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An extended cost-effectiveness analysis

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ACKNOWLEDGMENTS

The preparation of this report was carried out under the World Bank Global Tobacco Control Program, supported by the Bill & Melinda Gates Foundation and the Bloomberg Foundation. Earlier versions of this paper were presented during seminars at the Ministry of Health and Social Protection and the Ministry of Finance and Public Credit, Colombia.

We also received valuable comments from seminar participants as well as from Alejandro Gaviria, Andres Escobar, Juanita Carolina Bodmer Rico, Patricio Marquez, Francisco Meneses and Alan Fuchs. Finally, the World Bank would also like to acknowledge the valuable peer-review comments from Maria Eugenia Bonilla and Andre Medici, senior economists at the World Bank.

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Cover photos (clockwise from left): City view of Bogotá, Colombia. Photo by Dominic Chavez/World Bank. Student in a rural area of La Ceja del Tambo, Colombia. Photo by Charlotte Kesl/World Bank. El Bosque de Las Palmas, Salento. Photo by Dan Gold via Unsplash. Rubiel Rios Andrade dries cacao on his farm in the township of La Paz. Photo by Dominic Chavez/World Bank.

EXECUTIVE SUMMARY

Background

Since 2008, when Colombia ratified the Framework Convention for Tobacco Control, available evidence of the impact of tobacco consumption, its health effects, and low tax revenues resulting from low tobacco taxation and prices had grown. By 2015, Colombia's cigarette prices stood higher than only one other country in the region, and smoking had become the second leading modifiable risk factor for premature mortality. At that time, reduced fiscal revenues resulting from a sharp drop in oil prices, accompanied by growing demand for government spending arising partly from a change in legislation that increased health benefits for the lower socioeconomic population, led to a call for tax reform.

While the Ministry of Finance worked on the preparation of the larger tax reform proposal, the Ministry of Health and Social Protection, with support from the World Bank, proceeded to the immediate preparation of a technical document and a proposal of a law to encourage an increase in the tobacco tax, to be included in this reform. The preparation of the document was accompanied by technical training, studies, and public fora with national and international experts, civil society, and academia presenting evidences and arguing for increased taxation to lead to a reduction in tobacco consumption and, in the future, a reduction in costs to the health system. The fora and open dialogue helped align strategies of the Ministry of Health and Social Protection, and the Ministry of Finance in presenting the reform to Congress for approval with a larger academic and civil society support for this measure.

In December 2016, resulting from the above-mentioned efforts, Colombia passed a major tax increase on tobacco products with the goal of decreasing smoking and improving population health. While tobacco taxes are known to be highly effective in reducing the prevalence of smoking, they are often criticized as being regressive in consumption. This analysis attempts to assess the distributional impact (across income quintiles) of the new tax on selected health and financial outcomes.

Methods

This study pursues an extended cost-effectiveness analysis (ECEA) of the new tobacco tax in Colombia and estimates, across income quintiles of the current urban population (80% of the country population) between the ages of 0 and 79, the averted premature deaths, the financial benefits to households, the increased tax revenues, and health-care

savings for the government, all associated with a 70% relative price increase of a pack of cigarettes. Where possible, we use parameters that vary by income quintile, including price elasticity of demand for cigarettes (average of -0.44 estimated from household survey data).

Findings

The tax increase would avert an estimated 337,300 tobacco-related premature deaths among Colombia's current urban population (over approximately 75 years), with the largest number of deaths averted among the bottom two income quintiles. Since Colombia's health system provides high insurance coverage ($> 95\%$) and financial risk protection, only about 5,140 cases of tobacco-related disease catastrophic expenditures would be averted, with most of those averted cases among the bottom two quintiles. We also (conservatively) estimate total government savings tied to inpatient care of about COP\$3.096 trillion (over 75 years). The additional annual tax revenues raised would amount to about 3% of Colombia's total health expenditure in the short term, with the poorest quintiles bearing the smallest tax burden.

Interpretation

The tobacco tax increase passed by Colombia has substantial implications for the country's population health and financial well-being, with large benefits accruing to the poorest segments of the population.

Keywords

Smoking; tobacco tax; equity; distributional impact; extended cost-effectiveness analysis; Colombia.

INTRODUCTION

Like many other South American countries, Colombia faces a high burden of noncommunicable diseases (NCDs). The World Health Organization (WHO) estimates that in Colombia NCDs accounted for 71% of total deaths in 2014 [1]. As a middle-income country with a multi-payer health system that provides universal health care, Colombia is struggling with the financial implications tied to increasing demand for health services, driven in part by the management of NCDs [2].

In 2013, the Colombian government committed itself to substantially decreasing the burden of NCDs between 2012 and 2021, of which a key stated target was reducing the prevalence of smoking to 10% among 18–69 year-olds [3]. Colombia also committed itself to the Sustainable Development Goals (SDGs), which, under SDG 3 call for “healthy lives for all people” by 2030 [4]. Part of this goal is the reduction of premature mortality by one-third, which smoking cessation and prevention will help Colombia achieve. With around 3 million urban smokers, about 12% of the urban population between the ages of 10 and 79, smoking is the second leading risk factor causing deaths [5, 6]. Estimates from 2013 indicate that treating tobacco-related illnesses costs an estimated 4,230,000 million Colombian pesos (COP) annually, or almost US\$2.1 billion (using the World Bank 2013 exchange rate of about COP\$2,000 per U.S. dollars [7]), equivalent to 0.6% of the country’s gross domestic product (GDP) [8]. As such, decreasing smoking prevalence in Colombia holds promise in decreasing NCDs, and with it the financial burden of treating smoking-related diseases [3].

In 2008, Colombia ratified WHO’s Framework Convention on Tobacco Control (FCTC), thereby making a legal commitment to implement strong tobacco control policies. Within the FCTC, Colombia has implemented several cost-effective recommendations of reducing tobacco consumption, including national smoke-free areas, advertising and promotion bans, warning graphics on cigarette packaging, and excise taxes to reduce demand for tobacco [9].

Since 2008, national and international academic and civil society institutions had increasingly generated evidence on the prevalence and impact of smoking in Colombia. By 2015, this evidence grew in importance in the face of changes in the country’s economic and tax priorities. At that time, Colombia faced a reduction in oil revenues (given a sharp drop in oil prices) and a steady increase in public spending. In the health sector, a decision by the Constitutional Court requiring the equalization of the benefit packages of the two insurance regimens—the subsidized regime, which covers the cost of health services for the lower income population, and the contributory regime, for the non-poor and formally

employed—represented an additional source of pressure to the already strained fiscal scenario. It was in this context that in early 2015, the government set up a commission of experts to propose changes to the country's tax structure. The tax structure proposed by the commission included an increase in health taxes, giving rise to a discussion on the increase of tobacco taxes.

While the Ministry of Finance worked on the preparation of the larger tax reform proposal, the Ministry of Health and Social Protection with support from the World Bank proceeded to the immediate preparation of a technical document and a proposal of a law to encourage an increase in the tobacco tax, to be included in this reform. Existing sources of information were reviewed and initial estimates of elasticity and the impact on consumption, health, and tax revenues were produced, to propose an increase that would lead the country to a cigarette price closer to the average of the Latin American region. The estimates were used to generate a national dialogue in support of tobacco tax increases. Technical training, studies, and public fora, with national and international experts and stakeholders arguing for increased taxation to lead to a reduction in tobacco consumption and, in the future, a reduction in costs to the health system, were organized. The fora and open dialogue helped align strategies of the Ministry of Health and Social Protection, and The Ministry of Finance in presenting the reform to Congress for approval with a larger academic and civil society support for this measure.

Within this context, it was in December 2016 that Colombia took another major step toward decreasing tobacco consumption by legislating an increase in both excise taxes and value-added taxes (VAT) in the context of a general tax reform. Indeed, WHO recommends that excise taxes should be at least 70% of the retail price of cigarettes to maximize the effect against smoking [10]. Prior to the tobacco tax reform, Colombia fell short of this benchmark, as the former (pre-2017) excise tax of COP\$701 was only 26% of the retail price [11]. From 2017 onward, the reform doubles the excise tax to COP\$1,400 (year 2017), triples it to COP\$2,100 (year 2018), and subsequently (year 2019 and beyond) increases the price of cigarettes by the country's annual rate of inflation plus four percentage points [12]. The legislation also increases VAT from 16% to 19% of the base price of a cigarette pack in 2017. The new taxes (post-2019) will constitute about 60% of the retail price, still falling short of WHO's 70% benchmark. Nevertheless, tripling the excise tax, as recommended by WHO, is expected to substantially decrease tobacco consumption in Colombia [13].

Most evidence supports the use of large tax increases to decrease tobacco consumption [14, 15]: first, it discourages non-smokers (e.g., the young) from beginning to smoke; second, it pushes smokers to quit or to decrease their intensity of smoking; and third, it discourages former smokers from resuming tobacco use [16]. Another important effect of increasing the price of cigarettes on consumption is that the young appear to be more



price responsive than the old, which has the potential for large future gains in terms of decreasing tobacco use and associated mortality and morbidity [17, 18]. In addition, the poor also seem to be more price responsive than the rich within countries [17, 19, 20], meaning that they will decrease tobacco consumption more than the rich in response to similar price increases. This is particularly important since much of the controversy around raising tobacco taxes is consumption regressivity; in other words, the poor would assume a greater burden of the tax relative to their income than the rich. While there are many different tax structures for taxing tobacco products, increasing excise taxes remains one of the most effective means of decreasing tobacco consumption [17]. In particular, excise taxes increase the price of all tobacco products, which prevents potential substitution and switching to cheaper cigarette brands [16, 17]. In this paper, we examine the potential impact of Colombia's new tax increase, and use extended cost-effectiveness analysis (ECEA) methods [21, 22, 23] to model the impact of the tax on a variety of health and financial outcomes across socioeconomic groups (e.g., income quintiles) in Colombia.

METHODS

General approach

We use ECEA methods [21, 22, 24] to examine the distributional consequences of increasing tobacco taxes on Colombia's health and finances. ECEA was designed to pursue health policy assessment and to study the impact of policy (e.g., increase in tobacco taxes) along three dimensions: the health benefits (e.g., deaths averted); the out-of-pocket (OOP)/private expenditures "crowded out" for households and individuals, and correspondingly the financial risk protection (FRP) provided (e.g., cases of catastrophic health expenditures averted); and the distributional consequences (e.g., across socioeconomic groups, geographical settings). In particular, ECEA has been previously applied to the examination of increased tobacco taxes in China [25, 26], Lebanon [19], and Armenia [20].

In this paper, we build on previous ECEA tobacco tax model [25, 26] studies. In Colombia and across income quintiles of its urban population, the impact of increased tobacco taxes were studied on: (i) the premature tobacco-related deaths averted, (ii) the change in household cigarette expenditures, (iii) the change in a household's tobacco tax burden, (iv) the health-care savings tied to the foregone treatment of tobacco-related disease, and (v) the FRP provided.

Our study uses varying inputs across urban income quintiles and age groups (Table 1) to estimate tax policy impacts among the current urban population (77% of the country population as of 2016 [7]). Specifically, the population is divided into seven age groups (<15, 15–24, 25–49, 50–64, 65–69, 70–74, and 75–79-year-olds) further disaggregated by income quintile. Given that data on smoking prevalence by age group and income quintile were only available for Colombia's urban population [6], we restricted our analysis to the urban population under age 80, implying that our results capture a lower boundary of the costs and burden generated by tobacco in Colombia and thus a lower boundary of the policy impact. Moreover, the weaker tax enforcement capacity in rural areas of the country (as opposed to urban areas), in addition to the likely increased smuggling in those areas, suggests that the tax policy impact would be more uncertain in rural areas.

Following the design of the tax, we simulate three consecutive tax increases: in 2017, a three percentage point increase in VAT and doubling of the excise tax; in 2018, a tripling of the excise tax; and 2019 onward, an annual increment by the predicted inflation rate and an additional four percentage points. We assume no change in household income over time.

Table 1: Inputs and corresponding sources used in the analysis of the distributional impact of increased tobacco taxes in the urban population of Colombia

INPUT	VALUE	DATA SOURCES
Size of urban population in (ages 0–79)	35,317,947	DANE, population projections [27]
Urban population structure – distribution of population across age groups (years)		
<15	28%	DANE, population projections [27]
15–24	19%	
25–49	35%	
50–64	13%	
≥65	6%	
Urban smoking prevalence by age group		
<17	5%	ENCSPC and SABE study [6, 28]
18–24	16%	
25–34	16%	
35–44	11%	
45–64	14%	
≥65	12%	
Urban household smoking prevalence per income quintile (%)		
Quintile 1 (poorest)	11%	ENCV, 2014 household purchases [29]
Quintile 2	12%	
Quintile 3	13%	
Quintile 4	12%	
Quintile 5 (richest)	12%	
Urban individual cigarette consumption (cigarettes per day) per income quintile		
Quintile 1 (poorest)	5.7	ENCV, 2014 household purchases and Llorente, 2017 [29, 30]
Quintile 2	7.8	
Quintile 3	8.1	
Quintile 4	8.3	
Quintile 5 (richest)	10.1	

Table 1: Inputs and corresponding sources used in the analysis of the distributional impact of increased tobacco taxes in the urban population of Colombia

INPUT	VALUE	DATA SOURCES
Estimated mortality distribution of tobacco-related diseases (only the four major diseases), by cause (%)		
COPD	41%	Global Burden of Disease study—on GBD compare (Colombia 2015) [5].
Stroke	2%	
Heart disease	29%	
Neoplasm	28%	
Average government cost of treatment in COP\$ (2014 Standard Deviation in parentheses)		
Chronic obstructive pulmonary disease (COPD)	3,820,000 (1,900)	IECS, 2014 [8]
Stroke	4,290,000 (2,100)	
Heart disease	2,870,000 (1,400)	
Neoplasm	30,390,000 (15,200)	
Use of health care given medical necessity (%) among urban households		
Quintile 1 (poorest)	74%	ENCV, 2014 [29]
Quintile 2	80%	
Quintile 3	74%	
Quintile 4	78%	
Quintile 5 (richest)	86%	
Insurance coverage by income quintile among urban households		
Quintile 1 (poorest)	94%	ENCV, 2014 [29]
Quintile 2	95%	
Quintile 3	93%	
Quintile 4	94%	
Quintile 5 (richest)	96%	
Total fertility rate (children per woman of reproductive age, nationally)*		
Quintile 1 (poorest)	2.8	2015 DHs [31]
Quintile 2	2.3	
Quintile 3	1.9	
Quintile 4	1.5	
Quintile 5 (richest)	1.3	

Table 1: Inputs and corresponding sources used in the analysis of the distributional impact of increased tobacco taxes in the urban population of Colombia

INPUT	VALUE	DATA SOURCES
Mean annual household income (in COP\$, urban households)		
Quintile 1 (poorest)	27,600,000	ENCV, 2014 [29]
Quintile 2	53,400,000	
Quintile 3	78,100,000	
Quintile 4	112,000,000	
Quintile 5 (richest)	303,000,000	

*Mean total fertility rate in urban areas is 1.8 [31], and most of the urban population is within national income quintiles 2 to 5; hence, we distributed 1.3 to 2.3 among the five urban income quintiles studied.

We calculate the number of smokers by applying the specific age-group smoking prevalence and distribute this prevalence by income quintile so as to obtain the number of current smokers per quintile and age group. Within five-year age groups (age >15) income quintiles are evenly distributed. However, to account for the fact that households in lower income quintiles have more children (e.g., total fertility rate varies from about 2.3 to 1.3 children between the poorest and the richest within the urban population [31]), we further adjusted the population size of “future smokers” (age <15) by modifying the distribution of those future smokers per quintile. Consistent with findings from the literature, the model assumes that the participation elasticity is half the total price elasticity, implying that increased prices affect the smoking participation by half, and the other half affects the consumption of cigarettes among those who do not quit [10, 16, 32, 33].

We describe in detail below the five outcomes, examining impact on: (i) tobacco-related deaths averted; (ii) averted tobacco-related disease treatment expenditures tied to inpatient care; (iii) averted impoverishing and catastrophic health spending; (iv) changes in household tax burden; and (v) changes in household expenditures on cigarettes.

Tobacco-related premature deaths averted

The model estimates the number of premature deaths averted among those quitting smoking as a result of increased prices. We assume no health gains for those who do not quit but do reduce smoking consumption. The proportion of deaths attributable to smoking among current smokers is assumed to be 50% of the total deaths [25, 34]. There is an inverse relationship between risk reduction and age at quitting, with those who quit before age 15 facing no risk of death from smoking, and those who quit above age 70 getting only a 25% reduction in the risk of death upon quitting [26, 34]. Using the product

of the participation elasticity, the change in the price, and the age-specific risk reduction among those quitting, we obtain the change in smoking-related premature mortality. Using estimates from the Global Burden of Disease (GBD) study, we examine four broad causes of tobacco-related death (stroke, ischaemic heart disease or IHD, chronic obstructive pulmonary disease or COPD, and lung cancer) and distribute the share of these deaths across each of these four diseases.

Tobacco-related disease treatment expenditures tied to inpatient care averted

We estimate averted expenditures on treatment for tobacco-related diseases from both the government and the patient perspective. By using the estimates for the number of deaths averted by income quintile and type of tobacco-related disease, combined with estimates for specific disease treatment costs and health services utilization, we compute the savings to the health system in averting treatment of tobacco-related diseases. This is a conservative (lower boundary) estimate as it captures treatment tied only to inpatient care and mortality.

With respect to patients, the financial savings from averted treatment would account for the level of insurance and FRP provided by the Colombian health system. Most Colombians are covered by health insurance under either the “contributory” regime (CR), the “subsidized” regime (SR), or the special benefits regime (SBR). The CR includes workers in the formal sector, those receiving a pension, and the self-employed who earn more than the minimum wage and contribute to the health system, covering about half of the population [2]. The SR includes mostly low income and vulnerable populations (e.g., indigenous groups), covering about 43% of the population [2]. CR and SR are risk equalized and cross subsidized with equal health services benefits packages in both regimes [2]. Meanwhile, SBR, functioning as a separate system, includes the armed forces, teachers, and workers at the national petroleum company (Ecopetrol), covering about 2% of the population [2]. While there is also private health insurance, which covers about one million members, a very small proportion of the population [2]. In sum, about 96% of the population in Colombia is covered by health insurance [2].

For these three regimes, when looking at OOP payments for treatment, we need to distinguish between the types of procedures that these diseases require. Many tobacco-related diseases would be considered by the Colombian health system as “catastrophic” diseases, including treatment for lung cancer, for example, and as such, would be completely covered under the three regimes [35]. This means that we would see no co-payments associated with the treatment of such diseases [36]. Meanwhile, co-payment for other disease treatments would depend on the regime. For SR, the co-payment would be typically 10% of the cost, while for CR it would be about 23% of the cost [36].

As such, to determine individual savings as a result of averted treatment costs we incorporate the disease-specific co-payments. We use the same methodology—tied to averting tobacco-related mortality—as for the health system savings; however, we multiply treatment costs by the co-payment that we expect patients to face in seeking care.

Impoverishing and catastrophic health spending averted

To estimate the number of cases of impoverishing expenditures averted, we use average household total annual income per income quintile and the averted medical expenditures (described above). About 24% of the urban population is estimated to live under the national poverty line [37]. Cases of averted impoverishing expenditures are those households who had averted medical expenditures which, had they occurred, would have put their annual income below the national poverty line.

For calculating the number of cases of catastrophic expenditures averted, if OOP spending is high enough relative to household income, the OOP spending may result in a significant lowering of their standard of living [38]. Thresholds used for catastrophic spending vary between 5 and 40% of total household expenditures/income [38]. For the purpose of this study, we chose a threshold of 20% of household total income, which is close to the middle of that range and has been used elsewhere [39]. Cases of averted catastrophic expenditures are defined as those households who had averted medical expenditures which, had they occurred, would have made up 20% of their household income.

Change in additional tax revenues

We calculate tax revenues before and after tax increases and the change in revenues borne by each income quintile. We use baseline cigarette consumption by quintile (from 5.7 cigarettes per day among the poorest to 10.1 among the richest) and the average tax per cigarette pack (COP\$1,389) to calculate revenues before tax increases. We then estimate tax revenues under each of the three increases by using the number of smokers (at baseline and after each increase) by income quintile, times the number of cigarettes consumed by quintile. Lastly, we can derive the net change in revenues before and after each yearly tax increase.

Change in expenditures on cigarettes

Our approach is similar as described above. We use the estimates of the change in cigarette consumption by quintile among continuing smokers over the three tax increases and the average projected price of a pack of cigarettes before and after each of the three tax increases to obtain estimates of household consumption of cigarettes by

Figure 1: Projected price per pack of cigarettes including taxes between 2016 and 2019 under the newly passed 2016 legislation in Colombia.



Source: Llorente, 2017 [30].

quintile. We then compare these new estimates under the three tax scenarios to the pretax scenario to quantify the change in consumption and hence expenditures in cigarettes by quintile.

Input parameters

Average price and taxes per cigarette pack were sourced from a recently published report [30] (Figure 1). The report used the median cigarette price obtained from the *Departamento Administrativo Nacional de Estadística* (DANE) to calculate the total taxes per pack. It used government predictions of inflation plus 1%, as observed in terms of changes in prices for cigarettes in previous years, and the 2016 base price per pack to obtain future base prices of packs without taxes. Then taxes were added to the base price as outlined in the December 2016 law to obtain the predicted prices over 2017–19. We assume the tax is completely passed on to the consumer. In a sensitivity analysis (SA5 below), we also modeled the outcomes using the price of a premium pack of cigarettes (Marlboro Red according to WHO) with a tax inclusive retail price in 2016 of COP\$3,772 [11].

We obtained the disease treatment costs from a report issued by the *Instituto de Efectividad Clínica y Sanitaria* (IECS) that examined the tobacco-related disease burden in Colombia [8]. For those diseases that had different costs associated with different disease stages, we extracted the average cost (Table 1). We used the GBD study to derive the share of each specific disease within tobacco-related attributable mortality [5]. While there were about 20 tobacco-related diseases in the GBD, for simplicity and interpretability, we only retained four major diseases (IHD, stroke, lung cancer, and COPD, which captures about 90% of all tobacco-related mortality).

Those catastrophic illnesses such as lung cancer, requiring inpatient treatment, are fully covered by insurance, so we assumed that there would be no direct cost to the individual associated with treatment of lung cancer [36]. Meanwhile, for inpatient treatment of COPD, IHD, and stroke, patients would face an average co-payment of 10 to 23% of the full cost of treatment depending on whether they are in the subsidized or contributory regimes [36].

We used a Minister of Justice (*MinJusticia*) and Minister of Health and Social Protection (*MinSalud*) nationally representative survey, the *Estudio Nacional de Consumo Sustancias Psicoactivas*, exploring the use of psychoactive substances among urban Colombians aged 12 to 65 in 2013 to obtain urban smoking prevalence by age group [6]. The prevalence of smoking above age 65 was obtained from the 2015 *Estudio Nacional de Salud, Bienestar, y Envejecimiento* (SABE) [28].

To capture the distributional impact, we used parameters varying by income quintile (Table 2). We obtained the smoking prevalence, number of cigarettes smoked per day, and utilization of health services from the 2014 *Encuesta Nacional de Calidad de Vida* (ENCV), a nationally representative household survey administered by DANE [29]. We restricted our analysis of ENCV to the urban population only.

As for price elasticity, Maldonado and his colleagues used aggregate demand reported bi-monthly to the *Dirección de Impuestos y Aduanas Nacionales* (DIAN) by tobacco companies between 1994 and 2014 and estimated a price elasticity of demand for cigarettes of -0.78 in Colombia [40]. In our study, first we used the ENCV household surveys [27], combined with the *Encuesta Anual Manufacturera* (EAM) reporting cigarette sales [41, 42, 43, 44] for the years 2003, 2010, 2011 and 2014, to derive an average price elasticity estimated at -0.44 for Colombia (further detail is provided in the Supplementary appendix, section 1). Second, as price elasticity estimates per income quintile were not available for Colombia, we identified 11 other studies from South American countries of varying income levels (e.g., Argentina, Bolivia, Brazil, and Peru) [45–55] with price elasticity estimates ranging from -0.85 to -0.22 (Supplementary appendix, Table A1). Subsequently, we distributed the variation in these estimates (interquartile range of 0.42) across our average price elasticity of -0.44 to derive a price elasticity per income quintile (Table 2;

Table 2: Assumed price elasticity of demand for cigarettes by income quintile

INCOME QUINTILE	PRICE ELASTICITY OF DEMAND
1 (poorest)	-0.61
2	-0.53
3	-0.44
4	-0.35
5 (richest)	-0.26

Sources: ENCV, and [45-55].

Supplementary appendix, section 1) assuming the poor have a greater price elasticity than the rich [17, 19]. Third, we proceeded to two sensitivity analyses (SA1 and SA2, for which results are reported in the Supplementary appendix, section 2) using two alternative flat price elasticity estimates across income quintiles so as to better understand the distributional impact of the tax: -0.40 as indicated by IARC [16], and -0.78 as estimated by Maldonado and his colleagues [40].

Finally, since evidence from the literature consistently points toward youth as being more price elastic than those above age 25 [16, 17, 18], price elasticity among those under age 25 (current 15–24 year-old smokers and future under-15 year-old smokers) was set twice as high as among those above age 25. In two sensitivity analyses (SA3 and SA4, Supplementary appendix, section 3), we relaxed this assumption to two alternative youth multipliers (1 and 3, as opposed to 2 in the base case).

Sensitivity analyses

We pursued five univariate sensitivity analyses: (i) SA1, where the price elasticity was set flat to -0.40 ; (ii) SA2, where the price elasticity was set flat to -0.78 ; (iii) SA3, where the youth price elasticity modifier was set to 1; (iv) SA4, where the youth price elasticity modifier was set to 3; and (v) SA5, where the mean price of a pack of cigarettes was set to COP\$3,772. SA1–4 attempt to address the uncertainty underlying estimates of price elasticity, a key input in tax policy impact, while SA5 attempts to address the lack of evidence in the distribution in the price and consumption of the different cigarette brands in Colombia.

RESULTS

Tax increase policy

The first tax increase (2017) is expected to increase the average price per pack of cigarettes by 32%, compared with 2016 prices (Figure 1); the second increase (2018) by 61% (from 2016 prices); and the third tax increase by 68% (compared with 2016 prices).

Changes in smoking prevalence

Based on the prevalence of prior smoking tax increases, there were an estimated 3.48 million urban smokers in Colombia between the ages of 15 and 79 (Table 3). Assuming that in the absence of tax increases, the population aged 0–14 years would see a smoking prevalence of those currently aged 15–19 years, we would anticipate about 974,300 additional “future smokers” over the next 15 years as that population ages (Table 3).

The first tax increase would reduce the number of current smokers to about 3.18 million or by about 9% (Table 3). Almost 50% of both quitters and “averted future smokers” (those currently between age 0 and 15), would be from the bottom two income quintiles (45,100 and 37,600, respectively).

The second tax increase (2018) would reduce the number of current smokers to about 3 million, i.e., 6% of 2017 smokers would quit, while we would see a 10% reduction in the number of future smokers. Meanwhile, the third tax increase (2019) would further reduce the number of current smokers to about 2.96 million. Overall, we find similar effects of the second and third tax increases in terms of the distribution of quitters and averted smokers among the bottom two income quintiles as under the first tax increase (Figure 2).

We now report on the five ECEA outcomes, per income quintile: tobacco-related deaths averted; health-care expenditures averted; impoverishing and catastrophic health spending averted; changes in tax revenues; and changes in cigarette expenditures.

Averted tobacco-related deaths

The tax increases would result in 337,300 tobacco-related deaths averted (Table 4; Figure 3). The greatest number of averted deaths would be attributable to the first tax increase, and across tax increases, the bottom two income quintiles would see the greatest number of deaths averted. Overall, this represents about a 15% reduction in smoking-related mortality over 75 years (mortality averted being estimated among the current population and life expectancy at birth now being about 75 years in Colombia [56]).

Table 3: Number of smokers and quitters at baseline (before tax increase), after the first tax increase (2017), the second tax increase (2018), and the third tax increase (2019) and in parentheses, the projected number of “future smokers” (population currently aged 0–14 years) and corresponding “averted smokers,” among Colombia’s current urban population

INCOME QUINTILE	TOTAL NUMBER OF CURRENT SMOKERS BEFORE TAX (FUTURE SMOKERS IN PARENTHESES)	TOTAL NUMBER OF SMOKERS AFTER FIRST TAX INCREASE (2017) (FUTURE SMOKERS)	TOTAL NUMBER OF QUITTERS AFTER FIRST TAX INCREASE (2017) (AVERTED SMOKERS)	TOTAL NUMBER OF SMOKERS AFTER SECOND TAX INCREASE (2018)	TOTAL NUMBER OF QUITTERS AFTER SECOND TAX INCREASE (2018) (AVERTED SMOKERS)	TOTAL NUMBER OF SMOKERS AFTER THIRD TAX INCREASE (2019)	TOTAL NUMBER OF QUITTERS AFTER THIRD INCREASE (2019) (AVERTED SMOKERS)	TOTAL NUMBER OF QUITTERS POST ALL TAX INCREASES (AVERTED SMOKERS)
1 (poorest)	638,100 (229,300)	559,600 (184,200)	78,500 (45,100)	515,200 (160,400)	44,400 (23,800)	505,500 (155,500)	9,600 (4,900)	132,600 (73,800)
2	696,200 (223,000)	622,700 (185,400)	73,400 (37,600)	580,200 (164,900)	42,500 (20,500)	570,900 (160,500)	9,300 (4,300)	125,300 (62,400)
3	754,200 (212,100)	687,900 (182,300)	66,300 (29,800)	648,600 (165,500)	39,200 (16,800)	639,900 (161,900)	8,700 (3,600)	114,300 (50,200)
4	696,200 (168,600)	647,200 (149,600)	49,000 (18,900)	617,600 (138,600)	29,600 (11,000)	610,900 (136,200)	6,700 (2,400)	85,200 (32,400)
5 (richest)	696,200 (141,400)	659,400 (129,500)	36,700 (11,900)	636,800 (122,300)	22,700 (7,200)	631,600 (120,700)	5,200 (1,600)	64,600 (20,700)
Total	3,480,800 (974,300)	3,176,800 (831,000)	304,000 (143,300)	2,998,400 (751,700)	178,400 (79,300)	2,958,800 (734,700)	39,600 (16,900)	522,000 (239,600)

Note: Future smokers are those below age 15 who would smoke with a prevalence similar to those current 15–19-year-old smokers. The tax increases prevent some of these “future smokers” from smoking initiation and therefore are named “averted smokers.”

Figure 2: Projected number of smokers between 2016 and 2019, by income quintile, for those above 15 years of age, among Colombia's current urban population

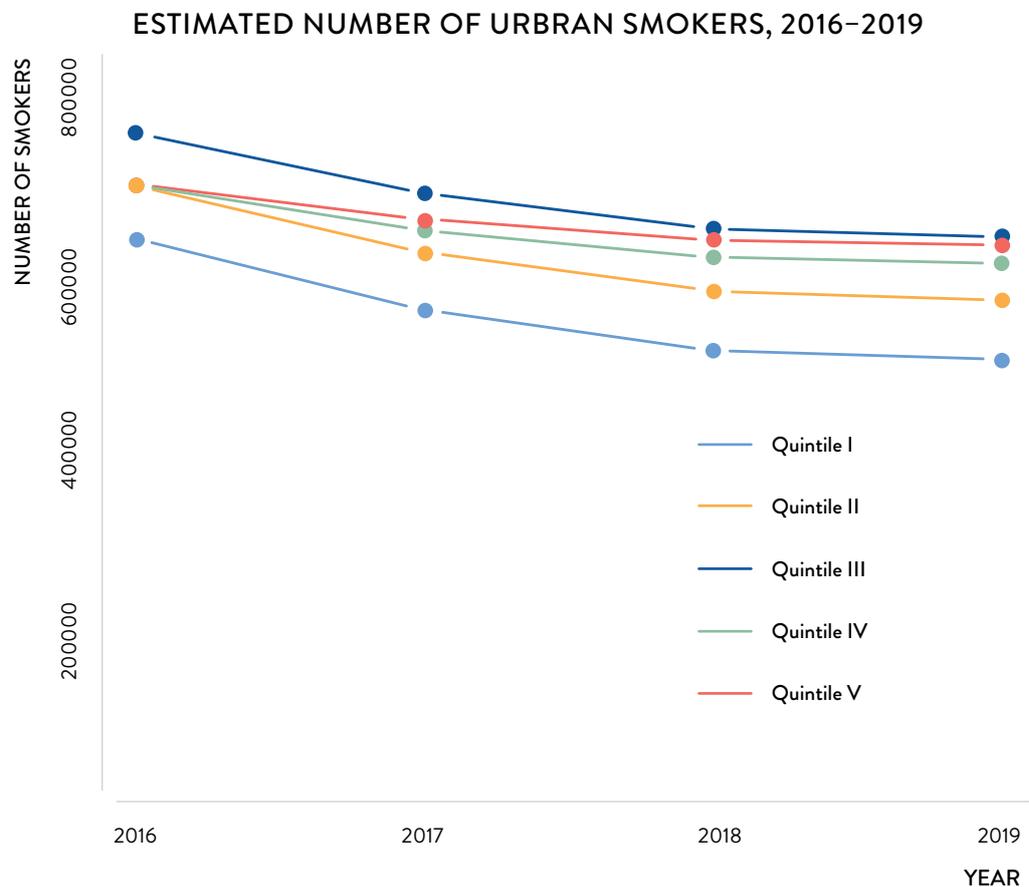
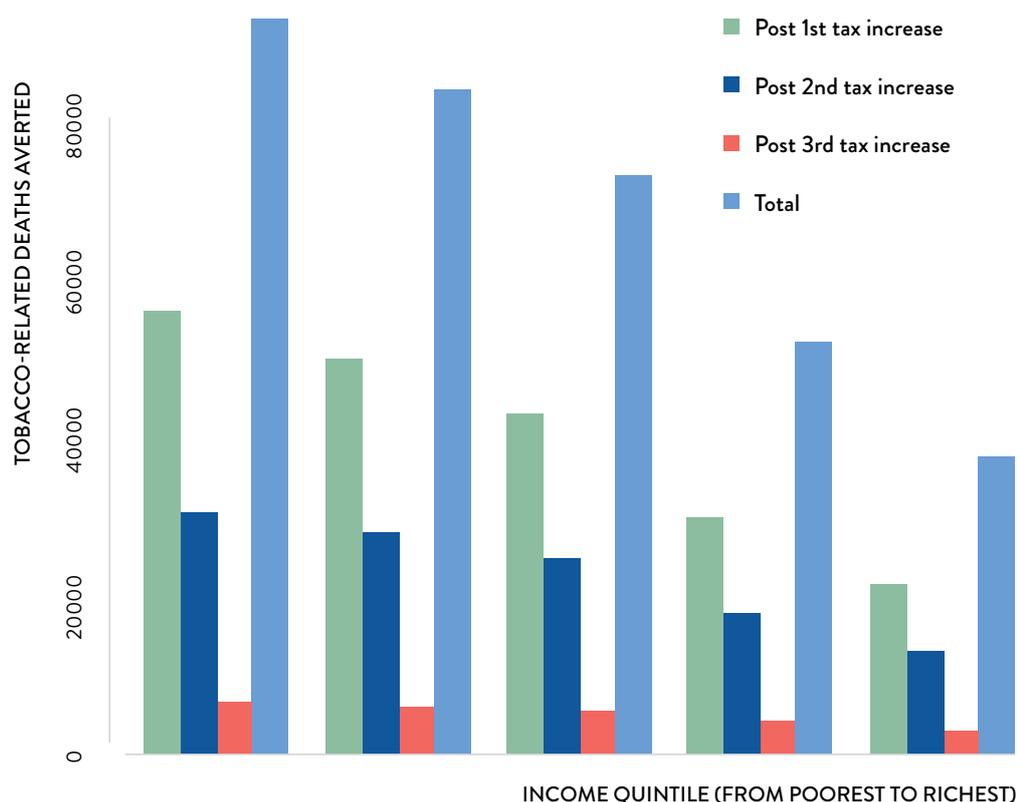


Table 4: Number and proportion of deaths averted under the first (2017), second (2018), and third (2019) tax increases under the base-case scenario, among Colombia's current urban population

INCOME QUINTILE	DEATHS AVERTED UNDER FIRST TAX INCREASE (2017)	PROPORTION OF DEATHS AVERTED UNDER FIRST TAX INCREASE (2017)	DEATHS AVERTED UNDER SECOND TAX INCREASE (2018)	PROPORTION OF DEATHS AVERTED UNDER SECOND TAX INCREASE (2018)	DEATHS AVERTED UNDER THIRD TAX INCREASE (2019)	PROPORTION OF DEATHS AVERTED UNDER THIRD INCREASE (2019)	TOTAL DEATHS AVERTED
1 (poorest)	55,400	0.28	30,300	0.27	6,500	0.26	92,200
2	49,500	0.25	27,900	0.25	6,000	0.24	83,400
3	42,600	0.21	24,700	0.22	5,400	0.22	72,700
4	29,900	0.15	17,800	0.16	4,000	0.16	51,700
5 (richest)	21,300	0.11	13,000	0.11	3,000	0.12	37,300

Figure 3: Tobacco-related deaths averted by income quintile, among Colombia's current urban population

TOBACCO-RELATED PREMATURE DEATHS AVERTED (CUMULATIVE)



Averted health-care expenditures

Using the estimated averted deaths above, we derived averted health-care expenditures tied to inpatient care and tobacco-related mortality.

Since most urban dwelling Colombians under the age of 80 are covered by health insurance for the cost of most tobacco-related diseases, the individual cost savings through averted treatment of these diseases would be driven by the small percentage of those uninsured and by possible copayments for COPD, IHD, and stroke treatment. The bottom income quintile would see the most savings from averted inpatient treatment, followed by the second quintile (about COP\$52.4 billion among the poorest, and roughly COP\$51.3 billion among the poorer) (Table 5); while the richest (quintile 5) would see the smallest savings.

As for government savings under the first increase, the health system would save roughly COP\$1.822 trillion from averted treatment of tobacco-related diseases (Table 6; Figure 4); a further COP\$1.045 trillion under the second increase; and about COP\$2.29 billion under the third increase. These would represent a total savings of over COP\$3.096 trillion (over

Table 5: Households savings due to averted treatment for tobacco-related diseases (tied to inpatient care and mortality averted only) under the first (2017), second (2018), and third (2019) tax increases, in Colombian Pesos (COP\$), among the current urban population

INCOME QUINTILE	UNDER FIRST TAX INCREASE	UNDER SECOND TAX INCREASE	UNDER THIRD TAX INCREASE	TOTAL SAVINGS
1 (poorest)	31,482,684,000	17,248,535,000	3,668,512,000	52,399,731,000
2	30,417,961,000	17,161,002,000	3,714,670,000	51,293,633,000
3	24,226,205,000	14,057,639,000	3,095,527,000	41,379,371,000
4	17,943,007,000	10,696,177,000	2,394,928,000	31,034,112,000
5 (richest)	14,082,168,000	8,614,005,000	1,960,185,249	24,656,358,249
Total	118,152,025,000	67,777,358,000	14,833,822,249	200,763,205,249

Note: This is a conservative estimate since it only includes those diseases that would require inpatient care tied to tobacco-related mortality.

Table 6: Government savings due to averted treatment for tobacco-related diseases (tied to inpatient care and mortality averted only) under the first (2017), second (2018), and third (2019) tax increases in Colombian Pesos (COP\$), among the current urban population

INCOME QUINTILE	UNDER FIRST TAX INCREASE	UNDER SECOND TAX INCREASE	UNDER THIRD TAX INCREASE	TOTAL SAVINGS
1 (poorest)	485,528,996,000	266,008,567,000	56,576,138,000	808,113,701,000
2	469,108,727,000	264,658,621,000	57,287,997,000	791,055,345,000
3	373,618,874,000	216,798,258,000	47,739,521,000	638,156,653,000
4	276,718,783,000	164,957,467,000	36,934,804,000	478,611,054,000
5 (richest)	217,176,551,000	132,846,013,000	30,230,166,000	380,252,730,000
Total	1,822,151,931,000	1,045,268,926,000	228,768,626,000	3,096,189,483,000

Note: This is a conservative estimate since it only includes those diseases that would require inpatient care tied to tobacco-related mortality.

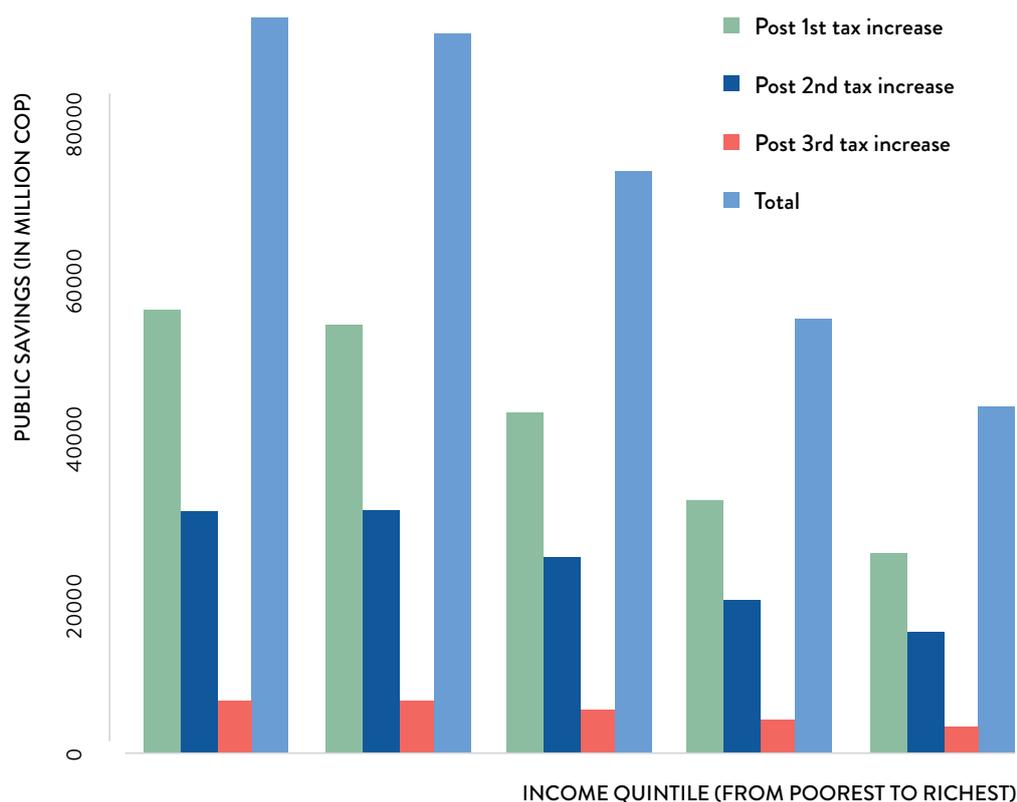
75 years), which represents about 7% of Colombia's annual public health expenditure and about 0.4% of Colombia's 2016 GDP.

Catastrophic and impoverishing spending averted

Averted cases of catastrophic and impoverish-related spending are largely driven by the small percentage of households without insurance. Given that the first quintile is already below the poverty line (24% of the urban population is under the national poverty line), by definition none of the averted impoverishing spending would come from this quintile. We do not see cases from the top three quintiles (Table 7; Figure 5), but only cases averted from the second quintile (about 2,250 averted cases of impoverishing spending). This is largely driven by the nature of the impoverishing spending metric.

Figure 4: Government savings due to averted treatments for tobacco-related diseases (tied to inpatient care and mortality averted only) by income quintile over the three tax increases, among the current urban population

PUBLIC HEALTHCARE SAVINGS (TIED TO INPATIENT CARE, CUMULATIVE)



Note: This is a conservative estimate since it only includes those diseases that would require inpatient care tied to tobacco-related mortality.

While the first quintile would not experience impoverishing spending, this does not mean the poorest would not be affected as a result of health spending. This can be notably captured in our estimates of catastrophic spending, defined as exceeding 20% of household income spent on treatment for tobacco-related diseases. Here, we find a gradient of averted cases of catastrophic spending with the greatest number of cases averted from the poorest quintile (Table 7; Figure 5).

Changes in tax revenues

The increase in annual tax revenues compared with pre-increase (2016) would be roughly COP\$714 billion (Table 8; Figure 6). Since the richest quintile is assumed to be most inelastic with respect to price, it would have the highest number of people who continue

Table 7: Cumulative averted cases of catastrophic spending (20% threshold of total household income) and impoverishing spending using the national poverty line encompassing 24% of the urban population (tied to inpatient care and mortality averted only), by income quintile, among the current urban population

INCOME QUINTILE	AVERTED CASES OF IMPOVERISH-RELATED SPENDING	AVERTED CASES OF CATASTROPHIC SPENDING
1 (poorest)	0	2,500
2	2,250	910
3	0	1,050
4	0	680
5 (richest)	0	0
Total	2,250	5,140

Note: This is a conservative estimate since it only includes those diseases that would require inpatient care tied to tobacco-related mortality.

smoking, so they would shoulder the highest burden of the projected tax revenues. We see that the two bottom income quintiles would shoulder about 31% of the additional tax burden, while the top two income quintiles would bear about 50% of this burden. The total annual tax revenues under the three tax increases would amount to about 1.5% of Colombia's public health expenditure and about 0.1% of its 2016 GDP.

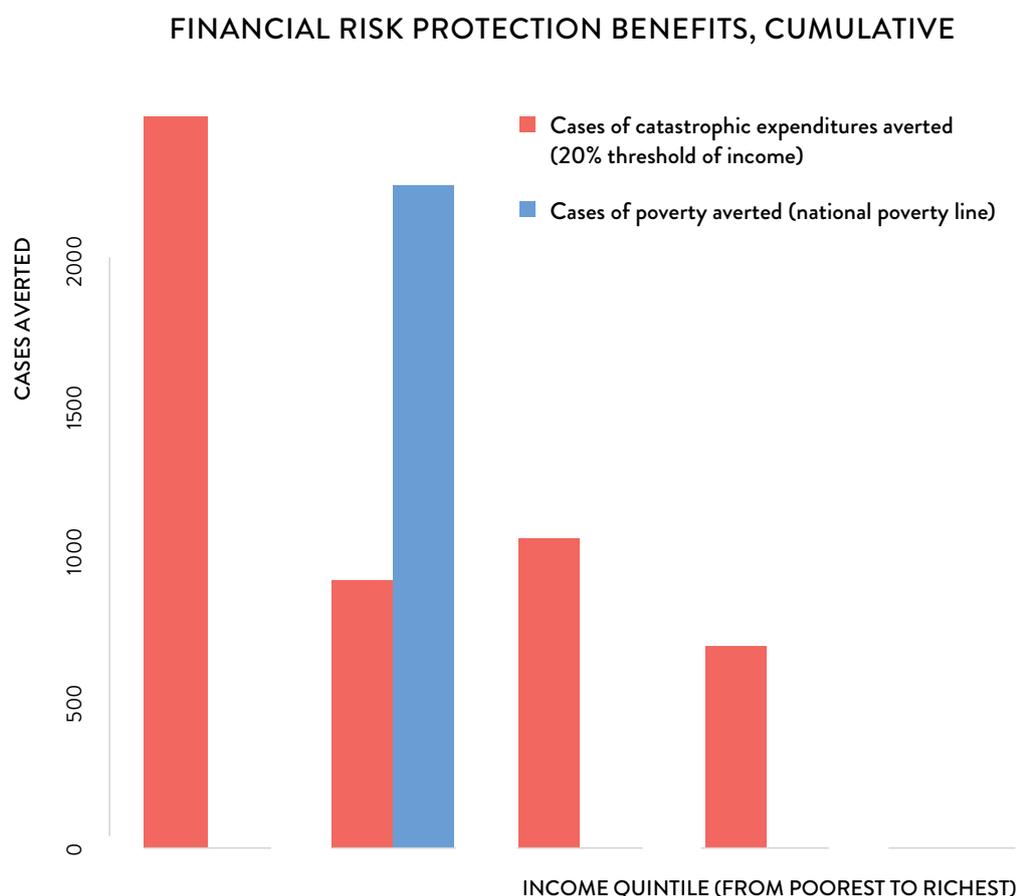
Change in expenditures on cigarettes

Under the first increase, the bottom income quintile would spend slightly less on cigarettes than before (Table 9; Figure 7). After the second increase, households across quintiles would spend more on cigarettes than before. We would see the greatest cumulative increase in cigarette expenditures over the three tax increases among the richest quintile and the smallest increase in the poorest income quintile.

Sensitivity analyses

Under the first sensitivity analysis (SA1), we used a flat price elasticity of -0.40 for all quintiles. We find the greatest number of quitters coming from the third income quintile, and the fewest number of quitters from the fifth quintile (Table A2). Meanwhile, the greatest number of deaths averted (66,700) comes from the third income quintile (Table A3). Similarly, the greatest government health care savings come from the second income quintile (Table A4). The greatest tax revenues are from the third income quintile, as they have the largest number of smokers after each tax increase under all three tax increases, and we see the greatest total tax revenues under the third tax increase (Table A5).

Figure 5: Cumulative averted cases of catastrophic spending (20% threshold of total household income) and impoverishing spending using the national poverty line encompassing 24% of the urban population (tied to inpatient care and mortality averted only), by income quintile, among the current urban population



Under the second sensitivity analysis (SA2), we used a flat price elasticity of -0.78 across all quintiles. We found that while the overall number of quitters increased in comparison to SA1 (1,286,900 in SA2 compared to 694,300 in SA1), the greatest number of quitters (687,000) also came from the third income quintile (Table A6). Meanwhile, we also saw similar patterns with the magnitude of the outcomes in SA2 being greater than under SA1, but the pattern for the relationship between income quintiles being the same as under SA1 (Tables A8–A9). However, since there are fewer smokers in this model than in SA1, we find that the tax revenues expected under each increase are smaller than under SA1 (Table A9).

Under SA3, using the base case price elasticity scenario, but using a youth elasticity multiplier of 1 instead of 2 (meaning the youth would not be more price elastic than adults), we see a decrease in the magnitude of the benefits (Tables A11–A13). However, we see greater tax revenues (Table A13).

Table 8: Change in tax revenues before and after the three tax increases in COP\$, by income quintile

INCOME QUINTILE	AFTER FIRST INCREASE	AFTER SECOND INCREASE	AFTER THIRD INCREASE
1 (poorest)	23,422,620,000	60,639,980,000	77,355,230,000
2	43,041,150,000	101,379,010,000	125,243,320,000
3	57,743,010,000	127,077,720,000	152,751,760,000
4	63,351,060,000	132,584,220,000	155,650,150,000
5 (richest)	87,503,500,000	176,313,740,000	202,774,990,000
Total	275,061,340,000	597,994,670,000	713,775,450,000

Table 9: Change in household expenditures on cigarettes, by income quintile, over three tax increases in COP\$

INCOME QUINTILE	AFTER FIRST TAX INCREASE	AFTER SECOND TAX INCREASE	AFTER THIRD TAX INCREASE	TOTAL CHANGE
1 (poorest)	-509,080,000	38,808,970,000	25,567,090,000	63,866,980,000
2	13,611,780,000	60,892,320,000	36,339,150,000	110,843,250,000
3	31,643,240,000	72,613,950,000	38,896,530,000	143,153,720,000
4	45,410,190,000	72,895,640,000	34,742,330,000	153,048,160,000
5 (richest)	73,961,040,000	94,159,460,000	39,589,680,000	207,710,180,000
Total	164,117,170,000	339,370,340,000	175,134,780,000	678,622,290,000

Similarly, under SA4 we changed the youth elasticity multiplier to 3. As expected, we find an increase in the size of the benefits (Tables A15–A17); yet, compared with SA3 and the base case, we obtain smaller tax revenues after all three increases (Table A17).

Under SA5, we used the mean price per pack of cigarettes of the premium brand of cigarettes (3,772 COP\$ in 2016). This changes the relative price increase under the tax policy, which leads to 709,600 quitters after tax increases, with most of them coming from the bottom income quintile (192,400) and the smallest number (79,400) coming from the top income quintile (Table A18). With this alternative price per pack, there are fewer deaths averted after tax increases than under the base case (Table A19), and savings to the government are likewise smaller (Table A20). Meanwhile, the tax revenues would be greater than in the base case, with large revenues from the top income quintile (Table A21).

Figure 6: Change in annual tax revenues under the three tax increases in COP\$ (2016–2019), by income quintile

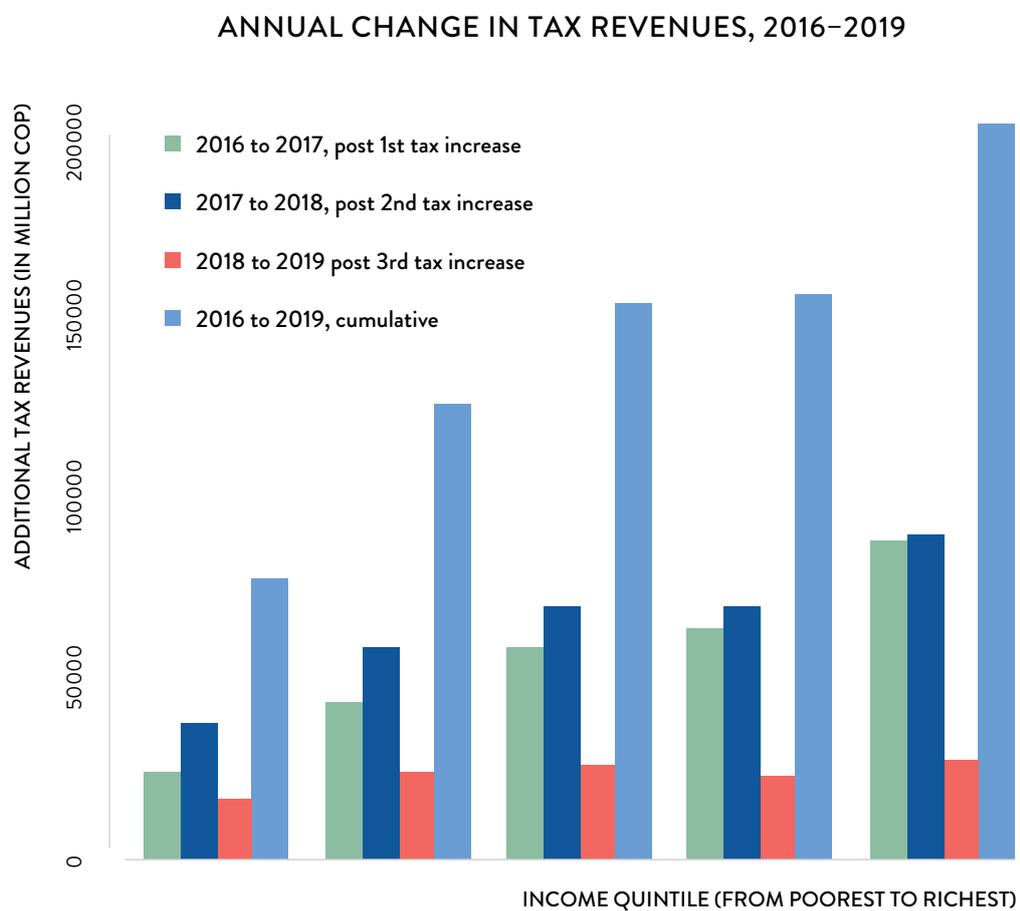
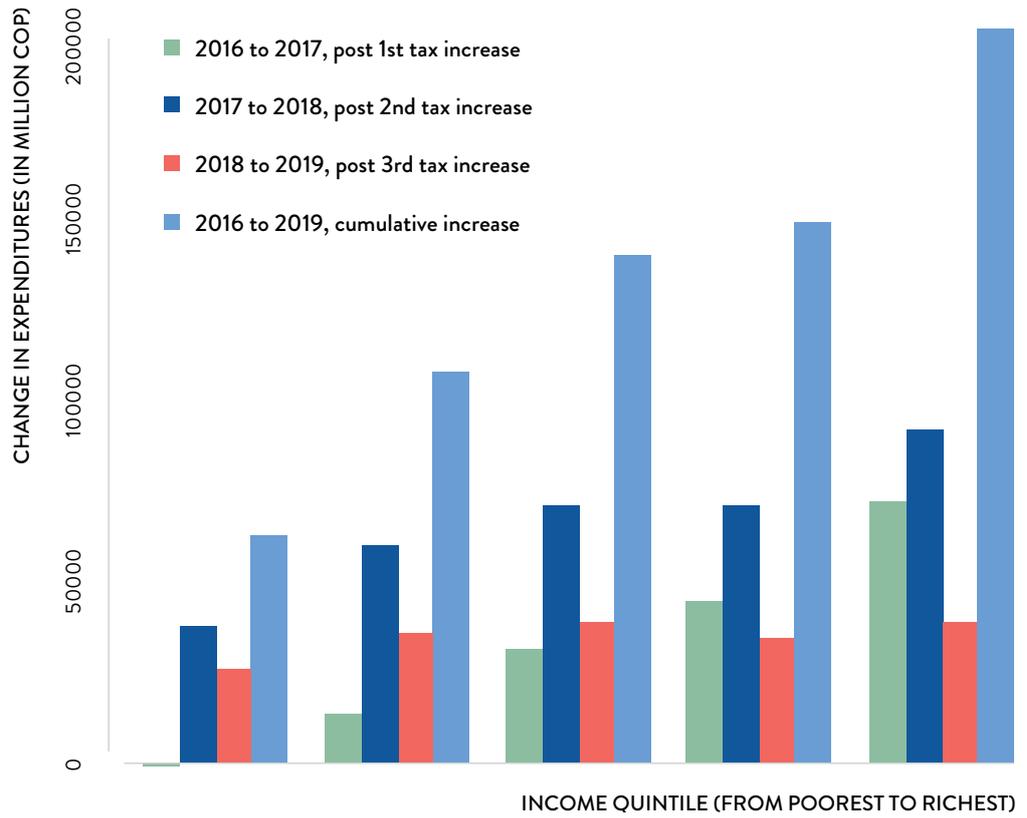


Figure 7: Change in annual household expenditures on cigarettes over three tax increases (2016–2019) in COP\$

CHANGE IN HOUSEHOLD CIGARETTE EXPENDITURES, 2016–2019



DISCUSSION

In December 2016, Colombia substantially proposed an increase in its tobacco taxes, tripling the excise tax over two years and increasing the VAT by three percentage points. These new tax measures are expected to result in a 68% relative price increase over three years (Figure 1). Such a large and swift increase in the price consumers will pay for cigarettes has substantial impacts in terms of reducing the number of smokers, decreasing the number of deaths attributable to tobacco, increasing government tax revenues, and producing savings for both households and the public health sector. Our analysis of the distributional impact of the tax policy demonstrates considerable benefits to poor segments of the Colombian population (Table 10).

Overall, we find the greatest number of deaths averted and the smallest net change in the tax burden among the bottom income quintile, with a gradient showing the number of deaths averted decreasing and the net change in tax burden increasing as we switch from the bottom to the top income quintile. These findings, along with greater benefits in financial risk protection accruing to the poorer income quintiles, point to the potentially pro-poor dimensions of increases in tobacco taxes in Colombia (Table 10).

Unlike other countries where such a tax increase would have huge benefits in terms of financial risk protection (FRP), the small effect of the tax on catastrophic/impoverish-related spending in Colombia is a testament to the robustness of the health system in the number of people covered by health insurance (under the contributory regimen,

Table 10: Summary findings of the ECEA of the tobacco tax increase among Colombia's current urban population

OUTCOME	TOTAL	QUINTILE 1	QUINTILE 2	QUINTILE 3	QUINTILE 4	QUINTILE 5
Deaths averted*	337,300	92,200	83,400	72,700	51,700	37,300
Health-care savings (COP\$)*	200,763,205,249	52,400,000,000	51,300,000,000	41,379,371,000	31,034,112,000	24,656,358,249
Changes in annual tax revenues (COP\$)	714,000,000,000	77,355,230,000	125,243,320,000	152,751,760,000	155,650,150,000	202,774,990,000
Financial risk protection provided*	5,140 cases of catastrophic spending averted	2,500	910	1,050	680	0

*These findings are best understood over a lifespan of 75 years corresponding to Colombia's life expectancy at birth.

subsidized regimen, and special benefits regimen). Since Colombia has achieved a high level of FRP, with most expenditures associated with inpatient tobacco-related diseases that contribute the most to mortality covered by insurance, the financial savings for the government can be substantial. Yet, our estimate of savings is conservative here since we only examine inpatient care tied to tobacco-related mortality.

Our analysis presents a number of limitations, primarily related to the model inputs. First, we derived Colombian price elasticity of demand for cigarettes by income quintile based on household survey data and a review of the literature from South American countries. However, we also ran two sensitivity analyses (SA1 and SA2, Supplementary appendix) with alternative values for price elasticity (-0.40 and -0.78) [16, 40] to understand the impact this key parameter would have on our distributional findings. Second, we relied on household surveys to estimate the prevalence of smoking, the number of cigarettes smoked per day, and health services utilization. However, we used the average price of cigarettes to determine cigarette consumption from weekly household cigarette expenditures using the ENCV and EAM [29, 41, 42, 43, 44]. Even though this could be problematic since the price per pack of cigarettes ranges depending on a number of factors, including brand, this was the better strategy for estimating units purchased from household surveys in this study. Third, we did not have the distribution of people seeking care for tobacco-related diseases by income quintile; hence, instead, we used the percentage of households reporting that they have sought treatment given medical necessity. Neither did we have the prevalence of smokers in rural areas for the population under 80, which did not allow us to produce estimates for the whole Colombian population, implying that our estimates would represent a lower boundary of the potential tax policy impact. Fourth, we only used a static model focusing on the current Colombian population and did not examine the evolution over time of the health and financial benefits in the future. Fifth, our model did not take cigarette smuggling into account (except in SA3 as incorporated by Maldonado and his colleagues in their estimation), which might increase in response to tax increases and bring cheaper cigarettes onto the market, thereby undercutting the health effects of the tobacco tax [57]. Despite concerns about smuggling, studies show that even when there is smuggling, tobacco tax increases still largely reduce smoking prevalence [58, 59]. Finally, our findings should be interpreted with caution as they are largely dependent on the utilization of many different data sources with varying underlying assumptions and methodologies, due to data limitations. Specifically, our focus on smokers in the urban population in Colombia overlooks possible benefits accruing to the rural population. While less is known about rural smokers and the cigarette markets in those areas, our model would likely underestimate the national benefits of the tax increases in Colombia.



While this analysis demonstrates the huge health and financial benefits that are likely to accrue under Colombia's new tobacco tax, it is absolutely critical that Colombia keeps raising the taxes in the future as Colombians' incomes grow and cigarettes become more affordable. Evidence from France with raising cigarette prices through tax increases points out that once prices stabilize, cigarette sales no longer decrease and smoking rates remain unchanged [15]. Through monitoring of the actual effects of the tax on consumption, health, and finance, Colombia can both understand the real-time dynamics of the tax and when the taxes are no longer as effective at discouraging smoking.

Our analysis shows that the 68% increase in the average price per cigarette pack will undoubtedly put Colombia closer to meeting its national and international commitments of decreasing smoking rates and the prevalence of NCDs. The tax increase will also help Colombia deal with the increasing financial strain that the growing burden of NCD prevalence places on the health system, while addressing health and economic inequalities overall.

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SUPPLEMENTARY APPENDIX

1. Price elasticity of demand for cigarettes

In this section, we detail the methods that lead to the derivations for the analysis of: (i) the average price elasticity drawing from household survey data (section 1.1); and (ii) of the price elasticity by income quintile drawing from studies from other South American countries (section 1.2).

1.1 Average price elasticity derived from household survey data

Price elasticity of demand for the purchase of cigarettes in Colombia was calculated using the National Quality of Life Survey (*Encuesta Nacional de Calidad de Vida*—ENCV) for the years 2003, 2010, 2011, and 2014 as the primary sources of information [29]. The ENCV collected information on household expenditures of cigarettes only for those four years. The ENCV is a nationally represented, repeated cross-sectional survey of approximately 20,000 households each survey year. The survey's analysis includes a total of 83,017 households of which 10,159 reported a purchase of cigarettes over the past seven days prior to their interview.

The ENCV provides information on the reported total weekly expenditures on cigarettes per household, yet not the number of cigarettes purchased nor their price. For this reason, the *Encuesta Anual Manufacturera* (EAM) was also used for each of the four years. The EAM provides information on the total annual number of cigarettes sold nationally and their value [41, 42, 43, 44]. The World Bank's World Development Indicators were used to extract the consumer price index for each survey year.

A log-log linear regression model was used to calculate the price elasticity of demand using the above described data. The model used is the following:

$$\ln(Q) = \beta_0 + \beta_1 (\ln(P)) + \beta_3 (\ln(Y)) + \sum \beta_x (hh) + \beta_4 (D) + \beta_5 (U) + \varepsilon \quad (1)$$

where the included variables are defined as:

- Q : quantity of cigarette packages (20 units) purchased by the household on a weekly basis. Calculated using the household weekly expenditures reported in ENCV, divided by the average cigarette package price on the given year (P) as reported in EAM.
- P : average price per cigarette package (20 units) for a given year of the survey, adjusted for inflation and tax. Calculated using EAM.
- Y : monthly total household income adjusted for inflation minus the monthly household expenditures on food in the household. Calculated using ENCV.

- *hh*: includes the natural log of the number of persons reported living in a given household, the natural log of the percentage of children under the age of 18 that live in the household, the gender of the household head, and the natural log of the age of the household head.
- *D*: department (subnational administrative unit). Departments included are only those from which data were collected across the four ENCV surveys included in the analysis.
- *U*: urban location of the household. As reported in ENCV.

The average price elasticity of demand calculated as per the above-mentioned methods is -0.439 (95% CI: -0.53 to -0.347).

Table A1: Price elasticity of demand for cigarettes from the eleven country studies, publication year and corresponding gross domestic product per capita (GDPc).

COUNTRY/STUDY	PRICE ELASTICITY	YEAR	GDPc (CONSTANT 2011 INTERNATIONAL DOLLARS)
MEXICO (Jimenez-Ruiz, et al., 2008)[2]	-0.52	1999	10,319
ARGENTINA (Gonzales-Rozada, 2006)[3]	-0.27	2000	11,810
ARGENTINA (Martinez, et al., 2008)[4]	-0.34	1999	11,769
ARGENTINA (Martinez, et al., 2015)[5]	-0.31	2002	10,217
BRAZIL (Carvahlo and Lobao, 1998)6	-0.8	1988	6,640
BRAZIL (Iglesias, et al., 2007)[7]	-0.8	1998	8,530
BOLIVIA (Alcaraz, 2006)[8]	-0.85	1995	2,994
CHILE (Debrott Sanchez, 2006)[9]	-0.45	1998	8,908
MEXICO (Olivera-Chavez, 2010)[10]	-0.25	1999	10,319
URUGUAY (Ramos and Curti, 2006)[11]	-0.55	1997	9,821
PERU (Gonzales-Rozada and Ramos-Carbajales, 2016)[12]	-0.7	1997	4,943

Price elasticity by income quintile

First, we sourced studies from Latin America that estimated the price elasticity of demand for tobacco products, and could identify eleven studies from eight countries, which are summarized in Table A1. The price elasticities reported ranged from -0.22 in Chile to -0.85 in Brazil and displayed an interquartile range of 0.42 and a standard deviation of 0.23 .

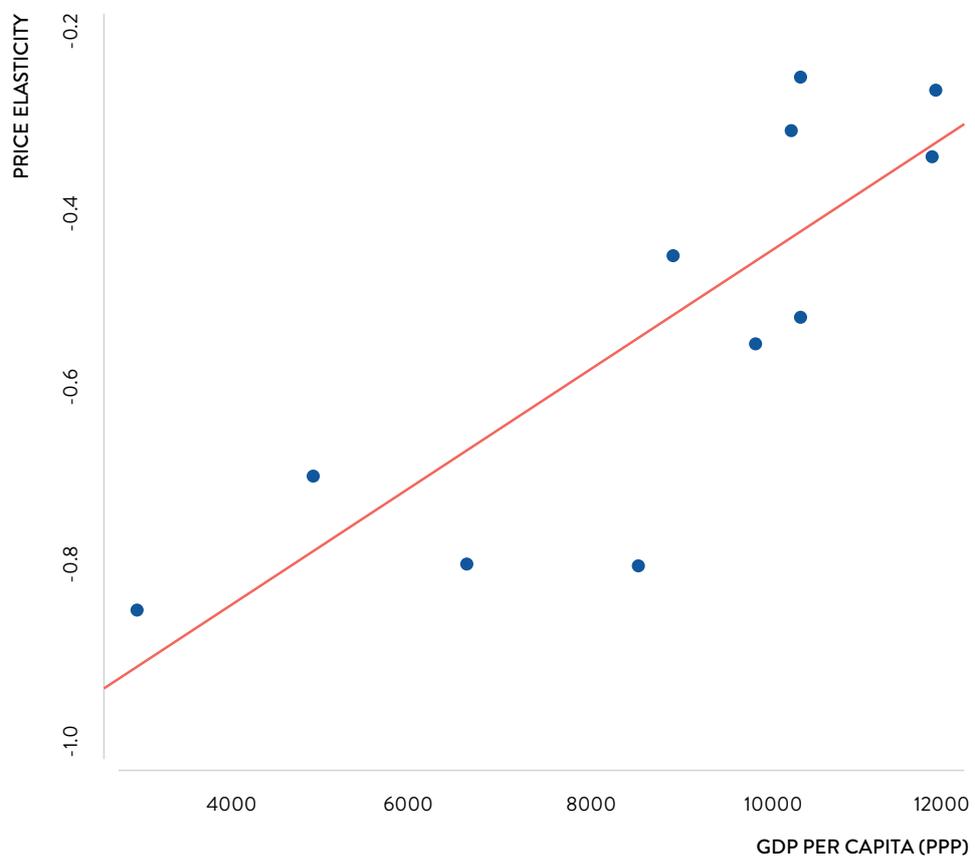
Second, we studied the association between country gross domestic product (GDP) per capita and price elasticity in a simple linear regression, to infer the potential relationship between price elasticity of demand for tobacco products and income. Specifically, we examined the relationship between price elasticity PE_i found in each study with each country's GDP per capita $GDP_{c,i}$ for the year of the study (Purchasing Power Parity (PPP), in constant 2011 international dollars):

$$PE_i = \beta_0 + \beta_1 GDP_{c,i} + \varepsilon \quad (2)$$

where ε is an error term.

Model (1) yielded a strong relationship between income and price elasticity: $\beta_1 = 6.67$ per 100,000 ($P = 0.002$) and a goodness of fit of $R^2 = 0.68$ (Figure A1).

Figure A1: Price elasticity of demand for cigarettes vs. gross domestic product per capita (GDPc, constant 2011 international \$)



Note: The red line corresponds to the regression line from model (2).

We then used the interquartile range (IQR) and the mean of these 11 studies (IQR = 0.42 and $m = -0.53$) and applied it to the Colombian context, i.e., to the average price elasticity of PE_{av} (as detailed in 1.1) in the following way so to derive price elasticity per income quintile, $PE_{q'}$ for Colombia:

$$PE_1 = PE_{av} + \frac{IQR}{2m} PE_{av} = -0.61; PE_2 =$$

$$PE_{av} + \frac{IQR}{4m} PE_{av} = -0.53;$$

$$PE_3 = PE_{av};$$

$$PE_4 = PE_{av} - \frac{IQR}{4m} PE_{av} = -0.35;$$

$$PE_5 = PE_{av} - \frac{IQR}{2m} PE_{av} = -0.26$$

2. Results for the first sensitivity analysis (SA1): flat price elasticity of -0.40 across income quintiles

Table A2. SA1: Cumulative number of smokers and averted smokers after three tax increases by income quintile (smokers include both current and “future” smokers)

INCOME QUINTILE	TOTAL NUMBER OF SMOKERS BEFORE TAX	TOTAL NUMBER OF SMOKERS AFTER ALL TAX INCREASES	TOTAL NUMBER OF QUITTERS AFTER ALL TAX INCREASES
1 (poorest)	867,400	729,100	138,300
2	919,100	774,100	145,000
3	966,300	815,600	150,700
4	864,700	731,600	133,100
5 (richest)	837,500	710,293	127,200
Total	4,455,000	3,760,693	694,300

Table A3. SA1: Cumulative number and proportion of averted deaths after tax increases by income quintile

INCOME QUINTILE	CUMULATIVE NUMBER OF DEATHS AVERTED AFTER TAX INCREASES	CUMULATIVE PROPORTION OF DEATHS AVERTED AFTER TAX INCREASES
1 (poorest)	61,800	0.20
2	64,500	0.21
3	66,700	0.22
4	58,600	0.19
5 (richest)	55,600	0.18
Total	307,200	1.00

Table A4. SA1: Cumulative individual and government savings from averted spending on treatment of tobacco-related diseases after tax increase, by income quintile

INCOME QUINTILE	SAVINGS TO INDIVIDUAL (IN COP\$)	SAVINGS TO HEALTH SYSTEM (IN COP\$)
1 (poorest)	35,151,800,000	542,114,900,000
2	39,641,700,000	611,358,000,000
3	37,905,500,000	584,582,000,000
4	35,111,400,000	541,490,900,000
5 (richest)	36,761,400,000	566,937,800,000
Total	184,571,800,000	2,846,483,600,000

Table A5. SA1: Change in tax revenues by income quintile before and after three tax increases

INCOME QUINTILE	TAX REVENUE BEFORE INCREASE (IN COP)	TAX REVENUE AFTER FIRST INCREASE (IN COP)	TAX REVENUE AFTER SECOND INCREASE (IN COP)	TAX REVENUE AFTER THIRD INCREASE (IN COP)
1 (poorest)	91,707,530,000	128,252,300,000	170,215,200,000	185,052,100,000
2	137,098,130,000	191,730,800,000	254,463,100,000	276,643,500,000
3	155,022,050,000	216,797,200,000	287,731,100,000	312,811,300,000
4	146,979,080,000	205,549,200,000	272,802,800,000	296,581,800,000
5 (richest)	178,739,260,000	249,965,600,400	331,751,800,000	360,669,100,000
Total	709,546,050,000	992,295,100,400	1,316,964,000,000	1,431,757,800,000

3. Results for the second sensitivity analysis (SA2): flat elasticity of demand of -0.78 across income quintiles

Table A6. SA2: Cumulative number of smokers and averted smokers after three tax increases by income quintile (smokers include both current and “future” smokers)

INCOME QUINTILE	TOTAL NUMBER OF CURRENT SMOKERS BEFORE TAX	TOTAL NUMBER OF SMOKERS AFTER ALL TAX INCREASES	TOTAL NUMBER OF QUITTERS AFTER ALL TAX INCREASES
1 (poorest)	867,400	611,400	256,000
2	919,100	650,500	268,600
3	966,300	687,000	279,300
4	864,700	617,800	246,900
5 (richest)	837,500	601,400	236,100
Total	4,455,000	3,168,100	1,286,900

Table A7. SA2: Cumulative number and proportion of averted deaths after tax increases by income quintile

INCOME QUINTILE	CUMULATIVE NUMBER OF DEATHS AVERTED AFTER THREE TAX INCREASES	CUMULATIVE PROPORTION OF DEATHS AVERTED AFTER THREE TAX INCREASES
1 (poorest)	114,300	0.20
2	119,200	0.21
3	123,300	0.22
4	108,500	0.19
5 (richest)	103,100	0.18
Total	568,400	1.00

Table A8. SA2: Cumulative individual and government savings from averted spending on treatment of tobacco-related diseases after tax increase, by income quintile

INCOME QUINTILE	SAVINGS TO INDIVIDUAL (IN COP\$)	SAVINGS TO HEALTH SYSTEM (IN COP\$)
1 (poorest)	64,955,200,000	1,001,745,700,000
2	73,288,600,000	1,130,264,200,000
3	70,117,400,000	1,081,356,600,000
4	64,988,200,000	1,002,254,000,000
5 (richest)	68,087,800,000	1,050,056,800,000
Total	341,437,200,000	5,265,677,300,000

Table A9. SA2: Tax revenues after by income quintile before and after three tax increases

INCOME QUINTILE	TAX REVENUE BEFORE INCREASE (IN COP\$)	TAX REVENUE AFTER FIRST INCREASE (IN COP\$)	TAX REVENUE AFTER SECOND INCREASE (IN COP\$)	TAX REVENUE AFTER THIRD INCREASE (IN COP\$)
1 (poorest)	91,707,530,000	105,010,500,000	139,333,700,000	157,396,300,000
2	137,098,130,000	156,985,300,000	208,296,800,000	235,299,500,000
3	155,022,050,000	177,509,300,000	235,529,100,000	266,062,000,000
4	146,979,080,000	168,299,600,000	223,309,200,000	252,258,000,000
5 (richest)	178,739,260,000	204,666,900,000	271,563,300,000	306,767,500,000
Total	709,546,050,000	812,471,600,000	1,078,032,100,000	1,217,783,300,000

4. Results for the third sensitivity analysis (SA3): youth price elasticity modifier of 1

Table A10. SA3: Cumulative number of smokers and averted smokers after three tax increases by income quintile (smokers include both current and “future” smokers)

INCOME QUINTILE	TOTAL NUMBER OF CURRENT SMOKERS BEFORE TAX	TOTAL NUMBER OF SMOKERS AFTER ALL TAX INCREASES	TOTAL NUMBER OF QUITTERS AFTER ALL TAX INCREASES
1 (poorest)	867,400	693,400	174,000
2	919,100	760,500	158,600
3	966,300	826,800	139,500
4	864,700	764,600	100,100
5 (richest)	837,500	764,700	72,800
Total	4,455,000	3,810,000	645,000

Table A11. SA3: Cumulative number and proportion of averted deaths after tax increases by income quintile

INCOME QUINTILE	CUMULATIVE NUMBER OF DEATHS AVERTED AFTER THREE TAX INCREASES	CUMULATIVE PROPORTION OF DEATHS AVERTED AFTER THREE TAX INCREASES
1 (poorest)	76,300	0.27
2	69,200	0.25
3	60,500	0.22
4	43,200	0.15
5 (richest)	31,300	0.11
Total	280,500	1.00

Table A12. SA3: Cumulative individual and government savings from averted spending on treatment of tobacco-related diseases after tax increase, by income quintile

INCOME QUINTILE	SAVINGS TO INDIVIDUALS (IN COP\$)	SAVINGS TO HEALTH SYSTEM (IN COP\$)
1 (poorest)	43,369,600,000	668,849,500,000
2	42,539,300,000	656,045,100,000
3	34,405,500,000	530,605,500,000
4	25,886,900,000	399,230,600,000
5 (richest)	20,648,300,000	318,440,600,000
Total	166,849,600,000	2,573,171,300,000

Table A13. SA3: Change in tax revenues by income quintile before and after three tax increases

INCOME QUINTILE	TAX REVENUE BEFORE INCREASE (IN COP\$)	TAX REVENUE AFTER FIRST INCREASE (IN COP\$)	TAX REVENUE AFTER SECOND INCREASE (IN COP\$)	TAX REVENUE AFTER THIRD INCREASE (IN COP\$)
1 (poorest)	91,707,530,000	122,684,900,000	162,182,500,000	177,868,300,000
2	137,098,130,000	189,820,200,000	251,441,900,000	273,940,800,000
3	155,022,050,000	221,887,700,000	294,658,000,000	319,005,300,000
4	146,979,080,000	217,250,100,000	289,348,100,000	311,380,100,000
5 (richest)	178,739,260,000	272,555,100,000	364,214,500,000	389,710,100,000
Total	709,546,050,000	1,024,198,000,000	1,361,845,000,000	1,471,904,600,000

5. Results for the third sensitivity analysis (SA4): youth price elasticity modifier of 3

Table A14. SA4: Cumulative number of smokers and averted smokers after three tax increases by income quintile (smokers include both current and “future” smokers)

INCOME QUINTILE	TOTAL NUMBER OF CURRENT SMOKERS BEFORE TAX	TOTAL NUMBER OF SMOKERS AFTER ALL TAX INCREASES	TOTAL NUMBER OF QUITTERS AFTER ALL TAX INCREASES
1 (poorest)	867,400	608,100	259,300
2	919,100	683,100	236,000
3	966,300	759,400	206,900
4	864,700	716,900	147,800
5 (richest)	837,500	730,600	106,900
Total	4,455,000	3,498,100	956,900

Table A15. SA4: Cumulative number and proportion of averted deaths after tax increases by income quintile

INCOME QUINTILE	CUMULATIVE NUMBER OF DEATHS AVERTED AFTER THREE TAX INCREASES	CUMULATIVE PROPORTION OF DEATHS AVERTED AFTER THREE TAX INCREASES
1 (poorest)	118,400	0.27
2	107,300	0.25
3	93,700	0.22
4	66,700	0.15
5 (richest)	48,000	0.11
Total	434,100	1.00

Table A16. SA4: Cumulative individual and government savings from averted spending on treatment of tobacco-related diseases after tax increase, by income quintile

INCOME QUINTILE	SAVINGS TO INDIVIDUALS (IN COP\$)	SAVINGS TO HEALTH SYSTEM (IN COP\$)
1 (poorest)	67,284,000,000	1,037,660,000,000
2	65,974,100,000	1,017,458,900,000
3	53,269,800,000	821,531,300,000
4	39,951,900,000	616,142,300,000
5 (richest)	31,709,300,000	489,024,500,000
Total	258,189,100,000	3,981,817,000,000

Table A17. SA4: Tax revenues by income quintile before and after three tax increases

INCOME QUINTILE	TAX REVENUE BEFORE INCREASE (IN COP\$)	TAX REVENUE AFTER FIRST INCREASE (IN COP\$)	TAX REVENUE AFTER SECOND INCREASE (IN COP\$)	TAX REVENUE AFTER THIRD INCREASE (IN COP\$)
1 (poorest)	91,707,530,000	107,575,400,000	143,831,000,000	161,371,400,000
2	137,098,130,000	170,458,400,000	226,960,600,000	251,986,000,000
3	155,022,050,000	203,642,400,000	270,678,900,000	297,534,900,000
4	146,979,080,000	203,410,200,000	270,468,700,000	294,490,300,000
5 (richest)	178,739,260,000	259,930,500,000	346,363,700,000	373,743,700,000
Total	709,546,050,000	945,016,900,000	1,258,302,900,000	1,379,126,300,000

6. Results for the fifth sensitivity analysis (SA5): mean initial price per pack of cigarettes of COP\$3,772

Table A18. SA5: Cumulative number of smokers and averted smokers after three tax increases by income quintile (smokers include both current and “future” smokers)

INCOME QUINTILE	TOTAL NUMBER OF CURRENT SMOKERS BEFORE TAX	TOTAL NUMBER OF SMOKERS AFTER ALL TAX INCREASES	TOTAL NUMBER OF QUITTERS AFTER ALL TAX INCREASES
1 (poorest)	867,400	675,000	192,400
2	919,100	744,200	174,900
3	966,300	813,000	153,300
4	864,700	755,100	109,600
5 (richest)	837,500	758,100	79,400
Total	4,455,000	3,745,400	709,600

Table A19. SA5: Cumulative number and proportion of averted deaths after tax increases by income quintile

INCOME QUINTILE	CUMULATIVE NUMBER OF DEATHS AVERTED AFTER THREE TAX INCREASES	CUMULATIVE PROPORTION OF DEATHS AVERTED AFTER THREE TAX INCREASES
1 (poorest)	85,900	0.27
2	77,800	0.25
3	67,800	0.22
4	48,300	0.15
5 (richest)	34,800	0.11
Total	314,600	1.00

Table A20. SA5: Cumulative individual and government savings from averted spending on treatment of tobacco-related diseases after tax increase, by income quintile

INCOME QUINTILE	SAVINGS TO INDIVIDUAL (IN COP\$)	SAVINGS TO HEALTH SYSTEM (IN COP\$)
1 (poorest)	48,857,400,000	753,483,300,000
2	47,813,700,000	737,388,000,000
3	38,562,800,000	594,719,100,000
4	28,915,200,000	445,933,300,000
5 (richest)	22,968,100,000	354,216,781,994
Total	187,117,200,000	2,885,740,500,000

Table A21. SA5: Tax revenues after by income quintile before and after three tax increases

INCOME QUINTILE	TAX REVENUE BEFORE INCREASE (IN COP\$)	TAX REVENUE AFTER FIRST INCREASE (IN COP\$)	TAX REVENUE AFTER SECOND INCREASE (IN COP\$)	TAX REVENUE AFTER THIRD INCREASE (IN COP\$)
1 (poorest)	104,120,400,000	125,332,300,000	169,894,900,000	194,530,700,000
2	155,654,800,000	196,102,200,000	265,944,900,000	301,861,000,000
3	176,004,800,000	231,619,100,000	314,592,000,000	354,137,400,000
4	166,873,200,000	228,968,400,000	311,763,400,000	348,217,800,000
5 (richest)	202,932,200,000	289,835,700,000	395,948,000,000	438,986,200,000
Total	805,585,400,000	1,071,857,700,000	1,458,143,200,000	1,637,733,100,000

SUPPLEMENTARY APPENDIX

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