Supplementary appendix

"Distributional health and financial benefits of increased tobacco taxes in Colombia: results from a modeling study" by Erin James, Akshar Saxena, Camila Franco Restrepo, Blanca Llorente, Andrés I. Vecino-Ortiz, Manuela Villar Uribe, Roberto F. Iunes, Stéphane Verguet

1. Estimating years of life gained, net change in tax revenues, and net change in household cigarette expenditure

We build here on previously published extended cost-effectiveness analysis studies of tobacco taxation [1,2] and summarize below our methods for estimating:

i) the years of life gained (YLG) upon smoking cessation associated with increased tobacco prices;

ii) the net change in annual tax revenues associated with increased tobacco taxes;

iii) the net change in household annual expenditure on cigarettes associated with increased tobacco prices.

1.1. Years of life gained associated with increased tobacco taxes

Colombia's life expectancy at birth is 73.8 years and its life expectancy at age *a*, denoted *l(a)* is: *l(a)* = {73.8; 70.7; 65.6; 60.9; 56.3; 52.9; 47.5; 43.1; 38.6; 34.1; 29.7; 25.4; 21.4; 17.6; 14.2; 11.2; 8.4} years at age *a* = {0; 5; 10; 15; 20; 25; 30; 35; 40; 45; 50; 55; 60; 65; 70; 75; 80} [3]. Furthermore, the health benefits of smoking cessation vary with age *a* at cessation: cessation can lead to 10, 9, 6, and 3 YLG when a smoker quits at age *a* = 30, 40, 50, or 60 years, respectively [4]. Therefore, we estimated the numbers of YLG as a function of age *a* at quitting by building on the following linear model:

$$YLG = \beta_0 + \beta_1 * a, \quad (1)$$

where: $\beta_0 = 17.80$, $\beta_1 = -0.24$, with $R^2 = 0.96$.

As a result, we could derive the following function $YLG\,(a)$:

$YLG\,(a) = 10$, when $a \leq 32.5$;

$YLG\,(a) = 17.80 - 0.24 * a$, when $32.5 < a \leq 72.5$;

$YLG\,(a) = 0.40$, when $a > 72.5$.

If we denote $S_{a,I}$ the number of smokers of age *a* among income quintile *I* prior tax increase, and $P_{a,I}$ the price elasticity for age *a* and quintile *I* (Table 2 in the main text), we could derive (assuming participation elasticity of 1/2) the following number of quitters at age *a* as:

$$Q_{a,I} = \frac{1}{2} * \frac{\Delta p}{p} * P_{a,I} * S_{a,I}, \qquad (2)$$

where p is the retail price of cigarettes, and Δp is the change in the price of cigarettes. Tables A1 and A2 below list the number of current smokers (above age 15) and potential "future smokers" (below age 15) before taxes are raised (Table A1), and the number of quitters (above age 15) and averted potential future smokers (below age 15) after taxes are raised (Table A2).

Subsequently, we can derive the total number of YLG, per age group *a* and income quintile *I* as:

$$TYLG_{a,I} = Q_{a,I} * YLG\,(a). \qquad (3)$$

Accounting for life expectancy at age *a* (*l(a)*), as discussed previously, $TYLG_{a,I}$ will be delayed and occur into the future at $\tau = l(a) - YLG(a)$. In other words:

$$TYLG_{a,I}(t) = Q_{a,I} * YLG(a) * \delta(t - \tau) . \quad (4)$$

For example: when $a = 80$, $\tau = 8.4 - 0.4 = 8$; when $a = 60$, $\tau = 21.4 - 3.4 = 18$.

As a result, over a 20-year time period post-tax policy, YLG will be obtained among those quitting at an age of roughly 55 years and above.

Table A1. Number of current smokers (age > 15) and potential "future smokers" (age < 15) before tax increase, by five-year age group and income quintile.

Future smokers

Age group	**0-4**	**5-9**	**10-14**
QI	76,500	75,900	77,000
QII	74,400	73,800	74,800
QIII	70,700	70,200	71,200
QIV	56,200	55,800	56,600
QV	47,200	46,800	47,500
Total	325,000	322,500	327,100

Current smokers

Age group	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**
QI	61,100	99,400	94,300	66,500	49,000	44,200	52,100	56,500	42,300	27,200	20,000	14,500	11,000
QII	66,600	108,500	102,800	72,500	53,500	48,300	56,900	61,600	46,100	29,700	21,800	15,800	12,000
QIII	72,200	117,500	111,400	78,600	57,900	52,300	61,600	66,800	50,000	32,200	23,600	17,100	13,100
QIV	66,600	108,500	102,800	72,500	53,500	48,300	56,900	61,600	46,100	29,700	21,800	15,800	12,000
QV	66,600	108,500	102,800	72,500	53,500	48,300	56,900	61,600	46,100	29,700	21,800	15,800	12,000
Total	333,100	542,400	514,100	362,600	267,400	241,400	284,400	308,100	230,600	148,500	109,000	79,000	60,100

Table A2. Number of current smokers who quit ("quitters" age > 15) and averted potential future smokers (age < 15) after tax increases, by five-year age group and income quintile.

	Averted potential future smokers		
Age group	**0-4**	**5-9**	**10-14**
QI	24,600	24,400	24,800
QII	20,800	20,700	21,000
QIII	16,800	16,600	16,900
QIV	10,800	10,700	10,900
QV	6,900	6,800	6,900
Total	79,900	79,200	80,500

	Quitters												
Age group	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**
QI	19,700	28,400	23,400	13,900	8,300	7,500	8,800	9,600	7,200	4,600	3,400	2,500	1,900
QII	18,700	26,900	22,100	13,100	7,800	7,100	8,300	9,000	6,800	4,300	3,200	2,300	1,800
QIII	17,100	24,600	20,200	12,000	7,100	6,400	7,600	8,200	6,100	4,000	2,900	1,600	2,100
QIV	12,800	18,400	15,000	8,900	5,300	4,800	5,600	6,100	4,600	2,900	2,200	1,600	1,200
QV	9,800	14,000	11,400	6,700	4,000	3,600	4,300	4,600	3,500	2,200	1,600	1,200	900
Total	78,100	112,300	92,100	54,600	32,500	29,400	34,600	37,500	28,200	18,000	13,300	9,200	7,900

1.2. <u>Net change in annual tax revenues</u>

The net change in annual tax revenues after tax increase, denoted $Tax_{a,I}$ in age group *a* and income quintile *I*, is given by:

$$Tax_{a,I} = S_{a,I} * Cig_I * [tax_{post} * (1 + P_{a,I} * \frac{\Delta p}{p}) - tax_{ante}], \qquad (5)$$

where Cig_I is the number of cigarette packs consumed per year among income quintile *I*, tax_{ante} is the share of taxes within the retail price of cigarettes before policy, and tax_{post} is the share of taxes within the retail price after policy.

As discussed in 1.1 above, $S_{a,I}$ will vary over time. Thus, over a 20-year time period post-tax increase, $Tax_{a,I}$ will be generated from the tobacco consumption of various age groups: in year 1, from the whole current smoking population (i.e. those with *a* > 15 years); in year 10, from the smoking population, which would be constituted of those currently aged 5-74 year-olds (i.e. those currently aged 75-79 year-olds will have already died 10 years later, and those currently aged 5-14 year-olds as they will have initiated smoking 10 years later at age 15); in year 20, from the smoking population, which would be constituted of those currently aged 0-54 year-olds (i.e. those currently aged 55-79 year-olds will have already died 20 years later, those currently aged 0-14 year-olds as they will have initiated smoking 20 years later at age 15, and an additional 0-5 year-olds, not yet born, as they will have initiated smoking 20 years later at age 15).

1.3. <u>Net change in annual household expenditure</u>

The net change in annual household cigarette expenditure after tax increase, denoted $Cons_{a,I}$ in age group *a* and income quintile *I*, is given by:

$$Cons_{a,I} = S_{a,I} * Cig_I * [p_{post} * (1 + P_{a,I} * \frac{\Delta p}{p}) - p_{ante}], \quad (6)$$

where p_{ante} is the retail price before policy, and p_{post} is the retail price after tax increase.

As discussed in 1.1 and 1.2, $S_{a,I}$ will vary with time, hence over a 20-year time period post-tax policy, $Cons_{a,I}$ will be generated from the consumption of various age groups: in year 1, from the whole current smoking population (i.e. those with *a* > 15 years); in year 10, from the smoking population, which would be constituted of those currently aged 5-74 year-olds (i.e. those currently aged 75-79 year-olds will have already died 10 years later, and those currently aged 5-14 year-olds as they will have initiated smoking 10 years later at age 15); in year 20, from the smoking population, which would be constituted of those currently aged 0-54 year-olds (i.e. those currently aged 55-79 year-olds will have already died 20 years later, those currently aged 0-14 year-olds as they will have initiated smoking 20 years later at age 15, and an additional 0-5 year-olds, not yet born, as they will have initiated smoking 20 years later at age 15).

2. Price elasticity of demand for cigarettes

In this section we detail the methods that lead to the derivations for the analysis of: the average price elasticity drawing from Colombian household survey data (2.1); and the price elasticity by income quintile drawing from studies from other Latin American countries (2.2).

2.1. 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 or ENCV) for the years 2003, 2010, 2011 and 2014 as the primary source of information [5]. The ENCV collected information on household expenditure on cigarettes only for these 4 years (i.e. we had four data points to estimate average price elasticity). The ENCV is a nationally representative, repeated cross-sectional survey of approximately 20,000 households each survey year. Our analysis includes a total of 83,017 households of which 10,159 reported a purchase of cigarettes over the past 7 days prior to their interview.

The ENCV provides information on the reported total weekly expenditure on cigarettes per household, yet not the number of cigarettes purchased nor their price. For this reason, we also used the Encuesta Annual Manufacturera (EAM) for each of the 4 years which provides information on the total annual number of cigarettes sold nationally and their value [6]. The World Bank World Development Indicators were used to extract the consumer price index for each survey year [7].

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:

$$\ln(Q) = \beta_0 + \beta_1(\ln(P)) + \beta_3(\ln(Y)) + \sum \beta_x(hh) + \beta_4(D) + \beta_5(U) + \varepsilon, \qquad (7)$$

where the included variables are defined as:

- Q: quantity of cigarette packs (20 units) purchased by the household on a weekly basis. Calculated using the household weekly expenditure reported in ENCV, divided by the average cigarette pack price on the given year (P) as reported in EAM.
- P: average price per cigarette pack (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 expenditure on food in the household. Calculated using ENCV.
- *hh*: includes the natural logarithm of the number of persons reported living in a given household, the natural logartihm of the percentage of children under the age of 18 that live in the household, the gender of the household head and the natural logarithm of the age of the household head.
- D: Department (subnational administrative unit). Departments included are only those from which data were collected across the 4 ENCV surveys included in the analysis.

- U: Urban location of the household. As reported in ENCV.

The average price elasticity of demand calculated was then: -0.44 (95% CI: -0.53 to -0.35).

2.2. 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 such 11 studies from 8 countries, which are summarized in Table A3. 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.

Table A3. Price elasticity of demand for cigarettes from the 11 Latin American country studies.

Country	Price elasticity	Source
Mexico	-0.52	Jimenez-Ruiz et al. 2008 [8]
Argentina	-0.27	Gonzalez-Rozada 2006 [9]
Argentina	-0.34	Martinez et al. 2008 [10]
Argentina	-0.31	Martinez et al. 2008 [11]
Brazil	-0.80	Lobao and Carvahlo 1998 [12]
Brazil	-0.80	Iglesias et al. 2007 [13]
Bolivia	-0.85	Alcaraz 2006 [14]
Chile	-0.45	Debrott Sanchez 2006 [15]
Mexico	-0.25	Olivera-Chavez 2010 [16]
Uruguay	-0.55	Ramos and Curti 2006 [17]
Peru	-0.70	Gonzalez-Rozada and Ramos-Carbajales 2016 [18]

Second, we used the interquartile range and mean of these 11 studies (IQR = 0.42 and m = -0.53) and applied it to the Colombian context i.e. the average price elasticity of -0.44 (as detailed in section 2.1), in the following so to derive price elasticity per income quintile:

$$PE_1 = PE_{av} + \frac{IQR}{2m} PE_{av} = -0.61;\ PE_2 = PE_{av} + \frac{IQR}{4m} PE_{av} = -0.53;\ PE_3 = PE_{av};\ PE_4 = PE_{av} - \frac{IQR}{4m} PE_{av} = -0.35;\ PE_5 = PE_{av} - \frac{IQR}{2m} PE_{av} = -0.26$$

(8) ,

where: IQR = 0.42, m = -0.53, and PE_{av} = -0.44.

3. Increased specific excise tax simulated after 2019

We use the base price per pack of cigarettes from 2019 (COP$ 1977) and the inflation rate from the International Monetary Fund of 3.5% per year [19] to calculate the new base price per pack in 2020 (COP$ 2046).

The projected value-added tax (VAT) for 2020 was calculated by adjusting the 2019 VAT for inflation (3.5% per year), and the surcharge was assumed to remain the same. Hence, the retail price without specific excise tax would be P = COP$ 3116.

When considering a specific excise tax constituting T of the retail price of cigarettes, we solve for X such that: T=X/(X+P). When T = 0.50, we obtain: X = COP$ 3116, and the retail price of cigarettes becomes COP$ 6232, i.e. a 18% increase compared with a 2019 price of COP$ 5269. When T = 0.70, we obtain: X = COP$ 7271, and the retail price of cigarettes becomes COP$ 10,386 i.e. a 97% increase compared with a 2019 price of COP$ 5269.

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