tobacconomics
Economic Research Informing
Tobacco Control Policy

A Toolkit on

Modeling the Impacts of Tobacco Taxes

INSTITUTE FOR
HEALTH RESEARCH
AND POLICY
UIC

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About Tobacconomics: Tobacconomics is a collaboration of leading researchers who have been studying the economics of tobacco control policy for nearly 30 years. The team is dedicated to helping researchers, advocates, and policy makers access the latest and best research about what's working—or not working—to curb tobacco consumption and its economic impacts. As a program of the University of Illinois Chicago, Tobacconomics is not affiliated with any tobacco manufacturer. Visit **www.tobacconomics.org**, follow us on Twitter **www.twitter.com/tobacconomics**, or add us on LinkedIn **https://www.linkedin.com/company/tobacconomics/**.

Improving Our Toolkit: The Tobacconomics team is committed to making this toolkit as clear and useful as possible. We would like your feedback on whether you found this toolkit useful in your research and, if so, we would appreciate learning about your experience on any successful implementation. We would also like to hear whether you have encountered any issues in applying the methodologies presented in the toolkit and your thoughts on how we can improve it.

For any comments or questions about the toolkit and its content, please email us at info@tobacconomics.org. We very much look forward to hearing from you.

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Introduction

1

1.1 Purpose of this toolkit

A large body of global evidence demonstrates that significantly increasing the price of tobacco products through taxation is the single most effective and cost-effective way to reduce tobacco use (NCI & WHO, 2016). Tobacco taxes are also an important source of government revenue. Domestic revenue mobilization is a central pillar of the 2015 Addis Ababa Action Agenda, which recognizes tobacco taxes as a key policy measure to reduce the global burden of noncommunicable diseases (NCDs) and help achieve the Sustainable Development Goals (SDGs) (United Nations, 2015). This recognition is supported by extensive evidence demonstrating that tobacco taxes are a powerful tool for reducing tobacco consumption while generating additional government revenues (Chaloupka et al., 2012).

The primary purpose of this toolkit is to review the three most commonly used models for forecasting the impacts of tobacco taxes on government revenues as well as the public health effects of decreased demand due to higher taxes and prices by describing their assumptions, data requirements, and design. Specifically, the toolkit describes the World Health Organization's (WHO) TaXSiM model, the University of Cape Town's (UCT) TETSiM model, and the Tobacconomics model of the University of Illinois Chicago (UIC). Through the explanation of the models in this toolkit, users can gain a more accurate understanding of the objectives and differences between them and adjust them based on data availability. As detailed technical guidance for each of the models is already available in separate publications, this toolkit does not repeat this information but rather refers the readers to the respective original sources.

1.2 Who should use this toolkit

Forecasting the revenue and public health impacts of a tobacco tax policy change is an important part of the budget process in every country because it can help a government strategize how much and how quickly a certain policy can meet its objectives. Therefore, this toolkit is designed for researchers and policy makers who are interested in evaluating the revenue and public health impacts of a tobacco tax increase.

This toolkit is one of several toolkits developed by the World Bank, WHO, and Tobacconomics to provide guidance for conducting economic analyses of tobacco demand and the impacts of tobacco consumption on employment, welfare and equity, illicit trade, and economic costs. This is also the fourth in a series of Tobacconomics toolkits designed to build capacity and core competencies in the economic analysis of tobacco taxation to build strong, local evidence bases for effective tobacco taxation policy.

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1.3 How to use this toolkit

The toolkit is designed as follows. Chapter 2 provides general guidance on forecasting the revenue and public health impacts of a tobacco tax increase, describing general assumptions, data requirements, and model design. Chapters 3, 4, and 5 present the models of the WHO, UCT, and Tobacconomics, respectively. These methods are selected as the most commonly used methods to estimate the impacts of tobacco tax on tax revenues and health outcomes. Finally, Chapter 6 briefly explores two other models with different approaches than the other three explored in greater depth.

General Guidance

2

2.1 Introduction

This chapter provides general guidance on modeling the price, revenue, and sales/consumption impacts of increases in tobacco taxes. It considers the three basic types of data: tax rates, tax bases, and how the quantity of cigarettes are measured, as well as data availability and how they differ between countries. All three types of data can be quite complex. The chapter also covers the main assumptions about the behavior of the tobacco industry and smokers that are needed to solve the models. The tobacco industry can increase or decrease their margins or profits. This full or partial pass-through of tax increases is a common way to control retail prices in order to influence demand for cigarettes.

The 'own-price elasticity' measures how increases in price affect demand for cigarettes, and thus, is a central component in modeling the impact of tobacco tax increases. When working with governments to plan tax changes, many tobacco tax models focus on the direct effects of a tax increase such as prices, quantities sold, and revenue generated. Estimates of the indirect effects of decreased consumption on health, including lower health care costs, improved productivity and avoidance of premature death can also be included in these models. Additionally, estimates of other elasticities (such as cross-price elasticity, which measures the change in demand for other brands or similar products from a price increase in one brand, or income elasticity, which measures changes in demand from changes in incomes) may be included.

Basic tax forecasting models used by ministries of finance calculate tax revenue based on the tax base, tax rate, and quantity. Tobacco tax models differ from these simpler forecasting models in that—along with examining the revenue effects of a change in excise taxes—they focus on the price and consumption effects, including the behavior of consumers, and often the impact on health as well. Therefore, unlike simple revenue forecasting models, all taxes and fees on cigarettes need to be included in tobacco tax models since they affect the final retail price.

Most tobacco tax models have a similar structure. They first re-create the current system to verify the data and model equations. This includes verifying the initial values of retail prices, consumption (or sales), excise taxes, and other taxes. The excise tax and/or tax rate—depending on whether excise taxes are specific (an amount per unit), ad valorem (a rate multiplied by the base), or both—is then increased, or the tax structure is changed. The model is rerun to calculate the new, higher prices due to the higher tax level or a changed tax structure. The new prices, reflecting the increased taxes, affect the quantity consumed and, therefore, tax and industry revenues.

The change in quantity of cigarettes sold can also be used to estimate the number of people who quit smoking, as opposed to smoking fewer cigarettes (decreased smoking intensity). The number of former smokers who will avoid premature death as well as decreases in health care costs, improved productivity, and premature deaths avoided can then be calculated.

Cigarettes are considered a normal good in economics. That is, as prices increase, overall consumption declines—as long as there are no other changes, such as changes in income. The own-price elasticity measures how much consumption of a good declines in response to an increase in its own price. In most countries, governments cannot control the retail price of a product directly but can increase excise taxes, which will increase the retail price of the product as long as producers or sellers of cigarettes pass on all or a part of the tax increase to the retail price. In the extreme, cigarette prices can be kept unchanged if the tobacco industry absorbs the full amount of the tax increase by cutting their profit margins (see Section 2.3.A).

Most models examine changes in demand for cigarettes, which account for the vast majority of tobacco consumption in most countries; the value of the global cigarette market is estimated to be around 85 percent of the total global market for products containing tobacco (Euromonitor International, 2022, p. 5).

Forecasts are only as good as the available data and reality of the assumptions. It is always good practice to test the sensitivity of results to changes in the main assumptions by calculating alternative scenarios. This chapter examines the basic components, data, and assumptions involved in building a model. Section 2.2 deals with model formulation and Section 2.3 with assumptions. Section 2.4 concludes the chapter.

2.2 Model formulation

The basic components needed to calculate tax revenues are: (1) the tax rate (or the tax amount, for a specific tax), (2) the tax base, and (3) the quantity sold. For an ad valorem tax this is:

$$\textit{Total excise tax revenue} = \textit{tax rate} \times \textit{tax base} \times \textit{quantity} \tag{2.1}$$

For a specific tax it is simpler:

$$\textit{Total excise tax revenue} = \textit{tax amount} \times \textit{quantity} \tag{2.2}$$

2.2.1 Tax rates

Tax rates of all taxes or levies on cigarettes are included in the model since they will affect the retail price.

The basic forms of excise taxes are specific (an amount), ad valorem (a rate), or a combination of the two. Of the 169 countries reporting for the WHO Report on the Global Tobacco Epidemic (RGTE) in 2021, 64 used a specific tax base, 40 an ad valorem tax base, and 65 had a mixed system with both specific and ad valorem components. 27 of the 65 countries with a mixed system are members of the European Union.

There can be a single rate for all cigarettes or multiple rates (i.e., a tiered system). A single rate or tax is the simplest in terms of modeling and also the best in terms of tax policy, since it limits the ability of the tobacco industry to manipulate cigarette characteristics to pay a lower tax. A single rate is also easier to administer. Tiered systems can include differentiation by price segments (different rates for low, mid-price, and premium cigarettes, for example), type (filter, non-filter, type of paper, length of cigarette, soft or hard pack), the type of production (hand rolled or machine made), or the amount of production (smaller producers pay a lower tax, for example). For example, in 2022 Indonesia had one of the most complex tobacco excise tax systems with 8 tiers of tax depending on the type of product (cigarettes or kreteks, which are cigarettes with clove added), production (machine made or hand rolled), volume of production, and price (Indonesia Ministry of Finance Regulation No. 109/PMK.010/2022, in SEATCA Tobacco Tax Program, 2023). Some countries require retail prices to be within bands or slabs.

2.2.2 Tax base

The base of the tobacco excise tax is measured by:

- pack (usually but not always 20 sticks per pack);
- individual cigarette stick;
- value or price: retail sales price (RP), production (also called the ex-factory) price, or import price (usually CIF (including cost, insurance, and freight));
- product weight (stick or pack); or
- a combination of these.

The most common base for ad valorem excise taxes, either alone or in a mixed system, is RP. It is used in most of Europe and the Americas. Overall, 47 countries reported using a RP base compared to 58 using other bases (RGTE, 2021). CIF price is a common alternative base. The two main trading and monetary unions in West Africa require the use of the CIF/import or production price as the base for the ad valorem part of tobacco excise taxes (ECOWAS, 2017; WAEMU, 2017).[1]

In order to understand how changes in taxes affect the retail price and, therefore, consumption, all other taxes and fees on tobacco products need to be included as well. The excise tax base usually includes the value-added tax (VAT) or sales tax as part of the base (see Equations 3.6 and 3.7 in Chapter 3: TaXSiM).

Some countries also impose import duties and other levies on import or production prices. Fees can include charges imposed by trade blocs (2.5 percent for WAEMU and ECOWAS, for example) and others such as special health levies. The tax bases for these other fees and levies may differ from that of the excise tax. For instance in the Tobacconomics model, to account for the issue of pre-tax-increase stockpiling, an inventory tax to tobacco products in stock can be applied when the tax increase goes into effect. Otherwise, the industry will delay its effects through pre-tax-increase stockpiling, which will consequently affect (reduce) government revenues.

[1] ECOWAS, the Economic Community of West African States, with 15 members and the WAEMU (also known by their French names, CEDEAO and UEMOA, respectively). The West African Economic and Monetary Union has 9 members, with some overlap.

2.2.3 Price and quantity data

The sources of price data will vary by country. In some countries producers and importers may be required to publish retail prices for all brands or print the price on the packs. Price data are sometimes collected by tax authorities or can be collected via market surveys or commercial data providers. Note that commercial data will be mainly available in more developed countries or those with a large market for cigarettes.

Most member countries of the World Health Organization (WHO) report the price of the most-sold brand every two years for the Report on the Global Tobacco Epidemic. This can be used as a proxy for the average price.

Quantity can be measured by the number of cigarette sticks, the number of packs, or by weight. Since this toolkit is designed to aid in understanding the impacts of tax increases on revenues and consumption, sales or consumption data are used for quantity. Data on sales, which are considered aggregate macro-level data, are often provided in government statistics. In most developed countries statistics are publicly available, often online. However, in many countries these data are not publicly available, so other sources are needed. Alternatives include production and import data or the number of excise stamps issued.

Most countries report import quantities and prices of cigarettes to United Nations (UN) Comtrade annually. Net imports can be used to estimate total cigarette imports and CIF prices. Domestic production can be calculated as the difference between total sales, if available, and imports. Alternatively, if there is an estimate of the share of domestic sales in total supply, that can be used (see Box 2.1 for an example of estimating imports, prices, and total consumption using an estimate of the share of domestic production). Official sales are the base for revenue collections, so using these will provide a better estimate of the revenue changes from a tax increase. However, they do not include the illicit market, so these data will not do as well in estimating health effects of tax changes.

Consumption, or household- and individual-level data, can be found from household expenditure or other government surveys. These will be broader than official sales data since they can include purchases of illegal, non-tax-paid cigarettes as well as consumption differences by gender, age, and income levels. Data for total consumption must be extrapolated from the sample of households or individuals. Survey data can be limited by biases, how often they are done, and whether the data are collected broadly in the country. The *National Cancer Institute Tobacco Control Monograph 21: The economics of tobacco and tobacco control* (2017) includes a discussion of the differences and impacts of using sales compared to survey data.

Given the elements of the basic calculations, and, of course, the same data, the differences between models are mostly due to assumptions about the tobacco industry's responses to changes in the tax and smokers' responses to changes in price, as well as the methods of some calculations. If there are missing or inconsistent data (from different years, for example), which is the case in many countries, assumptions or estimates will have to be made to complete the base year data. This can still yield meaningful results as to the magnitude of changes in taxes, prices, and consumption.

Box 2.1 Using UN Comtrade data to estimate quantities and import prices: Bosnia and Herzegovina, 2020

Comtrade import data can be used to estimate total import quantity and values using the trade classification for cigarettes containing tobacco (2402200). Assuming a weight of 1 gram/stick, including packaging, it is possible to use the net weight of cigarettes in kilograms, multiplied by 1000 grams per kilogram (kg), and divided by 20 cigarettes in a pack.

*The quantity of packs = net weight in kg * 1000 / 20*

If the country has no cigarette production, this will equal the total legal supply.

If there is also domestic production, some estimate of its portion of total supply will be needed. In the case of Bosnia and Herzegovina (BiH), demand for domestic cigarettes had been estimated to be 7.4 percent of total demand (*Bulletin No 199/200: OMA Bilten*, 2022, footnote 13). The same proportion was used to estimate domestic supply.

Total supply = imports / the percentage of imports in total supply

The percentage of imports in total supply in the BiH case equals 92.6 percent (100 percent – 7.4 percent). The difference between the total supply and imports is equal to domestic supply.

Comtrade also records the total USD value of cigarette imports. This is converted to the per-pack USD value by dividing by the number of packs calculated. This is then converted to local currency (BAM) using the average 2020 exchange rate.

Example: Bosnia and Herzegovina (BiH)

BiH 2020	Net weight (kg)	Trade value (USD)	Quantity # packs	USD value per pack	Local value/ pack	2020 BAM/ USD exchange rate avg.
Imports	3,365,794	39,478,498	168,289,700	0.23	0.61	2.62
Domestic		(7.4% total)	13,448,637			
Total			181,738,337			

Models solve for the new retail price after a tax increase, so the calculations of other variables, such as VAT and ad valorem excise taxes with a retail price base, also depend on the retail price. This causes a circular reference error in Excel, which is used with most models, so it cannot be solved. Models deal with this in different ways. One way is to calculate the change in prices separately from the rest of the model and keep that amount fixed for the simulations. Another way to eliminate the circular reference is to substitute the equations for VAT and ad valorem excise taxes with a retail price base into the price and quantity equations. Other models fix the import (CIF), producer price, margins, or the entire industry portion (net-of-price or NoT) of the price and add a parameter that allows an assumed amount of increase. The online version of WHO's Tobacco Tax Simulation Model (TaXSiM), uses the Excel solver function to perform iterations to solve the circular reference of price and quantity.

2.3 Assumptions

The main assumptions needed for modeling the impacts of tobacco tax changes on revenues and consumption are: (1) the reactions of the tobacco industry, measured through the amount of pass-through of tax increases to the retail price, and (2) changes to smokers' demand in response to price changes. Smokers' responses can include smoking fewer cigarettes (decreasing smoking intensity), leaving the market altogether (quitting), or moving to cheaper brands or the illicit market (measured through price elasticities and demand shifts).

2.3.1 Tax changes and tax pass-through

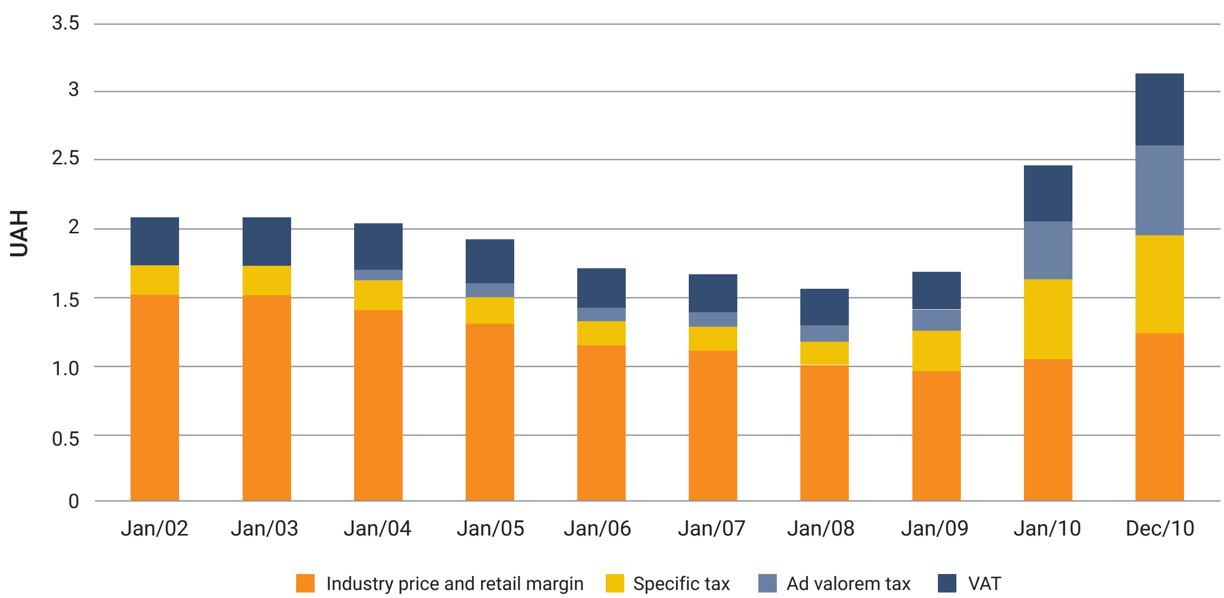
The tobacco industry can affect consumption by increasing or limiting the price effects of a tax increase. The tax pass-through refers to the amount of the tax increase that is transferred onto consumers via higher prices. The industry can increase or decrease their margins or profits, which along with costs are the net-of-tax (NoT) portion of the retail price, in order to increase retail prices by more or less than a tax increase. The tax burden can be fully shifted (100 percent) by increasing the price by the full amount of the tax increase, under-shifted (less than 100 percent) by increasing the price by less than the tax increase or over-shifted (more than 100 percent) by increasing the price by more than the tax increase.

Some producers under-shift, or reduce the effect of tax changes on the retail price of their products, in order to increase the price by less than competitors to maintain or increase their share of the market relative to other brands. On the other hand, prices are sometimes increased by more than the tax increase (over-shifting) in attempts to hide an additional increase in price, while the industry claims the price change was caused by the tax increase only. Figure 2.1 shows an example from Ukraine of how the pass-through decreased to keep prices from increasing until much larger tax increases were implemented after 2009. Even though the industry portion of the price (in red) increased after 2009, by the end of 2010, the industry portion of the price was still well below that at the start of the period.

Since the tobacco industry does not share information on their pricing strategies, assumptions must be made as to the amount of pass-through. The amount of pass-through can only be calculated after a tax change and can vary over time, as can be seen over the 10 years covered in the Ukraine example in Figure 2.1. Many models start by assuming 100 percent, or full pass-through, but include a factor to increase or decrease net-of-tax (NoT, or retail price minus all taxes) amount. The NoT portion can be changed by a factor of λ in the TETSiM model (see Chapter 4, Equation 4.7). In the 2018 version of TaXSiM, the NoT is divided into the producer price and an industry distribution margin (DM) for domestic production including imports when there is no data about the import price. The DM is assumed to be a percent (η) of the retail price. This is used in equation 3.8 to calculate the producer price. For imports, if the import (CIF) price is known, an import margin (MM) is calculated as the residual of the retail price minus the CIF price, DM and all taxes (Equation 3.10).

The Tobacconomics model assumes that the tax increase is fully passed onto the consumer and adjusted for inflation (applies to all tobacco products). This assumption can be modified, including either over- or under-shifting. Since the actual amount of pass-through depends on industry pricing strategies and cannot be known in advance, scenarios with different assumed levels of pass-through can be helpful to provide a range of outcomes with different levels of pass-through.

Figure 2.1 **Illustration of changing pass-through in Ukraine: Price, tax, and industry share (2002–2010)**



Source: Ross et al., 2012

2.3.2 Smokers' reactions to price increases

Own-price elasticity of demand

How smokers react to changes in prices due to tax increases is extremely important for measuring the revenue and consumption effects of tax changes. A change in quantity demanded with respect to a price change is measured by the own-price elasticity of demand. A price elasticity of -1 is proportional: a 10 percent increase in price causes an equal 10 percent decrease in demand. However, the response is usually less than proportional or inelastic—that is, a 10 percent increase in the price will cause a less than 10 percent fall in demand. For example, an elasticity of -0.3 indicates that a 10 percent increase in price causes a three percent decrease in demand. Measuring consistent elasticities can be difficult, since they depend on the data available and differ by country, incomes, estimation methods, and over time.

Most tobacco tax models include own-price elasticities. If there are no country-specific own-price elasticities available, estimates from similar countries can be used. Own-price elasticities calculated for different countries using different methods have shown similar ranges of results. The range for

Box 2.2 Measuring the health impact of a decline in demand for cigarettes

Part of the decline in demand from a tax and price increase comes from people who quit smoking, and the other part comes from people who smoke fewer legal cigarettes (decreased smoking intensity). Tax and price increases also discourage some people from starting to smoke, particularly young people (Section III below). In order to calculate the effects on lives saved, or avoidance of premature death, the number of smokers who quit must be estimated. A review of studies in the International Agency for Research on Cancer (IARC) 2011 report found that about a third to half of a decline in demand is attributable to quitters, and two thirds to one half are due to decreases in smoking intensity.

The IARC 2011 review also concluded that one fourth to one half of those who quit would avoid premature death from smoking-related diseases. A study in the United Kingdom that followed doctors who smoked over 50 years is summarized in Di Cicco et al. (2016). The 40-year report (Doll et al., 1994) found that half of regular smokers would die from smoking-related diseases and that lifelong smokers have a death ratio twice that of never smokers. As examples, the assumptions for the number of quitters who would avoid premature death used by Jha and Chaloupka (1999) is 50 percent and by the U.S. Department of Health and Human Services (2000) is 25 percent.

Models that calculate health effects, using these studies as the basis of assumptions as to the percentage of smokers who quit and avoid premature death, often assume that 33–50 percent of the decline in demand is from smokers who quit and that 25–50 percent of quitters will avoid premature death. Some models are deliberately conservative to understate the potential number of lives saved. For a more robust understanding, it may be useful to calculate alternative scenarios using different values.

A decrease in cigarette consumption occurs due to the combination of a decrease in smoking prevalence (SP) and a decrease in smoking intensity (often measured by the average number of cigarettes smoked per day). Using the studies above, the percentage of the decrease in consumption Q attributed to a decrease in smoking prevalence ρ is between 0.33 and 0.50 percent.

The change in smoking prevalence after a tax and price increase is calculated as:

$$SP_1 \times (\%\ change\ in\ Q \times \rho) \qquad (2.3)$$

The new level SP_2 is:

$$SP_2 = SP_1\,(1 + \%\ change\ Q \times \rho) \qquad (2.4)$$

The number of lives saved N is calculated as:

$$N = (SP_1 - SP_2)\ x\ total\ adults\ \ x\ \ \omega \qquad (2.5)$$

Where ω is the assumed smoking-related mortality averted if a smoker quits. The percentage used is usually 50 percent, based on the discussion above.

high-income countries has been estimated between -0.2 and -0.6, with most observations around -0.4. For lower- and middle-income countries, the range is wider, from -0.2 to -0.8, with most around -0.5 (IARC, 2011; NCI & WHO, 2017).

Cross-price elasticities

Cross-price elasticities measure the change in demand for one brand when the price of another changes. It measures the extent of substitution (that is, switching brands or trading down to less expensive brands) when prices increase. This will affect revenue estimates if demand shifts to cheaper cigarettes with an ad valorem tax or out of the legal market entirely regardless of the type of excise tax. With an ad valorem system, a rate increase will cause larger increases in more expensive cigarettes—increasing the price differentials more than with a specific tax with an equal amount of tax regardless of price —which may cause even more brand-switching. There are fewer studies on cross-price elasticities of cigarette consumption, and those have mainly been from high-income countries (NCI & WHO, 2017). Studies of low- and middle-income countries have so far shown mixed results (Chaloupka et al., 2022). Measuring cross-price elasticities is even more complex than own-price elasticities and will vary at least with relative price levels, income levels, and over time.

Some models deal with the lack of cross-price elasticity estimates by using an assumed percentage of trading up or down or a substitution factor to act like a cross-price elasticity. TaXSiM (Figure 3.3: Step 2 in Chapter 3) uses an assumed percentage change for the amount of brand-switching (trading up or down in response to changes in price rather than a cross-price elasticity. The Tobacconomics model allows the substitution between tobacco products in response to the simulated tax increase, depending on data availability. For example, the US model includes other tobacco products, generally with a goal of tax equalization (parity among products) to eliminate switching between tobacco products.

There are various factors impacting price elasticity estimates, and the use of different elasticities may affect the results of the model differently. For example, more detailed elasticity estimates by socioeconomic group, age, and gender may be available, making the projected impact on revenues more accurate. However, they are usually based on consumption data from surveys rather than sales data. Detailed data on sales by different groups are not usually available. The discussion below presents the major differences in elasticity estimates and their potential implications.

Consumption versus sales elasticity

Consumption includes all sources of cigarettes, including the illegal market. Sales data usually comes from tax statistics and therefore include only tax-paid legal sales. Elasticities have been estimated using both macro sales and consumption using micro survey data. There are strengths and weakness of each method. Sales data are usually used for time-series analysis but do not include the illegal market. Many low- and middle-income countries do not have data for a long enough time period to give meaningful results. Survey data allow for study of subgroups—such as comparing results by gender, age, and income—but may have problems with representativeness, due to small subgroup sizes, and consistency over time. Both types of data have been used to calculate own-price elasticities, and the results are similar overall. Elasticities for high-income countries are around -0.4, and in low- and middle-income countries they are around -0.5 (NCI & WHO, 2017).

Short-term versus long-term elasticity

The decline in consumption from a tax and price increase also accelerates over time. Studies have shown that a price elasticity of -0.4, for example, holds true for the first one to two years but doubles once the market has adjusted fully, usually considered to happen after five to 10 years (NCI & WHO, 2017). Therefore, the elasticity chosen for a single-year forecast should be lower than for a forecast over five years.

Elasticity by subgroups

Although most tax models have not differentiated by subgroups, as more information becomes available, these can be added. Elasticities differ by both age and gender. Elasticities for different groups can only be calculated using survey data. Young people who smoke are more likely to smoke less or quit smoking after a tax and price increase and have been shown to have higher price elasticities—around double that of adults (NCI & WHO, 2017). That would indicate elasticity estimates for young people at around -0.8 for higher-income and -1.0 for lower- and middle-income countries. Tax and price increases also have an effect on smoking initiation in young people. There are fewer estimates of smoking initiation. Estimates range from -0.84 to -1.2 for boys and much lower (-0.24) for girls in the United States (US) (NCI & WHO, 2017; Cawley et al., 2004).

Studies of the impact of gender on price elasticities have been done mainly in higher-income countries that conduct more surveys on tobacco use. The results are very mixed; some show that women have higher price elasticities, some lower, and others find no difference. There are few gender studies of lower- or middle-income countries (NCI & WHO, 2017).

Since elasticities within a country vary with income levels, some models assume smokers with higher incomes smoke more expensive cigarettes, whereas poorer smokers smoke cheaper brands. The models thus use higher elasticities for higher-priced brands or market segments and lower for cheaper brands assuming that low-income smokers are more price sensitive.

Point versus arc elasticity

Price elasticities of demand measure the demand response to a price change. Since the exact shape of the demand curve for cigarettes is unknown, especially with large tax increases, it is usually estimated using two points: price and demand before and after a tax change.

The point elasticity of demand uses the percentage change in quantity divided by the percentage change in price and has been used in many models, including the online version of TaXSiM (Chapter 3).

The arc, or midpoint, elasticity divides the difference between the changes in both price and quantities demanded at the midpoint, or average, of the two points. It is consistent on the same curve and is the same whether the curve is increasing or decreasing. The point elasticity differs since the denominator changes if the price is increasing or decreasing, producing different elasticities. The arc formulation is used in the TETSiM model in Chapter 4.

If the changes in price and quantity demanded are small, the two methods will yield similar results. However, with larger changes, the arc elasticity is more appropriate. In models, an elasticity estimate is used to calculate the change in quantity due to the tax and price increase. That calculation uses the point or arc elasticity equations (see Box 2.3 for the calculation and Equation 6

Box 2.3 Calculation of point and arc (midpoint) elasticities

The point elasticity of demand measures the percentage change in quantity divided by the percentage change in price between the starting and ending points of demand at prices before and after a tax increase:

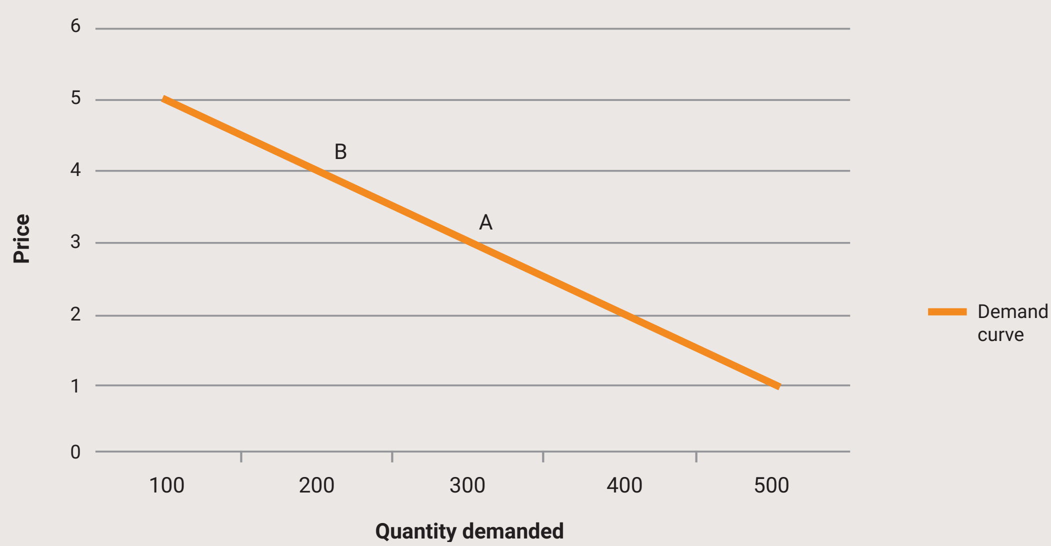
$$\frac{(Q_2-Q_1)\div Q_1}{(P_2-P_1)\div P_1} \qquad (2.6)$$

The arc, or midpoint, elasticity divides the difference between the changes at the midpoint between (or the average of) the two points:

$$\left[\frac{(Q_2-Q_1)}{\frac{(Q_2+Q_1)}{2}}\right] \Big/ \left[\frac{(P_2-P_1)}{\frac{(P_2+P_1)}{2}}\right] \qquad (2.7)$$

Example

The price per pack (*P*) increases from 3 to 4 (A to B) units and the quantity demanded (*Q*) falls from 300 to 200.



Point elasticity with the price increasing from A to B. The subscripts *1* and *2* indicate before and after the tax increase, respectively.

Box 2.3 Calculation of point and arc (midpoint) elasticities (cont'd)

Quantity (Q) decreases from 300 to 200: $Q_1 - Q_2 = 200 - 300 = -100$

$$\% \text{ decrease} = \frac{-100}{300} = -0.333$$

The price (P) increases from 3 to 4: $P_1 - P_2 = 4 - 3 = 1$

$$\% \text{ increase} = \frac{1}{3} = -0.333$$

The point elasticity of demand $= \frac{0.333}{-0.333} = -1.0$

Midpoint (arc) elasticity with the price increasing from A to B.

$$Q \text{ midpoint} = \frac{(200\text{-}300)}{((200+300)\div 2)} = \frac{-100}{250} = -0.4$$

$$P \text{ midpoint} = \frac{(4\text{-}3)}{(3+4)\div 2} = \frac{1}{3.5} = -0.29$$

Arc elasticity of demand $= \frac{-0.4}{0.29} = -1.4$

Source: Nasrudin, 2022

in TaXSiM for the point and TETSiM for the arc or midpoint calculation (Chapters 3 and 4)). The arc elasticity is appropriate for any magnitude of tax change.

In the Tobacconomics model, point elasticities are applied and are constant across the whole range of prices. The assumption can be modified to allow the elasticity to increase as prices are higher. Additionally, price elasticity can be adjusted for cross-border opportunities and other legal tax avoidance, tax administration, and other factors. In case of the youth population, elasticity estimates are applied (youth smoking is twice as sensitive (SPDC, 2022) to price as adult smoking), or existing estimates for specific countries are used.

Prevalence elasticity and smoking-attributable deaths

The prevalence elasticity accounts for the changes in number of smokers due to price changes. Total elasticity of demand consists of prevalence and intensity elasticity.

In case there is no estimate, the Tobacconomics model assumes that prevalence elasticity represents a 50-percent share in the total elasticity (Nargis et al., 2010). According to the global evidence, half of the impact on higher prices comes from the reduction in smoking prevalence.

Using prevalence data, modeling allows one to estimate the number of averted deaths in case of price increases, in both adult and youth populations. In the case that youth smoking prevalence data is unavailable, it is assumed that current adult smoker prevalence is applied to an estimated number of youth to obtain the number of future smokers. Additionally, two more assumptions are applied to obtain the estimates of smoking-attributable deaths: premature death among 30–50 percent of smokers, and a 70-percent reduced risk of premature death among 30-50 percent of quitters. For instance, it is assumed that 30 to 50 (depending on the research) percent of potential quitters could die prematurely in case of no price increase. With the tax and price increase, 70 percent of them would survive. So the number of averted deaths is calculated as follows: number of quitters*percent of smokers who would die prematurely* risk of premature death.

Consumption of illicit tobacco products

There are many studies measuring the extent of illicit trade in various countries. However, few have studied the type of cross-price elasticity that would measure how much demand shifts out of the legal market with tax and price increases. Of these, the results are mixed. However, studies of 84 countries with differing income levels (Joossens et al., 2009) and of the EU (Joossens & Raw, 1988) both found that higher-income countries with higher prices had lower levels of illicit trade than those with lower incomes and lower prices. This would indicate that tax and price increases do not necessarily lead to increases in illicit trade. Other factors, such as corruption and ineffective tax and customs administrations are at least as responsible, particularly in cases of organized large-scale smuggling. What is known is that tax and price increases are still effective in increasing tax revenues and decreasing consumption, even in countries with illicit cigarette markets (NCI & WHO, 2016).

Government tax revenues depend on tax-paid sales, so changes in sales do not depend on the illegal market except for sales lost to the illicit market. Survey data on consumption include illegal purchases but cannot provide an estimate of the cross-price elasticity from the legal to the illegal market.

Many models implicitly assume that, whatever the size of the illicit market, tax and price changes will not affect the size of the illegal tobacco market. Models can account for the loss of sales to illicit markets by using cross-price elasticities to take into account losses to illicit trade. For example, TaXSiM (Chapter 3) can do this in two ways: assuming that the trading-down factors equal zero, so any decrease in demand for a brand increases demand in the illegal market rather than increasing demand for cheaper brands. Another way is to assume that trading down goes only from a higher price segment to the price segment below. In this case trading down would be from premium only to mid-price, mid-price only to economy, and only from economy to the illegal market. This implicitly assumes that illicit cigarettes are cheaper than legal brands, which is not always the case.

An example using the trading-down factors could be -3 percent from premium to mid-price cigarettes. That means that a 10 percent increase in the premium market segment would shift 3 percent of demand for premium cigarettes to the mid-priced segment. A cross-price elasticity of -2 percent for mid-price to cheaper brands would move 2 percent of demand from mid-price to economy brands. Finally, a factor of -4 percent would move 4 percent of demand for cheaper brands to the illicit market. For TETSiM, the amount of pass through is adjusted directly with the NoT amount (retail price – all taxes). This can be an assumed percentage change (assumptions in Table 4.1) or assuming a different NoT total for simulations (Table 4.2, Row 5). In the Tobacconomics model, assumed certain percentages of illicit trade or existing estimates for specific countries can be used.

Given the lack of estimates of cross-price elasticities from the legal to the illicit market, modeling different scenarios with varying cross-price elasticities to get an idea of the magnitude of their impact could be useful.

Income elasticity of demand

Demand changes as people get richer or poorer. Demand for all normal goods increases with rising real (inflation-adjusted) incomes so the income elasticity of demand for cigarettes is usually positive. Many countries in Africa have seen rising real incomes over the last 10–20 years, so demand would be expected to increase for all normal goods, including cigarettes, in response. Using an income elasticity matters less for short-term forecasts, but forecasts over several years should take it into account, especially when incomes are growing.

Income elasticities of cigarette consumption are less studied than own-price demand elasticities, so experience in other countries may need to be used. Often real, inflation adjusted, gross domestic product (GDP) per capita is used as an estimate of real incomes since it measures the average growth per person. However, in a country with a wide dispersion of incomes, this may not be a good proxy because income growth is sometimes lower among those in lower socioeconomic groups. Survey data can provide data on income growth by subcategories, but it may not be available on a regular or countrywide basis.

2.4 Conclusions

This chapter covers some of the main issues in tobacco tax modeling. These include the types of data needed to calculate changes in revenue, prices, and consumption from changes in excise taxes as well as the main assumptions that are used for these calculations. Both the tobacco industry and smokers react to higher taxes. The industry may try to either diminish the impact of a tax increase by decreasing their profits, assuming no other changes in their costs, by passing through the full tax increase, or raising prices even higher than the tax increase to disguise a price and profit increase.

Smokers change their consumption depending on how tax increases affect the price if there are no changes in incomes. Their sensitivity to price increases is measured by the own-price elasticity of demand, or the percentage change in demand resulting from a percentage change in price. Some smokers will keep smoking despite higher prices, but many will smoke less, switch to cheaper cigarettes, stop smoking, or drop out of the tax net completely by moving to the illegal market.

Other elasticities that influence demand are the cross-price elasticity, or the amount by which smokers switch to a different brand in response to a price change, and the income elasticity, measuring the percentage increase in demand from a percentage increase in real incomes.

There has been a great deal of research into own-price elasticities in particular. The findings in general have been consistent, using both sales and survey data. The general range for high-income countries has been found to be between -0.2 and -0.8, with most being around -0.4. The range is larger for low- and middle-income countries: from -0.2 to -1.0, with most around -0.5. Most studies have found that own-price elasticities for youth are around double those of adults, as are long-run compared to short-run price elasticities. Results according to gender in high-income countries have been inconclusive (NCI & WHO, 2016).

Models that also calculate health effects use assumptions as to the percentage of the decline in demand from a tax and price increase due to quitting, rather than smoking fewer cigarettes, and how many of the quitters will avoid premature death. Studies have shown that a third to half of the decline in demand is due to people quitting, and a quarter to half of quitters will avoid premature death. The number of smokers who quit and the number of those who avoid premature death can be calculated using data on prevalence with these assumptions and the results from tax changes (Box 2.2).

3 TaXSiM Model

3.1 Introduction

The World Health Organization (WHO) has worked with countries on tobacco tax issues since 2008. WHO initially developed ad hoc tobacco tax forecasting models with individual countries to better facilitate technical assistance. The online version of WHO's Tobacco Tax Simulation Model (TaXSiM) was developed to help officials and policy analysts assess the short-run impact of tobacco tax changes with a tool available on the WHO website. The beta version of the web-based model was launched in 2013 (WHO, 2018). The modeler works with an interface that populates an Excel model. It will produce different results each time a parameter is changed. Results are exported to an Excel file as values, so the equations are never visible.

TaXSiM is currently being updated and is offline. The next version, to be available in 2023, is to include the impacts of changes in prevalence and add a multi-year option that allows comparisons to the base year, rather than annual changes, as well as changes in equations that correct some programming issues.

Along with the online tool, WHO uses custom-built models in its work with individual countries. Like the online version, these models examine the structure of the market—prices, consumption, and tax revenues—by brand and market segment. They can be more flexible than the online version by including health impacts as well as other behaviors that are not included in the current version of the online model. They can also be adapted to deal with missing or inconsistent data. The country-specific versions of TaXSiM are more comparable to other models such as the Tobacco Excise Tax Simulation Model (TETSiM). An Excel template similar to the model in the online version of TaXSiM can be used to start discussions with counterparts, although the variables and equations are often worked out with counterparts in countries.

The general approach starts with discussion and analysis, with practitioners from the finance and health ministries, to understand the economic and political context, the market structure, and the strengths and weaknesses of the existing tax system, as well as what changes are politically possible. These consultations are sometimes confidential, so the results are not always in the public domain.

3.2 Basic form: Online model

The online model allows for a great deal of detail: individual brand levels and up to 20 tax tiers (different rates or taxes for different prices or other criteria, such as cigarette length or type of pack). The model also allows for different tax bases—such as the retail or production and import prices—and different tax structures, including specific, ad valorem, or mixed excise taxes, as well as a minimum tax level. It allows changes in behavior in both demand responses to price increases and changing distribution margins in order to affect prices. The net-of-tax portion of the price (NoT, retail price minus all taxes) is divided into the producer or import price and all other margins (revenues minus costs) along the supply chain. For domestic producers and sellers this distribution margin allows tax increases to be passed through in full or in part so retail prices increase by the full tax increase or only part of it. For imports, there is an additional import margin, if the import (CIF) price is available.

For domestically produced cigarettes—or imports, if there is no data on the import (CIF) price—the retail price is:

$$\begin{aligned}&\textit{Retail price}=\\&\textit{producer or importer price}+\\&\textit{distribution margin}+\\&\textit{all taxes}\end{aligned} \tag{3.1}$$

For imports, when the import (CIF) price is available, an import margin is added to the basic equation:

$$\begin{aligned}&\textit{Retail price}=\\&\textit{import price (CIF)}+\\&\textit{import margin}+\\&\textit{distribution margin}+\\&\textit{all taxes}\end{aligned} \tag{3.2}$$

The effect of price changes on consumption are calculated using the point elasticity formula although the midpoint or arc elasticity is sometimes used in country work. The arc elasticity is also used in the TETSiM model (see Box 2.3 on elasticities in Chapter 2.)

Model equations for the 2018 online version

The WHO TaXSiM User Guide (2018) does not include the actual equations, but an earlier model explanation (WHO, 2012) contains most. The 2018 version adds other taxes or duties besides VAT and excise as well as import (CIF) prices.

These equations show totals, but prices and quantities are also indexed by brand and/or market segment.

$$RP_1 = PP_1 / CIF_1 + DM_1 + ET_1 + VAT_1 + AoT_1 \tag{3.3}$$

RP_1 is the retail price in the base year. The subscript *1* indicates the base year with the initial data. The subscript *2* refers to the simulation including tax changes. For domestic production, *PP* is the producer price, or import price if there is no actual or estimated average CIF price. The distribution margin, *DM*, is an assumed percentage of the retail price. The default amount of 10 percent can be changed. *ET* is the total excise tax amount per pack, including the value of a specific and/or ad valorem tax. *VAT* is the value added or sales tax, and *AoT* includes all other taxes or duties on cigarettes.

$$RP_1 = CIF_1 + DM_1 + MM_1 + ET_1 + VAT_1 + AoT_1 \tag{3.4}$$

Equation 3.4 shows the calculation for imports when the CIF price is available. It adds an import margin (*MM*).

The NoT amount of the retail price therefore equals *PP + DM* for domestic production and *CIF + DM + MM* for imports when the CIF price is available. For domestic production, the producer price (*PP*) is the residual that depends on all the other variables. For imports where the CIF price is known, the residual is the import margin (*MM*).

The excise tax is divided into a specific component (*ETS*), and an ad valorem amount using the rate, Φ with the retail price as the base (3.5).

$$ET = ETS + \Phi \times RP_1 \tag{3.5}$$

A value-added tax (VAT) or sales tax of $\mathcal{T}$ percent is levied on the retail price (RP_1) if the VAT is part of the excise tax base (VAT inclusive) (3.6).

$$VAT_1 = \mathcal{T}_1 \times RP_1 \tag{3.6}$$

Since (*PP + DM + ET + VAT + AOT*) is equal to the retail price (RP) for domestic production, $\mathcal{T}$ multiplied by this sum can also be used to calculate VAT inclusive of excise tax.

If the VAT base is net, exclusive, of VAT, the retail price is multiplied by ($1/(1+\mathcal{T}_1)$).

$$VAT_1 = \frac{1}{(1+\mathcal{T}_1)} \times RP_1 \tag{3.7}$$

For domestic production, or imports when the import CIF price is not available, the producer price is obtained with:

$$PP_1 = RP_1 - [(\eta \times RP_1) + ETS_1 + (1+\Phi) \times RP_1 + AoT_1 + \mathcal{T}_1 \times RP_1 \tag{3.8}$$

Where (η) is an assumed percentage of the retail price used for the distribution margin (*DM*). Equations 3.8, 3.9 and 3.10 use the VAT inclusive base as in 3.6. Equation 3.7 is used when the retail price exclusive of VAT is the base which will be reflected in Equations 3.8, 3.9, and 3.10.

When cigarettes are imported and the import (*CIF*) price is available, Equation 3.9 is used. This equation adds a term called the import margin (*MM*) that replaces the producer price (*PP*) in 3.8.

$$CIF_1 = RP_1 - [(\eta \times RP_1) + MM_1 + ETS_1 + (1+\Phi) \times RP_1 + AoT_1 + \mathcal{T}_1 \times RP_1] \tag{3.9}$$

A tax increase will increase the retail price through each term in the calculations of the retail price. The new retail price after a tax increase when the CIF price is not available is calculated as:

$$RP_2 = PP_2 + DM_2 + ET_2 + \mathcal{T}_2 \times RP_2 + AOT_2 \quad (3.10)$$

The subscript *2* indicates the post-tax-increase values. ET_2 is the sum of the new specific and ad valorem taxes. VAT, here VAT inclusive, will change since the retail price has changed.

Note that changes in any of the assumptions—price elasticity, retail margins, distribution margins, the percent trading up or down, or any increase in CIF/producer prices—are assigned to market segments in the model, so changes to the individual brands will depend on which segment they are in.

Once the new retail price, RP_2, has been calculated for each brand and market segment, the new level of consumption, Q_2, is estimated for each brand using the price elasticity chosen for each segment. The point formula for calculating the change of the price elasticity, ε_p, is:

$$Q_2 = Q_1 + \varepsilon_p \times [\frac{P_2 - P_1}{P_1}] \quad (3.11)$$

The worksheets containing the simulation results show all components of the price by brand and segment, along with the weighted average retail price and totals for consumption (sales), expenditure, total excise and tax revenues, as well as all percentage changes.

3.3 TaXSiM Method-Online version

The online TaXSiM model requires a great deal of detailed data on consumption, prices, and taxes since it does all calculations by brand and market segments. For many countries, this level of detail is not available. In these cases, it is a matter of using what data are available. The model gives the best results if there is information on brands that make up at least 80 percent of the market (WHO, 2018), but if a few brands dominate the market, their data can be used, with everything else making up another brand or market segment. The model can also be run with total data using an average retail price, or the price of the most-sold brand reported every two years by most WHO member countries.

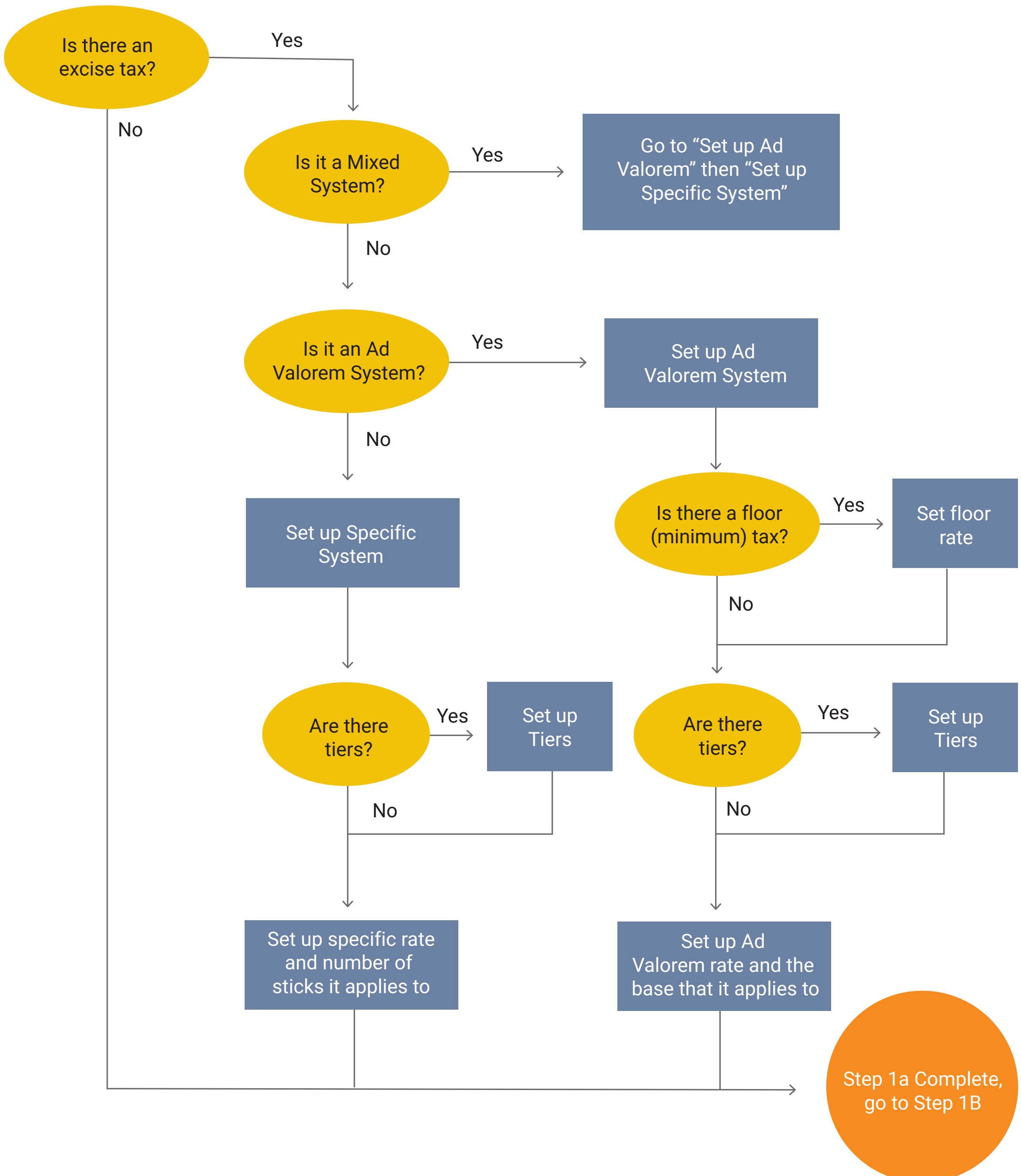
TaXSiM uses an interface that populates a model in Excel. The model requires the use of several options in Excel. Iterative calculations, all macros, and trust access to the VBA (Visual Basic for Applications) project object model must be enabled in order to use the model.

The WHO User Guide (2018) contains complete step-by-step instructions with screen shots and definitions. The interface divides the input of data and assumptions into four steps.

Step 1: Set up the base tax system: 1a and 1b

In section 1a the parameters of the basic system, ad valorem, specific or mixed, and rates and bases, including any minimum taxes, are added, followed by the details of the VAT and specific systems and any additional taxes on cigarettes, including import tariffs and other taxes or levies in 1b. A maximum of two additional specific taxes and two ad valorem taxes can be added. Finally, the rates and bases for a tiered system can be added. Figure 3.1 below shows the flow chart for Step 1a included in the manual.

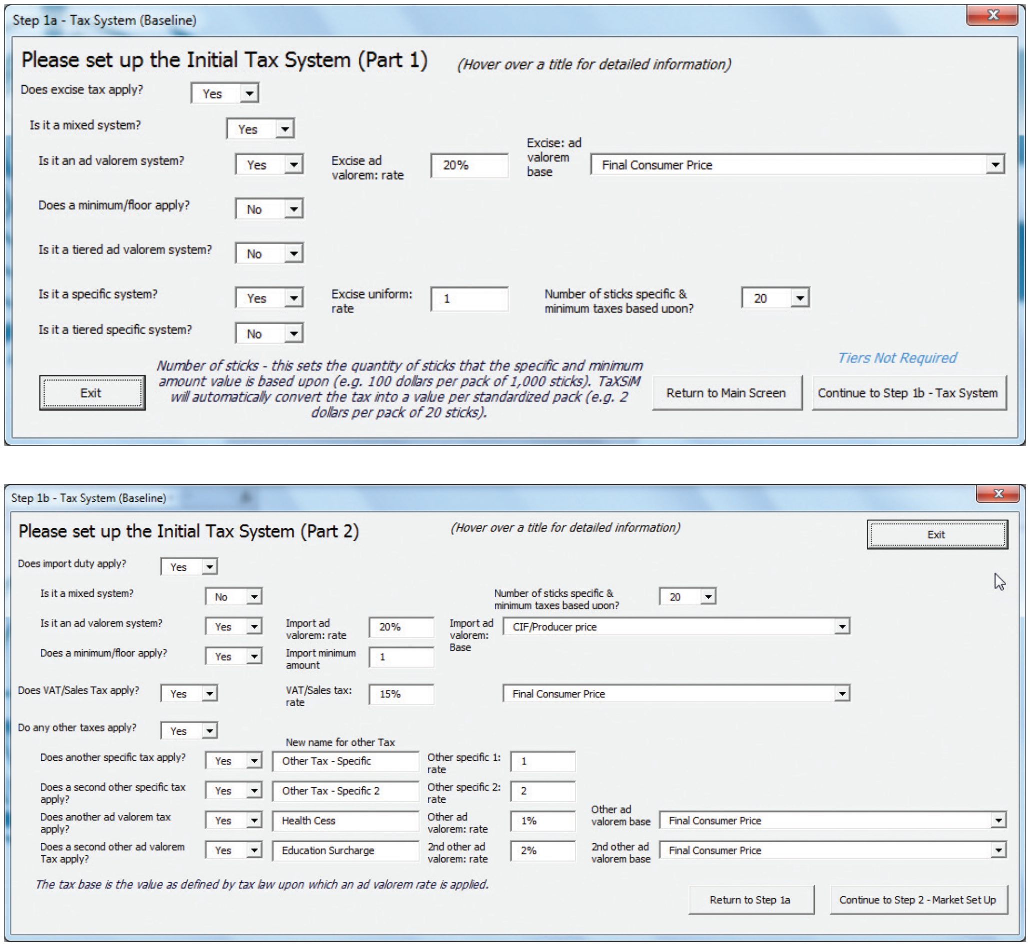
Figure 3.1 Diagram illustrating setting up the excise tax system for the baseline system



Source: WHO (2018)

The input screens for Steps 1a and 1b in Figure 3.2 show the actual interfaces.

Figure 3.2 Steps 1a and 1b – Baseline Tax System



Source: WHO (2018)

Step 2: Set up market segments with assumptions.

Segment names (premium, mid-price, and economy, for example) and the retail prices that determine each segment are defined in Step 2 (Figure 3.3). A default distribution margin of 10 percent of the retail price is programmed for both the base and simulation. If these are changed to zero, the model will make no changes in the producer or import prices or margins.

Figure 3.3 Step 2: Segment data input

Definition of Segment (Maximum 10)

Please Hover over a red triangle for more detailed information

Return to Step 1b - Data Input | Proceed to Step 3 - Data Input

Segment Name (Descending order in terms of Price)	Price Elasticity of Demand (Descending Order)	Distribution Margin (Baseline)	Distribution Margin (Simulation)	Trading-Down	Trading-Up	Allocate Brands to a segment if equal/above this Final Consumer Price	% Increase in CIF/Producer Price

Source: WHO (2018)

Step 3: Input data for the base model including:

All price, quantity and import or domestic origin is input here along with brands, segments, and tiers if applicable.

Figure 3.4 Cigarette Data Input

Cigarette Data Input (Maximum 100)

Please Hover over a red triangle for more detailed information

Return to Step 2 - Market Data | Continue to Step 4 - Simulation Tax Set Up

Auto Allocate Segments

No.	Brand Name	Final Consumer Price	Segment	Tier (if needed)	CIF/Producer price (if available)	Number of Cigarettes per pack	Quantity sold	Domestic/Import Designation?
1	Brand A	30.00	Segment A	Tier 1	12.00	20	10,000	Imported - Import Duty Exempt
2	Brand B	35.00	Segment A	Tier 2	12.00	20	9,000	Imported - Import Duty Paid
3	Brand C	25.00	Segment B	Tier 1	12.00	20	12,000	Imported - Import Duty Paid
4	Brand D	15.00	Segment C	Tier 3	9.00	20	20,000	Domestic
5	Brand E	18.00	Segment C	Tier 2	9.00	20	17,000	Domestic
6	Brand F	27.00	Segment B	Tier 1	12.00	20	11,000	Imported - Import Duty Exempt

Source: WHO (2018)

Step 4: Set up the tax system for the simulation.

This will include rate changes as well as changes in the system for the simulation. This step has the same format as Step 1: input rates and bases. The model automatically populates this section from step 1 if only rates are changed.

Model Outputs

The model output contains brand and market segment results in four worksheets: the base case, simulation results (after tax changes), a summary report comparing the baseline with the simulation, and graphs comparing the baseline and simulation results.

Running new simulations will overwrite previous results, so the results of each simulation must be saved under a different name.

3.4 Conclusions: Pros and limitations

TaXSiM is a flexible tool that allows anyone with some familiarity with tax models and Excel to analyze the economic and revenue impacts of tax changes. A complete user guide is available with step-by-step instructions. However, partly because of the complexity of the online version, with all of the possible variations to choose from and so much data needed, it can be difficult to understand and use, particularly if limited data are available. *The next update, to be available in 2023 is to include the impact of changes in prevalence and a multi-year version that can be compared to the base year, not just each prior year, as well as other updates and corrections.*

The online TaXSiM is a black box model, with users not needing, or being able to see, the background calculations. Although easier than starting from scratch with equations, it can be limiting in understanding how the model works. That is an advantage of custom models built with counterparts from the country; the intent and actual calculations can be seen and discussed as they are constructed. The custom TaXSiM models are more similar to models like TETSiM and others. The differences are mostly in the assumptions and some of the calculations, such as the method used to calculate the effects of the own-price elasticity. The current online version can be a bit difficult to use, particularly for someone not very familiar with these types of models.

4 TETSiM Model

4.1 Introduction

The original aim of the University of Cape Town's (UCT) Tobacco Excise Tax Simulation Model (TETSiM) is to facilitate reasonable estimates of the impacts of tobacco tax increases for countries with limited data (van Walbeek, 2010). The relatively simple online model can predict changes in cigarette consumption and excise revenue in response to excise tax changes. It also allows calculations of health impacts as well as the effects of several years of sustained tax increases. The model is particularly useful for countries that lack robust data about the cigarette market, including many in Africa, that want to increase tobacco taxation. Some countries do not collect or keep detailed tax or market data, and others do not make these data public.

The main advantages of the online TETSiM model are that it requires only basic aggregated data for the simulations and it is in Excel, without an interface, so the calculations can be more easily understood. Much of the data can be found in the WHO Report on the Global Tobacco Epidemic (RGTE) which includes country-reported data on the price of the most-sold brand, which can be used as a proxy for the average price, as well as excise structures and rates. Prices for premium and the cheapest brands are also reported. Other data, such as import (CIF) prices and import quantities can be calculated from the UN Comtrade database (see Box 2.1 in Chapter 2).

Even working with aggregated data, results can be very useful to estimate the magnitude of changes in prices and impact on revenues. The estimated increase in revenue is particularly important for ministries of finance to counter the tobacco industry argument that revenues will decrease after a tax increase.

One limitation of the online version is that it is programmed in an older programming language. Models used in country work are in Excel for UCT as well as WHO. An Excel version of TETSiM is planned to replace the previous version and to be available online in 2023. In the meantime, countries can access the Excel model by contacting the Research Unit on the Economics of Excisable Products (REEP) at UCT, as well as through workshops and individual country work. There are limitations with the average retail sale price as the base for the ad valorem tax. Many countries, notably in West Africa, use the CIF/import or producer price as the excise tax base. The country-specific TETSiM Excel models, used for country modeling work, allow for as much complexity as there are data available, taking into account market segments and more complex tax systems. Recent examples of papers using the current version of TETSiM include studies of Nigeria and Ghana (Akanonu et al., 2019).

4.2 Basic form: Online version

The first step, as in most models, is to divide the retail price into its components: all taxes on cigarettes and what is left, the residual, net-of-tax (NoT) amount. This represents the industry portion of the price, which includes costs, margins, and profits. Current versions add a component for all other taxes on cigarettes (AoT) to excise and value-added taxes.

$$\textit{Retail price = excise tax + VAT or sales tax + AoT + NoT} \qquad (4.1)$$

Any tax system with a single rate—specific, ad valorem, or mixed—can be modeled. However, specific and ad valorem taxes are input as a percentage of both types of excise in the retail price per pack. All model outputs are also given as the percentage change.

The new retail price is equal to the NoT amount, increased by an assumed amount of the pass through of the tax increase to consumers, plus the new amount of excise tax, all multiplied by one plus the VAT rate, assuming that the VAT base is exclusive of VAT:

New retail price=

[(Excise tax x (1+% tax change)+(NoT x (1+% pass through)] x
(NOT × (1+% pass through)]) (1+VAT rate) (4.2)

The change in consumption depends on how consumers react to the higher prices, measured by the price elasticity of demand. The effects of the price increase on consumption are calculated using the arc, or midpoint, formula (Box 2.3 in Chapter 2).

4.3 Model equations for the single-market-segment online model

This section is updated based on van der Zee and van Walbeek (2020). The initial retail price of a pack of cigarettes is given as RP_1. This is the average price for the market. *ET* is the total excise tax amount, *VAT* is the value-added or sales tax, *AoT* is the amount of all other taxes on cigarettes, and *NoT* is the industry portion of the retail price. The subscript *1* represents the initial baseline values.

The existing excise tax burden (ET_1/RP_1) is calculated using the initial total excise tax, including specific and ad valorem tax amounts, divided by the average retail price.

$$RP_1 = NoT_1 + ET_1 + VAT_1 + AoT_1 \qquad (4.3)$$

If the VAT base is inclusive of VAT, the retail price multiplied by $1 + \mathcal{T}$ in equation (4.3A) below.

$$VAT_1 = (1+\mathcal{T}) \text{ x } RP_1 \qquad (4.4A)$$

If the value-added tax (VAT) or sales tax of ($\mathcal{T}$) percent is levied on the retail price exclusive (net) of VAT, RP_1 is calculated using $1/(1+\mathcal{T}_1)$ in 4.4B.

$$VAT_1 = \frac{1}{(1+\mathcal{T}_1)} \times RP_1 \qquad (4.4B)$$

For a retail price exclusive of VAT, the industry portion is obtained as:

$$NoT_1 = \quad (\frac{RP_1}{1+\mathcal{T}} - ET_1 - AoT_1) \tag{4.5}$$

Note that all outputs are in the form of percentage changes, so the quantity of cigarettes sold is not needed for the solution of per-pack prices, only to calculate total quantity.

Total cigarette consumption, in number of packs, at the outset is Q_1. Therefore, the total base year excise tax revenue is equal to ET_1 times Q_1, and the total industry portion equals NoT_1 times Q_1.

Once the initial model has been set up, the excise tax is increased by Φ percent. The new tax amount is calculated as:

$$ET_2 = ET_1\,(1+\Phi) \tag{4.6}$$

The tobacco industry can choose to pass the entire tax increase onto the retail price or pass on more or less than the tax increase. The industry part of the price (NoT) is changed by an assumed λ percent increase along with the tax increase. Any λ greater than zero indicates that prices will increase by more than the tax increase (over-shifting). A λ less than zero indicates that prices will increase by less than the tax increase, or that the industry is decreasing profits in order to limit the price increase (under-shifting).

$$NoT_2 = NoT_1\,(1+\lambda) \tag{4.7}$$

The new retail price (RP_2) is calculated as:

$$RP_2 = [NoT_1\,(1+\lambda) + ET_1\,(1+\Phi) + AoT_1]\,(1+\mathcal{T}) \tag{4.8}$$

Once the new average price RP_2 has been calculated, the new level of consumption is estimated using the price elasticity. The model uses the arc or midpoint formula of the price elasticity, ε_p.

The new number of packs sold is Q_2:

$$Q_2 = Q_1\{[(1 + \frac{\frac{\varepsilon(RP_2 - RP_1)}{(RP_2+RP_1)}}{2}] \Big/ [1 - \frac{\varepsilon(RP_2-RP_1)}{(RP_2+RP_1)}]\} \tag{4.9}$$

The new excise revenues and NoT revenues are calculated as before: $ET_2 \times Q_2$ and $NoT_2 \times Q_2$, respectively.

The model then calculates the resulting percentage changes in average retail price, consumption, total expenditure, excise tax revenue, and the industry portion.

Health Impacts

The model can also estimate the health impacts of changes in smoking prevalence and smoking intensity and the potential number of lives saved due to an increase in the price of cigarettes. A decrease in cigarette consumption is due to a combination of a decrease in the number of people who smoke or the rate of prevalence times the adult population (SP) and a decrease in intensity (the average number of cigarettes smoked per smoker). The user sets the percentage of the decrease in consumption attributed to a decrease in smoking prevalence at ρ percent.

The change in the number of people who smoke $(SP_2) = SP_1$ x percent change in $Q \times \rho$. Using the arc elasticity SP_2 is:

$$SP_2 \; = \; SP_1(1 + {}^{\{1 + [(Q_2 - Q_1)}\!\big/_{((Q_2 + Q_1)/2)]\}} \times \rho) \qquad (4.10)$$

An index of smoking intensity (SI) is initially calculated as the total quantity of cigarettes divided by the number of adult smokers: $SI_1 = Q_1 / SP_1$.

At the new equilibrium smoking intensity is:

$$SI_2 = Q_2 / SP_2 \qquad (4.11)$$

The number of lives saved (N) is calculated as the change in the number of smokers multiplied by the assumed smoking-related mortality averted if a smoker quits ω.

$$N = (SP_2 - SP_1) \times \omega \qquad (4.12)$$

The model can also calculate the likely impact of excise tax increases that are maintained over a number of years. This requires additional data: the annual planned percentage increase in the excise taxes and forecast price, income and population growth. The income elasticity of demand will need to be estimated or assumed.

Multi-year forecasts:
For multi-year forecasts, planned future excise tax increases are needed along with forecasts for income or GDP per capita growth and inflation, if GDP growth is in real terms. In fact, both can have an impact in a single forecast year. However, the original model did not take income or GDP growth into account in the single-year forecast. This can be interpreted as showing real, inflation adjusted, changes in price, quantity and revenues. A real increase is thus a conservative revenue estimate.

4.4 Method

This section is based on the more recent extensions of TETSiM (van der Zee & van Walbeek, 2020).

Step 1: Describe the initial tax and price structure for the base scenario (Table 4.1). The data needs are the same as for the online model, except that data on at least three market segments (premium, popular, and discount) are used. Data for each segment is needed for consumption, the average retail price, and any tax tiers, different rates for different prices, or other criteria, if they exist.

There are 3 sets of assumptions: industry and smoker reactions (pass-through and own-price elasticity), health effects (percentage decrease in smoking due to quitting and percentage of quitters who avoid premature death) and multi year calculations (income elasticities and income or nominal GDP per capita growth).

Step 2: Increase the excise tax and make any structural changes. The new retail price per market segment is equal to the new total of taxes plus the new NoT per pack.

Table 4.1 Example of TETSiM data and assumption inputs, online model

Data	Value
Price, most popular brand, currency units/pack	700
Market share: Premium	20%
Market share: Mid-price	30%
Market share: Economy	50%
Specific excise tax - currency units/pack	300
Ad valorem excise (retail price base)	20%
VAT rate	15%
Sales of cigarettes, 2020 (all imported, number of packs)	620,000
Total adult (15+) population (in millions)	270
Total prevalence among adult population (percent)	35.00%
GDP (million currency units)	100,000
Assumptions	
Industry response: Increase to net-of-tax (NoT) price	5%
Price elasticity	-0.5
% decrease in cigarette consumption due to decrease in smoking prevalence	50%
% quitters who avoid premature death	50%
Income elasticity	0.55
Nominal GDP per capita growth rate (includes inflation)	3.2%

With the new quantities due to the tax and price increases, the model calculates new total tax revenues and NoT components by segment. With more than one market segment, the model can accommodate demand shifting down to cheaper cigarettes with assumptions as to the percentage shift in demand for each segment due to higher prices.

An additional module estimates the health impacts of the decline in prevalence and premature deaths avoided. To model changes over a planned series of tax increases, the model uses population and average nominal, including inflation, income growth forecasts for subsequent annual simulations.

Table 4.2 gives an example of a TETSiM model including assumptions and the calculations. Section I (starting in Row 3) includes the data for the baseline (Column B) and a scenario with changes in

Table 4.2 Example of a TETSiM model with baseline and scenario with formulas (Column C)

Row	Column: A	B	C
3	**I. Data and Assumptions**	**Baseline**	**Scenario**
4	Consumption	1,000,000	
5	Net-of-tax price (NoT)	5	5
6	Excise tax per pack	4	6
7	VAT rate	10%	10%
8	Assumed price elasticity		-0.5
9			
10	**II. Baseline**	**Values**	**Formulas**
11	**1. Retail price**		
12	Retail price = NoT + Excise + VAT		
13	• VAT (exclusive) = (NoT + excise) x VAT rate	0.9	=(B5+B6)*B7
14	• Retail price = NoT + Excise + VAT	9.9	=B5+B6+B13
15	**2. Total government revenue from excise tax**	4,000,000	=B6*B4
16	**3. Total industry revenue (NoT x total consumption / sales)**	5,000,000	=B5*B4
17			
18	**III. Scenario (increase excise tax from 4 to 6, no change in NoT)**		
19	• VAT_2 = (NoT + $excise_2$) x VAT rate	1.1	=(C5+C6)*C7
20	**1. Retail $price_2$ = NoT + $excise_2$ + VAT_2**	12.1	=B19+C5+C6
21	• % change in the retail price	22.20%	=(B20-B14)/B14
22	**2. New total excise revenue**	5,333,333	=B27*C6
23	• % change in total excise tax revenue	33.30%	=(B22-B15)/B15
24	**3. New total industry revenue**	4,444,444	=B27*C5
25	• % change in industry portion	-11.10%	=(B24-B16)/B16
26	**4. % decrease in consumption, price elasticity = -0.5**	-11.10%	=B21*C8
27	• New level of consumption	888,889	=B4*(1+B26)

Note: In this version, the point elasticity calculation is used.

the excise tax and assumptions (Column C). The following two sections contain the results for the baseline (starting in Row 10) and alternate scenario (row 18), respectively. For these sections, Column A includes the descriptions with the values in Column B and the cell references for the calculations in Column C.

4.5 Conclusions: Pros and limitations

The main advantage of the original online model was that it made it possible for countries with very little data to do serious analysis of the impacts of tobacco tax changes on consumption and revenues. Even the simple version is capable of estimating changes in prevalence and premature deaths avoided. The move towards customizing the models in work with countries often starts with a simple template, but it allows for market segments and multiple rates when data are available. The structure of TETSiM, as used today, is similar to that of TaXSiM and other models. This is partly due to discussions among tobacco tax modelers. The main differences among models are in the data available, the assumptions and how the industry portion of the retail price is handled. The formatting of the excel spreadsheet and some calculations, such as the use of the arc rather than point elasticity calculation for the price elasticity of demand also differ.

Tobacconomics Model

5

5.1 Introduction

The general Tobacconomics model was developed by the Tobacconomics team (a program of the University of Illinois Chicago), with a more extensive version developed for the United States (US) by Tobacconomics, Campaign for Tobacco-Free Kids (CTFK), and the American Cancer Society Cancer Action Network (ACS-CAN). The model simulates the increase in government revenues and public health benefits due to changes in cigarette excise taxes. The results show the benefits of taxation policy changes specifically through reduced tobacco use in the population (decreased prevalence, consumption, and mortality). The Tobacconomics model can simulate any excise tax increase(s). For, example, in the US model, excise tax increases are assumed to be substantial, not gradual, as small changes do not typically generate optimal increases in government revenues, due to the industry's easier adaptation to such changes (such as various forms of promotional discounting).

In addition to adult smokers, the simulation also addresses youth use of tobacco products, which is critical for smoking prevention and control. Youth and young adults, according to the literature (Chaloupka & Grossman, 1996), are more responsive to price changes compared to adults, due to low income, lower levels of addiction, and peer influence.

There are different variations of the model, which have been applied in various countries, such as Bangladesh, Egypt, India, Pakistan, the Philippines, Turkey, and the US. The Bangladesh study, in addition to revenue and health impacts, also addresses the issue of tobacco tax increases' effects on employment in the tobacco sector (Ahmed et al., 2019). The Pakistan and Turkey research, in order to provide more precise and conservative projections, incorporates illicit trade as a factor in modeling. The US model goes much further in that it is adapted to account for tax evasion and avoidance, impact on health care costs, and impacts of other tobacco control policies such as smoke-free air policies. In the part that relates to health care cost savings, the model covers the impacts of tax increases on pregnancy cost savings, which is important due to increased risks for pregnancy complications and smoking's adverse effects on babies before and after they are born. Additionally, lung cancer and cardiovascular diseases (stroke) are included as the most prevalent smoking-related diseases.

The model can incorporate other tobacco products besides cigarettes, such as roll-your-own tobacco, smokeless tobacco, cigars, and e-cigarettes. If the excise taxes on and prices of other tobacco products (OTP) remain unchanged when cigarette taxes are raised, smokers can switch to these now relatively cheaper products. To take into account the effect of switching to cheaper products, the model may also include the calculation of OTP taxes as a percentage of the cigarette tax rate of the national wholesale price or retail price.

The analysis gives the option of separate estimations of tax increase impacts in the case of data unavailability (for example, projections on revenues only). The projections can be updated annually and given for longer periods (two to ten years). The model can be applied broadly as a custom-built model for different countries, in terms of different tax structures and types of tobacco products.

5.2 Formulation of the model

5.2.1 Model description and assumptions

The Tobacconomics model consists of two parts: projections of government revenues and public health benefits.

The first part uses data on price, excise taxes, price elasticity, and quantity of tobacco products consumed as a baseline to assess the changes in government revenues due to an excise tax increase. Depending on the consumer sensitivity to higher prices (or price elasticity of demand), the model calculates the change in tobacco products consumption. This consumption represents a basis for the estimation of the new government revenue. The extent of illicit trade can be also taken into account in the simulations.

The second part focuses on public health benefits, seen in reduced prevalence or number of quitters and lower mortality (number of premature deaths averted). The model input data refer to the population (youth and adults), adult prevalence, and prevalence elasticity. Due to an increase in tobacco taxes, the smoking prevalence will be reduced, depending on prevalence elasticity and projected price increase. Applying reduced smoking prevalence to the number of current adult smokers, the simulations produce the number of quitters (or future adult smokers deterred from smoking initiation, in the case of youth), which will consequently impact the number of avoided smoking-attributable deaths. The changes in deaths result from data on quitters and assumptions about the percent of regular smokers who would die prematurely from disease caused by smoking as well as reduced risk from cessation.

5.2.2 Revenue simulation

In this part—using the available data on price, consumption of tobacco products, excise tax, and VAT—the model simulates the change in government revenues caused by an excise tax increase. The first step in the simulation is to assume the change of excise taxes through an increase in the specific and/or ad valorem tax, which is expressed as a percentage of the price. Industry adds their margin or net-of-tax in retail price.

The baseline scenario comprises initial retail or weighted average price of tobacco products (P_0), which is constructed based on excise taxes (specific ET_{S0} and ad valorem ET_{A0}), net-of-tax price or NOT_0, and VAT rate. The VAT is inclusive.

$$P_0 = (ET_{S0} + ET_{A0} \times P_0 + NOT_0) \times (1 + VAT) \qquad (5.1)$$

Total tax burden is also determined in the baseline scenario and defined as ratio of total tax revenue or TT_0 (excise taxes and VAT) and initial retail price. The profit of the tobacco industry or NOT_0 equals the difference between price, or P_0, and total tax, or TT_0.

$$NOT_0 = P_0 - TT_0 \tag{5.2}$$

All values in equations 5.1–5.2 refer to a unit of a tobacco product (for example, a pack of cigarettes). To obtain the total amount of government revenues (R_0) excise taxes and VAT amount (*VATa*) are multiplied by the initially determined consumption(C_0).

$$R_0 = (ET_{S0} + ET_{A0} \times P_0 + VATa) \times C_0 \tag{5.3}$$

Where, VAT amount (*VATa*) in absolute terms is calculated as follows:

$$VATa = (ET_{S0} + ET_{A0} \times P_0 + NOT_0) \times VAT \tag{5.4}$$

or, if calculated based on the retail price

$$VATa = \frac{VAT}{1-VAT} \times P_0 \tag{5.4a}$$

According to the assumption of the planned excise tax increase, in the following part of the simulation the new price is calculated:

$$P_1 = (ET_{s1} + NOT_1) * (1 + VAT) / (1 - ET_{A1} - ET_{A1} * VAT) \tag{5.5}$$

Where P_1 represents the new price, ET_{s1} stands for the increased specific excise tax, and ET_{A1} is the increased ad valorem tax. Depending on the industry reaction to changed excise taxes, NOT_1 could be increased (over-shifting), corrected for inflation, unchanged (excise tax is fully passed onto the consumers), or decreased (industry can bear part of the increase in taxes, decreasing its profit) compared to the baseline scenario.

After changing to the new price, applying the same procedure explained above, the new VAT amount, total tax, and tax burden are derived. The percentage of the price increase ($\%p = {(P_1 - P_0)}/{P_0}$) is multiplied by the estimated demand own price elasticity or ε_p (obtained from the empirical research), providing the result of the percentage decrease in tobacco consumption. Using this result, it is possible to calculate the amount of new (decreased) consumption (C_1).

$$C_1 = C_0 \times \varepsilon_p \times \%p \tag{5.6}$$

Total new revenue (R_1) is calculated from the sum of the new excise tax (ET_1) and VAT revenue ($VATa_1$), multiplied by the new (decreased) consumption (C_1).

$$R_1 = (ET_{s1} + ET_{A1} \times P_1 + VAT_{a1}) \times C_1 \tag{5.7}$$

The increase in revenues due to the excise tax increase is obtained by calculating the difference between the new (additional new revenue for the first full year the tax increase is in effect) and baseline revenue.

The simulation provides the option to incorporate alternative elasticities assumptions, such as the lowest, average, and highest estimated elasticity in empirical studies for a certain country and estimated elasticities by income groups or by market segments/tiers. Therefore the values for price, consumption, and own price elasticity have to be determined in each scenario for all income groups or market segments.

Because the cigarette market consists of a certain share of illicit products, this effect can be also addressed in the model by comparing total cigarette sales (*TS*) and taxable cigarette sales (*S*) (SPDC, 2022). Taxable cigarette sales for the baseline simulation year (S_0) can be obtained from the Ministry of Finance or national statistical office. These data refer to the quantity produced in millions of packs. In order to estimate the impact of a price increase on tobacco consumption, it is necessary to use the estimated own price elasticity of demand ε_p. Therefore, the impact of price increase *%p* on new taxable cigarettes sales (S_1) in the current year can be estimated through the following equation:

$$S_1 = S_0 \times (1 + \%p \times \varepsilon_p) \qquad (5.8)$$

Total cigarette sales volume or *TS* represents the sum of taxable cigarette sales and volume of illicit sales. The share of the illicit market could be defined as an assumption or taken from available sources such as national tobacco surveys or a pack examination survey (Guidon et al., 2014; Stoklosa & Ross, 2014; Paraje et al., 2020; Joossens et al., 2014). Total cigarette sales volume for the baseline simulation year (TS_0) are calculated using the assumed or already available estimate of the share of illicit sales. The impact of price increase *%p* on new total sales of cigarettes volume (TS_1) in the current year can be calculated applying cross-price elasticity between legal and illicit cigarettes ε_c through the following equation:

$$TS_1 = TS_0 \times (1 + \%p \times \varepsilon_c) \qquad (5.9)$$

Illicit sales (*IS*) in the current year are calculated as:

$$IS_1 = TS_1 - S_1 \qquad (5.10)$$

5.2.3 Public health benefits simulation

The part of the model related to public health benefits refers to the results of increased cessation and deterred initiation, resulting from the excise tax increase. The outcomes of those changes would be visible in the improved health of the population.

The baseline scenario includes the data on the number of adults (aged 18+) and youth (aged 0–17), adult smoking prevalence (adult prevalence is used as expected prevalence for youth), percent of regular smokers who would die prematurely from diseases caused by smoking, reduced risk from cessation, smoking prevalence elasticity,[2] and youth elasticity factor (in case there are no available estimates of elasticities related to the youth population, the assumption of higher elasticity is applied for this group, using the youth elasticity multiplication factor, which commonly equals two).

[2] If there are no available data on smoking prevalence elasticity, the data can be estimated by applying the corresponding prevalence elasticity share, commonly equalling 0.5 of total demand elasticity (unconditional elasticity).

The first step involves the calculation of the number of current adult smokers by multiplying the number of adults (aged 18+) by adult prevalence. Using the data on youth population, the number of future smokers is obtained by multiplying expected smoking prevalence (same as for adults) by the number of the youth population (aged 0–17). The number of adults and future smokers are multiplied by the percent of regular smokers who die prematurely from diseases caused by smoking, to obtain the total number of deaths.

The simulation starts with the estimation of the reduction in smoking prevalence (*%SP*), generated as:

$$\%SP = \varepsilon_{prev} \times \%p \qquad (5.11)$$

Where ε_{prev} stands for prevalence elasticity, while *%p* refers to percent of price increase. Consequently, in absolute values, number of quitters (Q_n) is generated as:

$$Q_n = AS_n \times \%SP \qquad (5.12)$$

Where AS_n refers to the number of adult smokers from the baseline scenario. In this manner, the simulation gives a number of new adult smokers (AS_{n1}):

$$AS_{n1} = AS_n - Q_n \qquad (5.13)$$

With the assumptions of the percent of regular smokers who die prematurely from diseases caused by smoking (*%DM*) and reduced risk from cessation (*%RRC*), fewer adult smoking-attributable deaths (SD_f) can be estimated as:

$$SD_f = Q_n \times \%DM \times \%RRC \qquad (5.14)$$

Following the obtained results, the number of new adult deaths caused by smoking, SD_n, are calculated by subtracting the reduced number of adult smoking-attributable deaths from the total smoking-attributable deaths SD_b (baseline scenario).

$$SD_n = SD_b - SD_f \qquad (5.15)$$

The same procedure applies for the youth population. The difference is that, instead of quitters, in this part the interpretation is related to the number of future smokers deterred from smoking initiation. The reduction in smoking-attributable deaths is the reduction in future smokers multiplied by the probability of premature death from smoking (there is no need to account for partial effects from cessation). The sample consists of youth aged 0–17 (youth alive today and prevented from smoking and dying), and ages 18–24, for the projection of the decreased number of young adult smokers.

5.3 Data requirements and sources

5.3.1 Revenue simulation

Input data:

- the weighted average retail price per unit of tobacco products (calculated from different prices by market shares if there are data on market segmentation by brands);
- tobacco products consumption;
- tax revenues;
- VAT;
- excise tax rates as percentage of retail price; and price elasticity.

The data can be obtained from sources such as (depending on the country):

- Ministry of Finance (government revenues, tobacco consumption, and prices);
- legislation or law on excise taxes (excise tax rates);
- national statistical office, household expenditure survey (prices, tobacco consumer price index, tobacco consumption); and
- empirical research, national research, or approximations from other related findings (price elasticity).

5.3.2 Public health benefits simulation

Input data:

- adult prevalence for the whole population (18+), which may be adjusted for an existing downward trend in prevalence, recent and scheduled tax increases, and subpopulation-specific prevalence;
- elasticity of adult smoking prevalence;
- youth prevalence (under 18 years old);
- elasticity of youth smoking prevalence (or youth elasticity factor, if estimate is not available);
- future prevalence among current youth;
- probability of dying prematurely;
- reduced risk of premature death following cessation; and
- population projections, by age.

The data can be obtained from sources such as (depending on the country):

- Institute of Public Health, Ministry of Health, national survey on tobacco consumption or on drug use with a tobacco module (adult prevalence);
- national statistical office (population projections); and
- empirical research, including scientific research or approximations from other related findings (prevalence, elasticity of smoking prevalence, and price elasticity of smoking initiation of youth and adults).

Other relevant international sources:

- **Centres for Disease Control (CDC) and Campaign for Tobacco-Free Kids (CTFK) Tax Burden on Tobacco Report** https://chronicdata.cdc.gov/Policy/The-Tax-Burden-on-Tobacco-1970-2019/7nwe-3aj9 (adult prevalence);
- **Pan American Health Organization (PAHO)** https://www.paho.org/en/enlace/risk-dying-prematurely-ncds (probability of dying prematurely, reduced risk of premature death following cessation);
- **World Health Organization (WHO)** https://www.who.int/data/gho/publications/world-health-statistics (health-related statistical information);
- **More detailed national information on tobacco** https://www.who.int/news-room/fact-sheets/detail/tobacco (prevalence, health consequences of tobacco use, MPOWER measures);
- **WHO Framework Convention on Tobacco Control (WHO FCTC)** https://fctc.who.int/who-fctc/overview;
- **WHO Report on the Global Tobacco Epidemic** (WHO, 2021), https://www.who.int/publications/i/item/WHO-NMH-PND-2019.5 (tax structure, tobacco control policies);
- **World Bank Tobacco Control at a Glance, 2003** (World Bank, 2003) https://openknowledge.worldbank.org/handle/10986/9730 (tobacco control policies);
- **Economics of Tobacco Toolkit, 2002** (World Bank, 2002) https://www.worldbank.org/en/topic/health/publication/economics-of-tobacco-toolkit (tobacco taxes, smuggling);
- **World Bank Indicators, WDI** https://data.worldbank.org/indicator/SH.PRV.SMOK?locations (data on prevalence, mortality rates, population trends);
- **United Nations (UN)** https://data.un.org/ statistical national databases available online (economic indicators, social indicators);
- **Food and Agriculture Organization (FAO)** https://www.fao.org/faostat/en/#data/QCL, food and agriculture data (tobacco production and harvest area, tobacco prices and trade, macroeconomic indicators);
- **International Monetary Fund** http://www.imf.org (total revenues, revenues from excise taxes and all taxes);
- **GlobalData** https://www.globaldata.com/# (aggregate cigarette sales); and
- **Euromonitor International** https://www.euromonitor.com/ (cigarette retail prices, aggregate cigarette sales).

5.4 Example

Tables 5.1 and 5.2 give an example of the first part of the Tobacconomics model: government revenues simulations. In Table 5.1, Section I includes baseline input data (consumption, VAT, price, and excise tax per cigarette pack) and estimation of the baseline tax revenue. Section II presents assumptions of own-price elasticity and excise tax increase and corresponding price and tax revenues changes per pack of cigarette.

Table 5.1 Government revenues simulation

Baseline data/estimates	Values	Explanation
Section I		
Consumption	32,500,000	millions of packs (20 sticks per pack)
Price	4.5	per pack of cigarettes
Excise tax per pack	1	(amount of specific excise per 1,000 packs/1,000) * 20 cigarettes in a pack. In this example specific excise amounts 50 US dollars per 1,000 cigarettes.
Excise tax as percent of price	22.2%	excise tax per pack/price
VAT	21.0%	VAT rate
VAT amount per pack (inclusive)	0.8	price*(VAT/(1+VAT))
Total tax per pack	1.8	total tax = excise tax per pack + VAT
Total tax as % of price	39.6%	total tax / price
Net-of-tax price	2.7	price - total tax
VAT revenue	25,382,231	VAT * consumption
Excise tax revenue	32,500,000	excise tax per pack * consumption
Total tax revenue	57,882,231	VAT revenue + excise tax revenue
Section II		
Elasticity		% change in consumption due to the % change in price
• Low	-0.62	
• Average	-0.72	
• High	-0.82	
Excise tax per pack	2.4	excise tax per pack increases from 1 to 2.4 US dollars
Net-of-tax price	3.2	net-of-tax price per pack increases from 2.7 to 3.2 US dollars
New price	6.8	price per pack increases from 4.5 to 6.8 US dollars (50% increase)
VAT	21.0%	
VAT amount per pack	1.2	
Total tax per pack	3.6	
Excise as % of price	35.0%	
Total tax as % of price	52.4%	

Note: The price increase of 50% is applied in all simulations. Revenues and price are given in US dollars

Using input data, assumptions and estimations from previous table, simulation results are presented in Table 5.2, showing the effect of the tax increase in reducing consumption and increasing government revenues.

Table 5.2 Government revenues simulation – results

Results – revenue simulations	Elasticity scenarios			Explanation
	low	average	high	
% reduction consumption	-31.0%	-36.0%	-41.0%	elasticity * price change
New consumption	22,425,000	20,800,000	19,175,000	(1 + change in consumption) * baseline consumption
New excise tax revenue	52,979,063	49,140,000	45,300,938	excise tax per pack * new consumption
New VAT revenue	26,270,610	24,366,942	22,463,275	VAT amount per pack * new consumption
Total new tax revenue	79,249,672	73,506,942	67,764,212	excise tax revenue + VAT revenue
Additional excise tax revenue	20,479,063	16,640,000	12,800,938	excise tax revenue – baseline excise tax revenue
Additional VAT revenue	888,378	-1,015,289	-2,918,957	VAT revenue - baseline VAT revenue
Additional tax revenue	21,367,441	15,624,711	9,881,981	Total tax revenue – baseline total tax revenue
% increase total tax revenue	36.9%	27.0%	17.1%	change in total tax revenues

Note: Revenues and price are given in US dollars

The next two tables (5.3 and 5.4) show examples of public health benefit projections (the second part of the Tobacconomics model). Section I of Table 5.3 includes input data and assumptions, while Section II gives youth and adult smoking-attributable deaths in the baseline scenario.

Table 5.3 Public health benefits (averted deaths) simulation – baseline and assumptions

Baseline data	Values	Explanation
Section I		
Total population	90,000,000	
Population 15+	59,400,000	
Population 0–14	30,600,000	
Adult prevalence	20.0%	
Prevalence elasticity	0.5	estimated share of total demand elasticity in case prevalence elasticity is not available
Adult smokers	11,880,000	population (15+) * adult prevalence
% die prematurely	40%	% of individuals who die prematurely from smoking-attributable diseases
% survive if quit	70%	% of survivors in case of cessation
Youth elasticity factor	2	factor applied to adult prevalence elasticity, in case data on youth elasticity are not available
Section II		
Future smokers	6,120,000	population (aged 0–14) * prevalence
Adult smoking-attributable deaths	4,752,000	% of individuals who die prematurely from smoking-attributable diseases * number of adult smokers
Youth smoking-attributable deaths	2,448,000	% of individuals who die prematurely from smoking-attributable diseases * number of future smokers
Total smoking-attributable deaths	7,200,000	adult smoking attributable deaths + youth smoking attributable deaths

Table 5.4 shows the results of public health benefit simulations. Based on elasticity and price change assumptions (given in Table 5.1, Section II) this table gives projections of fewer reductions in the number of youth and adult smokers and smoking attributable deaths due to the simulated excise tax increase.

Table 5.4 Public health benefits (averted deaths) simulation – results

Results – health benefits	Elasticity scenarios			Explanation
	low	average	high	
% reduction in adult prevalence	-15.5%	-18.0%	-20.5%	prevalence share elasticity * elasticity * price change
Fewer adult smokers	-1,841,400	-2,138,400	-2,435,400	reduction in adult prevalence * baseline number of adult smokers
New adult smokers	10,038,600	9,741,600	9,444,600	decrease in adult smokers + baseline number of adult smokers
Fewer adult smoking-attributable deaths	-515,592	-598,752	-681,912	fewer adult smokers * % survive if quit * % die prematurely
New adult smoking-attributable deaths	4,236,408	4,153,248	4,070,088	adult smoking-attributable deaths + fewer adult smoking-attributable deaths
% reduction in youth prevalence	-31%	-36%	-41%	prevalence share elasticity *elasticity * youth elasticity factor * price change
Fewer youth smokers	-1,897,200	-2,203,200	-2,509,200	number of future smokers * reduction in youth prevalence
New youth smokers	4,222,800	3,916,800	3,610,800	future youth smokers + fewer youth smokers
Fewer youth smoking-attributable deaths	-758,880	-881,280	-1,003,680	fewer youth smokers * % die prematurely
New youth smoking-attributable deaths	1,689,120	1,566,720	1,444,320	fewer youth smoking-attributable deaths + youth smoking-attributable deaths
Fewer total smoking-attributable deaths	-1,274,472	-1,480,032	-1,685,592	fewer youth smoking-attributable deaths + fewer adult smoking-attributable deaths

5.5 Conclusions: Pros and limitations

The Tobacconomics simulation model provides an opportunity to forecast the impacts of tobacco excise tax increases on government revenues, public health, and health care costs. The model has been applied in Bangladesh, Egypt, India, Pakistan, the Philippines, Turkey, and the US, with the findings consistently confirming the positive impacts of increased taxes in each simulated area:

- Significant increase of government revenues.
- Adults quit smoking and youth are deterred from initiating.
- Smoking-attributable deaths and prevalence are reduced among adults and youth.
- Premature deaths among non-smokers are averted, with fewer deaths and increased health care costs savings.

The main advantage of this model is that it can be easily applied in all countries, due to its flexibility and ability to be adjusted to country specificities. The Tobacconomics model is customizable to the excise tax system for individual countries (programmed in Excel). Moreover, simulations do not necessarily require much data to give accurate and defendable simulation results. The degree of the model's complexity depends on the structure of the excise tax system and the availability of the tobacco market data (lack of this data could be the main weakness of the model).

Other Models

6

6.1 Introduction

To combat high levels of tobacco use, researchers have developed various simulation models to anticipate the effects of tobacco control policies, including tobacco taxation. Some of the models are more focused on policy impacts, such as SimSmoke, whereas others estimate the impacts of tax increases on smoking prevalence, government revenues, and other consequences including smoking-attributable deaths, as in the American Cancer Society (ACS) model. Models have evolved over time to incorporate greater complexity, such as the capacity to distinguish between sociodemographic groups and characteristics, tracking population trends over time, encompassing illicit trade and tax avoidance, and allowing for adjustments specific to the characteristics of a country's tax system. The dynamic social factors require more complex simulation models that can broaden the public and policy makers' understanding of the role of tobacco taxes in reducing tobacco use, as well as their fiscal and public health effects (Feirman et al., 2016). With the system dynamics model of smoking behavior, it is possible to explore the potential for cessation and reduced consumption due to a change in tobacco control policies (Skinner et al., 2021). This chapter focuses on two widely applied tobacco taxation models: SimSmoke and the ACS model.

6.2 SimSmoke

The SimSmoke model was developed by researchers at the Pacific Institute for Research and Evaluation (PIRE) (Levy, 2011) to assist government bodies in the process of tobacco control surveillance. Empirical evidence shows that policies have substantial impacts on smoking rates. SimSmoke is an aggregate tobacco control simulation model for estimating the impact of tobacco control policies on smoking prevalence and smoking-attributable deaths. The cornerstones of this model are policies of the greatest importance to reducing the immense health burden caused by tobacco. In addition to past tobacco control policies, the model can also assess the role of ones not yet implemented.

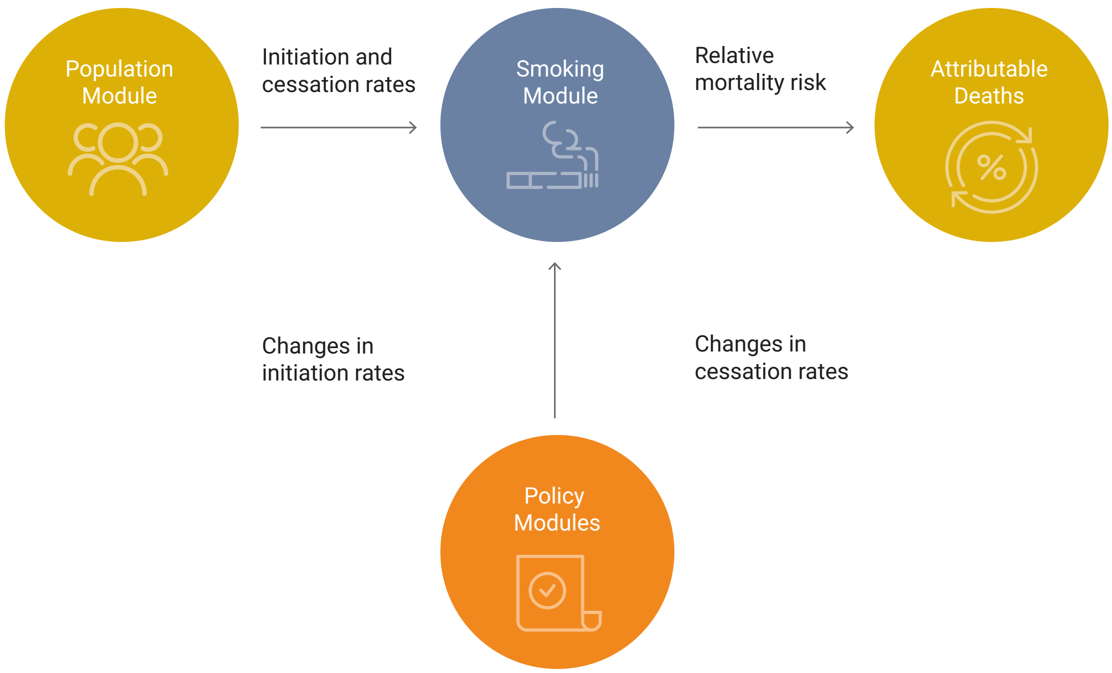
SimSmoke is dynamic, as it accounts for changes in population and projects smoking prevalence trends by demographic characteristics (age, gender, and other specific characteristics such as distinctions by urban/rural residence, income level, and racial/ethnic subgroups). In addition to prevalence, the model also estimates the number of smoking-attributable deaths. SimSmoke results therefore represent a very important input for efficient evidence-based policy making with respect to the health impacts of policies, while not considering the impact of tax changes on government revenues.

The model can be applied in different countries and adjusted for nations' specific characteristics. The first SimSmoke model was applied in the US as a whole and in several states including Arizona and California (Levy et al., 2005). It has been extended to other countries, including Vietnam (Levy et al., 2006), Thailand (Levy et al., 2008), Korea (Levy et al., 2010), and England (Levy et al., 2021), and has assessed not only prevalence but also cessation and quit attempts.

SimSmoke modules

In order to implement the SimSmoke model, it is necessary to provide inputs for its three components (modules). The model and its components are illustrated in Figure 6.1 (Levy, 2011).

Figure 6.1 SimSmoke model process



The **population (demographic) module** analyzes and tracks changes in population according to birth and death rates. Data on the total population are required, divided by age, racial/ethnic group, and gender. Ages used in the simulation are between 18 and 85, with the evolution of the population over time following the pattern of a discrete first-order Markov process. Demographic data are used as a baseline of the simulation model, being particularly helpful in relation to policies.

The **smoking module** uses the data on population trends from the demographic model as an input. In this module, the smoking population evolves through initiation, cessation, and relapse, according to the smoking status of individuals. Therefore, the main goal of the smoking module is to determine prevalence rates, which will be incorporated into the estimation of smoking-attributable deaths. The model uses the data on the number of current smokers, never smokers, and ex-smokers to simulate future initiation, cessation, and relapse rates.

The **policy module** uses the impact on the change of smoking status and rates from the smoking module to produce the final outputs of the model. SimSmoke has separate policy modules for each of the following tobacco control policies: taxation, clean indoor air laws, mass media campaigns, advertising restrictions, youth access to cigarettes, and cessation promotion. Reduction and continued decreases in smoking rates are the results of effective and robust tobacco control policies that alter the prevalence trajectories through their effect on cessation and initiation rates. The overall effect of tobacco control policies on prevalence and other smoking rates is subject to policies' initial levels, the magnitude of changes, and the conditions of their implementation. These induced changes in smoking rates determine the number of smoking-attributable deaths. Besides the estimation of the independent effect of individual policies, the model also allows for the synergistic effect of multiple policies' interactions (Levy et al., 2006). The introduction of different policies in the model is justified by their diverse effect on different smoking or demographic groups. Non-tax policies mainly depend on information from the MPOWER Report (WHO, 2021), the World Bank Report (World Bank, 2021), and the Global Adult Tobacco Survey (Global Adult Tobacco, n.d.).

The outputs of the simulation are **prevalence rate trends** and the **number of smoking-attributable deaths**. The change in prevalence is simulated with the assumption of no change in tobacco control policies (status quo), to project and estimate the prevalence rate given the adjustments and modifications to tobacco control policies (intervention). The same procedure is applied in the case of the second main output: smoking-attributable deaths. Smoking-attributable deaths refer to total mortality caused by smoking-attributable diseases (such as lung cancer and cardiovascular diseases) and are estimated for both smokers and ex-smokers. The number of deaths is generated from the changes in prevalence rates (smoking component), death rates (population component), and relative risk of smoking-attributable deaths (Levy, 2011).

6.3 ACS Model

The American Cancer Society (ACS) tax model, sometimes also called the Prevent20 model, was developed as a response to the goals set by the UN General Assembly in 2011 related to the reduction of deaths from four big noncommunicable diseases (NCDs) (cancer, diabetes, lung disease, and cardiovascular disease). This model can predict the level of tax increase during a certain period needed to achieve a specific targeted reduction in smoking prevalence. In the original development of the model, the ACS team used the WHO target of a 30-percent relative reduction in smoking prevalence by 2025 (WHO, n.d.) from a 2010 baseline. The model is flexible so the size of the relative reduction and the start and end years can be easily manipulated.

Data incorporated into the model include smoking prevalence from the baseline year and the current smoking prevalence, to show the prevailing trends, as well as cigarette tax rates related to the current period. The analysis typically uses the prices of the most-sold brands of cigarettes, though the market can be segmented in the model if more data are available (for example, discount, most-sold, and premium brands). Users can also expand the number of segments to include additional tobacco products (such as waterpipes and smokeless tobacco products) in the model. In that manner, using the estimation of price elasticity, the simulations will provide the percentage change in prevalence due to the percentage change in price.

Unlike the SimSmoke model, which has modules for various tobacco policies, the ACS model takes into account only the effect of taxation. The ACS model uses the following data: smoking prevalence, price of the most-sold brand of cigarettes, cigarette production, imports and exports, excise tax revenue, excise taxes, value-added tax, import duty, other taxes, inflation rate, population (by age), and population growth. ACS consists of three steps.

Step 1. Define the required rate of annual reduction in smoking prevalence.

In this step it is necessary to define the estimation period and the target of smoking prevalence reduction to be reached at the end of this period. For example, assume that a prediction is needed for how much tax increase is required between 2020 and 2030 to achieve the target of reducing smoking prevalence by 20 percent. Assuming that the prevalence in country *I* is equal to X percent, the planned reduction of 20 percent would lead to the target of 0.8X percent or (1 - 0.2)X percent.

For a period of 10 years, if smoking prevalence decreases at an exponential rate of *y* percent (Equation 6.1), *y* is calculated as follows:

$$X(1+y)^{10} = 0.8X \text{ or, } y = (0.8)^{\frac{1}{10}} - 1 = -0.022 \qquad (6.1)$$

Over 10 years, smoking prevalence needs to be reduced by an average of 2.2 percent annually to achieve the set target.

For years that have already passed (since 2020 in this example), current smoking prevalence may have changed from the baseline level. Therefore, this required annual reduction rate needs to be adjusted:

- if smoking prevalence is reduced at an annual rate faster than 2.2 percent, the required rate of reduction for the remaining period would be lower than 2.2 percent; or
- if smoking prevalence is reduced at a slower rate than 2.2 percent, the required rate of reduction for the remaining period would be higher than 2.2 percent.

Step 2. Define the required price increase.

Determination of the required price increase depends primarily on the price elasticity parameter. In the first major use of the model to produce country fact sheets for many countries in 2016, the ACS team used global price elasticities of prevalence based on the level of country development (-0.15 in high-income, -0.2 in middle-income, and -0.25 in low-income countries) from the empirical research. Still, it is recommended to prioritize local and the most current elasticities, then default first to similar countries and/or regional recent elasticities, before using the global elasticities.

The model also considers income elasticity, as both price and income affect the affordability of tobacco products and, consequently, consumption. It is assumed that income elasticity has a positive sign. In step two, the model estimates how much price increase is required to yield the targeted reduction in smoking prevalence defined in the first step. The required annual change in price depends on price and income elasticity and annual change in income.

The overall change in smoking prevalence due to the price changes is the result of the cumulative reduction in prevalence in each year over this period, projected by the price and income elasticity parameter.

$$lnSP = \in_p lnP + \in_Y lnY + \beta X + e \qquad (6.2)$$

where *SP* is smoking prevalence, *P* and *Y* represent price and income, respectively, $\in_p$ price and $\in_Y$ income elasticity, and *X* stands for other factors that affect smoking prevalence (*e* error term).

Step 3. Define the required tax increase.

In this last step, it is important to define the relationship between the tax and price increases, described through a price regression that includes the amounts of excise tax, value-added tax, import duty, and other taxes. To determine the average effects of a tax increase on the increase in price, the model utilizes a regression predicting prices using 178 WHO member countries' tax and price increases with country- and year-fixed effects from 2008–2014, using data from recent WHO RGTEs. Because the evidence suggests differences in the relationship between tax change and price change among different tax systems, the regression includes dummies for specific, ad valorem, and hybrid systems that can be incorporated into the model. The estimated coefficient of tax changes from the regression is taken to calculate the tax increase necessary to achieve the required price change from the second part of the model. Generally, the other factors remain constant, but if there are simultaneous changes that might affect this outcome, such as a VAT reform, these can be incorporated directly in the model.

The model can also calculate the change in the number of smokers (the initial number is calculated by prevalence and population) and, from these changes, estimate the number of lives saved. Data needed, such as prevalence elasticity and the proportion of smokers who die of tobacco-attributable disease can be based on assumptions (described in the chapter on the Tobacconomics model) or can be adjusted if there are credible national-level estimates that suggest a different estimate.

When the data are available, the model can include a revenue component. As a starting input, the model includes any historical revenue data and then bases changes on those initial revenues. Historical revenue data is more accurate compared to the anticipated revenue (tax rate multiplied by cigarettes produced). The model allows for predictions of future consumption (using production data when available as a proxy for consumption) and the revenue predictions follow from that.

In some countries, users have added illicit trade to the ACS model. Typically, users have added illicit trade in models with different price segments by adjusting the elasticities of the different segments to account for these changes. It is known that when prices increase, some tobacco users may seek out and switch to less expensive brands. Ideally, this dynamic would be incorporated by using cross-price elasticities (how much demand changes for one product when the price of another changes), but these are very rarely available in most countries. Instead, if possible, the elasticities of different cigarette price categories can be adjusted. Accordingly, the elasticities can be adjusted by a certain amount, for example 0.1, in either direction, setting the baseline elasticity for the cheaper segment at 0.1 less (for example, from -0.4 to -0.3) (Goodchild et al., 2016)—assuming that some smokers of the higher-priced brands will substitute down to these lower-priced domestic brands—and at 0.1 more for the more expensive segments.

In sum, the ACS model can predict how much tax increase for a certain period is required to achieve the targeted reduction in smoking prevalence, while generating implications for changes in the number of smokers (and lives saved or deaths prevented) and revenue. The model is user-friendly and relatively easy to apply for taxation policy simulation.

6.4 Conclusions: Pros and limitations

SimSmoke and the ACS model represent important tools used in modeling tobacco tax and policy impact. While the first focuses more on policy impact, the latter estimates the impacts of tax increases on smoking prevalence, government revenues, and other consequences including smoking-attributable deaths.

The SimSmoke model shows how much smoking prevalence and how many smoking-attributable deaths would be reduced due to policy changes. Only with this model, one can estimate how many lives would be saved by applying certain tobacco control policies. The SimSmoke model addresses policies which are of the greatest importance in reducing the immense health burden caused by tobacco. The model is useful in predicting how current and future regulation changes affect a country's tobacco use prevalence and smoking-attributable deaths in the long term (up to 50 years). The results of the previous research show that these effects are more pronounced in less developed countries, due to the lower level of tobacco control regulation adoption and enforcement. Still, there are several limitations of the model such as:

- Poor quality and availability of the data especially in the low-income countries;
- Weak knowledge on policy impact on different age groups due to low number of empirical research studies considering this subject;
- Uncertainty related to the various policies' mutual interaction or their synergetic effects;
- As in case of other models, the data on relative risk is used mainly from large epidemiological studies (primarily availailable from the US), due to the lack of local research of this type. The main obstacle of using this data is related to under- or over-estimation of relative risks in other countries.

The ACS model encompasses three main steps, defining the required change in smoking prevalence, price change, and tax changes, respectively. The analysis only includes the excise system of the country through dummy variables, but this is generally sufficient to generate a credible estimate of these changes. It should be emphasized, as a potential limitation, that this model does not account for tobacco control policies and does not simulate the impact of tax changes on some other important effects of tobacco use, such as health costs. However, this limitation also applies to TaXSiM and TETSiM, mostly due to data limitations.

7

Conclusion

Although the basic tax and price calculations are straightforward, there are many complexities in actual tobacco tax modeling. These include the types of data needed and available to calculate changes in revenue, prices, and consumption from changes in excise taxes as well as the main assumptions that are used for these calculations. In practice, the biggest constraint is almost always lack of data. Although many countries have good data that is publicly available, many others do not. Even when some data such as retail prices and quantities sold are available, tax bases, particularly if the producer or import price is the base, can be difficult to access and must be estimated.

The primary purpose of this toolkit is to review the most commonly used models for forecasting the impacts of tobacco taxes on demand for cigarettes and government revenues as well as the public health effects of decreased demand. While some variations have been published by different authors, most of them are based on the three models presented in this toolkit, namely TaXSiM, TETSiM, and the Tobacconomics model. The differences are mostly in the assumptions and some of the calculations, such as the method used to calculate the effects of the own-price elasticity or the format of the spreadsheets (calculations going across a spreadsheet in most TaXSiM models rather than vertical as in many TETSiM based models). Through the explanation of the design of the models, assumptions, and data requirements, users can gain a more accurate understanding of the objectives along with the similarities and differences between them and how they can be adjusted based on data availability.

While the online TaXSiM model is flexible as it can deal with both average prices and many different brands and market segments, it is a black box model, with users not needing, or being able to see, the background calculations. Partly because of the complexity of the online version, with all of the possible variations to choose from and so much data needed, it can be difficult to understand and use, particularly if limited data are available. On the other hand, the custom models are built country-by-country where the intent and actual calculations can be seen and discussed with counterparts as they are constructed. The custom TaXSiM models are more similar to models like TETSiM and others.

The main advantage of the original TETSiM online model was that it made it possible for countries with very little data to analyse the impacts of tobacco tax changes on consumption and revenues. Even the simple version is capable of estimating changes in prevalence and premature deaths avoided. The move towards customizing the models in work with countries often starts with a simple template, but it allows for market segments and multiple rates when data are available. The structure of TETSiM, as used today, is similar to that of TaXSiM and other models.

The complexity of the Tobacconomics model varies by country depending on data availability, from being very detailed, such as for the U.S., to being much simpler, as in the case of Pakistan and Bangladesh. While the Tobacconomics model is, in general, very similar to the TETSiM and TaXSiM models, there are certain differences, specifically considering the latter. For instance, Tobacconomics uses basic aggregate data and it is easily applied in Excel, with no online version available for now (compared to TaXSiM which requires more detailed data by brand, industry portion of retail price, etc.). Additionally, Tobacconomics gives the option to apply inventory tax to tobacco products in stock when the tax increase goes into effect, to avoid pre tax-increase stockpiling.

Even though both Tobacconomics and TETSiM models include a simulation of the health impact of the excise tax increase, the Tobacconomics model goes a step further by including the impact on youth. In case of the youth population, elasticity estimates are applied by either assuming that youth prevalence is twice as sensitive to price as adult prevalence, or using estimates for specific couuntries. Contrary to TETSiM, to estimate the number of averted deaths, this model uses the prevalence elasticity, whereas in case of no estimates, the Tobacconomics model assumes that half of the impact of higher prices comes from a reduction in smoking prevalence. Moreover, the Tobacconomics model for the US also accounts for the impact of a tobacco tax increase on health-care costs, pregnancy cost savings, as well as the impact of other tobacco control policies such as smoke-free air policies on the number of averted smoking-attributable deaths.

Overall, given the similarities and differences between these three models, the choice of an appropriate model depends on the objective and scope of the analysis and data availability.

References

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Ahmed, N., Nargis, N., Zaman, M. M., Huq, S. M., Rouf, M. A., Begum, S. A., Ekram, M. N., & Hassan, Md. T. (2019). *The Revenue and Employment Outcome of Biri Taxation in Bangladesh*. National Board of Revenue, Government of Bangladesh. https://cdn.who.int/media/docs/default-source/searo/bangladesh/pdf-reports/cat-2/biri-study-report-03-12-2019.pdf?sfvrsn=b8fea69_2

Akanonu, P. C., Ishaku, J., & Onyekwena, C. (2019). *The Economics of Tobacco Control in Nigeria: Modelling the Fiscal and Health Effects of a Tobacco Excise Tax Change* (Working Paper 99). International Centre for Tax & Development. https://www.ictd.ac/publication/economics-tobacco-control-nigeria-modelling-fiscal-health-excise-tax/

Bulletin No 199/200: OMA Bilten. (2022). Macroeconomic Unit of the Governing Board of the Indirect Taxation Authority. http://www.oma.uino.gov.ba/bilteni/Oma_Bilten_eng_199_200.pdf

Cawley, J., Markowitz, S., & Tauras, J. (2004). Lighting up and slimming down: The effects of body weight and cigarette prices on adolescent smoking initiation. *Journal of Health Economics, 23*(2), 293–311. https://doi.org/10.1016/j.jhealeco.2003.12.003

Chaloupka, F., Fuchs Tarlovsky A., Gonzales Icaza M.F., Rodrigues-Iglesias G., Vulovic V., (2022). Toolkit for Estimating the Distributional Impact of Tobacco Taxes. A Tobacconomics Toolkit. Chicago, IL: Tobacconomics, Health Policy Center, Institute for Health Research and Policy, University of Illinois Chicago. www.tobacconomics.org

Chaloupka, F., & Grossman, M. (1996). Price, Tobacco Control Policies and Youth Smoking. *Economics of Substance Abuse II*, w5740. https://doi.org/10.3386/w5740

Chaloupka, F. J., Yurekli, A., & Fong, G. T. (2012). Tobacco taxes as a tobacco control strategy. *Tobacco Control, 21*(2), 172–180. https://doi.org/10.1136/tobaccocontrol-2011-050417

Chaloupka, F. J., Straif K., & Leon M. E. (2011); Working Group, International Agency for Research on Cancer. Effectiveness of tax and price policies in tobacco control. *Tobacco Control. 20*(3), 235-8. https://tobaccocontrol.bmj.com/content/20/3/235

Di Cicco, M. E., Ragazzo, V., & Jacinto, T. (2016). Mortality in relation to smoking: The British Doctors Study. *Breathe, 12*(3), 275–276. https://doi.org/10.1183/20734735.013416

Doll, R., Peto, R., Wheatley, K., Gray, R., & Sutherland, I. (1994). Mortality in relation to smoking: 40 years' observations on male British doctors. *BMJ (Clinical Research Ed.), 309*(6959), 901–911. https://doi.org/10.1136/bmj.309.6959.901

Economic Community of West African States (ECOWAS). (2017). *Directive CIDIR.1.12.17 on the Harmonization of Excise Duties on Tobacco Products in ECOWAS Member States*. https://untobaccocontrol.org/impldb/wp-content/uploads/sierra_leone_2018_annex-5_ECOWAS_directive_tobacco_2017.pdf

Euromonitor. (n.d.). Euromonitor. Retrieved December 9, 2022, from https://www.euromonitor.com/

FAOSTAT. (2022, February 17). Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat/en/#data/QCL

Feirman, S. P., Donaldson, E., Glasser, A. M., Pearson, J. L., Niaura, R., Rose, S. W., Abrams, D. B., & Villanti, A. C. (2016). Mathematical Modeling in Tobacco Control Research: Initial Results From a Systematic Review. *Nicotine & Tobacco Research: Official Journal of the Society for Research on Nicotine and Tobacco, 18*(3), 229–242. https://doi.org/10.1093/ntr/ntv104

Global Adult Tobacco Survey. (n.d.). World Health Organization. Retrieved November 23, 2022, from https://www.who.int/teams/noncommunicable-diseases/surveillance/systems-tools/global-adult-tobacco-survey

Goodchild, M., Perucic, A.-M., & Nargis, N. (2016). Modelling the impact of raising tobacco taxes on public health and finance. *Bulletin of the World Health Organization, 94*(4), 250–257. https://doi.org/10.2471/BLT.15.164707

Guindon, G. E., Driezen, P., Chaloupka, F. J., & Fong, G. T. (2014). Cigarette tax avoidance and evasion: Findings from the International Tobacco Control Policy Evaluation (ITC) Project. *Tobacco Control, 23 Suppl 1*(0 1), i13-22. https://doi.org/10.1136/tobaccocontrol-2013-051074

Home. (n.d.). GlobalData. Retrieved December 9, 2022, from https://www.globaldata.com/

IARC. (2011). Effectiveness of Tax and Price Policies for Tobacco Control (Vol. 14). https://publications.iarc.fr/Book-And-Report-Series/Iarc-Handbooks-Of-Cancer-Prevention/Effectiveness-Of-Tax-And-Price-Policies-For-Tobacco-Control-2011

International Monetary Fund—Homepage. (n.d.). IMF. Retrieved December 9, 2022, from https://www.imf.org/en/Home

Jha, P., & Chaloupka, F. (1999). *Curbing the epidemic.* World Bank. https://doi.org/10.1596/0-8213-4519-2

Joossens, L., Lugo, A., La Vecchia, C., Gilmore, A. B., Clancy, L., & Gallus, S. (2014). Illicit cigarettes and hand-rolled tobacco in 18 European countries: A cross-sectional survey. *Tobacco Control, 23*(0), e17–e23. https://doi.org/10.1136/tobaccocontrol-2012-050644

Joossens, L., Merriman, D., Ross, H., & Raw, M. (2009). *How Eliminating the Global Illicit Cigarette Trade Would Increase Tax Revenue and Save Lives* (p. 36). International Union Against Tuberculosis and Lung Disease. https://www.tobaccofreekids.org/assets/global/pdfs/en/ILL_global_cig_trade_full_en.pdf

Joossens, L., & Raw, M. (1998). Cigarette smuggling in Europe: Who really benefits? *Tobacco Control, 7*(1), 66–71. https://doi.org/10.1136/tc.7.1.66

Levy, D. T. (2011). *User's manual to SimSmoke model.* Pacific Institute for Research and Evaluation. https://extranet.who.int/fctcapps/fctcapps/fctc/kh/tobacco-taxation/e-library/users-manual-simsmoke-model

Levy, D. T., Nikolayev, L., & Mumford, E. (2005). Recent trends in smoking and the role of public policies: Results from the SimSmoke tobacco control policy simulation model. *Addiction (Abingdon, England), 100*(10), 1526–1536. https://doi.org/10.1111/j.1360-0443.2005.01205.x

Levy, D. T., Bales, S., Lam, N. T., & Nikolayev, L. (2006). The role of public policies in reducing smoking and deaths caused by smoking in Vietnam: Results from the Vietnam tobacco policy simulation model. *Social Science & Medicine (1982), 62*(7), 1819–1830. **https://doi.org/10.1016/j.socscimed.2005.08.043**

Levy, D. T., Bauer, J. E., & Lee, H. (2006). Simulation Modeling and Tobacco Control: Creating More Robust Public Health Policies. *American Journal of Public Health, 96*(3), 494–498. **https://doi.org/10.2105/AJPH.2005.063974**

Levy, D. T., Benjakul, S., Ross, H., & Ritthiphakdee, B. (2008). The role of tobacco control policies in reducing smoking and deaths in a middle income nation: Results from the Thailand SimSmoke simulation model. *Tobacco Control, 17*(1), 53–59. **https://doi.org/10.1136/tc.2007.022319**

Levy, D. T., Cho, S., Kim, Y.-M., Park, S., Suh, M.-K., & Kam, S. (2010). SimSmoke Model Evaluation of the Effect of Tobacco Control Policies in Korea: The Unknown Success Story. *American Journal of Public Health, 100*(7), 1267–1273. **https://doi.org/10.2105/AJPH.2009.166900**

Levy, D. T., Sánchez-Romero, L. M., Li, Y., Yuan, Z., Travis, N., Jarvis, M. J., Brown, J., & McNeill, A. (2021). England SimSmoke: The impact of nicotine vaping on smoking prevalence and smoking-attributable deaths in England. *Addiction (Abingdon, England), 116*(5), 1196–1211. **https://doi.org/10.1111/add.15269**

Nargis N., Ruthbah U. H., Fong G. T. (2010). Taxation of Tobacco Products in Bangladesh: Findings from the 2009 ITC Bangladesh Survey. ITC Project Working Paper Series. Waterloo, Ontario, Canada: University of Waterloo. **https://itcproject.s3.amazonaws.com/uploads/documents/bdtaxreportfinalregularformat.pdf**

Nasrudin, A. (2022, April 14). Arc Elasticity: Meaning, How to Calculate, Difference with Point Elasticity. *Penpoin*. **https://penpoin.com/arc-elasticity/**

National Cancer Institute (NCI) and World Health Organization (WHO). (2017). *NCI Tobacco Control Monograph 21: The Economics of Tobacco and Tobacco Control* (NIH Publication No. 16-CA-8029A). U.S. National Cancer Institute and World Health Organization. **https://cancercontrol.cancer.gov/sites/default/files/2020-06/m21_complete.pdf**

Paraje, G., Araya, D., & Drope, J. (2020). Illicit cigarette trade in Metropolitan Santiago de Chile. *Tobacco Control, 29*(1), 68–73. **https://doi.org/10.1136/tobaccocontrol-2018-054546**

Risk of Dying Prematurely from NCDs. (n.d.). PAHO/WHO Pan American Health Organization. Retrieved December 9, 2022, from **https://www.paho.org/en/enlace/risk-dying-prematurely-ncds**

Ross, H., Stoklosa, M., & Krasovsky, K. (2012). Economic and public health impact of 2007-2010 tobacco tax increases in Ukraine. *Tobacco Control, 21*(4), 429–435. **https://doi.org/10.1136/tc.2010.040071**

SEATCA Tobacco Tax Program: Indonesia, Indonesia Ministry of Finance Regulation No. 109/PMK.010/2022, **https://tobaccotax.seatca.org/indonesia/**, accessed February 2, 2023.

Skinner, A., Occhipinti, J.-A., & Osgood, N. D. (2021). A dynamic modelling analysis of the impact of tobacco control programs on population-level nicotine dependence. *Scientific Reports, 11*, 1866. **https://doi.org/10.1038/s41598-021-81460-9**

Social Policy and Development Centre (SPDC). (2022). *Budget 2022-23: Revenue and Health Implications of Cigarette Tax Policy Options in Pakistan [Policy Note]* (p. 1—12) [Policy Note]. Social Policy and Development Centre (SPDC). Retrieved November 23, 2022, from https://tobacconomics.org/files/research/786/spdc-policy-note-on-finance-act-2022-final.pdf

Stoklosa, M., & Ross, H. (2014). Contrasting academic and tobacco industry estimates of illicit cigarette trade: Evidence from Warsaw, Poland. *Tobacco Control, 23*(e1), e30-34. https://doi.org/10.1136/tobaccocontrol-2013-051099

The Tax Burden on Tobacco, 1970-2019 Dataset. (2021, March 22). Centers for Disease Control and Prevention (CDC) Chronic Disease and Health Promotion Data & Indicators. https://chronicdata.cdc.gov/Policy/The-Tax-Burden-on-Tobacco-1970-2019/7nwe-3aj9

Tobacco. (2022, May 24). World Health Organization (WHO). https://www.who.int/news-room/fact-sheets/detail/tobacco

UEMOA (WAEMU). (2017). *Harmonisation des législations en matière de droits d'accise applicables aux tabacs: Directive n°01/2017/CM/UEMOA*. https://www.droit-afrique.com/uploads/UEMOA-Directive-2017-01-droits-accise-tabacs.pdf

UNdata. (n.d.). UNdata. Retrieved December 9, 2022, from https://data.un.org/

United Nations. (2015). *Report of the third International Conference on Financing for Development, Addis Ababa, 13–16 July, 2015*. United Nations.

U.S. Department of Health and Human Services. (2000). *Reducing Tobacco Use: A Report of the Surgeon General*. https://www.cdc.gov/tobacco/data_statistics/sgr/2000/complete_report/pdfs/fullreport.pdf

van der Zee, K., & van Walbeek, C. P. (2020). *The TETSiM model* (REEP Back to Basics Policy Brief No. 8). WHO Framework Convention on Tobacco Control & Research Unit on the Economics of Excisable Products. https://portal-uat.who.int/fctcapps/fctcapps/fctc/kh/tobacco-taxation/e-library/tetsim-model-reep-back-basics-policy-brief-no-8

van Walbeek, C. (2010). A simulation model to predict the fiscal and public health impact of a change in cigarette excise taxes. *Tobacco Control, 19*(1), 31–36. https://doi.org/10.1136/tc.2008.028779

WHO Framework Convention on Tobacco Control overview. (n.d.). WHO Framework Convention on Tobacco Control (FCTC). Retrieved December 9, 2022, from https://fctc.who.int/who-fctc/overview

World Bank. (2002). *Economics of Tobacco Toolkit* [Text/HTML]. World Bank. https://www.worldbank.org/en/topic/health/publication/economics-of-tobacco-toolkit

World Bank. (2003). *Tobacco Control* (Knowledge Note No. 23179). World Bank. https://openknowledge.worldbank.org/handle/10986/9730

World Bank. (2021). *The World Bank Annual Report 2021: From Crisis to Green, Resilient, and Inclusive Recovery* [Annual Report]. World Bank. http://hdl.handle.net/10986/36067

World Health Organization (WHO). (2012). *The WHO Tobacco Tax Simulation Model (TaXSiM)*. http://tobacco.cleartheair.org.hk/wp-content/uploads/2012/12/The-WHO-Tobacco-Tax-Simulation-Model.pdf

World Health Association (WHO). (2018). *The WHO Tobacco Tax Simulation Model WHO TaXSiM User Guide*. **https://apps.who.int/iris/bitstream/handle/10665/260177/WHO-NMH-PND-18.3-eng.pdf?sequence=1&isAllowed=y**

World Health Organization (WHO). (2021). *WHO Report on the Global Tobacco Epidemic, 2021: Addressing new and emerging products* (p. 1—210). World Health Organization. **https://fctc.who.int/who-fctc/overview**

World Health Organization (WHO). (n.d.). *Noncommunicable Diseases: Countries commit to achieving 30% reduction in tobacco use by 2025*. World Health Organization - Regional Office for the Eastern Mediterranean. Retrieved November 23, 2022, from **http://www.emro.who.int/noncommunicable-diseases/highlights/countries-commit-to-achieving-30-reduction-in-tobacco-use-by-2025.html**

World Health Statistics. (n.d.). World Health Organization (WHO) The Global Health Observatory. Retrieved December 9, 2022, from **https://www.who.int/data/gho/publications/world-health-statistics**

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