	58%	24%	51%	24%	21%	50%	56%	
40-44	12%	50%	33%	48%	56%	66%	68%	19%	50%	24%	17%	50%	55%	
45-49	14%	45%	36%	48%	62%	68%	67%	23%	45%	27%	13%	50%	53%	
50-54	12%	42%	31%	47%	60%	67%	58%	21%	42%	29%	16%	47%	49%	
55-59	10%	32%	26%	45%	64%	64%	58%	17%	32%	27%	17%	44%	44%	
60-64	8%	33%	19%	43%	47%	60%	47%	19%	33%	24%	19%	44%	40%	
65-69	7%	20%	18%	40%	45%	55%	38%	15%	20%	20%	21%	34%	35%	
70-74	6%	16%	22%	36%	34%	51%	21%	10%	16%	16%	21%	34%	31%	
Smoking prevalence, by income quintile														(2–14)
Q1	8%	72%	26%	32%	58%	49%	59%	21%	32%	31%	16%	48%	30%	
Q2	11%	63%	29%	31%	53%	61%	63%	26%	41%	27%	18%	57%	38%	
Q3	10%	52%	26%	28%	42%	59%	58%	24%	50%	22%	19%	46%	46%	
Q4	10%	51%	33%	27%	40%	49%	44%	27%	45%	22%	17%	40%	48%	
Q5	10%	41%	26%	24%	38%	42%	44%	27%	34%	15%	18%	18%	51%	
Number of cigarettes consumed daily per person														(2–14)
Q1	4	18	8	10	14	24	16	13	18	6	6	9	18	
Q2	4	19	8	9	10	24	16	10	19	11	8	9	15	
Q3	4	18	7	10	10	24	14	8	18	14	8	7	11	
Q4	4	17	7	9	10	24	13	9	17	11	8	9	11	
Q5	4	16	8	7	9	24	13	8	16	12	10	10	10	
Share to the total deaths														(15)
COPD	23%	9%	31%	10%	11%	7%	19%	8%	15%	2%	19%	83%	14%	
Stroke	18%	50%	16%	35%	47%	24%	39%	12%	24%	5%	22%	37%	34%	
Heart disease	44%	40%	49%	49%	28%	63%	30%	47%	46%	7%	52%	33%	42%	
Lung cancer	15%	2%	5%	6%	13%	6%	12%	33%	15%	1%	7%	16%	10%	
Annual treatment cost from tobacco attributable diseases (in USD PPP-adjusted)														(7,8,16–28)
COPD	240	2 977	431	601	400	425	2 256	767	1 604	879	1 289	426	552	
Stroke	895	825	431	1 873	866	350	2 197	3 527	1 850	2 963	1 446	937	4 433	
Heart disease	494	3 935	431	774	1 384	1 724	11 774	4 152	1 537	1 484	968	1 163	3 946	
Lung cancer	895	5 372	644	720	1 319	4 781	14 794	11 811	1 902	2 308	10 240	2 399	21 738	

	Lower middle Income						Upper middle Income							
Indicators	**IND**	**IDN**	**BGL**	**PHL**	**VNM**	**ARM**	**CHN**	**MEX**	**TUR**	**BRA**	**COL**	**THA**	**CHL**	**Source**
Probability of seeking care														(7,8,25,29–34)
COPD	65%	70%	41%	80%	52%	25%	33%	96%	70%	79%	70%	99%	88%	
Stroke	67%	70%	41%	80%	52%	75%	80%	96%	70%	88%	70%	99%	88%	
Heart disease	70%	70%	41%	80%	52%	75%	81%	96%	70%	87%	70%	99%	88%	
Lung cancer	72%	70%	41%	80%	52%	40%	50%	96%	70%	90%	70%	99%	88%	
Health utilization (relative)														(7,8,,19,30,35–42)
Q1	0.8	0.6	0.5	0.8	0.6	0.7	0.79	0.8	0.8	0.7	1.0	1.0	0.9	
Q2	0.9	0.7	0.9	0.9	0.7	0.7	0.98	0.8	1.0	0.9	1.1	1.0	1.0	
Q3	1.0	1.0	1.0	1.0	1.0	1.0	1.00	1.0	1.0	1.0	1.0	1.0	1.0	
Q4	1.1	1.2	1.7	1.0	0.9	1.1	1.08	1.1	1.1	1.1	1.1	1.0	1.2	
Q5	1.2	1.5	2.0	1.1	1.2	1.2	1.15	1.1	1.2	1.1	1.2	1.0	1.4	
Insurance coverage rate														(7,8,29,43–53)
	11%	55%	26%	88%	60%	28%	97%	91%	85%	100%	91%	98%	90%	
Financial support														(26,43,44,46–49,54–56)
	40%	70%	40%	40%	60%	100%	30%	70%	100%	80%	100%	100%	90%	
Household income per capita (in USD PPP-adjusted)														(57–65)
	1 559	1 940	1 437	2 888	2 436	2 888	5 405	4183	10 865	7 511	3 075	7 788	9 419	
Gini														
	0.3	0.4	0.3	0.4	0.4	0.3	0.5	0.5	0.4	0.5	0.5	0.4	0.5	(66)
Individual Income (by quintile)														Authors' calculation
Q1	899	1 008	857	1 393	1 309	1 739	2 435	1 861	5 567	3 017	1 192	4 158	3 886	
Q2	1 243	1 478	1 164	2 125	1 883	2 346	3 866	2 972	8 229	5 100	2 055	6 009	6 467	
Q3	1 501	1 841	1 391	2 711	2 326	2 792	5 027	3 886	10 310	6 881	2 797	7 438	8 654	
Q4	1 791	2 264	1 645	3 401	2 831	3 292	6 423	4 980	12 712	9 042	3 721	9 065	11 293	
Q5	2 352	3 104	2 133	4 795	3 823	4 255	9 260	7 227	17 492	13 550	5 641	12 292	16 813	
Price elasticity														(28 67–79)
	-0.35	-0.30	-0.49	-0.87	-0.53	-0.56	-0.54	-0.52	-0.39	-0.38	-0.78	-0.39	-0.21	
PPP conversion factor														(80)
	19	4 800	31	20	8 836	202	4	10	2	2	1 292	13	376	

India(IND); Indonesia (IDN); Bangladesh (BGD); Philippines (PHL); Vietnam (VNM); Armenia (ARM): China (CHN); Mexico (MEX); Turkey (TUR); Brazil (BRA); Colombia (COL); Thailand (THA); Chile (CHL)

Appendix Table 2. Number of individuals avoiding catastrophic health expenditure and averting poverty

Quintile	Lower middle Income					Upper middle Income		Range of quintile share Min-Max (%)	Median (share)	Mean (share)
	IND	IDN	BGL	PHL	VNM	CHN	MEX			
Number of people avoiding catastrophic expenditures from treatment related costs (in millions)										
Q1 (bottom 20%)	0.43	0.64	0.07	0.23	0.11	2.78	0.16	24-34	29	27
Q2	0.55	0.50	0.11	0.19	0.09	2.95	0.16	24-31	26	27
Q3	0.41	0.43	0.08	0.14	0.08	2.07	0.15	18-23	22	21
Q4	0.29	0.34	0.12	0.09	0.04	1.12	0.13	11-19	16	16
Q5 (top 20%)	0.16	0.16	0.05	0.04	0.03	0.58	0.06	6-10	8	8
Total=15.5	1.83	2.07	0.44	0.70	0.35	9.49	0.66			
Q1/Q5	**2.6**	**3.9**	**1.3**	**5.5**	**4.1**	**4.8**	**2.5**			
Number of people averting poverty from treatment related costs (in millions)										
Q1 (bottom 20%)	0.38	0.59	0.06	0.22	0.11	2.69	0.16	16-68	37	38
Q2	0.55	0.50	0.11	0.16	0.08	0.91	0.16	23-37	31	31
Q3	0.35	0.43	0.08	0.12	0.01	0.18	0.12	5-27	21	18
Q4	0.22	0.08	0.11	0.07	<0.01	0.10	0.04	2-12	8	10
Q5 (top 20%)	0.13	0.02	0.01	<0.01	<0.01	0.05	0.02	0-4	1	2
Total=8.8	1.63	1.62	0.37	0.57	0.20	3.93	0.50			
Q1/Q5	**0.2**	**0.4**	**0.2**	**0.4**	**0.5**	**0.7**	**0.3**			

Note: India(IND); Indonesia (IDN); Bangladesh (BGD); Philippines (PHL); Vietnam (VNM); Armenia (ARM): China (CHN); Mexico (MEX); Turkey (TUR); Brazil (BRA); Colombia (COL); Thailand (THA); Chile (CHL)

Appendix Table 3a: Sensitivity Analysis- additional life years gained (in millions)

	Lower middle Income						Upper middle Income									
Quintile	**IND**	**IDN**	**BGL**	**PHL**	**VNM**	**ARM**	**CHN**	**MEX**	**BRA**	**TUR**	**COL**	**CHL**	**THA**	**Range of quintile share Min- Max (%)**	**Median (share)**	**Mean (share)**
25%																
Q1	6.1	11.2	2.7	2.7	2.8	0.1	41.8	1.9	3.3	1.6	0.5	0.4	2.2	26-40	31	33
Q2	6.8	7.9	2.4	2.0	2.0	0.1	35.8	1.9	2.2	1.7	0.4	0.4	2.1	26-32	28	29
Q3	4.7	4.8	1.6	1.4	1.2	0.1	24.6	1.3	1.3	1.5	0.3	0.4	1.3	17-25	20	20
Q4	3.0	3.2	1.3	0.9	0.8	<0.05	12.3	0.9	0.9	0.9	0.2	0.3	0.7	10-16	12	13
Q5	1.6	1.2	0.5	0.4	0.4	<0.05	6.0	0.5	0.3	0.3	0.1	0.1	0.2	2-8	5	5
Total	**22.3**	**28.3**	**8.6**	**7.3**	**7.1**	**0.2**	**120.5**	**6.4**	**8.0**	**6.1**	**1.5**	**1.5**	**6.5**			
50%																
Q1	12.3	22.5	5.4	5.3	5.6	0.1	83.6	3.7	6.5	3.3	0.9	0.8	4.5	26-40	31	33
Q2	13.7	15.8	4.8	4.0	4.1	0.1	71.6	3.8	4.5	3.4	0.8	0.8	4.2	26-32	28	29
Q3	9.4	9.7	3.3	2.8	2.4	0.1	49.2	2.5	2.7	3.1	0.7	0.7	2.6	17-25	20	20
Q4	6.0	6.3	2.7	1.8	1.5	0.1	24.6	1.9	1.8	1.8	0.4	0.5	1.5	10-33	13	17
Q5	3.2	2.5	1.1	0.8	0.7	<0.05	12.0	0.9	0.6	0.7	0.2	0.3	0.3	2-8	5	5
Total	**44.7**	**56.8**	**17.2**	**14.7**	**14.3**	**0.5**	**241.0**	**12.8**	**16.1**	**12.2**	**3.0**	**3.1**	**13.0**			
100%																
Q1	24.6	44.9	10.8	10.6	11.2	0.3	167.0	7.4	13.0	6.5	1.8	1.6	9.0	26-40	31	33
Q2	27.3	31.6	9.6	8.1	8.1	0.3	143.0	7.5	8.9	6.8	1.7	1.6	8.4	26-32	28	29
Q3	18.9	19.4	6.6	5.6	4.8	0.2	98.4	5.1	5.4	6.1	1.3	1.4	5.1	17-25	20	20
Q4	12.0	12.6	5.4	3.5	3.1	0.1	49.2	3.8	3.7	3.6	0.8	1.0	2.9	10-16	12	13
Q5	6.4	4.9	2.1	1.5	1.4	<0.05	24.0	1.9	1.2	1.3	0.4	0.5	0.6	2-8	5	5
Total	**89.2**	**113.4**	**34.4**	**29.3**	**28.6**	**1.0**	**481.6**	**25.7**	**32.2**	**24.3**	**6.0**	**6.2**	**26.0**			
50% (country-specific elasticity)																
Q1	10.7	16.8	6.6	11.6	7.4	0.2	113.0	4.8	6.1	3.2	1.8	0.4	4.4	26-40	31	33
Q2	11.9	11.9	5.9	8.8	5.4	0.2	96.6	4.9	4.2	3.3	1.6	0.4	4.1	26-32	28	29
Q3	8.2	7.3	4.0	6.1	3.2	0.1	66.4	3.3	2.5	3.0	1.3	0.4	2.5	17-25	20	20
Q4	5.2	4.7	3.3	3. 8	2.0	0.1	33.2	2.4	1.7	1.8	0.8	0.3	1.4	10-52	13	18
Q5	2.8	1.8	1.3	1. 7	0.9	<0.05	16.2	1.2	0.6	0.6	0.4	0.1	0.3	2-8	5	5
Total	**38.8**	**42.6**	**21.1**	**31. 9**	**18.9**	**0.7**	**325.4**	**16.7**	**15.1**	**11.9**	**5.9**	**1.6**	**12.8**			

Note: India(IND); Indonesia (IDN); Bangladesh (BGD); Philippines (PHL); Vietnam VNM); Armenia (ARM): China (CHN); Mexico (MEX); Turkey (TUR); Brazil (BRA); Colombia (COL); Thailand (THA); Chile (CHL)

Appendix Table 3b: Sensitivity Analysis- Additional tax revenue (in billions)

	Lower middle Income						Upper middle Income							Range of quintile share	Median (share)	Mean (share)
Quintile	**IND**	**IDN**	**BGL**	**PHL**	**VNM**	**ARM**	**CHN**	**MEX**	**BRA**	**TUR**	**COL**	**CHL**	**THA**	**Min- Max (%)**		
25%																
Q1	0.7	2.0	0.2	0.2	0.4	<0.05	8.2	0.3	0.2	0.8	<0.05	0.1	0.5	9-27	15	15
Q2	1.2	2.0	0.3	0.2	0.3	<0.05	10.3	0.4	0.4	1.5	<0.05	0.2	0.6	16-24	19	19
Q3	1.2	2.3	0.3	0.2	0.3	<0.05	9.7	0.3	0.6	2.1	0.1	0.2	0.5	15-26	20	21
Q4	1.5	3.0	0.5	0.2	0.3	<0.05	7.6	0.5	0.5	2.2	0.1	0.2	0.7	17-27	24	23
Q5	2.0	2.0	0.5	0.2	0.3	<0.05	8.5	0.5	0.4	1.8	0. 1	0.3	0.4	15-31	20	21
Total	**6.6**	**11.3**	**1.9**	**1.0**	**1.6**	**0.2**	**44.2**	**2.1**	**2.2**	**8.4**	**0.3**	**1.0**	**2.7**			
50%																
Q1	0.9	2.1	0.2	0.2	0.5	<0.05	9.5	0.3	0.2	0.6	<0.05	0.1	0.4	5-22	10	11
Q2	1.6	2.6	0.4	0.2	0.4	0.1	14.2	0.5	0.5	1.6	0.1	0.2	0.8	13-21	17	17
Q3	1.9	3.4	0.5	0.3	0.4	0.1	14.9	0.4	0.8	2.8	0.1	0.2	0.8	16-26	21	21
Q4	2.5	4.8	0.8	0.4	0.5	0.1	12.7	0.8	0.8	3.2	0.1	0.3	1.0	19-30	27	26
Q5	3.5	3.4	0.8	0.3	0.5	0.1	15.0	0.9	0.7	2.9	0.1	0.4	0.7	19-35	23	26
Total	**10.4**	**16.4**	**2.6**	**1.5**	**2.4**	**0.3**	**66.3**	**2.9**	**3.1**	**11.1**	**0.4**	**1.3**	**3.6**			
100%																
Q1	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0-4	0	1
Q2	1.3	1.5	0.1	0.1	0.4	<0.05	10.4	0.1	0.2	0.1	<0.05	<0.05	0.2	0-14	7	7
Q3	2.3	3.9	0.4	0.4	0.6	0.1	18.3	0.4	0.9	2.6	0.1	0.2	0.8	14-25	21	20
Q4	3.8	7.2	1.1	0.5	0.8	0.1	19.5	1.1	1.2	4.5	0.1	0.5	1.5	26-40	34	33
Q5	6.2	6.0	1.4	0.6	0.9	0.1	26.4	1.5	1.3	4.7	0.2	0.8	1.2	31-51	35	38
Total	**13.5**	**18.6**	**3.0**	**1.6**	**2.7**	**0.3**	**74.6**	**3.1**	**3.6**	**11.9**	**0.5**	**1.5**	**3.7**			
50% (country-specific elasticity)																
Q1	1.1	3.4	<0.05	<0.05	0.3	<0.05	3.0	<0.05	0.3	0.7	<0.05	0.3	0.4	0-17	8	6
Q2	1.8	3.5	0.2	<0.05	0.3	<0.05	8.6	0.3	0.6	1.7	<0.05	0.4	0.8	0-21	17	14
Q3	2.0	4.0	0.4	<0.05	0.4	<0.05	11.5	0.3	0.8	2.9	<0.05	0.4	0.8	5-26	19	19
Q4	2.6	5.3	0.7	0.2	0.5	0.1	11.1	0.7	0.9	3.3	0.1	0.4	1.0	22-40	27	29
Q5	3.6	3.6	0.8	0.3	0.5	0.1	14.2	0.8	0.7	2.9	0.1	0.5	0.7	18-64	27	32
Total	**11.1**	**19.8**	**2.1**	**0.5**	**1.9**	**0.2**	**48.4**	**2.1**	**3.3**	**11.4**	**0.2**	**2.0**	**3.7**			

Note: India(IND); Indonesia (IDN); Bangladesh (BGD); Philippines (PHL); Vietnam (VNM); Armenia (ARM): China (CHN); Mexico (MEX); Turkey (TUR); Brazil (BRA); Colombia (COL); Thailand (THA); Chile (CHL)

Appendix Table 3c: Sensitivity Analysis- Number of treatment cost averted (in billions)

Quintile	Lower middle Income						Upper middle Income							Range of quintile share Min- Max (%)	Median (share)	Mean (share)
	IND	IDN	BGL	PHL	VNM	ARM	CHN	MEX	BRA	TUR	COL	CHL	THA			
25%																
Q1	0.4	2.1	<0.05	0.3	0.1	<0.05	16.7	1.1	0.9	0.2	0.2	0.2	0.4	16-34	29	28
Q2	0.5	1.6	0.1	0.3	0.1	<0.05	17.7	1.1	0.9	0.3	0.2	0.2	0.4	24-32	27	27
Q3	0.4	1.4	0.0	0.2	0.1	<0.05	12.4	1.0	0.6	0.3	0.1	0.2	0.3	19-26	22	22
Q4	0.3	1.1	0.1	0.1	0.1	<0.05	6.7	0.8	0.4	0.2	0.1	0.2	0.1	11-27	15	16
Q5	0.2	0.5	0.0	0.1	0.0	<0.05	3.5	0.4	0.1	0.1	0.0	0.1	<0.05	2-12	7	7
Total	**1.7**	**6.7**	**0.3**	**1.0**	**0.5**	**<0.05**	**57.0**	**4.4**	**3.0**	**1.0**	**0.6**	**1.0**	**1.3**			
50%																
Q1	0.8	4.1	0.1	0.6	0.3	<0.05	33.4	2.2	1.9	0.4	0.4	0.5	0.9	16-34	29	28
Q2	1.0	3.2	0.1	0.5	0.2	<0.05	35.5	2.3	1.7	0.6	0.4	0.5	0.8	24-32	27	27
Q3	0.8	2.8	0.1	0.4	0.2	<0.05	24.9	2.0	1.2	0.5	0.3	0.4	0.5	19-26	22	22
Q4	0.5	2.2	0.1	0.3	0.1	<0.05	13.4	1.6	0.9	0.3	0.2	0.4	0.3	11-27	15	16
Q5	0.3	1.1	0.1	0.1	0.1	<0.05	7.0	0.8	0.3	0.1	0.1	0.2	0.1	2-12	7	7
Total	**3.5**	**13.4**	**0.5**	**2.0**	**0.9**	**0.1**	**114.2**	**8.8**	**5.9**	**2.0**	**1.2**	**2.0**	**2.6**			
100%																
Q1	1.6	8.2	0.2	1.3	0.6	<0.05	66.8	4.3	3.7	0.9	0.7	0.9	1.8	16-34	29	28
Q2	2.1	6.4	0.3	1.1	0.5	<0.05	70.9	4.5	3.4	1.1	0.7	1.0	1.7	24-32	27	27
Q3	1.6	5.5	0.2	0.8	0.4	<0.05	49.8	4.0	2.3	1.1	0.5	0.9	1.0	19-26	22	22
Q4	1.1	4.4	0.3	0.5	0.2	<0.05	26.9	3.2	1.8	0.6	0.3	0.7	0.6	11-27	15	16
Q5	0.6	2.1	0.1	0.2	0.1	<0.05	14.0	1.6	0.6	0.3	0.2	0.4	0.1	2-12	7	7
Total	**7.0**	**26.7**	**1.0**	**3.9**	**1.8**	**0.1**	**228.4**	**17.7**	**11.8**	**4.0**	**2.5**	**4.0**	**5.1**			
50% (country-specific elasticity)																
Q1	0.7	3.1	0.1	1.4	0.4	<0.05	45.1	2.8	1.7	0.4	0.7	0.2	0.9	16-34	29	28
Q2	0.9	2.4	0.2	1.2	0.3	<0.05	47.9	2.9	1.6	0.6	0.7	0.3	0.8	24-32	27	27
Q3	0.7	2.1	0.1	0.9	0.3	<0.05	33.6	2.6	1.1	0.5	0.5	0.2	0.5	19-26	22	22
Q4	0.5	1.6	0.2	0.6	0.2	<0.05	18.1	2.1	0.8	0.3	0.3	0.2	0.3	11-27	15	16
Q5	0.3	0.8	0.1	0.3	0.1	<0.05	9.4	1.1	0.3	0.1	0.2	0.1	0.1	2-12	7	7
Total	**3.0**	**10.0**	**0.6**	**4.3**	**1.2**	**0.1**	**154.1**	**11.5**	**5.5**	**1.9**	**2.4**	**1.0**	**2.5**			

Note: India(IND); Indonesia (IDN); Bangladesh (BGD); Philippines (PHL); Vietnam (VNM); Armenia (ARM): China (CHN); Mexico (MEX); Turkey (TUR); Brazil (BRA); Colombia (COL); Thailand (THA); Chile (CHL)

Appendix Table 3d: Sensitivity Analysis- Number of individuals averting catastrophic expenditures from treatment related costs (in millions)

Quintile	Lower middle Income IND	IDN	BGL	PHL	VNM	Upper middle Income CHN	MEX	Range of quintile share Min- Max (%)	Median (share)	Mean (share)
25%										
Q1	0.21	0.32	0.03	0.11	0.06	1.39	0.08	16-33	29	27
Q2	0.27	0.25	0.06	0.10	0.04	1.47	0.08	24-31	26	27
Q3	0.20	0.21	0.04	0.07	0.04	1.03	0.08	19-23	22	21
Q4	0.14	0.17	0.06	0.05	0.02	0.56	0.06	12-27	16	16
Q5	0.08	0.08	0.03	0.02	0.01	0.29	0.03	6-12	8	8
Total	**0.92**	**1.03**	**0.22**	**035**	**0.17**	**4.75**	**0.33**			
50%										
Q1	0.43	0.64	0.07	0.23	0.11	2.78	0.16	16-33	29	27
Q2	0.55	0.50	0.11	0.19	0.09	2.95	0.16	24-31	26	27
Q3	0.41	0.43	0.08	0.14	0.08	2.07	0.15	19-23	22	21
Q4	0.29	0.34	0.12	0.09	0.04	1.12	0.13	12-27	16	16
Q5	0.16	0.16	0.05	0.04	0.03	0.58	0.06	6-12	8	8
Total	**1.83**	**2.07**	**0.44**	**0.70**	**0.35**	**9.49**	**0.66**			
100%										
Q1	0.86	1.28	0.14	0.46	0.23	5.55	0.31	16-33	29	27
Q2	1.09	1.00	0.23	0.38	0.18	5.90	0.33	24-31	26	27
Q3	0.81	0.86	0.17	0.29	0.15	4.14	0.31	19-23	22	21
Q4	0.57	0.68	0.23	0.18	0.09	2.23	0.25	12-27	16	16
Q5	0.33	0.33	0.11	0.08	0.06	1.16	0.12	6-12	8	8
Total	**3.66**	**4.14**	**0.87**	**1.40**	**0.70**	**18.98**	**1.32**			
50% country specific elasticity										
Q1	0.37	0.48	0.15	0.50	0.15	3.75	0.20	23-33	31	29
Q2	0.48	0.37	0.12	0.42	0.12	3.98	0.21	24-31	25	27
Q3	0.35	0.32	0.10	0.31	0.10	2.79	0.20	21-23	22	22
Q4	0.25	0.25	0.06	0.20	0.06	1.51	0.16	12-19	13	14
Q5	0.14	0.12	0.04	0.09	0.04	0.78	0.08	6-9	8	8
Total	**1.59**	**1.55**	**0.46**	**1.52**	**0.46**	**12.81**	**0.86**			

Note: India(IND); Indonesia (IDN); Bangladesh (BGD); Philippines (PHL); Vietnam (VNM); Armenia (ARM): China (CHN); Mexico (MEX); Turkey (TUR); Brazil (BRA); Colombia (COL); Thailand (THA); Chile (CHL)

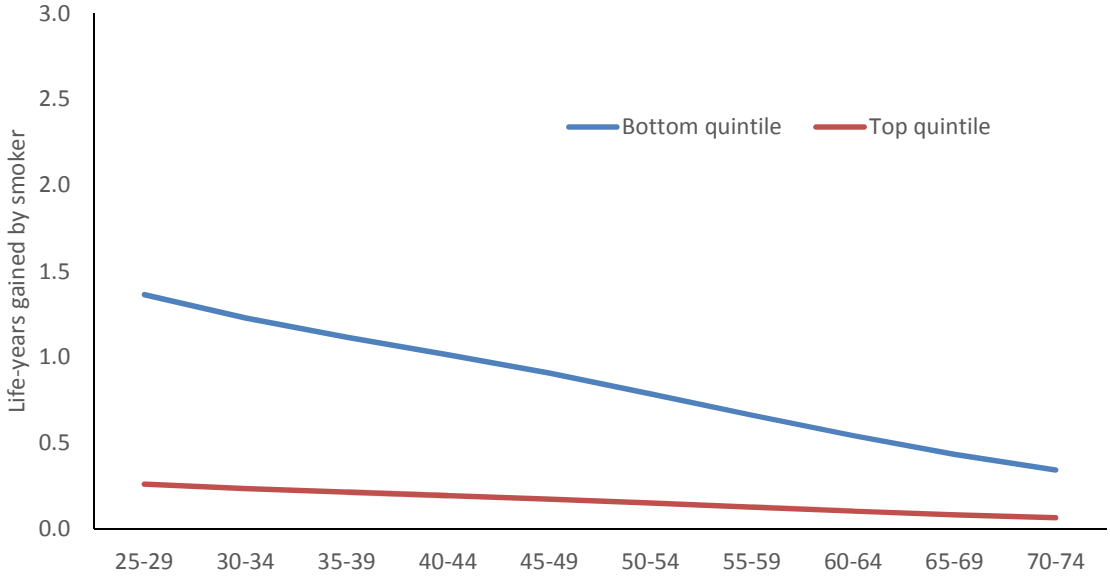
Appendix Table 4: Estimated impact excluding China and India and including females in Colombia Mexico and Chile

Indicators	13 countries (main analysis)	12 countries (excluding China)	11 countries (excluding China and India)	11 countries (excluding China and India but including females in Chile, Colombia and Mexico)
Number of smokers (in millions)	490	199	153	160
Number of life-years gained (in millions)	449	208	164	171
Disease cost averted (in billion USD) PPP-adjusted	157	43	39	44
Marginal tax gained (in billion USD) PPP-adjusted	122	55	45	47
Number of individuals averting catastrophic expenditure (Q1/Q5)	18.2	18.5	22.2	19.0
Number of individuals averting poverty (Q1/Q5)	4.0	3.2	3.5	3.3

Appendix Table 5: Estimated number of resources to achieve 5% government health expenditure/GDP and SDG

Countries	Government health expenditure		Share of government health expenditure to GDP	Estimated government health expenditure to reach 5% of the current GDP		Deficit per capita (in USD)	Additional revenue		Share of additional revenue to deficit	Share of additional revenue needed to reach 2030 health SDGs
	Total (in million USD)	per capita		Total	per capita		Total (in million USD)	per capita		
India	29 538	23	1.4%	104 442	80	57	3 548	4	7%	1%
Indonesia	9 674	38	1.1%	43 097	167	130	7 779	35	27%	7%
Bangladesh	1 385	9	0.7%	9 754	61	52	901	6	11%	1%
Philippines	4 667	46	1.6%	14 623	145	99	804	6	6%	1%
Vietnam	7 058	77	3.6%	9 680	106	29	983	11	37%	2%
Armenia	210	69	2.0%	526	174	105	119	36	35%	8%
China	321 085	234	2.9%	553 233	403	169	41 065	27	16%	6%
Mexico	44 528	351	3.9%	57 190	450	100	1 427	11	11%	2%
Thailand	12 034	177	3.0%	19 758	291	114	1 233	24	21%	6%
Chile	10 098	563	4.2%	12 040	671	108	924	40	37%	10%
Turkey							3 046	65	NA	16%
Brazil			already attained the target threshold				2 763	14	NA	4%
Colombia							162	4	NA	1%
Median	**9886**	**73**	**2.4%**	**17191**	**171**	**103**	**1108**	**18**	**19%**	**4%**

Appendix figure 1: Life-years gained per smoker by age and income quintile



Derivation of outcomes

We estimated the impact of a 50% price increase in cigarette prices on the following health and financial outcomes for each of the 13 countries:

a. Baseline number of male smokers by age and quintiles
b. Years of life gained after price intervention
c. Treatment cost averted
d. Individuals averting catastrophic health expenditures and poverty
e. Additional tax revenue

Baseline number of male smokers by age and quintiles

Data Sources: (1) 2015 population from UN Population Division; (2) smoking prevalence, by quintile and age-group (5-year) from GATS and similar local surveys.

We defined a current smoker as one who smokes cigarettes either daily or at least once every week. We focused only on manufactured cigarettes and not on bidis, small and locally-grown cigarettes sold commonly in India and Bangladesh. We used asset index as measure of income. For countries without readily[Available asset index in their respective surveys, we used educational attainment as proxy, and applied the relative prevalence of smoking among illiterate or completion of primary, secondary or high school or college. The following countries have readily[Available asset index: Bangladesh, Philippines, Chile, Colombia, Armenia and Mexico.

Procedure:

In each quintile (i) and for each 5-year age group (a), we applied the estimates of smoking prevalence, $Prev_{a,i}$ from the most recent rounds of the Global Adult Tobacco Survey (GATS) or similar nationally representative survey for all $a > 15$. For future smokers i.e. $a < 15$ we assume the same smoking prevalence as for the 15-19 year olds. If P is the population and $P_{i,a}$ is the smoking prevalence of quintile i and age group a, then the baseline number, bl of smokers, $Sk_{bl,i,a}$ can be calculated by the following formula:

$$Smk_{\ bl,i,a} = P_{i,a} Prev_{a,i} \qquad \text{(i)}$$

Years of life gained after price intervention

Data Sources: (1) risk-reduction by age-group from Verguet et al; ⁽(81) and (2) model-based estimates from the IHME's Global Burden of Disease.

Procedure*:*

A price increase results in reduction of number of smokers and is subject to the responsiveness of smoker to price change. The price elasticity, ϵ of a smoker in turn is influenced by a and i. As per the literature, the ϵ for cigarettes is about -0.4 meaning a 50% price increase will reduce smoking by about 20%.[82,83] Of this reduction, about half (10%) is attributable to participation elasticity i.e. quitting by current smokers and half to demand elasticity resulting in less amount smoked. Consistent with the published literature showing greater price responsiveness in the young and among the poor[82,83], we doubled the national ϵ among younger smokers (15-24 years old), and also applied this higher price elasticity to future smokers below 15 years old that have not yet started to smoke.[84,85] Similarly, we used a relative weighted price elasticity matrix by income and age drawn from existing studies with the smokers in the bottom quintile (20%) of the population being more price responsive compared to the top quintile. Therefore, the number of quitters is estimated by:

$Quit_{\ i,a} = Smk_{\ bl,i,a} - Smk_{\ cur,i,a}$, where;

$$Smk_{\ cur,i,a} = Smk_{\ bl,i,a}\left(\frac{1}{2}\epsilon_p \frac{\Delta price}{price} + 1\right) \qquad \text{(ii)}$$

Among persistent smokers, about half of prolonged smokers who do not quit are killed by smoking. This risk is particularly relevant to smokers below age 35 years in LMIC who are likely to have smoked from early in adult life. [86] Here, we conservatively assumed half of current and future smokers would be killed, given that smoking cessation rates in most LMICs are far lower than that in high-income countries. [86,87] Reductions in the excess (all-cause) mortality from smoking are greatest in smokers who quit early in life (and naturally in those who do not start). We applied age-specific benefits of cessation from epidemiological studies in the US and the UK among men and women, [77,88,89] corresponding roughly 97% of smokers avoided excess mortality by quitting by at 15-44 to about 25% avoided excess mortality by quitting by age 65 years. We adopted the risk reduction estimates $RR(a)$ by age group from Verguet et al. Further, we fitted a cubic spline to derive the age-specific life years gained from smoking cessation for all ages $Y(a)$. [81] To be conservative, we ignored the beneficial effects of reduced smoking amount. We proportioned the reductions in overall mortality across income quintiles and across four main causes of smoking-related mortality: chronic obstructive pulmonary disease (COPD), stroke, heart disease and tobacco attributable cancers from model-based estimates from the

Global Burden of Disease. [15] For China and India, we were able to compare the GBD with direct large epidemiological studies, which yielded generally consistent results for male smoking deaths, but not for women where the GBD estimated wrongly that about 8% of Chinese adult female deaths are due to smoking when the prevalence of adult female smoking is only 2% and even lower in the cohort of women born after 1950. [89] This discrepancy did not, however affect the calculations for males. The total deaths averted are estimated by:

$$D_{averted,i} = \left(\frac{1}{2}\sum_{a=1}^{18} Quit_{i,a}\right) RR(a) \quad \text{(iii)}$$

Further, the life years gained (LYG) are estimated by:

$$LYG_{i,a} = \left(Quit_{i,a}\right) Y(a) \quad \text{(iv)}$$

Treatment cost averted

Data Sources: (1) treatment cost, insurance coverage rate, financial support, and healthcare utilization were obtained from peer-reviewed journals and country reports; (2) Purchasing Power Parity (PPP) adjustment factor, and Consumer Price Index were obtained from World Bank

Procedure:

We calculated the treatment cost averted by smokers who quit after price intervention. We obtained local treatment cost estimates, C_d for each of the 4 disease conditions d each country. To equalize the purchasing power of local currencies, we adjusted our cost estimates using a 2015 PPP conversion factor. We estimated the averted total healthcare expenditure (treatment cost), $TC_{averted,i,d}$ conditional to seeking health-care or being ill, HC using the following formula:

$$TC_{averted,i,d} = D_{averted,i,d}\, C_d HC_{i,d} \quad \text{(v)}$$

We also derived the averted OOP health expenditure, $OOP_{averted,i,d}$ by adjusting the treatment cost with coverage rate of the publicly-funded system, Cov, probability of seeking health-care conditional on being ill, HC, and the percentage of total costs covered by the public healthcare system, $Copay$:

$$OOP_{averted,i,d} = D_{averted,i,d}\, HC_{i,d}\, EC \text{ where, } EC = Cov\, Copay\, C_d \quad \text{(vi)}$$

Individuals averting catastrophic health expenditures and poverty

Data Sources: (1) Gini Coefficient from the World Bank; (2) average household income capita (2015) were obtained from statistical offices of countries (PPP-adjusted).

Procedure:

Individuals averting catastrophic health expenditures i.e. greater than 10% of their income, attributable to tobacco: We applied the World Bank definition of poverty i.e. earn less than US$ 1.9 /day/capita, World Health Organization's definition of catastrophic health expenditures meaning when out-of-pocket treatment costs exceed 10% of an individual's income for our analysis. We used average household income per capita obtained from statistics offices of respective countries and Gini Coefficient from World Bank to construct gamma distribution of per capita household income.[90] The probability $P_{i,d}$ of individuals falling into poverty or incurring catastrophic health expenditures was derived from this distribution of household income. We estimated the total number of individuals having catastrophic health care expenditures attributed to out-of-pocket cost $C_d EC$ that would be averted by a 50% increase in price by following formula:

$$\sum_d D_{averted,i,d}\, P_{i,d} HC_{i,d}$$

Additional tax revenue

Data Sources: (1) price of most sold brand cigarette, and the share of tax to retail price from the World Health Organization; (2) average number of cigarette of current smokers from GATS.

Procedure:

The tax collected at the baseline is given by the formula:

$$Total\ tax_{bl,q} = Smk_{\ bl,i,a}\left(365\frac{Cig_q}{20}\right) TR_{bl} \text{ and,} \quad \text{(vii)}$$

$$Total\ tax_{post,q} = Smk_{\ cur,i,a}\left(365\frac{Cig_q}{20}\right) TR_{new}, \text{ where;} \quad \text{(viii)}$$

Cig_q is the average number of sticks consumed by smokers in quintile q, TR_{bl} is the tax rate per pack of cigarettes at the baseline, and TR_{new} is the new tax rate post price increase. Thus, marginal tax revenues, $MTax_i$ gained is given by:

$$MTax_i = Total\ tax_{post,q} - Total\ tax_{post,q} \quad \text{(ix)}$$

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