An extended cost-benefit analysis of tobacco taxation in Brazil*

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Executive Summary

Brazil has experienced a persistent and substantial reduction in the prevalence of smoking in the population since 2006 due to increased taxes on tobacco and other tobacco control policies. Despite the effectiveness of these measures, however, the socioeconomic costs of smoking are still very high. The objective of this study is to perform a comprehensive cost-benefit analysis resulting from a one-time tax increase on manufactured cigarettes using estimated conditional price elasticity of cigarette consumption and probability of smoking by income and age quartiles. The study uses data from the National Household Sample Survey (PNAD) of 2008 and the National Health Survey (PNS) of 2013 and applies cross section, pooled, and probit estimations. The study distinguishes between legal and illegal cigarette markets by using the minimum cigarette price defined by the government. The results of the study indicate that a tax increase of 10% in the cigarette price generates significant social benefits by reducing tobacco spending and medical expenses on tobacco-related diseases and increasing future years of life and net income. We recommend, in one of the possible scenarios, a raise in PIS/COFINS to generate the 10 percent increase on manufactured cigarettes. Most importantly, this policy is highly progressive, as its economic effects are much stronger for the poorest than for the richest individuals according to the quartiles of income.

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Key messages

- A tobacco tax increase would reduce cigarette consumption and benefit the entire Brazilian population, above all, the poorer and the younger.
- A 10% price increase due to higher tobacco taxes reduces cigarette consumption by about 5%.
- Higher tobacco taxes lead to lower medical expenses on tobacco related diseases and a longer, healthier and more productive life.
- Tobacco tax increases is a very effective progressive policy as it benefits the poorer the most. For each 10% price increase (BRL 0.54), poor smokers lead to net income gains by about BRL 39.00 per month (in 2019 values).
- The illegal cigarette market in Brazil is very large and consumers of illicit cigarettes do not completely share the price increase and the associated benefits.
- Strong tax administration and enforcement to prevent illicit trade is key in reaping the socio-economic benefits of tobacco tax increases.

Policy recommendation → The government should increase tobacco taxes and fight cigarette smuggling concomitantly in order to protect public health by reducing tobacco use and preserve the public budget by avoiding tobacco-related medical expenses and lost productivity.

Keywords: Price elasticity; Cigarette taxation; Illegal cigarette market; Cost-benefit analysis.

JEL Codes: I18; C21; H29.

1 Introduction

Brazil is usually referred to as a successful case of application of tobacco control policies, having experienced a persistent and substantial reduction in the prevalence of smoking in both total population and distinct cohorts since 2006. According to data from VIGITEL (Risk Factor Surveillance and Protection for Chronic Diseases by Telephone Survey), the percentage of smoking adults in the population decreased from 15.7 percent in 2006 to 10.1 percent in 2017. The country's adoption of the World Health Organization Framework Convention on Tobacco Control Convention (WHO/FCTC) and subsequent ratification by the Brazilian National Congress in 2005 coupled with a rigorous tax policy on cigarette production are considered milestones for this sharp decrease in smoking prevalence.

Two major mechanisms were employed to discourage smoking. First, tax policy was used to increase the price of cigarettes and secondly, legal restrictions were imposed to make smoking socially disfavored. This strategy was effective because it raised the monetary costs of smoking by raising taxes on the price of cigarettes and increased the inconvenience of smoking by imposing several legal restrictions on smoking behavior, such as forbidding smoking in public places, restricting cigarette marketing and sales, advertising against smoking, and others.

Despite the effectiveness of these tobacco control policies, the socioeconomic costs of smoking are still very high in Brazil. A recent study by Pinto et al. (2017), for instance, reports that cigarette consumption accounted for about 150,000 deaths in Brazil in 2015. Premature deaths that reduce the working life of smokers and healthcare costs for treatment of tobacco-related illness represent some of the major economic costs of tobacco consumption. The total cost to society amounts to 1 percent of gross domestic product (GDP) according to the estimates by Pinto et al. (2017).

A substantial fraction of these costs could be mitigated through an appropriate tax policy on tobacco products, especially on manufactured cigarettes. A tax increase on cigarettes contributes not only to raising the price of cigarettes and reducing consumption, but also to generating additional tax revenue to the government that could be used to defray the socioeconomic costs resulting from smoking. As of 2018, the total tax burden on cigarette prices was around 80 percent in most of the Brazilian states. This tax policy places Brazil among the countries with the highest tax burden on manufactured cigarette prices in the world.

Another important element to consider in tobacco tax policy is the illegal market of cigarette sales. Data from the Federal Revenue of Brazil indicate a decrease close to 50 percent in the legal production of manufactured cigarettes from 2006-2018. At the same time, the size of the illicit cigarette market in Brazil fluctuates: 28.6 percent (2012), 28.8 percent (2014), 42.8 percent (2016), and more recently, 31.4 percent (2018).[1] Thus, to some extent, Brazil could be

[1] The attempts to measure the illicit cigarette market in Brazil show different estimations, as illustrated in Table 9 of Ribeiro and Pinto (2019).

experiencing a substitution of legal cigarettes by illicit ones, which requires additional policy measures focused on curbing illicit trade.

The cigarette market is complex in all its dimensions and requires an optimal combination of public policies in order to mitigate the economic costs of smoking to the society as a whole. The objective of this study is to provide a comprehensive cost-benefit analysis resulting from tobacco taxation in Brazil using estimated price elasticities of cigarette consumption by different cohorts of the population. This analysis is essential to understanding the smoking behavior of individuals and to evaluate the associated economic costs of smoking to the Brazilian society.

Based on the National Household Sample Survey (PNAD) of 2008 and the National Health Survey (PNS) of 2013, the study estimates conditional price elasticities of cigarette consumption and probability of smoking by quartile of income and age groups. This study applies a novel identification strategy based on the minimum cigarette price defined by the government in order to capture the effects of the illegal market of cigarettes on the estimation of price elasticity. The potential endogeneity problem is accounted for by using the average regional price instead of the unit price as a regressor. By doing so the study reduces the risk of correlation between the unit price and the residual in the estimated models. The study also implements a distributive incidence analysis of tobacco taxation to estimate the effect of increasing tobacco excise taxes, considering tobacco consumption, healthcare costs, and household income. As in Fuchs and Meneses (2017) and Fuchs et al. (2018), three types of effects resulting from a change in the tax scheme are considered: i) increase in tobacco spending, ii) reduction in medical expenses and iii) increase in income due to the gain in future years of working life. Based on the empirical findings, the study provides policy recommendations for tobacco taxation in the country.

The major results indicate that, considering the legal market of cigarettes and correcting for endogeneity, the estimated conditional price elasticity (or smoking intensity) of cigarette consumption ranges from -0.37 in the first quartile of income to -0.44 in the fourth quartile. The unconditional price elasticity, which considers the probability of starting or quitting smoking in the entire population, ranges from -0.27 to -0.30 from the first to fourth income quartile, respectively. Thus, the total price elasticity of demand for cigarettes is -0.47 in the first quartile and -0.55 in the fourth quartile of income. These elasticities of demand for cigarettes suggest that a tax policy that increases cigarette prices could be very effective to reduce cigarette consumption in Brazil.

Considering age groups, the study finds a conditional price elasticity (or intensity) of cigarette consumption of -0.54 for people between 15 and 29 years old and a conditional price elasticity of -0.19 for people 60 or more years old. Given that unconditional (or smoking prevalence) price elasticity ranged from -0.24 to -0.39, the total price elasticity of demand ranges between -0.45 and -0.40 for people within those age groups, respectively. Again, these estimated values suggest a demand for cigarettes among age groups that is very sensitive to price variation. Thus, adoption of public policies based on tax increases to reduce the smoking behavior is supported by the evidence.

The extended cost-benefit analysis considers an increase of 10 percent in the price of cigarettes resulting from higher taxes on manufactured cigarettes. The analysis uses the estimated price elasticities of demand to simulate the effect of the price increase on tobacco spending, medical expenses and wage income due to the gain in future years of employment. The positive net income effect of the decrease in cigarette consumption due to a 10 percent increase in cigarette taxes reaches 4.24 and 5.13 percent in the first and second income quartiles, respectively. These gains in income come from combining the increase in cigarette expenses due to the higher price, reduction in medial expense with the decrease in smoking, and gain in future years of working life due to health improvement. These gains decrease as the quartiles of income increase, indicating the progressiveness of this tax policy.

Considering the net income effect by age group, there are similar results. The highest income effects are for the young, (15-29 years old) and middle aged (40-59 years old). This is because younger people have lower income and thus a higher benefit from future years of working life by reducing or quitting smoking. Middle-aged people also have high net income effects because smoking-related illnesses and disease usually appear at this age and result in elevated medical expenses for treatment.

The paper is organized as follows. The next section discusses the related literature. The third section describes the tax policy for cigarettes in the Brazilian economy. The fourth section reports and analyzes data on the smoking behavior of the Brazilian population. The econometric method used in the estimations of the price elasticity of demand is presented in the fifth section. The sixth section reports and explains the estimated values of the price elasticity by quartile of income and age groups, controlling by type of market (legal, illegal, and both) and correcting for endogeneity. The seventh section reports and discusses the extended cost-benefit analysis resulting from an increase in cigarette taxes. Finally, the eighth section is dedicated to the concluding remarks and policy recommendations.

2 Literature

The empirical literature on tobacco economics is extensive and includes applications to several countries around the world. Theoretically, it relies on the studies of addictive goods, as pioneered by Stigler and Becker (1977), Becker and Murphy (1988), Becker (1996), among others. Chaloupka (1991) applied the rationality model of Becker and Murphy (1988) and concluded that addiction increases the price elasticity of demand by cigarettes in the long run. In addition, the young and the less educated are myopic when compared to adults or those more educated and prohibition of smoking in public places is a very effective policy against cigarette consumption. For the Brazilian economy, there are a few empirical applications mostly focused on the estimation of price and income elasticities of cigarette consumption.

Carvalho and Lobão (1998) are among the first to estimate regressions of demand for cigarettes in Brazil. They used aggregate quarterly data from 1983 to 1983 and computed price and income elasticity of cigarette consumption. They found price elasticities of -0.11 and -0.80 in the short

and long run, respectively, in their estimates by OLS. Using the so-called rational model, they found price and income elasticities of -0.14 and 0.23, respectively, in the short run and -0.49 and 0.80 in the long run.

Another contribution is provided by Iglesias (2006), who analyzed the demand for cigarettes in the period from 1991 and 2003 and found short run price elasticity of -0.25 and long run price elasticity of -0.42. The relation between cigarette consumption and income, besides being positive, was not statistically significant in the OLS estimates. Thus, tax policies that increase the price of cigarettes would be more effective in the long run to affect the cigarette demand.

Later on, Iglesias et al. (2007) extended the original sample up to 2007 and found values of -0.27 and -0.48 for the re-estimated price elasticities in the short and long run, respectively. The income elasticity kept a positive relationship with consumption of cigarettes but remained statistically not significant. These findings confirmed the results by Iglesias (2006).

Ribeiro and Pinto (2019) also estimated aggregate price-elasticity of cigarette consumption for the Brazilian economy using data for the period from 2000 to 2018 and considering implicit per capita consumption as a proxy of consumption and per capita disposable earnings as a proxy of income. Their estimates for the legal tobacco consumption indicate price-elasticity ranging from -0.55 to -0.65, depending on model specification and sample considered.

An attempt to estimate the price elasticity of participation, that is, the individual's decision of smoking or not, was made by Lampreia et al. (2015). They used household survey data from the 2008 National Household Sample Survey (PNAD) and found very low values for price and income elasticities of participation. Specifically, they estimated values of -0.05 and -0.06 for the price and income elasticities of individuals' participation in the consumption of cigarettes. Their estimated values were not statistically significant at the standard 95 percent confidence level. Conditional on participation, that is, considering only individuals that reported a strictly positive consumption of cigarettes in the sample, they estimated price and income elasticities of -0.06 and -0.04 for the demand of cigarettes. These results, however, could be biased because of the effects of the illegal market of cigarette sales, which they did not account for in the estimations. As illustrated in the next section, using the same PNAD 2008 data base, the price elasticity of demand increases considerably once controlling for the effect of the illegal market of cigarettes because it makes the demand very insensitive to price variations.

The economic information resulting from the estimated coefficient of the price-elasticity by itself disentangles the effect of a cigarette price increase on cigarette consumption. In addition, this elasticity is also a fundamental input to the estimation of the net economic costs of tobacco consumption according to the extended cost-benefit methodology proposed by Fuchs and Meneses (2017) and Fuchs et al. (2018). The price-elasticity is used to simulate the impacts of alternative excise tax schemes on cigarette prices, consumption, and tax revenue of the government.

According to Fuchs et al. (2018), there are three channels by which a tobacco tax increase could affect social welfare. The first channel is that higher cigarette prices due to higher tobacco

taxation reduces cigarette consumption and prevents smoking initiation. The second channel comes from the reduction in healthcare expenses associated with the averted treatment costs of tobacco-related diseases and the third one is the increase in income due to gains in years of employment derived from an extension in life expectancy. Based on Fuchs and Meneses (2017), Fuchs et al. (2018) estimates the impact of these channels by estimating price elasticity of tobacco and calculating the welfare gains among various income groups resulting from a tobacco tax increase that raises cigarette prices and lowers tobacco consumption.

We will apply a similar methodology to access the welfare gains resulting from a tax increase in manufactured cigarettes for Brazil by using household survey data from 2008 and 2013. We will estimate price elasticity of cigarette consumption by gender, income quartiles, and age groups and use the minimum price defined by the government for cigarette sales to identify the effect of the illegal market on the price elasticity of cigarettes. The estimated elasticities will be used to implement an extended cost-benefit analysis of increasing tobacco taxes on aggregate welfare by income quartiles and age groups.

3 Cigarette taxes

Taxes that could affect cigarette prices directly are import taxes and typical consumption taxes given by IPI, ICMS, and PIS/COFINS. The PIS/COFINS is a social contribution levied on the turnover of the companies with special treatment for cigarette taxation.[2] Taxes on imports, IPI, and PIS/COFINS are federal taxes, while ICMS is a state tax. There are no local taxes on cigarettes. This section considers the IPI, ICMS, and PIS/COFINS as representative taxes for manufactured cigarettes because regular imports of cigarettes in Brazil are very small relative to the cigarette consumption. In the last three years, for instance, cigarette imports reached 2.8 percent of the legal market. Therefore, the import tax is not a relevant issue for cigarette price formation. At the same time, the three other taxes (IPI, ICMS, and PIS/COFINS) are also levied on imports of goods, including cigarettes. These consumption taxes also apply to imports, but they are not levied on exports. However, there is a 150 percent export tax on cigarettes exported to South and Central America, including Caribbean countries (to curb cigarette smuggling back to Brazil).

3.1 Tax on manufactured goods

The IPI (also called the tax on manufactured products) is a federal tax. It is considered the closest to an excise tax because the tax rate varies according to the relevance of the good to the society. IPI is also levied on imports, and the tax base is the same as the tax on imports plus the amount of import tax due in the same import operation. The IPI is a non-cumulative tax (a VAT type of tax). However, the tax is levied only within the production chain. This means that manufactured

[2] This section is derived from a more comprehensive work by Valadao (2019), not yet published (IDB). For a more detailed description of Taxation of cigarettes in Brazil see also Ribeiro and Pinto (2019).

inputs are charged with IPI and the legislation allows for credit for the next link of the production chain.

For cigarettes, the IPI can also be levied under a specific rate, together with the ad valorem, under a special tax regime, which is adopted by all cigarette manufacturers (resulting in lower taxation than the regular regime, with an ad valorem tax rate of 300 percent) (Ribeiro & Pinto, 2019 p. 15) . This methodology was introduced by Decree no 7.555/2011, which also introduced a minimum price for price of cigarettes at retail level. In 2016, Decree no 8.656/2016 (Brasil, 2016) amended the 2011 decree, introducing changes to the final rates, but did not change the final minimum price. The tax base for the ad valorem rate is 15 percent of the retail price (which manufacturers must disclose to the Federal Revenue Service) (art. 15, Law n. 12.546/2011 (Brasil, 2011)). The schedule of the rates is in Table 1 (Decree no 7.555/2011, as amended, art. 5o).

Table 1: IPI tax rate and specific values

		Specific (BRL)	
Period in force	Ad Valorem (%)	Soft pack	Hard pack
01/12/2011 to 30/04/2012	0.0	0.80	1.15
01/05/2012 to 31/12/2012	40.0	0.90	1.20
01/01/2013 to 31/12/2013	47.0	1.05	1.25
01/01/2014 to 31/12/2014	54.0	1.20	1.30
01/01/2015 to 30/04/2016	60.0	1.30	1.30
01/05/2016 to 30/11/2016	63.3	1.40	1.40
01/12/2016 onwards	66.7	1.50	1.50

3.2 PIS/COFINS

The PIS (Contribution for the Social Integration Program) and COFINS (Contribution for Financing Social Security) are levied on all the production and commercial trade chain, from the extraction of raw material from nature to the retail sales, it may be VAT type depending on the company. For the cigarette sector, the PIS/COFINS calculation is subject to a special regime called tax substitution. Under this special tax regime, the importer or manufacturer of cigarettes is responsible for the PIS/COFINS. As illustrated in Table 2, this special regime also applies different tax rates to PIS/COFINS and different tax basis, which has been changing over time (presumably also due to tobacco policy). The importer of cigarettes will have to pay the PIS/COFINS on imports under the cumulated rate of 11.75 percent (before May 1st, 2015 it was 9.25 percent), but this tax paid will not be considered as tax credit when calculating the PIS/COFINS due to domestic sales, making imports even more costly in terms of taxation. In 2019, the RFB issued the Revenue Ruling (Cosit) n. 49/2019 (Brasil, RFB, 2019) stating that in situations where retail prices of the same brand vary among Brazilian states, the import company (and presumably the manufacturer) must use the highest cigarette pack price at the retailer to calculate the amount due of PIS/COFINS.

Table 2: PIS/COFINS tax rates and tax basis

Period in force	PIS (BRL)	COFINS (BRL)
Until 28/02/2006	0.65% x 1.38 x Retail Price	3% x 1.18 x Retail Price
01/03/2006 to 30/06/2009	0.65% x 1.98 x Retail Price	3% x 1.69 x Retail Price
01/07/2009 onwards	0.65% x 3.42 x Retail Price	3% x 2.9169 x Retail Price

Additionally, the PIS/COFINS legislation also imposes some restrictions on the cigarette sector. For instance, it is forbidden by law to sell cigarette paper to companies other than cigarette manufacturers (Law no 10.833/2003, art. 54 (Brasil, 2003). This prohibition intends to inhibit the supply of inputs to illegal cigarettes manufacturers, inside and outside the country.

3.2 ICMS

The ICMS (tax on the circulation of goods and services) is a state tax (Constitution, art. 155, II), and is the most important source of tax revenue of the Brazilian states. By constitutional rule, the ICMS is non-cumulative, that is, it is a VAT type of tax. Thus, each taxpayer may deduct the previous paid ICMS from the ICMS due for its sales. It is levied on sales of goods and services in general, from raw materials to final retail sales. The tax rates are not uniform across states. However, as a general rule, the states apply 17 percent or 18 percent for internal transactions (intrastate transactions), but there are exceptions, both to higher tax rates (applicable to non-essential goods, such as cigarettes) or lower tax rates (in general, to food-related goods). The interstate rates are lower and depend on the geographical region of origin of the merchandise. The tax rates on imports are the same as those applicable to intrastate transactions.

The tax burden on cigarettes due to ICMS and the related tax structure is of interest. Cigarettes are also submitted to the same simplification tax measure applied to PIS/COFINS, which is the tax substitution or tax anticipation (Silva, 2017, 393-394). Under this special tax regime, the ICMS tax rate is applied to the retail price, but the tax is collected from the cigarette manufacturer or the importer. Additionally, states can apply an additional ICMS tax rate (a surtax) on non-essential goods to fund public policy addressing poverty, named as Fund to Fight and Eradicate Poverty (FFEP) (Queiroz, Valadão and Lopes, 2016). Cigarettes are included in FFEP. However, not all states have adopted such a measure.

The variation of ICMS tax rates is one of the reasons why cigarette prices vary across states. Other reasons are different values for freight and insurance and market conditions. ICMS is calculated in a way that the final price also includes the tax itself (the tax is part of its own tax basis). For detailed information on the ICMS tax rates for the 26 Brazilian states and the Federal District along with the respective FFEP surtax see Ribeiro and Pinto (2019, p. 29).

3.3 Cigarette prices and tax collection

Until May 1st, 2012 there was no mandatory minimum price for cigarettes in Brazil. Art. 7o of the Decree no 7.555/2011, as amended, imposed a minimum price, which has evolved as illustrated in Table 3 below.

Table 3: Cigarette minimum price (20 cigarettes per pack)

Period in force	Minimum price
01/05/2012 to 31/12/2012	BRL 3.00
01/01/2013 to 31/12/2013	BRL 3.50
01/01/2014 to 31/12/2014	BRL 4.00
01/01/2015 to 30/04/2016	BRL 4.50
01/05/2016 onwards	BRL 5.00

Considering all taxes levied on cigarettes (IPI, PIS/COFINS and ICMS), Table 4 illustrates how cigarette production and tax revenue, at constant prices of 2000, evolved from 2000 to 2018 in the Brazilian economy. It is worth mentioning the sharp decline in the tax revenues from IPI and PIS/COFINS of -15.4 percent and -13.2 percent, respectively. This decline was compensated by an increase of 91.3 percent in revenue from ICMS, resulting in an 11.5 percent increase in the total tax collection from manufactured cigarettes.

Table 4: Cigarette tax revenues by tax type (Prices of 2000, BRL million) and production

Year	IPI	PIS/COFINS	ICMS	TOTAL	Production (Packs)
2000	1,998.0	671.0	881.0	3,550.0	4.867.922.778
2001	1,864.0	619.5	1,031.8	3,515.3	5.346.219.997
2002	1,587.9	653.7	872.4	3,113.9	5.110.545.058
2003	1,504.9	662.2	992.9	3,160.1	5.353.050.062
2004	1,617.6	649.1	1,645.6	3,912.3	5.540.029.712
2005	1,529.2	699.2	1,669.3	3,897.6	5.614.441.534
2006	1,542.5	710.1	1,407.3	3,660.4	5.603.383.165
2007	1,727.5	846.2	1,341.0	3,914.7	5.701.585.971
2008	1,868.6	699.5	1,390.8	3,958.9	5.410.313.930
2009	1,848.8	1,042.1	1,387.5	4,278.4	4.925.672.958
2010	1,951.6	1,194.2	1,605.0	4,750.9	4.860.072.153
2011	1,851.8	1,281.5	1,572.8	4,706.1	4.878.812.545
2012	1,905.2	1,265.5	1,613.6	4,784.3	4.455.585.589
2013	2,249.0	1,258.8	1,648.0	5,155.8	3.827.238.968
2014	2,344.5	1,244.4	1,724.2	5,312.7	3.635.198.380
2015	2,128.1	1,072.7	1,648.6	4,849.4	3.160.289.540
2016	2,011.8	727.2	1,741.7	4,480.7	2.660.457.115
2017	1,747.3	631.8	1,603.9	3,982.6	2.885.369.269
2018	1,691.2	582.2	1,685.2	3,958.7	2.932.061.782
Change 2018/2000	-15.4%	-13.2%	91.3%	11.5%	-39.8%

4 Smoking behavior

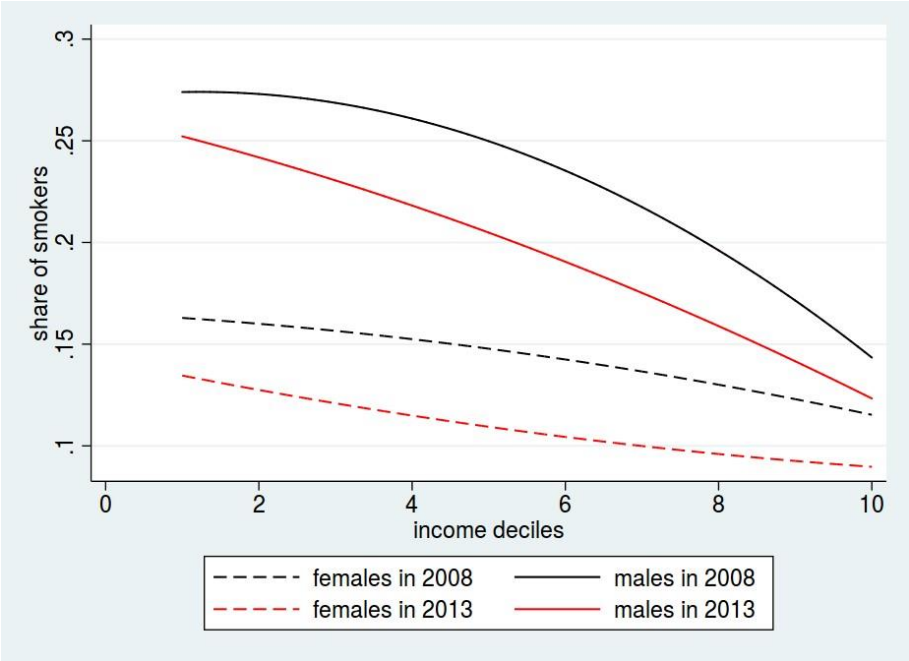
In order to describe the smoking behavior of the Brazilian population and to estimate the sensitivity of cigarette consumption regarding cigarette prices, this study uses two individual surveys: the PNAD from 2008 and the PNS from 2013. Both are repeated surveys for distinct purposes, but in the two selected years, their questionnaires includes a special section on smoking behavior. We select those relevant items that are identical in both questionnaires to guarantee comparability between the two years and uniformity of analysis. The PNAD and the PNS are representative surveys, which are organized by the Brazilian Institute for Geography and Statistics (IBGE). Both have a household and an individual component. This study focuses on the latter questionnaire because smoking behavior is essentially individual. The use of the provided sample weights makes the following statistics representative of the entire population. For further details about the surveys, see INCA (2010) and Szwarcwald et al. (2014).

This analysis focuses on individuals aged 15 and above who smoke cigarettes. The PNAD and PNS provide the usual socioeconomics characteristics, such as gender, age, education, and aggregate monthly income of the respondent. This latter variable will be of particular importance because the question of whether tax changes are progressive, regressive, or income neutral is crucial for policy makers when it comes to gathering support for the reform. Moreover, price sensitivity of consumers may vary according to the income level and, consequently, the outcome in the extended cost-benefit may be more or less pronounced. The study also distinguishes between gender and age because the following descriptive statistics make clear that there are pronounced differences between men and women.

Figure 1 shows the proportions of regularly smoking men and women across income deciles in 2008 and 2013. The data confirm that women have a lower probability of smoking than men. In 2008, 14.2 percent of all women smoked cigarettes as compared to 22.1 percent of men. These shares dropped to an average of 11.2 percent and 18.5 percent, respectively. The figure also reveals that, independent of gender, the propensity of smoking declines monotonically with income. About 17 percent of women and 27 percent of men in the lowest income decile smoked in 2008, as compared to 12 percent and 15 percent in the highest income decile. Again, these shares unambiguously decreased over time.

One of the reasons for the observed reduction of cigarette smokers in Brazil is the continuous increase of tobacco taxes and thus cigarette prices. Two features of cigarette taxes are important for the understanding of the changes in smoking behavior between 2008 and 2013. First, in 2011, the government established a minimum price for a pack of cigarettes through federal law number 12.546. In 2013, this minimum price was equal to 3.50 BRL. Secondly, several specific tobacco taxes determine the final price of cigarettes. Some of them are the same across the country while others are specific by federal states. Therefore, notwithstanding differences in cost for transport, distribution, among others, cigarette prices differ substantially between regions.

Figure 1: Proportions of smokers by gender and income decile in 2008 and 2013



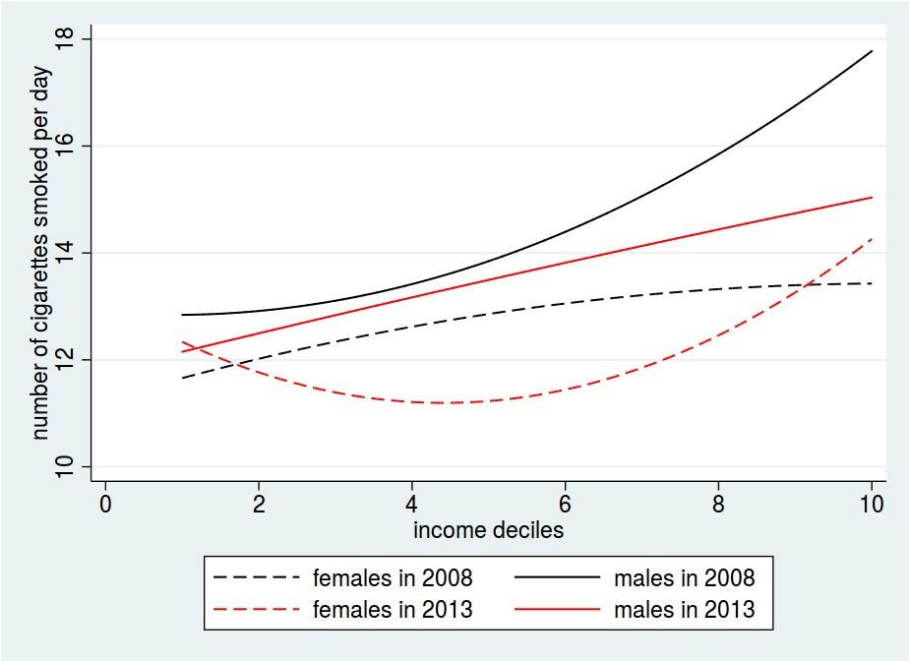
Notes: The graph visualizes the share of individuals aged 15 and above who smoke cigarettes according to the PNAD and PNS survey in 2008 and 2013, respectively. The calculation uses the survey weights.

Furthermore, the respondents indicate how many cigarettes they smoke per day and at what age they started smoking. A key distinction of the chosen PNAD and PNS data in comparison to household survey price data is that the information regarding the quantity and total price of cigarettes refers to the last purchase. The first advantage of this type of question is that it includes all kinds of markets where cigarettes are sold and thus prices are highly accurate and relevant. According to INCA / the Ministry of Health, the size of the illicit market decreased recently from 37.5 percent in 2017 to 31.4 percent in 2018. A collection of market prices is thus unlikely to reflect the actual prices that consumers face regularly. Second, since the question concerns a single and individual purchase the answer is precise and less likely to be subject to measurement error. The calculated price per cigarette is therefore much closer to the true market price of a cigarette than the unit values inferred in common household survey data, where several household members may smoke distinct brands and pay different prices.

Consequently, it will be very fruitful to exploit the official minimum price for a 20-cigarette pack, which in 2013 was equal to BRL 3.5. Purchases below this price most likely occurred in the illicit market. In the PNS data, one-third of all consumers purchased cigarettes below that official price floor. Since there was no official minimum price in 2008, a price floor of BRL 2.6 was imputed using the assumption that the share of the illicit market remained constant.[3]

[3] The percentile in the reported cigarette price distribution in 2008 that corresponds to the percentile of the minimum price in 2013 was used to impute the minimum price in 2008, resulting in a minimum price equal to BRL 2.60.

Figure 2: Cigarette consumption by gender and income decile in 2008 and 2013

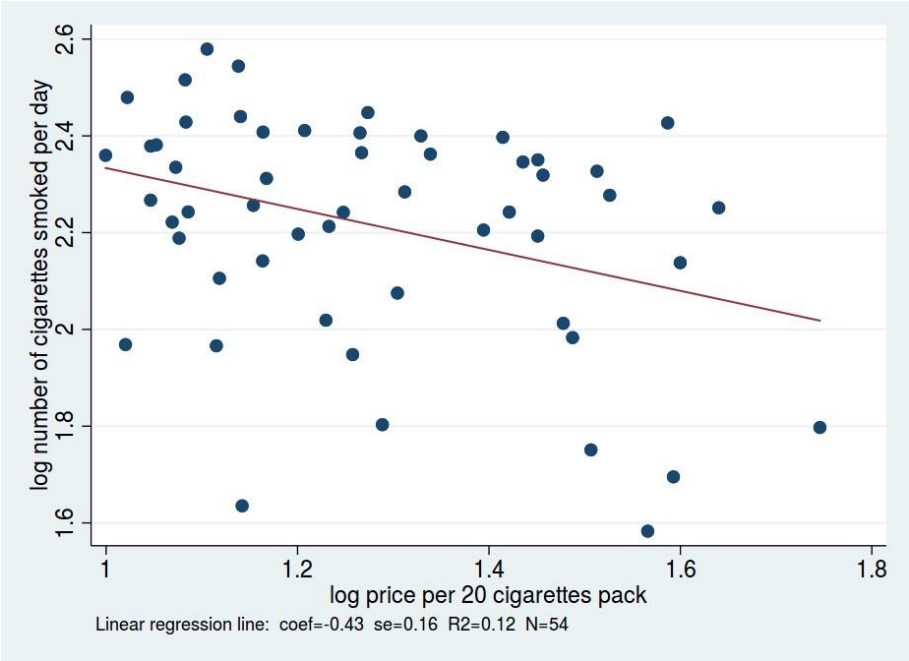


Notes: The graph visualizes the average number of cigarettes smoked by individuals aged 15 and above who smoke regularly according to the PNAD and PNS survey in 2008 and 2013, respectively. The calculation uses the survey weights.

Figure 2 shows how the intensive margin of smoking (smoking intensity) differs between income deciles of men and women. In contrast to the extensive margin (or smoking prevalence), individuals with high incomes tend to smoke more cigarettes per day. This difference is more pronounced for men than for women, where the difference between the highest and lowest income decile is not more than two cigarettes per day. For men the difference is about twice as high. Not only do men have a higher propensity to smoke regularly, they also are heavier smokers. In 2008, men smoked about 4 cigarettes more per day, while this number fell to between 0 and 3 in 2013, depending on income. The figure thus reconfirms the general reduction in smoking over time.

Finally, Figures 3 and 4 show the main information for the estimation of the price elasticities. Because the data do not follow individuals over time, the identification of elasticities stems from the smoking behavior of different individuals who face different cigarette prices, mainly because of regional taxation differentials. Figure 3 is a graphical representation of a simple linear regression of log cigarette consumption on log prices across federal states in the two observation periods. Although there are differences in income and other economic characteristics across Brazilian regions, the amount of variation in the relatively homogeneous cigarette products is extraordinary. The relation between the two variables in clearly negative, highly significant and the estimated coefficient of -0.43 can be interpreted as a first, unconditional price elasticity.

Figure 3: Price and consumption across federal states and years



Notes: The graph shows the relation between the average price of cigarettes and the consumption of cigarettes by individuals aged 15 and above who smoke regularly according to the PNAD and PNS survey in 2008 and 2013, respectively. Each dot in the graph represents the average of a federal state in either 2008 or 2013. Because both variables are measured in logarithmic scale, the estimated linear fit can be interpreted as a price elasticity.

Figure 4 displays how the prices for a cigarette pack in the last purchase differ by gender and income decile in 2008 and 2013. Whereas graph (a) shows the results for all smokers, graphs (b) and (c) distinguish between purchases in the legal (or formal) and illegal (or informal) market. Cigarette purchases below the minimum price fixed by the government according to federal law number 12.546 from 2011 are considered to be illegal. In the legal market, no cigarette brand can be sold below the minimum price, which was fixed as BRL 3.50 in 2013. This strategy identifies only a fraction of the entire illegal market because premium brands are sold above the minimum price in both legal and illegal markets. The descriptive statistics indicate that individuals who buy their cigarettes in the illicit market are heavier smokers. Moreover, these individuals are also older, more likely to have lower educational attainment and lower income, and have smoked for more years. All of these characteristics support the interpretation that customers in the informal market are more addicted to tobacco and thus are less sensitive to price changes.

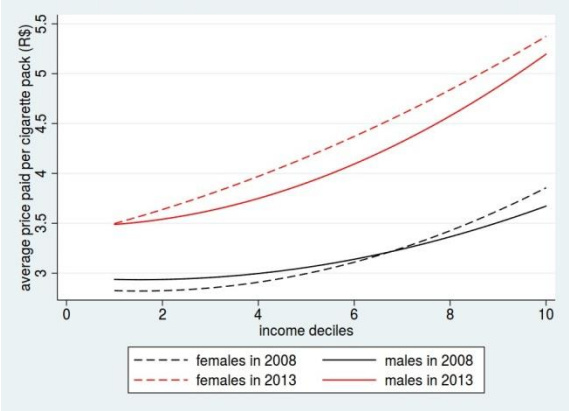
The illegal cigarette market is of special interest for tobacco control policy making because it directly affects some of the most vulnerable groups in the society. This identification strategy captures the effects of the illegal cigarette sales on these social groups.

In all three cases, men and women in the same income decile spend about the same amount of money for a 20-cigarette pack. Yet, there are important differences between the legal and illegal markets. The aggregate representation in graph (a) suggests that a less constrained budget leads smokers to buy more expensive brands. In 2013, for example, the average price in the

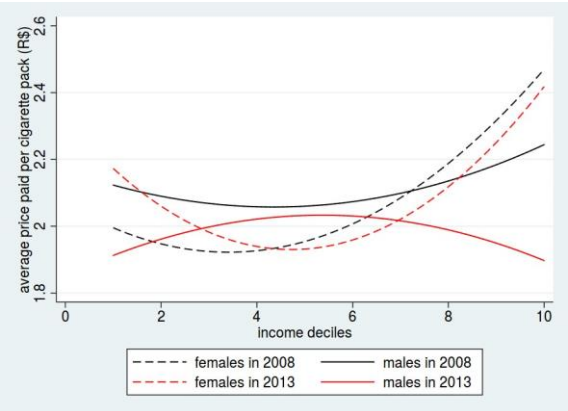
lowest income decile is close to the then recently introduced minimum price of 3.5 BRL, while consumers in the top decile spend 1.5 BRL more per pack. These differences are reasonable but still lower than those observed by Fuchs and Meneses (2018) in Moldova, where the average prices between the first and last income decile differ by a factor of more than two.

Figure 4: Cigarette prices by gender, income decile, and market in 2008 and 2013

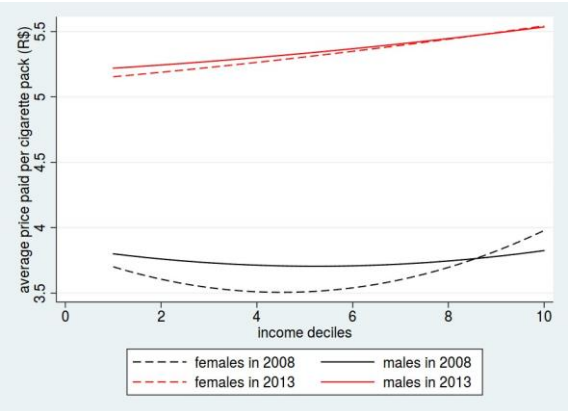
(a) licit and illicit



(b) illicit



(c) licit



Notes: The two graphs illustrate the average price of cigarettes paid by individuals aged 15 and above who smoke regularly according to the PNAD and PNS survey in 2008 and 2013, respectively. The left figure includes only smokers who obtain their cigarettes over (or in?)the illicit market. The right figure refers to purchases in the licit market. The calculations use the survey weights.

However, the distinction by source of the cigarette market reveals that the price paid per pack is almost constant along the income distribution in the legal market and not higher than 20 percent in the illegal market. Most importantly, the cigarette tax increases between 2008 and 2013 mostly affected prices in the legal market. In the illegal market, prices could also have increased by a smaller fraction because cigarettes are close substitutes in the two markets and sellers could have taken the chance to raise profit margins in the illegal market. Considering the whole market, prices increased by about 50 percent on average, while the general price level increased by 28.5 percent as measured by the official consumer price index (IPCA). The truth

about the rising price paid per pack along the income distribution is that richer individuals tend to acquire their cigarettes in the formal market, whereas a larger share of low-income individuals resort to illegal sources of cigarettes and could avoid restrictions from the price regulations and tax increases.

For completeness, Table 5 reports summary statistics for the main variables in the estimations. Years 2008 and 2013 are pooled but the sample is divided into the three dimensions that are important in the following price elasticity estimations and for the calculations in the consequent extended cost-benefit analysis. Columns (1) to (4) divide the sample according to income quartiles, the following two columns distinguish between the source of cigarette purchases, that is, the licit or illicit market and, finally, columns (7) and (8) show the characteristics for the group of smokers vs. non-smokers. Despite the observations from the previous figures, one also sees that the share of income spent on cigarette consumption varies between 16 percent in the lowest income quartile and 3 percent in the fourth quartile. Males are misrepresented in the two highest income quartiles. Women represent 62 percent of the smokers in the lowest income quartile. The Table confirms that male smokers, poorer individuals, and those from the lower two education groups are more likely to buy cigarettes from the illicit market. Finally, the socioeconomic characteristics are much more balanced between smokers and non-smokers.

Table 5: Descriptive statistics by subgroups – 2008 and 2013

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample:	Inc. Q1	Inc. Q2	Inc. Q3	Inc. Q4	Licit	Illicit	Non-sm.	smokers
% smokers	0.18	0.18	0.17	0.14	1.00	1.00	0.00	1.00
	[0.39]	[0.38]	[0.37]	[0.34]	[0.00]	[0.00]	[0.00]	[0.00]
% income	0.16	0.08	0.06	0.03	0.10	0.08	0.00	0.09
cigarettes	[0.24]	[0.08]	[0.05]	[0.03]	[0.16]	[0.13]	[0.00]	[0.15]
age	44.30	39.95	42.31	46.21	42.25	43.55	43.53	42.70
	[18.95]	[16.36]	[16.25]	[14.93]	[14.13]	[14.54]	[17.46]	[14.28]
Educ. [1]	0.38	0.21	0.18	0.07	0.16	0.34	0.21	0.22
	[0.48]	[0.41]	[0.39]	[0.26]	[0.36]	[0.47]	[0.41]	[0.41]
Educ. [2]	0.35	0.34	0.32	0.20	0.38	0.45	0.29	0.40
	[0.48]	[0.47]	[0.46]	[0.40]	[0.48]	[0.50]	[0.45]	[0.49]
Educ. [3]	0.23	0.37	0.37	0.31	0.32	0.18	0.32	0.27
	[0.42]	[0.48]	[0.48]	[0.46]	[0.46]	[0.38]	[0.47]	[0.44]
Educ. [4]	0.04	0.08	0.13	0.41	0.15	0.04	0.18	0.11
	[0.20]	[0.27]	[0.34]	[0.49]	[0.36]	[0.19]	[0.38]	[0.31]
% male	0.38	0.46	0.58	0.63	0.62	0.63	0.48	0.63
	[0.49]	[0.50]	[0.49]	[0.48]	[0.48]	[0.48]	[0.50]	[0.48]
income	440.9	717.1	1119.1	3986.5	1781.0	872.8	1590.9	1467.8
	[199.3]	[101.8]	[232.8]	[5972.0]	[2992.6]	[946.1]	[3480.1]	[2522.2]
Obs.	28,809	11,846	20,472	20,126	6,473	3,335	68,086	9,808

Notes: The table shows mean values and standard deviation (in brackets) for the main variables in different subsamples using the sample weights. Columns 1 to 4 refer to the four income quartiles. Columns 5 and 6 divide the subgroup of smokers into those that bought their cigarettes in the legal and illegal markets, respectively. Columns 7 and 8 divide the entire sample according to smokers and non-smokers, respectively.

5 Methodology

The main purpose of this research is to estimate price elasticities of tobacco consumption by distinct population cohorts and conduct an extended cost-benefit analysis following Fuchs and Meneses (2018). To this end, we will estimate the overall effect of increasing tobacco taxes on i) spending on cigarettes, ii) medical expenses, and iii) income in future years of working life.

The key parameter in this cost-benefit analysis is the price elasticity of cigarette consumption. Its value indicates how individuals adjust their consumption to price changes. Specifically, the price elasticity (ε) measures how many percentage points the amount of cigarette consumption will decrease if the final price of cigarettes is increased by one percent. To account for the potentially different effects of a tobacco tax increase over the income distribution, price elasticities are estimated for each income decile. Therefore, the results can capture whether the tax change is progressive or regressive, that is, whether rich individuals are relatively more or less affected.

The conditional price elasticities are derived from the following estimation:

$$lnQ_{idt} = \alpha + \sum_d \varepsilon_d lnP_{idt}.I_{dt} + \beta \boldsymbol{X}_{idt} + e_{idt} \qquad (1)$$

where Q_{idt} is the number of cigarettes smoked per day by individual i in income decile d and year t, P_{idt} is the price that individual i actually paid per cigarette, I_{dt} is a binary variable that indicates to which income decile the individual belongs and the vector X_{idt} includes control variables for age, education, years of smoking, income, gender and federal state fixed effects. e_{idt} is the random error term of the regression. Some alterations are then made to this baseline equation. Among others, eq. (1) is estimated for the two years and gender groups either in combination or separately. Income quartiles are used instead of income deciles and the sample is divided in further subgroups according to age and the source of cigarette purchase, that is, the legal or illegal market.

A critical issue with eq. (1) is that tax and price increases could induce individuals to either reduce consumption, change to cheaper brands or both. In theory, the price elasticity should only indicate how much price affects individuals' actual consumption, correcting for an expenditure reduction based on substitution in favor of cheaper brands. Deaton (1988) proposed a solution to this problem. Under two relatively restrictive assumptions it is possible to impute the quality substitution using the income elasticities of quality and quantity: (1) household utility is weakly separable and (2) it is possible to identify local markets between which prices vary but within a local market individuals face the same prices. Deaton's method is applied in many empirical papers, including the estimation of cigarette price elasticities. For instance, see McKelvey (2011) for a critical discussion.

The Deaton (1988) correction was developed for household survey data, whereas this study uses individual survey with a different questionnaire structure. First, under the plausible assumptions that smokers did not buy different brands in their last purchase and that it is representative for their usual consumption behavior, the inferred unit price for cigarettes P_{id} is

more precise than those inferred in household consumption surveys. Unit value could not be equal to the actual price because it is an approximation from the households' total expenditure divided by total physical quantity, which is usually measured in kilograms (John et al. 2019).

Second, it is likely that more than one member of a household smokes and that the different smokers consume cigarettes of different brands. Moreover, the expenditure share for this product class may be mixed with other tobacco related products. Thus, average unit values do not indicate how much prices, brand and quality vary within the household. The problem of varying unit values is more pronounced for more heterogeneous goods and for categories with a broader definition, such as meat. The average unit values also tend to be less precise, the longer the observation period in the household survey, whereas in this case, a single purchase is identified.

Since the product is highly similar but prices between different brands vary quite substantially, consumers may adjust to price changes by switching to a cheaper brand. To deal with a possible endogeneity bias and the problem of misreporting the price of the individuals' last purchase, leading to measurement error and the well-known attenuation bias in the coefficients towards zero, reported prices are substituted with average prices in each federal state. Prices differ substantially between federal states because a part of the tobacco tax rate is state-specific and because distribution and transport costs to the interior of the country are quite high due to poor infrastructure (Ehrl and Monasterio, 2019). These average prices can be seen as exogenous to the individual consumer and this procedure can be understood as an adaptation of the Deaton (1988) method to the context of individual-level data.

Another threat to the correct identification of tax adjustments is that a price change may induce individuals either to start smoking or to quit. This issue is also well known in the literature on tobacco, although, mainly due to data availability, not all studies are able to deal with those problems. Following the exposition in WHO (2010), this study estimates the unconditional price elasticity related to the quantity of smokers from the following probit model.

$$Pr(S_{ist}) = \phi(\gamma_1 P_{st} + \delta \boldsymbol{X}_{ist}) \qquad (2)$$

The dependent variable is an indicator whether individual i is a smoker or not, and P_{st} is the average price in federal state s and year t. The explanatory variables X are essentially the same as in the conditional price elasticity estimation by equation (1). The price elasticity from the smoking decision model for an individual with average characteristics is calculated as follows:

$$\bar{X} as\ \varepsilon_u \equiv \frac{\partial E(S|\bar{X})}{\partial P_{st}} \frac{\bar{P}_{st}}{E(S|\bar{X})}$$

It is important to note that this elasticity indicates how many percentage points smoking prevalence would change after a 1 percent alteration in cigarette prices.

Combining both equations (1) and (2) to a two-part model gives the overall effect of how a price increase would affect total cigarette consumption. The total price elasticity thus reflects adjustments along two dimensions: (1) the consumption quantity (smoking intensity), that is, the intensive margin; (2) the smoking prevalence, that is, extensive margin. Following WHO

(2010: 47), we compute the total price elasticity as the sum of the conditional price elasticity from equation (1) and the price elasticity from the smoking decision model in equation (2).

6 Results

6.1 Conditional price elasticity of cigarette consumption

Table 6 reports the estimated price elasticities by income decile according to eq. (1). The nine columns in the Table stem from three different regressions: one combined regression and two separate ones for each gender, as indicated in the third line of the Table. For the sake of space, Table 6 does not indicate the coefficients' confidence levels by stars, but from the upper (UL) and lower (LL) limits of the 95 percent level confidence intervals. It is clear that only 3 out of 30 estimated coefficients are not statistically significant from zero. All of the significant estimates also have the expected negative sign. However, most of them are not statistically different from each other because of the overlapped confidence intervals.

Table 6: Price elasticities and confidence intervals by income decile and gender

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	LL	Coef.	UL	LL	Coef.	UL	LL	Coef.	UL
gender	Both			Female			Male		
1.decile	-0.16	-0.10	-0.03	-0.22	-0.13	-0.04	-0.16	-0.08	0.01
2.decile	-0.16	-0.11	-0.06	-0.24	-0.16	-0.08	-0.14	-0.07	0.00
3.decile	-0.14	-0.09	-0.04	-0.21	-0.13	-0.06	-0.13	-0.07	-0.00
4.decile	-0.15	-0.10	-0.04	-0.21	-0.13	-0.05	-0.15	-0.07	0.01
5.decile	-0.17	-0.12	-0.07	-0.21	-0.13	-0.05	-0.18	-0.11	-0.05
6.decile	-0.17	-0.11	-0.06	-0.25	-0.16	-0.07	-0.15	-0.08	-0.02
7.decile	-0.18	-0.13	-0.07	-0.22	-0.13	-0.05	-0.18	-0.11	-0.05
8.decile	-0.22	-0.17	-0.11	-0.26	-0.17	-0.07	-0.22	-0.16	-0.09
9.decile	-0.23	-0.17	-0.11	-0.27	-0.15	-0.04	-0.25	-0.17	-0.09
10.decile	-0.26	-0.18	-0.09	-0.30	-0.16	-0.02	-0.28	-0.18	-0.07
N	8,277			3,410			4,867		
R^2	0.09			0.07			0.09		

Notes: The Table reports price elasticities and confidence interval by income decile according to the estimation of eq. (1) using data from both 2008 and 2013. The upper limit (UL) and lower limit (LL) are calculated based on White-Huber heteroscedasticity robust standard errors and a 95 percent confidence level. All regressions include controls for age group, education group, years of smoking, log income and federal state fixed effects. Columns (1) and (4) also include a gender dummy.

Several interesting patterns stand out. First, estimates are in the interval between -0.3 and 0. Secondly, price sensitivity seems to increase with the individuals' income level, despite controlling for other socioeconomic characteristics. That is, an increase in cigarette prices by 10 percent should lead to a reduction in cigarette consumption by 1 percent for the lowest incomes, whereas the reduction is almost 2 percent for the richest individuals. Nevertheless, the confidence intervals of the first and tenth decile still overlap, and thus the differences are not statistically significant. Differences between male and female smokers in each income decile are also insignificant, throughout. Yet, especially male smokers with low incomes are the least sensitive to price changes in cigarettes.

As discussed in section 4, the illegal (or informal) market for cigarettes in Brazil is one of the largest in the world. Therefore, a major concern for policy makers is to what extent a potential tax increase actually affects cigarette consumption. At the same time, the possibility to resort to the informal market may explain the relatively inelastic price elasticities in Table 2. When policy makers raise tobacco taxes, the price in the legal market certainly increases. In the illegal market, however, prices could not show the same behavior, even considering that cigarettes are substitute goods between the two markets and that sellers have an incentive to also increase prices in order to raise profit margins. Consumers that used to buy their cigarettes in stores, could begin to purchase them illegally at an even lower price, thus avoiding the intended consumption reduction with the tax and price increases. The detailed data enables differentiation between cigarette purchases in the legal and illegal markets, according to the reported price being above or below the official minimum price.[4] Because the distinction among groups already results in considerably smaller samples, price elasticities are estimated by income quartile instead of deciles, as in Table 6.

The estimations in Table 7 show that the distinction between the formal and informal cigarette market is substantial. As expected, consumers in the illicit market are much less sensitive to price changes. Elasticities in the informal market vary between -0.15 and -0.18, whereas consumers in the formal market show values between -0.28 and -0.34. This is expected because prices in the illegal market, according to the identification strategy of this study, are below the fixed minimum price and so do not suffer the same fluctuations as the prices in the regular market, see figure 4. One of the possible explanations for the lower sensitivity of price changes is the different consumption behavior and individual characteristics in line with the descriptive statistics. It is also possible that the sub-estimation of the illicit market based on the minimum price alone creates some bias in the estimates. The differences between price elasticities between both types of consumers are statistically significant in all income quartiles, at least in the pooled sample. Finally, the estimated price elasticities in absolute values increase by income quartile, as observed previously. Columns (4) to (6) in Table 7 report the results when unit

[4] Note that although the price floor in 2008 is imputed, as explained in the text, estimations of the regression in Table 3 separately for 2008 and 2013, produces similar results, which are not reported due to space constraints. The similarity between the price elasticities in 2008 and 2013 in both segments of the market thus supports the assumption that the minimum price imputation is valid.

cigarette prices are replaced by average price within each federal state.[5] As a consequence, the elasticities unambiguously increase in magnitude. This change is expected because the regional prices eliminate the endogeneity bias caused by possible adjustments to cheaper brands.

Table 7: Price elasticities by income quartile and market

	(1)	(2)	(3)	(4)	(5)	(6)
Market:	Both	Legal	Illegal	Both	Legal	Illegal
Price measure:		Unit price			State average	
1. quartile	-0.11***	-0.28***	-0.15***	-0.28***	-0.37***	-0.24*
	(0.02)	(0.05)	(0.05)	(0.05)	(0.06)	(0.13)
2. quartile	-0.12***	-0.28***	-0.14***	-0.30***	-0.38***	-0.25*
	(0.02)	(0.05)	(0.05)	(0.05)	(0.06)	(0.13)
3. quartile	-0.14***	-0.31***	-0.15***	-0.34***	-0.42***	-0.27**
	(0.02)	(0.04)	(0.05)	(0.05)	(0.06)	(0.13)
4. quartile	-0.18***	-0.34***	-0.18***	-0.36***	-0.44***	-0.29**
	(0.03)	(0.04)	(0.06)	(0.05)	(0.05)	(0.13)
N	8254	5521	2733	8254	5521	2733
R_2	0.09	0.10	0.09	0.05	0.07	0.04

Notes: The Table reports coefficients of price elasticities by income quartile according to the estimation of eq. (1). The White-Huber heteroscedasticity robust standard errors are in parenthesis. The second row indicates whether the individuals purchase cigarettes in the legal or illegal market or if both markets are considered. The third row indicates whether the price of cigarettes is unit price or state average. The estimations are based on pooled data from 2008 and 2013. All regressions include controls for gender, age group, education group, years of smoking, and log income. Federal state fixed effects were only included in the estimations in columns (1) to (3). *, **, and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 8 provides another extension from the baseline estimation in eq. (1). Price elasticities are estimated for five different age groups. Based on the previous findings, the distinction between legal and illegal markets is maintained. In the pooled sample and for the consumers in the licit market, price sensitivity decreases with age. While consumers below the age of 29 show a price elasticity of -0.42, the oldest cohorts aged 60 and above, only present a value of -0.11. As previously, the elasticities observed for consumers in the illicit market are much lower.

Columns (4) to (6) in Table 8 present the results for the price elasticities by cohort using the average regional cigarette prices in the pooled sample and the licit and illicit market, respectively. The regressions in columns (4) and (5) are based on the observed average prices in the legal market. Comparing these three estimations to the ones in the remainder three columns of Table 8 confirms that endogeneity bias seems to be a problem. As before, the absolute value of virtually all elasticities increases once the correction by state average prices is applied. While the overall age-sensitivity pattern and previous conclusions are maintained, the

[5] Since the identification of the elasticities now stems exclusively from variation between federal state and cohorts, we do not include federal state fixed effects in the regression estimations.

range of price elasticities is -0.54 to -0.19 in the legal market and goes from -0.3 to 0 in the illegal market.

Table 8: Price elasticities by cohort and market

	(1)	(2)	(3)	(4)	(5)	(6)
Market:	Both	Legal	Illegal	Both	Legal	Illegal
Price measure:	Unit price			State average		
Aged 15—29	-0.20***	-0.42***	-0.17***	-0.28***	-0.54***	-0.30**
	(0.03)	(0.05)	(0.06)	(0.05)	(0.06)	(0.13)
Aged 30—39	-0.19***	-0.38***	-0.20***	-0.27***	-0.49***	-0.32**
	(0.02)	(0.05)	(0.05)	(0.05)	(0.06)	(0.13)
Aged 40-49	-0.14***	-0.33***	-0.16***	-0.21***	-0.43***	-0.27*
	(0.02)	(0.04)	(0.05)	(0.05)	(0.05)	(0.13)
Aged 50—59	-0.12***	-0.28***	-0.17***	-0.18***	-0.37***	-0.27**
	(0.02)	(0.05)	(0.05)	(0.05)	(0.06)	(0.13)
Aged 60+	0.01	-0.11**	-0.09	-0.01	-0.19***	-0.17
	(0.03)	(0.05)	(0.06)	(0.05)	(0.06)	(0.13)
N	8,277	5,545	2,732	8,277	5,545	2,732
R^2	0.08	0.09	0.08	0.08	0.06	0.03

Notes: The Table reports coefficients of price elasticities by income quartile according to the estimation of eq. (1). The White-Huber heteroscedasticity robust standard errors are in parenthesis. The second row indicates whether the individuals purchase cigarettes in the legal or illegal market or if both markets are considered. The third row indicates whether the price of cigarettes is unit price or state average. The estimations are based on pooled data from 2008 and 2013. All regressions include controls for gender, age group, education group, years of smoking, and log income. Fixed effects for federal states were only included in the estimations in columns (1) to (3). *, ** and *** indicate statistical significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

6.2 Unconditional price elasticity of smoking probability

Table 9 contains the results from a single probit estimation according to eq. (2). Because it is a non-linear regression, indicator variables for income quantiles or age groups are not included, but by using the average values $\bar{X}_{ist}$ in each of the groups, one can directly calculate the respective price elasticities. The surprising increase of the price elasticity for people aged 60 and above can be explained using descriptive statistics. Among this group of individuals, the prevalence of smoking drops to 13 percent, as compared to 22 percent among the 50 to 59 year-old individuals. Dictated by demographics, the oldest cohort also contains a considerably higher share of women, who were shown to smoke less and tend to have a more elastic price elasticity. For the remaining age groups, as for the income quartiles, one observes little differences in price elasticities. That is, for the majority of Brazilians, a 10 percent cigarette price

increase should reduce the number of smoking individuals by about 2.6 percent. These numbers resulted from adding up the conditional price elasticities from Tables 3 and 4 and are used in the extended cost-benefit analysis in the next section.

Table 9: Price elasticities by cohort and income from the smoking-probability model

	15–29	30–39	40–49	50–59	60+
Age group:	-0.24***	-0.25***	-0.25***	-0.26***	-0.39***
	(0.10)	(0.10)	(0.10)	(0.10)	(0.16)
Income quartile:	Q1	Q2	Q3	Q4	
	-0.27***	-0.27***	-0.27***	-0.30***	
	(0.11)	(0.11)	(0.11)	(0.12)	

Notes: The table shows the estimated price elasticities and their White-Huber heteroscedasticity robust standard errors in parenthesis. All elasticities are calculated from a single probit estimation according to eq. (1), where the smoking indicator is regressed on the observed price of cigarettes in each region and controls for year, gender, education group, years of smoking, and log income. The estimations are based on the entire sample of smokers and non-smokers pooled for the years 2008 and 2013. *** indicates significance at the 1 percent level.

7 Extended cost-benefit analysis

The cost-benefit analysis presented here is based on Fuchs and Menezes (2018) and Fuchs et al. (2019). The main hypothesis is that the change in tobacco consumption has a direct impact not only on household tobacco expenditures, but also on medical expenditures and productivity costs. Although this assumption may not be plausible in the short-run, it provides insights regarding the effects of tobacco price changes in medium- and long-run periods.

In this sense, the net income effect due to a tobacco price change can be decomposed into three effects: (i) Change in tobacco expenditure; (ii) Change in medical expenses, and (iii) Change in income related to years of productive life lost.

The change in cigarette expenditures (ΔCE) is given by

$$\Delta CE_q = \left((1+\Delta P)(1+\varepsilon_q \times \Delta P) - 1\right) \times \rho_{c,q} \tag{5}$$

where ΔP is the change in cigarette price, ε_q the cigarette price elasticity for quartile q and $\rho_{c,q}$ the cigarette expenditure proportional to total expenditures (percent) for quartile q.

The change in medical expenditures (ΔME) can be obtained by

$$\Delta ME_q = \varepsilon_q \times \Delta P \times \rho_{m,q} \tag{6}$$

where $\rho_{m,q}$ is the medical treatment expenditures (with tobacco related diseases) to total expenditures ratio for quartile q. That is, the weight of medical costs added to the total household expenditures in a given period of time.

Lastly, the change in income due to yll - years of productivity life lost - (ΔI_{yll}) is given by

$$\Delta I_{yll} = \varepsilon_q \times \Delta P \times \rho_{wy,q}$$
$$\omega_q = wy_q \times \omega_{yll}, \quad wy_q = \frac{yll \times s_q}{n_q} \tag{7}$$

where the working years, wy_q, is the yll distributed across quantile q proportionally to the number of smokers s_q / n_q; ω_{yll} is the monetary cost of one year of life cost, thus ω_q is the monetary cost of wy_q, and $\rho_{wy,q}$ is the working years cost to total expenditures ratio for quartile q.

The rationale of (7) is that a reduction in tobacco consumption, due to a price increase, diminishes the years of productive life lost (that is, less premature death and less people living with poor quality of life). Since people potentially will live more years (or live years with a better quality of life), they will also have an income gain.

Although the changes defined in equations (5) to (7) are expressed in quantiles, they can be represented by any other kind of cohort. The procedure is the same. We have to distribute the measure of interest (in our case cigarette expenditures, medical costs and years of life lost) across cohorts taking into account the proportion of smokers in each one of them. One drawback in this method is that the measure of interest per person does not change through cohorts. This assumption is necessary since many measures of interest are not available for each individual. This assumption is also made by Fuchs and Menezes (2018) and Fuchs et al. (2019). Following this approach, our calculations using equations (5) to (7) are presented by quartile and age cohort.

In order to calculate the components of the net income effects, the price elasticities estimated and discussed in the previous sections are used. Table 10 reproduces the full price elasticities by cohort and income quartiles.

The medical and productivity costs attributable to smoking, Tables 11 and 12, came from Pinto et al. (2017). Additionally, in our simulations, it is considered a linear price increase of 10 percent. For the sake of example, São Paulo is the biggest Brazilian state in terms of participation in the country GDP.

Table 10: Smoking full price elasticities by cohort and income quartile

	Age group				
Price Elasticity	15-29	30-39	40-49	50-59	60+
Lower-bound	-0.66	-0.66-0.62		-0.62	-0.74
Estimated	-0.45	-0.45-0.41		-0.39	-0.40
upper-bound	-0.20	-0.20-0.16		-0.12	0.02
	Income quartile				
Price Elasticity	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Lower-bound	-0.68	-0.69-0.71		-0.75	
Estimated	-0.47	-0.49-0.52		-0.55	
upper-bound	-0.23	-0.25-0.28		-0.31	

Notes: The full price elasticity is the sum of values in column (4) in Table 3, the bottom panel in Table 5, and their product, for income quartiles, and the sum of values in column (4) in Table 4, the top panel in Table 5, and their product, for age groups. Lower-bound and upper-bound stand for 95% percent confidence interval.

Table 11: Medical costs and deaths attributable to smoking

Chronic condition	Total cost (BRL bi)	# events	Cost per event (BRL)	# deaths
COPD	15.99	378,594	42,235.70	31,120
Cardiovascular disease	10.26	477,470	21,497.44	34,999
Stroke	2.17	59,509	36,536.16	10,812
Pneumonia	0.15	121,152	1,205.70	10,900
Lung cancer	2.29	26,850	85,124.20	23,762
Other cancers	4.00	46,650	85,783.96	26,651
Total medical cost	34.86	1,110,225	272,383.16	138,244

Notes: COPD: chronic obstructive pulmonary disease. Source: Pinto et al. (2017).

Table 12: Productivity related costs attributable to smoking

		Cost per YLL (BRL)
YLL - years of life lost (# years)	3,719,814	
Premature death (BRL bi)	7.51	2,815.97
Living with poor quality of life (BRL bi)	9.99	9,492.96
Total (BRL bi)	17.50	12,308.92

Source: Pinto et al. (2017).

The current tax burden in São Paulo is 79.09 percent of the price of the highest selling cigarette brand. A linear cigarette price increase of 10 percent is equivalent to raising PIS/COFINS from 11 percent to approximately 16 percent, i.e., a 5 basis points increase. The new total tax burden will be 81.72 percent. In this case, as discussed in the previous section, it is worth noticing that the increase in the PIS/COFINS tax rate is relatively easy to implement and, most importantly,

the tax revenue resulting from this increase is earmarked to finance social programs and social security expenses[6].

Table 13: Percentage change scenario for a 10% increase on cigarette prices by income quartile

Panel A - Change in Cigarette Expenditures				
Price elasticity	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Lower-bound	0.40	0.19	0.13	0.05
Estimated	0.77	0.37	0.26	0.12
upper-bound	1.20	0.58	0.41	0.20
Complete pass-through	1.60	0.80	0.60	0.30
Panel B - Change in Medical Costs				
Price elasticity	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Lower-bound	-3.50	-2.19	-1.44	-0.43
Estimated	-2.44	-1.55	-1.05	-0.31
Upper-bound	-1.17	-0.78	-0.57	-0.18
Panel C - Change in income (years of life lost cost)				
Price elasticity	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Lower-bound	-3.68	-5.58	-2.01	-0.50
Estimated	-2.57	-3.95	-1.47	-0.37
Upper-bound	-1.22	-1.98	-0.80	-0.21
Panel D - Net income effect				
Price elasticity	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Lower-bound	6.77	7.57	3.32	0.87
Estimated	4.24	5.13	2.26	0.56
Upper-bound	1.19	2.18	0.96	0.18

Notes: Panel A shows the results from equation (5). Panel B shows the results from equation (6). Panel C shows the results from equation (7). Complete pass-through refers to elasticity equal to zero. All calculations use values from Tables 12 to 14. Panel D is the negative of the sum of Panels A to C.

Table 13 reports the effects of a 10 percent increase in the price of cigarettes by income quartile. This could result from a tax increase of 5 basis points in the PIS/COFINS, for instance. According to Panel A, the 25 percent poorest individuals experience the largest increase in cigarette expenditure (0.77 percent). Following the literature, we can assume what would happen if the individuals have no sensitivity at all to cigarette price changes (smoking price elasticity equal to zero). This complete pass-through scenario can be seen as a baseline scenario where all individuals experience a net income loss since they have an increase in their cigarette expenses with no other income benefit (in terms of reduction in medical expenses and years of life lost costs, for instance). It is worth highlighting that the poorer would be in disadvantage in this case since they face the highest net income loss (1.6 percent). However, they benefit most from

[6] For comparison purposes, we also report the required increases in IPI and ICMS in order to generate the same 10 percent raise in cigarette price, always taking the state of São Paulo as reference. The IPI *ad valorem* should be raised from 66.5 percent to 100 percent, which represents an increase of 50 percent in the IPI tax rate. Alternatively, the IPI specific value should be raised from 1.50 to 1.82 BRL per pack. Considering the ICMS, the tax rate should increase from 32 percent to 37 percent, an increase of 16 percent or 5 basis points.

reduction in medical expenses (2.44 percent) and decrease in years of life lost (2.57 percent). There is a net income gain of 4.24 percent. Similar results could be observed for quartile 2, where individuals obtain a net income gain of 5.13 percent as a result of the 10 percent increase in cigarette prices. Thus, this is a very effective progressive tax policy as it benefits the poorer most.

The complete pass-through scenario could also help to illustrate what would be the response of those individuals engaged in the illegal market for cigarette purchases. At first glance, there is no reason to expect a price change in this market due to a tax increase in the legal market. However, the smugglers have an opportunity to increase their profit margins by raising prices of the illegal market cigarettes, which are close substitutes for the legal market counterparts. This means that any estimation using the complete pass-through scenario will fail to capture the real effects of higher taxes on cigarettes.

Table 14: Percentage change scenario for a 10% increase on cigarettes price by age cohort

Panel A - Change in Cigarette Expenditures					
Price elasticity	15-29	30-39	40-49	50-59	60+
Lower-bound	0.27	0.25	0.32	0.26	0.15
Estimated	0.50	0.45	0.55	0.45	0.45
Upper-bound	0.78	0.70	0.82	0.69	0.82
Complete pass-through	1.00	0.90	1.00	0.80	0.80
Panel B - Change in Medical Costs					
Price elasticity	15-29	30-39	40-49	50-59	60+
Lower-bound	-1.31	-0.86	-0.75	-0.65	-0.87
Estimated	-0.90	-0.59	-0.49	-0.41	-0.46
Upper-bound	-0.39	-0.26	-0.19	-0.13	0.03
Panel C - Change in income (years of life lost cost)					
Price elasticity	15-29	30-39	40-49	50-59	60+
Lower-bound	-2.50	-1.51	-2.17	-3.02	-1.71
Estimated	-1.71	-1.03	-1.43	-1.92	-0.91
Upper-bound	-0.75	-0.45	-0.56	-0.60	0.05
Panel D - Net income effect					
Price elasticity	15-29	30-39	40-49	50-59	60+
Lower-bound	3.53	2.12	2.59	3.41	2.43
Estimated	2.11	1.17	1.37	1.88	0.92
Upper-bound	0.37	0.01	-0.07	0.03	-0.90

Notes: Panel A shows the results from equation (5). Panel B shows the results from equation (6). Panel C shows the results from equation (7). Complete pass-through refers to elasticity equal to zero. All calculations use values from Tables 12 to 14. Panel D is the negative of the sum of Panels A to C.

Table 14 illustrates the effects of a 10 percent increase of cigarette prices by age cohort. It is noticeable that cigarette expenditures increase by 0.48 percent on average, with small differences across age groups. However, individuals aged between 30 and 49 years old enjoy larger benefits in terms of reductions in medical expenses than individuals aged above 50. Those between 50 and 60 years old benefit most in terms of reduction in years of life lost cost. This

result is a little surprising since this age group has higher income on average. A possible explanation for this finding could be found in the lower price elasticity of cigarette consumption for the older individuals. Thus, they have a smaller probability of reducing, or even stopping, smoking. The younger group experiences the largest reduction in medical expenses and productivity costs. However, the probability they suffer from any tobacco related decease described in Table 13 is quite small due to their lower age.

The same reasoning, described previously and based on Fuchs and Menezes (2018) and Fuchs et al. (2019), could be applied to simulate scenarios for changes in death rates attributable to smoking behavior. Let ΔDR_q be the change in death rate for quartile q , thus

$$\Delta DR_q = \varepsilon_q \times \Delta P \times \rho_{d,q} \tag{8}$$

where $\rho_{d,q}$ is the death rate for quartile q , i.e., the number of deaths attributable to smoking to the number of people ratio distributed across quartile q , proportionally to the number of smokers s_q / n_q .

Table 15 reports the changes in death rates for quartiles of income and age groups resulting from the same previous 10 percent increase on cigarette prices. It can be observed that individuals between 40 and 60 years old benefit the most. The reduction is between 10 and 15 deaths per 10,000 people in these groups. For the sake of comparison, the overall death rate in Brazil is stable - around 6.4 deaths per 1,000 people for the last five years. The reduction in deaths due to cigarette price increases represents a decrease between 15 percent and 23 percent of the overall death rate in the country. This is a significant result since Pinto et al. (2017) estimates that the deaths attributable to smoking represent almost 28 percent of the total number of deaths.

Table 15: Change in death due to a 10% increase on cigarette prices by cohort and income quartile (per 10,000 people)

			Age group		
Price elasticity	15-29	30-39	40-49	50-59	60+
Lower-bound	-10.39	-9.54	-14.75	-23.65	-12.00
Estimated	-7.13	-6.53	-9.75	-15.05	-6.41
Upper-bound	-3.14	-2.86	-3.83	-4.68	0.37
			Income quartile		
Price elasticity	Q1	Q2	Q3	Q4	
Lower-bound	-5.87	-14.50	-8.16	-7.19	
Estimated	-4.10	-10.27	-5.95	-5.31	
Upper-bound	-1.96	-5.16	-3.25	-2.98	

Notes: Lower-bound and upper-bound stand for 95 percent confidence interval.

8 Conclusion and policy recommendations

The results of this research suggest that a tobacco tax increase would benefit the entire Brazilian population, above all, the poorest and the youngest. The positive effects emerge because higher tobacco taxes reduce cigarette consumption and lead to lower medical costs and longer, healthier, and more productive lives, which ultimately results in higher incomes for everyone. Because price and consumption adjustments as well as the associated income gains are much lower when cigarettes are bought in the illegal market, the government should continue to act against cigarette smuggling to guarantee full gains of the tax reform to the society.

Brazil is usually referred to as a successful case of application of anti-smoking public policies, having experienced a persistent and substantial reduction in the prevalence of smoking in both total population and distinct cohorts since 2006. The country's adoption of the World Health Organization Framework Convention on Tobacco Control Convention (WHO\FCTC) and subsequent ratification by the Brazilian National Congress in 2005 coupled with a rigorous tax policy on the manufactured cigarette production are considered milestones for this sharp decrease in smoking prevalence.

Despite the effectiveness of the anti-smoking policies, the socioeconomic costs associated with smoking behavior is still very high for Brazilian society. A substantial fraction of these costs might be mitigated through an appropriate tax policy on tobacco products, especially on manufactured cigarettes. The increase of tax burden on cigarettes would not only raise the price of cigarettes and reduce consumption but would also generate tax revenue that could be used to defray the socioeconomic costs resulting from the smoking behavior. As of 2018, the total tax burden on cigarette prices was around 80 percent in most of the Brazilian states. This tax policy places Brazil among the countries with the highest tax burden on manufactured cigarette prices in the world.

In this analysis of the smoking behavior of the Brazilian population and the sensitivity of cigarette consumption to price changes, two individual surveys are used—the PNAD from 2008 and the PNS from 2013. Both are repeated surveys for distinct purposes, but in the two selected years, their questionnaire includes a special section on smoking behavior. The study uses those relevant items that are identical in both questionnaires to guarantee comparability between the two years and uniformity of analysis. Additionally, the study uses the official minimum price for a 20-cigarette pack to identify those consumers engaged in the illicit market, that is, purchases below this price are considered to have occurred in the illicit market. In the PNS data, for instance, more than one-third of all consumers purchased cigarettes below that official price floor.

From the results of the analysis, it can be highlighted that the price elasticity estimations indicate that there is a significant difference between the legal and illegal cigarette markets. Specifically, the consumption of cigarettes is much more sensitive to price variation in the legal market than in the illegal market of manufactured cigarettes. This difference is robust to controls for income quartile and age cohorts. This happens because the cigarette price in the illegal market is below the minimum price defined by the government and it might not be affected by any excise tax

policy on tobacco products. Thus, price variation is smaller in the illegal market, resulting in a more inelastic price elasticity of demand.

In the legal market of cigarettes, the estimated conditional price elasticity of demand ranged from -0.37 percent in the first quartile to -0.44 percent in the fourth quartile of income. The same elasticity calculated for the illegal cigarette market, which considers only cigarette sales at prices below the minimum official price, varied from -0.24 percent to -0.29 percent. Thus, not only the coefficients are smaller for a given quartile of income between the two markets but also variations in estimated values are quite smaller among quartiles of income in the illegal market.

The extended cost-benefit analysis considers a 10 percent price increase resulting from a raise in taxes on manufactured cigarettes. The average net income effects were 4.24 percent and 5.13 percent increases in the first and second quartiles, respectively. These gains in income result from combining the effects of higher cigarette expenses due to the higher price, reduction in medical expenses with the decrease in smoking, and gain in future years of employment due to the health improvement. More importantly, the effects of such a policy are progressive in the sense that they are more beneficial for the poorest individuals in the society. Thus, the gains increase as the income quartile decreases.

The findings are similar by age cohorts. The highest net income effects were observed for the youngest, aged between 15 to 29 years, and for middle aged people, between 40 to 59 years old. This is the case because the youngest have low income and thus a higher benefit on future years of employment by reducing or quitting smoking. Middle-aged people also experienced high net income effects because smoking related diseases usually appear at this age and imply high medical expenses for treatment.

We recommend, in one of the possible scenarios, a raise in PIS/COFINS be used to generate the 10 percent increase on manufactured cigarettes price used in the simulation exercises. The advantages are that the tax change could be more easily implemented by the government because the additional tax revenue is earmarked for social expenses. For example, a 10 percent price growth is roughly reached by a tax increase of about 5 basis points in the PIS/COFINS tax rate. Tobacco tax increases have an important advantage, meaning that the poorest individuals represented by the 1st quartile of income experience the largest increase in cigarette expenditures and biggest reductions in medical expenses and in years of life lost. As a result, they have the largest gain in net income.

In the illegal market, however, the scenario is disadvantageous. According to the estimated price elasticities, the cigarette consumption is more insensitive to price variations. In addition, the proposed tax increase affects prices of cigarettes sold in the legal market and could have a much smaller effect on prices in the illegal market, as highlighted by Ribeiro and Pinto (2019). People that buy cigarettes in the illegal market would have a zero or limited impact in consumption due to tax increases because prices in this market would not be directly affected by the government tax policy. However, they are still demanding medical treatment for tobacco related diseases

and losing future years of employment due to cigarette related health problems. They will not benefit from the net income increase resulting from any tobacco taxation policy in the country.

To broaden the social reach of the tobacco control policy, it is advisable that the tax increase policy on manufactured cigarettes be accompanied by other measures that increase the economic and social costs of smoking and curb illicit trade through better policy coordination, higher levels of monitoring and penalties. A good example comes from the state of São Paulo, which has the highest tax burden on cigarette prices in the country and recently prohibited smoking in all municipal parks across the city. Coupled with the highest cigarette tax burden, this measure adds to several others adopted by the state focused on raising the social inconvenience of smoking by imposing several legal restrictions on the smoking behavior. It is also essential that the country adopts an effective and rigorous policy to fight cigarette smuggling and reduce the illegal market of cigarette sales in Brazil. Given the length of the Brazilian land border, this is a big challenge and should involve integrated efforts by various entities of public administration, such as the Federal Revenue Service, the Federal Police, the Federal Highway Police and the Ministry of Economy, among others.

The road is hard but Brazil has reached undeniable progress in reducing smoking prevalence trough an adequate combination of public policies. Our key message is that the country can go one step further on the tax increase policy to reduce cigarette consumption and increase net income due to the positive effects of this policy to lower medical costs and increase years of working life. This is a highly progressive tax policy, meaning that the most vulnerable social groups are the ones who benefit the most from it.

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