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Optimal Taxation Of Cigarettes And E-Cigarettes: Principles For Taxing Reduced-Harm Tobacco Products

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PRINCIPLES FOR TAXING REDUCED-HARM TOBACCO PRODUCTS

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Abstract

As the tax base for traditional tobacco excise taxes continues to erode, policymakers have growing interest to expand taxation to novel and reduced-risk tobacco products. Chief among the latter are electronic nicotine delivery systems (ENDS; commonly known as e-cigarettes), although other reduced-risk tobacco products such as heated tobacco and smokeless tobacco products are also being considered for taxation. There are many possible rationales for taxing such products: to raise revenue, to correct for health externalities, to improve public health, to correct for internalities caused by irrationality or misinformation, and to redistribute income. Although each rationale leads to a different objective function, the conclusions regarding relative tax rates is largely the same. The relatively higher price elasticity of demand for e-cigarettes (compared to cigarettes) and the lower marginal harms from use imply in each case that taxes on e-cigarettes and other harm-reduced products should be relatively lower, and likely much lower, than those on cigarettes. Additional considerations concerning the policy goal of discouraging use of any tobacco product by youth are discussed as well.

I. Introduction

As fewer and fewer people smoke, the base for excise tax revenue from tobacco products continues to shrink. Accordingly, policymakers around the world have growing interest to expand taxation to novel and reduced-risk tobacco products. Chief among the latter are electronic nicotine delivery systems (ENDS), commonly known as e-cigarettes, although other reduced-risk tobacco products such as heated tobacco (also called heat-not-burn products) and smokeless products such as nicotine pouches (snus)[1] are also starting to be taxed. In addition to the need for revenue, taxes on ENDS and other reduced-risk tobacco products are often also intended to discourage their use, particularly for youth. In the US, there is currently no federal excise tax on ENDS, but some states tax reduced-harm tobacco products, and both federal and many state proposals to do so have been floated in recent years (Boesen, 2020). In some of these proposals, and in jurisdictions such as Minnesota, the tax structure is designed so that using ENDS would be as expensive or more expensive than smoking cigarettes.[2]

The demand and health-related parameters involved for reduced-harm products are too uncertain at this point to compute optimal tax rates precisely, regardless of the objective function being optimized. However, the analysis herein leads to the conclusion that—whatever the level of the tax rates—taxes on ENDS should be relatively lower, and likely

[1] Snus is a smokeless product with moist, ground tobacco in a sachet to be placed behind the upper lip.
[2] Minnesota taxes ENDS with a 95% wholesale tax rate. By contrast, the state cigarette tax is only 66.3 cents per pack, much less than the wholesale price of cigarettes.

much lower, than those on cigarettes. This conclusion is shown to hold under a variety of motivations for taxation.

II. Background on ENDS

There is much confusion about ENDS among consumers and policy makers. Three important findings from the scientific literature are: 1) ENDS are likely much less harmful than cigarettes, 2) ENDS can help some people achieve cessation from smoking, and 3) ENDS and cigarettes are economic substitutes in consumer demand. First, while not harmless, vaping (i.e. inhaling the aerosol produced by ENDS) appears to be much less harmful than smoking cigarettes. The most recent report on ENDS from the US National Academy of Science (NAS, 2018) states that there is “substantial evidence” that vaping exposes users to significantly lower levels of toxic substances (apart from nicotine) compared with smoking and that switching from smoking to ENDS results in improved short-term health outcomes.[3] In 2015-16, Public Health England and the Royal College of Physicians in the UK adopted the position that vaping is at least 95% less harmful to health than smoking (McNeill et al., 2015; Royal College of Physicians, 2016). The differential impact on health translates into 1.6 million to 6.6 million potentially averted premature deaths in the US if cigarette use were to be replaced by ENDS use (Levy et al., 2018). The short- and long-term health effects of using ENDS are still being studied, but given the very large health risks associated with smoking it is highly unlikely that vaping will be found to be as dangerous as smoking.[4]

[3] See Conclusion 5-3 in NAS (2018) for the former results and Conclusion 18-2 for the latter.
[4] The incidents of lung injury associated with vaping that were prominently covered in the media in 2019 do not reverse these conclusions. The cases of e-cigarette/vaping-associated lung injury (EVALI) were eventually strongly linked to cannabis vapes, and in particular certain illicit products (Dank Vapes). See

The second important fact is that ENDS can help some smokers achieve cessation. A recent review of 61 randomized controlled trials and other studies found that using ENDS to help quit smoking led to success rates for cessation higher than for attempts using nicotine replacement therapies, behavioral counselling, or willpower alone (Hartmann-Boyce et al., 2021).[5] Some smokers take up dual use of ENDS and cigarettes with no intention of quitting, of course. However, even among smokers not intending to quit, the use of ENDS is associated with eight times higher odds of quitting smoking than those for smokers who do not use ENDS (Kasza, et al., 2021).

Third, a small but growing literature examines consumers' demand for cigarettes and ENDS and finds them to be economic substitutes (Allcott & Rafkin, 2021; Cotti et al. 2022; Huang et al., 2014; Saffer et al., 2020; Stoklosa et al., 2016; Yao et al., 2020; Zheng et al., 2017). I.e., when the price of ENDS rises, demand increases for cigarettes, and vice versa. This finding has many practical implications for tax policy regarding nicotine products, because increasing taxes on ENDS will drive some users to smoke instead. Thus, one study found that if ENDS were taxed just as highly as cigarettes, the number of people smoking would increase by over 8% and about 2.75 million smokers in the US would be deterred from quitting (Saffer et al., 2020). The economic literature estimating the degree of substitution between ENDS and cigarettes is reviewed fully in the online appendix.

Krishnasamy et al. (2020) and *Tobacco Business*, "CDC Links Mysterious Dank Vapes and Others to Vaping Illness,"Dec. 9, 2019.

[5] Most attempts to quit smoking fail. The success rate from these trials averaged 9-14% with ENDS, 6% using nicotine replacement therapy, and 4% without using any aids or with counseling only. The best method is pharmacotherapy, which has a success rate (with the drug varenicline) of about one in five.

These three facts about ENDS imply that tax policy could be employed to reduce harm for smokers. Keeping taxes relatively low on ENDS, compared to cigarette taxes, will encourage smokers to switch to less-harmful products. Lowering existing taxes on any reduced-harm product will stimulate demand for it. Some smokers will quit using cigarettes altogether as they satisfy their craving for nicotine with less-risky products. That is, differential taxation is called for these products due to their differential risks (Chaloupka et al., 2015).[6] Ensuring that taxes are chosen to make nicotine more expensive to consume via cigarettes than ENDS can incentivize smokers to move to vaping without the reverse also happening (Friedman and Tam, 2021). This should not be difficult to accomplish, at least in the aggregate, since even before ENDS were taxed they were known to provide a larger offramp from smoking than an onramp to smoking (Kozlowski & Abrams, 2016). The analysis below shows that the conclusion that it is better to tax ENDS less than cigarettes turns out to be robust, regardless of the policy goals for taxation.

III. Motivations for taxing ENDS and implications for optimal tax rates

This section reviews the major rationales for taxing ENDS: to raise revenue, to correct for externalities, to improve public health, and to provide corrective incentives to misinformed

[6] Chaloupka et al. (2015) state: "We believe that national, state, and local policymakers should consider an approach that differentially taxes nicotine products in order to maximize incentives for tobacco users to switch
from the most harmful products to the least harmful ones. Sizable public health benefits could derive from current cigarette smokers' switching to ENDS…." The authors also note that tax authorities already differentially tax nicotine products in accord with risk, since nicotine replacement therapies (which are safe) have no excise taxes at all.

and irrational users. Since taxation for purposes of income redistribution is another common goal for tax policy in the US, albeit not typically for excise taxes, it is also discussed. While each rationale leads to a different objective function, analysis of each case leads to the same conclusion: any taxes on ENDS should be lower—almost certainly much lower—than taxes on cigarettes.

A. Rationale #1: Raising revenue

Tobacco taxes raise large amounts of revenue around the world. In the US, federal excise taxes on tobacco raised $12.1 billion in 2021,[7] and states raised $16.9 billion from taxing cigarettes alone.[8] However, as the prevalence of smoking declines, the base for this revenue source has shrunk. Federal revenue collected today is down from its high of $17.1 billion in 2010. State revenue has been in the vicinity of $17 billion since 2010, but only because most states have raised their excise tax rates—sometimes more than once—since then. As fewer cigarettes are sold, tax authorities and politicians have turned their attention to ENDS and other novel tobacco products as a source of additional revenue.

If raising revenue from distortionary tobacco taxation were the only consideration involved, then the familiar Ramsey Rule from public finance theory would apply to the optimal commodity tax rates. The constrained optimal tax rates minimize consumers' deadweight loss subject to raising a required amount of revenue, and at the solution the marginal harm from a dollar of extra tax revenue raised is equalized across the set of commodities that are

[7] See Office of Management and Budget, *Historical Tables of the Budget of the US Government*, "Table 2.4—Composition of Social Insurance and Retirement Receipts and of Excise Taxes: 1940–2026" (https://www.whitehouse.gov/wp-content/uploads/2022/03/hist02z4_fy2023.xlsx).
[8] See CDC's *The Tax Burden on Tobacco* database (from Orzechowski and Walker), https://chronicdata.cdc.gov/Policy/The-Tax-Burden-on-Tobacco-1970-2019/7nwe-3aj9/data.

taxed. Note that the efficiency losses from taxation in this case stem solely from lost self-perceived consumer benefits from consumption; the case when these are irrational is treated in the discussion of rationales 3 and 4 below. For present purposes, it is sufficient to note that many smokers act as if the personal satisfaction gained from smoking is large, even when they wish to quit (Ashley et al., 2015).

For the simplest setting (constant marginal cost, competitive supply, independent demand for the goods, and no income effects in demand) the optimum requires that the tax rates satisfy the following equation:

$$\tau_i = \frac{\lambda}{\varepsilon_i} \quad \text{for all goods } i$$

where τ_i is the relative tax rate (defined as t_i/P_i, where P_i is the tax-inclusive consumer price of good *i* and t_i is the unit tax rate on commodity *i*), the price elasticity of demand for good *i* is ε_i, and λ is a constant (Gruber, 2019). Thus, optimal taxation requires that the tax rate for a commodity be set proportionally to the inverse of its elasticity of demand. The Ramsey Rule can be rewritten as:

$$\frac{\tau_i}{\tau_j} = \frac{\varepsilon_j}{\varepsilon_i}$$

for any two commodities *i* and *j*. This form of the Ramsey Rule emphasizes that the relative tax rates depend inversely on the relative demand elasticities. For example, if demand for good *i* is twice as price-elastic as demand for good *j*, then the optimal tax rate for good *i* will be half that of the tax for good *j*, regardless of how much revenue must be raised. The assumptions underlying the simple form of the Ramsey Rule are restrictive, of course, and thus the taxes derived for this case are best viewed as being approximately optimal when any interdependency of demand, income effects, cost increases, or market power is small.

The implications of the simple Ramsey Rule for taxing cigarettes and ENDS are immediate. Numerous studies indicate that the price elasticity of demand is much lower for cigarettes than for ENDS. It follows therefore that tax rates for ENDS should be lower than those for cigarettes to minimize efficiency losses. The demand elasticity for cigarettes is well studied and the consensus price elasticity is -0.4 or lower (see the Appendix for literature on all elasticities mentioned here). A reasonable range for the price elasticity for ENDS is -2.3 to -1.3. These figures imply a tax ratio of 3.25 to 5¾ instead. Thus, the optimal tax rates on cigarettes would be more than three to five times the tax rates on ENDS by this rule.

The Ramsey Rule above is stated in terms of relative tax rates, but finding the unit taxes on the commodities themselves is straightforward. Using median figures for cigarette taxes in the US ($2.81 per pack) and the midpoint of the range above for the optimal tax ratio leads to a specific tax of about $0.11 on a (pre-tax) dollar's worth of e-cigarettes (see the Appendix). To see that this tax level is indeed much lower for ENDS than for cigarettes, note that if, in the absence of taxes, an e-cigarette product cost the same as cigarettes, then the total tax for the e-cigarette product would be only $0.40 (compared to the $2.81 tax on the pack of cigarettes).

The optimal tax formula can be adjusted to reflect that ENDS are substitutes for cigarettes as well as for income effects. Allowing for nonzero cross-price and income elasticities leads to the modified Ramsey Rule, derived in the Appendix:

$$\frac{\tau_{cig}}{\tau_{ENDS}} = \frac{\varepsilon_{ENDS} - \varepsilon_{cig,ENDS} + \left(\varepsilon^{I}_{ENDS} - \varepsilon^{I}_{cig}\right)S_{ENDS}}{\varepsilon_{cig} - \varepsilon_{ENDS,cig} + \left(\varepsilon^{I}_{cig} - \varepsilon^{I}_{ENDS}\right)S_{cig}} \tag{1}$$

where ε_{ij} is the elasticity of demand for good *i* with respect to the price of good *j* , income elasticity ε_i^I is the income elasticity of demand for good *i*, and S_i is the budget share of good *i*.[9] While this expression contains some quantities for which we have little information, we can say the following. The terms involving the budget shares can safely be ignored, at least in the US context, because they are very small for the representative consumer (see discussion in the Appendix). The cross-price elasticities are likely not ignorable, given evidence that taxing ENDS appears to stimulate demand for smoking (Cotti et al., 2022; Pesko et al., 2020; Saffer et al., 2020). The estimates of cross-price elasticity range from statistically insignificant to fairly large; see the Appendix for a review. Using the estimates of Cotti et al. (2022) in the formula (and ignoring the income elasticity terms) yields a tax ratio of 1.75.[10] Given that there is no consensus in the literature on the cross-price elasticities, other than that they are likely to be positive, this tax multiple is tentative and subject to revision as better estimates become available and a consensus begins to form around them. Nevertheless, the example shows that substitution between ENDS and cigarettes lowers but need not reverse the relationship between the optimal tax rates on the two goods. Thus, either form of the Ramsey Rule shows that, if the rationale for taxing cigarettes and ENDS is to raise revenue, and it is desired to do so in the most efficient manner possible (by the

[9] The formulas here are stated in terms of uncompensated (Marshallian) demand, to match estimates available in the literature.
[10] For Cotti et al. (2022), ε_{cig} = -0.41, ε_{ENDS} = -2.25, $\varepsilon_{ENDS,cigs}$ = 1.14, and $\varepsilon_{cigs,ENDS}$ = 0.46. Elasticities are taken from this study because it contains the most recent, high quality econometric estimates.

traditional metric of consumer surplus), then the tax rate on ENDS would be much lower than the unit tax rate on cigarettes.

B. Rationale #2: Externalities

A traditional economic rationale for taxation is to correct faulty incentives created by externalities. The relevant externalities from use of tobacco are any direct effects of consumption that create adverse consequences others.[11] If the externalities are quantifiable and known, then Pigouvian tax rates can be chosen to force consumers to internalize the external costs created by their consumption. The externalities most commonly mentioned for consumption of tobacco are the burdens imposed on taxpayers and the health burdens imposed on non-smokers. When smokers degrade their future health by smoking, they create costs for publicly funded health programs such as Medicare, thus ultimately creating costs for other taxpayers. The more direct externality from smoking is the nuisance and harm to the health of others created by second-hand and third-hand smoke.[12]

The externalities created by smoking are almost certainly much larger than any externalities from vaping. Take the different kinds of externalities in turn. First, some economists contend that there is no evidence that cigarette smoking creates a fiscal burden on Medicare (Darden & Kaestner, 2022). Even if they exist, fiscal externalities would depend on the health harms caused by smoking to the smoker. As discussed above, the health harms from vaping are nearly certainly much lower than for smoking. Therefore, the expected cost

[11] This section draws on Prieger (2021) and Warner et al. (1995).
[12] *Third hand smoke* refers to toxic residues left behind on surfaces which may be picked up by other people.

that vaping would place on publicly funded health services would be a small fraction of those from smoking.

Second, while health harm from second-hand smoke is well established (CDC, 2006), there appear to be little to no harms from second-hand vapor (more correctly termed second-hand aerosol) in most settings. Any second-hand harms from vapor would come only from exhaled vapor; vaping produces no sidestream emissions (i.e., there is nothing analogous to a smoldering cigarette). The literature is growing on this topic, but research to date shows little potential for serious harm from exhaled vapor. Some studies find that exhalations include dangerous volatile organic compounds, but often in only small amounts (US HHS, 2015). For example, vaping within a confined space the size of a small conference room has been found to result in air quality that meets or exceeds WHO and EU workplace standards for clean air (O'Connell et al., 2015).

Studies vary on the type and amount of harmful substances found in second-hand vapor, often coming to conflicting conclusions. E.g., some studies detect formaldehyde, others do not (Geiss et al., 2015). However, virtually all studies find that the amounts of potentially harmful substances in second-hand vapor are a small fraction of pollutants found in second-hand smoke (Ruprecht et al., 2014; Schripp et al., 2013). For example, studies have found that total exposure to nicotine and various particulates from e-cigarette vapor is only one-tenth what it is from conventional cigarettes.[13]

[13] See Saffari et al. (2014) for a variety of particulates and Czogala et al. (2014) for nicotine. Both arrive at a ratio of 10 to 1 comparing cigarette smoke to e-cigarette aerosol.

A more important question, separate from the measurement of particulates in ENDS vapor, is what the ultimate health harms may be. One study concluded that “the data suggest that any additional chemicals present in indoor air from the exhaled e-cigarette aerosol are unlikely to present an air quality issue to bystanders at the levels measured when compared to the regulatory standards that are used for workplaces or general indoor air quality” (O'Connell et al., 2015). A lab study found no impact of exposure to e-vapor on vital signs after 20 minutes of exposure (except that blood pressure went down; McClelland, 2020), while another found no impact on heart rate, blood pressure, breathing frequency, blood glucose, or other vital signs apart from a slightly increased body temperature (McClelland, 2021). In contrast to these lab studies, a widely reported recent observational study found that exposure to second-hand e-vapor is associated with bronchitic symptoms and shortness of breath in youth. Observational studies suffer from many potential limitations; for example, the cited study relied on self-reports of vaping behavior from youth. If some youth claimed to have only second-hand exposure to aerosol from ENDS but dissembled about not vaping (or not smoking cigarettes or cannabis) themselves, for example, then respiratory harms due to vaping or smoking could appear to be associated with second-hand aerosol.

Unlike for second-hand cigarette smoke (Fischer & Kraemer, 2015), no study has found any association between second-hand aerosol and actual diagnosed disease. No doubt the evidence on any harms from second-hand will become clearer as the research progresses. However, given the highly toxic nature of smoke from cigarettes, it seems unlikely that second-hand aerosol from ENDS will ever be found to be as harmful as second-hand smoke. Both a systematic review of the scientific literature (Hess et al., 2016) and a report by the

National Academies of Science (2018) concluded that any health risk from exposure to others' vapor is likely to be less harmful than second-hand smoke.

The implications for optimal taxes to correct for such externalities are clear: the lower externalities associated with vaping implies that the optimal Pigouvian tax on ENDS products are much lower than those on cigarettes. The efficiency loss at the market equilibrium is caused by the deficient incentives of consumers, who are assumed to (selfishly) not take the marginal external costs into account.[14] The corrective taxes are set to the marginal harm for each product at the optimal quantity consumed to the market outcome into line with the social optimum. It follows directly that goods that create less external harm should be taxed less. From the discussion of the public-finance externalities due to publicly funded healthcare and the health harms from second-hand exposure to the products of consumption (smoke or vapor), it is clear that the optimal externality-correcting taxes on ENDS would be much lower than those for cigarettes.

The existence of substitution between ENDS and smoking (i.e., positive cross-price elasticities) strengthens the conclusion that ENDS should be taxed relatively less. For example, a recent study has found that higher taxes on ENDS appear to lead to more maternal smoking during pregnancy: A dollar increase in the e-cigarette tax led to a 7.7% increase in prenatal smoking. Fewer smoking mothers who otherwise would have switched to ENDS during pregnancy did so when prices of ENDS rose (Abouk et al., 2021).[15] In this

[14] It is interesting to note that many actual and potential smokers *do* appear to take externalities from secondhand smoke into account when making their consumption decisions, and that the consideration is a reason to vape instead of smoke. See the survey evidence in Yong et al. (2019).

[15] Other research has found that indoor vaping restrictions and minimum age laws for purchasing ENDS also appear to encourage prenatal smoking (Cooper & Pesko, 2017; Pesko & Currie, 2019).

case negative externalities are created for the yet-to-be-born child, since voluminous literature has documented many adverse health effects stemming from prenatal exposure the parental smoking.[16] Keeping taxes on ENDS lower than on cigarettes would shift the externalities away from smoking, where they are larger, toward ENDS, where they appear to be much smaller if present at all.

C. Rationale #3: Improving public health

A common approach taken by public health researchers to taxing harmful products is to focus on health and longevity benefits from reduced consumption, setting aside the personal benefits from consumption of the products altogether (Ashley et al., 2015). That is, the only consequences of cessation from smoking, for example, are assumed to be the gross health and longevity benefits, without subtracting the monetary value of the consumer's lost satisfaction to arrive at net benefits.[17] This approach does not take into account the preferences of the individuals consuming the products, which is sometimes justified by arguing that consumption decisions regarding addictive goods, particularly those of youth, are inherently irrational (Chaloupka et al., 2015; Song et al., 2014). Some economists also state that the lost satisfaction from using tobacco should hold no account in cost-benefit analyses for smoking regulations, while other economists (including some from the Food

[16] Some of the health harms to the child from prenatal parental smoking include inhibited fetal growth and lower birthweight, interference with brain development, obesity later in life, and adverse effects on cardiovascular and respiratory health. See the review of Banderali et al. (2015).
[17] See also Crampton et al. (2012) on the difference in economic and public health measures of the social cost of consuming harmful products.

and Drug Administration) argue that lost consumer benefits virtually negate health benefits from tobacco regulation.[18]

One practical difficulty for optimal taxation of ignoring benefits from consumption of harmful products presents itself immediately: If the only goal is to improve public health, why not set infinitely high tax rates? I.e., if personal benefits to the consumer (and the problems caused by illicit markets and other potential social costs of prohibition) are ignored, it follows that the best taxes are those set so high as to choke off all demand for the harmful goods. However, excise taxes in the US have never been set so high as to effectively constitute a general prohibition. To avoid an objective for optimal taxes that leads trivially to prohibition, a hybrid approach involving consumer preferences is instead analyzed here. The social goal is taken to be taxes that improve public health by a fixed amount while minimizing deadweight loss (harm to the consumer from lost self-perceived benefits from consumption). This approach can also be characterized by its dual problem of maximizing gains to public health while creating no more than a given amount of deadweight loss. These formulations of the problem give primacy to the public health goal by mandating a given level of (or maximizing) improvements in health; subjective preferences for tobacco products, rational or irrational, are used only to choose among the set of taxes that accomplish the primary goal. This formulation of the planner's problem can also be viewed as a nod to political constraints. That is, if political opposition to taxing tobacco and ENDS products increases with the lost self-perceived consumer benefits, then

[18] See Chaloupka et al. (2015) for the former stance and Ashley et al. (2015) for the latter. See also Levy et al. (2018).

politicians may prefer to achieve the health-improvement goal while minimizing the deadweight loss of their constituents.

To characterize formally the efficient set of health-improving taxes requires specifying the health harm function, *H*. Assume that *H* is a function of the quantities of cigarettes (Q_{cig}) and ENDS (Q_{ENDS}) consumed. *H* could measure quality-adjusted life years of the public expected to be lost, for example, or the monetized value of them. In addition to changes in the health of nicotine consumers, *H* can also include any health-related externalities as well. Under the simplest assumptions from section A (in particular, ignoring cross-price effects), the Appendix shows that the optimal commodity tax rates to achieve a given health-improvement goal while minimizing deadweight loss satisfy the following relationship:

$$\frac{MH_{cig}/P_{cig}}{MH_{ENDS}/P_{ENDS}} = \frac{\varepsilon_{ENDS}}{\varepsilon_{cig}} \qquad (2)$$

where $MH_i = \partial H/\partial Q_i$ is the marginal harm to health from the last unit of good *i* consumed and other notation is as before. The expression MH_i/P_i that appears on the left side of the equation is the additional harm to health from spending one more dollar on good *i*. Thus, this optimal tax rule states that the taxes should be set so that the ratio of the marginal harms from an additional dollar spent on each product is equal to the ratio of the price elasticities of demand. Note that the tax rates enter equation (2) directly through the tax-inclusive prices and indirectly through any function of the quantities.

It is helpful to gain the intuition behind the optimal taxes that result from this objective. The optimal taxes are set so that the marginal consumer harm from lost benefits of consumption created by an additional unit of public health gained are equalized across the set of commodities that are taxed. If not, the health gains can be rearranged among the commodities to reduce the deadweight loss from consumption while still gaining the overall desired improvement in health. For example, if taxes are set so that the public health gained from reductions in use of cigarettes is the same as the health gained from use of ENDS, then (due to the elasticity estimates discussed above) the marginal consumer harm, subjectively determined by the consumers' own estimation, would be much higher for ENDS. Reallocating the marginal gain in public health away from ENDS and toward cigarettes, by lowering taxes on the former and raising them on the latter, would therefore result in the same total health gained but with lower deadweight loss (or political opposition, in the alternate interpretation discussed above).

From equation (2), it is clear that relative taxes should be set to make cigarettes more expensive if

$$\frac{MH_{cig}}{MH_{ENDS}} > \frac{\varepsilon_{ENDS}}{\varepsilon_{cig}}$$

The computations above for rationale #1 showed that the ratio of elasticities is equal to between 3¼ and 5¾. On the other hand, the review of the evidence by Public Health England (McNeill et al., 2015) indicates that the harm ratio on the left side of the inequality is 20 or higher. Thus, the public health rationale also leads to the conclusion that cigarettes should be taxed much higher than ENDS. With nonzero cross-elasticities, the appendix shows that the right side of the inequality is replaced with the right side of equation (1), which the computation above showed is 1¾, making the inequality nearly certainly satisfied with even highly (and unrealistically) pessimistic views of the relative health harms.

D. Rationale #4: Internalities

With the ascendancy of behavioral economics, it is increasingly common in the economic study of demand for addictive or harmful goods to assume that consumers are misinformed or irrational. Misinformation is typically assumed to be of the form of insufficient knowledge about the health risks of consumption. There are many forms of irrationality suggested in the literature, often taking some form of time-inconsistent preferences. A time-inconsistent consumer can be thought of a collection of multiple selves with differing preferences. The present self wants to smoke a cigarette, while the future self, who has to bear the health consequences, wishes the past self had not. Time-inconsistency in preferences leads to regret: the future self learns the true costs of past actions, costs that, if the past self had understood them, would have led to a different set of consumption decisions. This phenomenon is a form of intrapersonal market failure, because the consumer does not make the optimal consumption decisions, even by his or her own standards of welfare (Gruber and Köszegi; 2001, DeCicca et al., 2017). In concordance with the notion of externalities, such effects of irrationality are called *internalities* in the behavioral economics literature.

Applying the behavioral approach to smoking and vaping is most compelling when based on assumed time-inconsistency instead of supposed consumer misinformation. There is evidence that smokers and others in the US today are well aware of the health risks of smoking and, if anything, overestimate them (Viscusi, 2010). People considering whether to try smoking may at the same time, however, underestimate the chance of becoming addicted or the difficulty of cessation (Masiero et al., 2018).

Since internalities drive a "behavioral wedge" between the true marginal cost of consumption and the true marginal benefits at the chosen quantity consumed (Farhi & Gabaix, 2020), the analysis (after deciding on a story for and a magnitude of the internalities) regarding optimal taxation proceeds as for externalities. The difference between internalities and externalities is conceptual: with externalities there is marginal external cost ignored by the consumer, while with internalities there is marginal personal cost ignored by the consumer at the present time. Corrective taxes are set to equal the size of the behavioral wedge for each good at its optimal quantity to restore proper incentives for consumers.

Therefore, the optimal tax rates on cigarettes and ENDS would reflect the relative amounts of misinformation and non-internalized harm at the optimal quantities. About 86% (95% CI = [85.8, 86.8]) of US adults in 2019 believed that cigarettes are "very harmful" or "extremely harmful" to health and only 1.4% [1.2, 1.6] thought smoking was "not at all harmful".[19] On the other hand, there appears to be a large amount of misinformation about ENDS, going in the direction of greatly overestimating the relative harms of vaping and smoking. Over half of adults in the US believe that e-cigarettes are just as harmful as cigarettes, a fraction that has grown steadily in the past decade (Huang et al., 2019). By 2019, 66.7% [65.9, 67.4] of adults believed that ENDS were about as harmful as cigarettes. More than one in four Americans think that vaping is *more* dangerous than smoking, while fewer than three out of a hundred adults think that e-cigarettes are much less harmful than cigarettes (as they likely

[19] Data are from the Wave 5 (Dec. 2018-Dec. 2019) PATH Study (US HHS 2021), with calculations by the author, and so with the other statistics in this paragraph unless otherwise noted. Estimates are for the population of individuals 18 years of age and older in the US The confidence intervals are computed using the replication weights provided in the Study and the Fay-adjusted balanced repeated replication method (Fay & Train, 1995).

are) and fewer than one in nine believes that e-cigarettes are less harmful to any degree.[20] Overestimating harm from ENDS diminishes the behavioral wedge for ENDS compared to that for smoking.

Setting misperception aside, how about the relative scale of non-internalized harm from consuming ENDS and cigarettes? Assuming that time-inconsistency takes roughly the same form for both, then the likely lower actual health harms associated with ENDS imply that the part of the behavioral wedge due to irrationality would be lower for ENDS than for smoking. This result reinforces the conclusion already reached regarding misperceptions. Thus, whether due to misperception of risk, irrational preferences, or both, the internalities rationale for taxation would lead to lower taxes on ENDS than on cigarettes. In fact, one study adopting the internalities approach noted that if ENDS and cigarettes are strong substitutes and ENDS are much less harmful than smoking, then the optimal tax on ENDS could even be negative: a subsidy (Allcott & Rafkin, 2021).[21] The National Health Service in the UK has proposed prescribing medicinally approved e-cigarettes for cessation from smoking, which, when adopted, would subsidize the products via the national health system (UK DHSC, 2021).

E. Rationale #5: Redistribution

A final common rationale for taxation in general is income redistribution, although this rationale is not typically proffered as a reason to tax tobacco products. Since excise taxes

[20] See NIH's *Health Information National Trends Survey* results for 2020 (https://hints.cancer.gov/view-questions-topics/question-details.aspx?red=1&qid=1282&PK_Cycle=13).

[21] While the study did not conclude that ENDS should be subsidized, it noted that the key parameters involved are uncertain enough that the possibility cannot be ruled out at present.

are regressive, in that they take a larger proportion of the disposable income of low-income households than from wealthier households, they tend to make the US tax system less progressive. The regressive nature of excise taxes is even stronger for cigarettes and ENDS since low-income individuals are the most likely to smoke and vape.

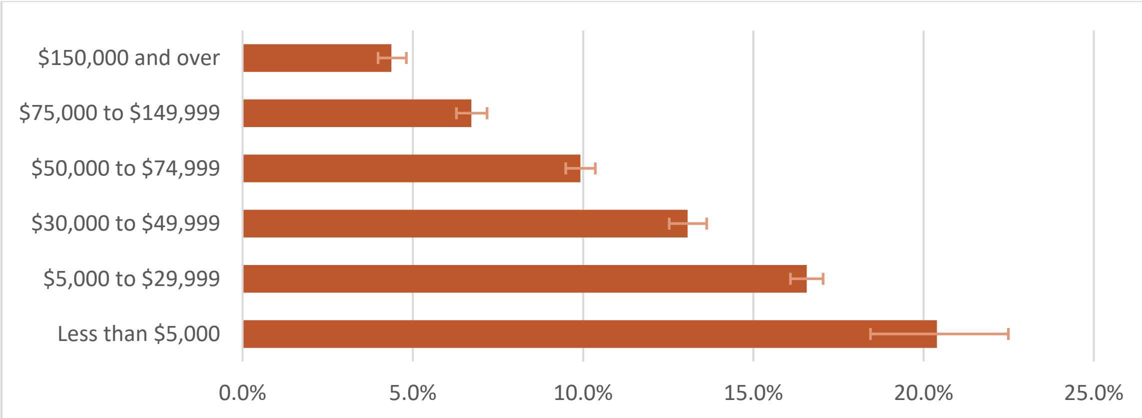
The negative relationship between household income and the likelihood of smoking can be seen in Figure 2. While fewer than 5% of adults in families earning more than $150,000 smoked in recent years, over 20% of adults in families earning less than $5,000 smoked. The income gradient for smoking is negative at each income level. The results are not as stark for vaping, although there is still an overall negative association between income and using ENDS (Figure 3).[22] Only 1.3% of adults in the highest-income families currently use e-cigarettes, while 3.4% in the lowest-income families do. The income gradient for vaping is not consistently downward sloping between these two extremes, but the single exception is not statistically significant and the overall pattern—more income, less chance of vaping—is clear.[23] After controlling for age, race, ethnicity, education, and gender, the probability of using ENDS rises with each income level.[24]

[22] For the relationship between income and demand for ENDS, see also (for example) Snider et al. (2017)

[23] The exception is that adults in the second-lowest income category ($5,000 to $29,999) are estimated to have a lighly lower probability of current vaping (2.5%) than the next highest category ($30,000 to $49,999) (2.7%). However, it is clear from the confidence intervals that there is no statistically significant difference in the likelihood of vaping between the two groups; the *p*-value of the hypothesis that the two income categories have the same probability of vaping is 0.21.

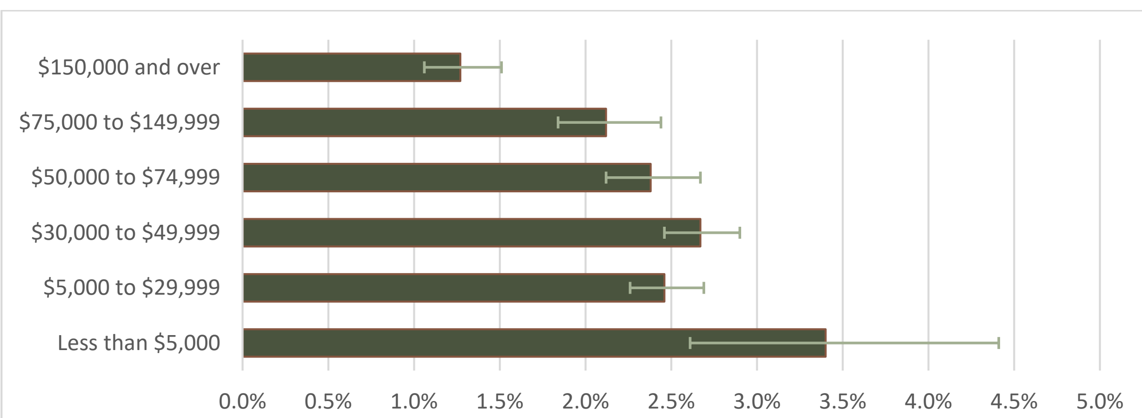
[24] This result is from a linear probability model for using e-cigarettes, where the latter is regressed on the income categories and other categorical variables for race, ethnicity, education, and gender and a quadratic in age. Data are from the TUS as in the figures. The income coefficients rise monotonically with income, and the test that the income coefficients are all jointly equal to zero has p-value = 8.4×10^{-10} (where the variance of the estimates accounts for the survey design effects).

FIGURE 1: CURRENT ADULT SMOKING BY LEVEL OF FAMILY INCOME



Notes: Data are from the 2018-2019 CPS Tobacco Use Supplement, with calculations by the author. Current smoking is restricted to individuals who have smoked at least 100 cigarettes and includes every-day and some-day smokers. The subpopulation is individuals 18 years of age and older. The confidence intervals denoted with the range bars are computed using the replication weights provided by the Census Bureau for the CPS and the Fay-adjusted balanced repeated replication method (Fay & Train, 1995).

FIGURE 2: CURRENT ADULT VAPING BY LEVEL OF FAMILY INCOME



Notes: Prevalences are calculated from the question “Do you now use an e-cigarette every day, some days or not at all?” and include every-day and some-day vapers. See also notes to Figure 2.

IV. Concluding Discussion

The analysis above shows that under a variety of motivations for taxing tobacco, optimal tax rates on ENDS would almost certainly be much lower than those on cigarettes. This conclusion is strongest when the rationale for taxing involves health considerations (rationales 2 through 4), since the evidence that ENDS are less harmful than cigarettes is better established than the cross-price elasticity estimates. The same conclusion regarding relative tax rates is also likely true for other reduced-harm products such as snus and heated tobacco, given evidence (reviewed in the appendix) of lower harm to the consumer or others and higher demand elasticity compared to cigarettes.

A final consideration to address is the common notion that ENDS must be highly taxed to discourage use by youth. In principle, there is nothing in this rationale that has not already been discussed for rationales 3 and 4. Only three brief points need to be made here. First, because of substitution, taxing and regulating ENDS encourages some youth to smoke instead of vape (Abouk et al., 2021; Pesko et al., 2016; Siegel & Katchmar, 2022). Because of the substitution to smoking found in its analysis, one study concluded that "the unintended effects of ENDS taxation may considerably undercut or even outweigh any public health gains" in the context of youth use of ENDS and cigarettes (Abouk et al., 2021). Second, taxes are blunt instruments to discourage consumption of a good by a minority of its purchasers, since the greatest weight of a tax would fall on adults, not youth. Regulations aimed specifically at youth, such as age restrictions on sales (and their enforcement) are more likely to reduce youth access to ENDS without hindering access by adult smokers desiring to switch. Third, given that the price elasticity of demand for ENDS is often assumed and sometimes shown to be higher among youth than adults, a tax on ENDS may not need to be very high to discourage use by many youths while at the same time still encouraging adult smokers to switch to ENDS.

Competing interests

The author has consulted for Altria Client Services on illicit trade in tobacco markets. The author has consulted for BOTEC Analysis, which has received grants from the Foundation for a Smoke-free World, which receives funding from but is independent of PMI Global Services Inc. None of these entities had any involvement with this research or Pepperdine University.

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Online Appendix

This appendix contains a review of the empirical literature on demand for tobacco products, focusing on econometric estimates of elasticity of demand, and derivations of the equations presented in the text.

A. Elasticity of demand for cigarettes and ENDS

Since many of the arguments in the text rely on the relative demand elasticities of cigarettes and ENDS, a review of the empirical literature on these magnitudes is presented here.

1. Demand for cigarettes

Hundreds of studies, performed over decades, have estimated the price elasticity of demand for combustible cigarettes. Note first that this elasticity is not zero. Despite cigarettes being addictive and despite the fact that addiction often popularly assumed to be irrational behavior, the evidence that the Law of Demand—that higher prices lead to lower demand—applies to cigarettes is "overwhelming," in the words of a highly respected tobacco control handbook (IARC, 2011).

Given the huge number of studies, the review here relies mainly on studies of these studies. Such meta-studies fall into two camps: narrative reviews relying on the expert judgment of the authors of the review and formal statistical syntheses based on meta-analysis. The most-cited narrative review in the literature on smoking is that of Chaloupka and Warner (2000), which concluded that most studies then to date produced price elasticities in a relatively narrow band (-0.3 to -0.5) centered around -0.4. A later, widely cited narrative review found that price elasticity as estimated from studies using aggregated data is "concentrated" in the range of -0.2 to -0.6 (IARC, 2011, p. 106). The same review further found that price elasticity estimated in the most recent studies using aggregated data lay in the narrower range of -0.2 to -0.5, and that the same range applied to econometric studies using individual-level data.[a]

A meta-analysis uses formal statistical methods to synthesize results from different quantitative studies of the same question, producing an overall or average estimate that is more precise than the results of any single study. Meta-analyses of elasticity for cigarettes are not as common as narrative reviews. An early meta-analysis by Andrews and Franke (1991) of 41 studies (25 of which were from the US) found a point estimate of -0.36 for the price elasticity of demand for cigarettes. These authors also found that elasticity decreased in magnitude over the period studied, becoming more inelastic (i.e., closer to zero). A more recent meta-analysis by Gallet and List (2003) covered 523 price-elasticity estimates from 86 empirical studies of the demand for cigarettes. The median price elasticity, whether short-run or long-run, was about -0.4. This study concurred with Chaloupka and Warner (2000) that demand for cigarettes became more inelastic over time.

In summary, an overall price elasticity of demand for cigarettes of **-0.4** appears to accurately reflect the scientific literature on the subject. A figure of -0.4 has been stated by the World Bank (for high-income countries such as the US) and tobacco-control handbooks (IARC, 2011, p.350) when a single or consensus figure is desired. And while some studies have found higher price elasticities for cigarettes, particularly some studies making use of retail scanner data instead of aggregate or individual-level data,[b] DeCicca & Kenkel (2015) show that if anything the agreed-upon consensus

[a] See IARC (2011, p.108) for the former and IARC (2011, p.176) for the latter.

[b] For example, the study of Zheng et al. (2017) finds a price elasticity estimate of around -1.0 for cigarettes. One reason that such studies return higher elasticity estimates is that they do not include all possible retail outlets for tobacco (e.g., Zheng et al. (2017) include data from convenience stores only). Thus, higher prices at the included stores in the dataset will merely drive some sales to stores not captured in the data. Another possible reason that studies using retail scanner data arrive at higher estimates of price elasticity is that they do not adequately account for cross-border or illicit sales. If so, then legal, fully-taxed sales in a particular location will appear to be more price-sensitive than actual consumption is. Finally, it is worth noting that a recent high-quality study using retail

estimate of -0.4 is too large (in magnitude) to explain why smoking declined as slowly as it did in the recent decades of large tax increases in the US.

These price elasticities are for the aggregate quantity demanded of cigarettes. Decreases in the quantity demanded can be decomposed into fewer people smoking (the *extensive margin*) and remaining smokers consuming less than they did before (the *intensive margin*). The conventional wisdom as distilled from the literature holds that about half of the overall price elasticity stems from each margin (Chaloupka & Warner, 2000; IARC, 2011; DeCicca & Kenkel, 2015).

The price elasticity of demand for cigarettes is often found to vary among groups of people. For example, the price elasticity has generally been found to be higher in magnitude (more elastic) for younger people and youth, likely because the lower disposable income of such individuals makes them more price-sensitive (Kjeld et al., 2021). However, the same is true for demand for ENDS, and there is not enough empirical evidence yet to suggest that the *relative* elasticities for cigarettes and ENDS change markedly with age. Other studies show that the price elasticity is not constant across the range of possible prices, but instead is higher at higher prices (Tauras et al., 2016). This opens the possibility that as tobacco taxes continue to increase, the price elasticity will as well. As with the results for age, however, the same is likely true for ENDS and it remains unknown whether the ratio of the elasticities would change materially.

2. Demand for ENDS

Given the recency of the widespread availability and usage of ENDS, the econometric literature estimating demand for these products is much smaller than for cigarettes. One recent study

scanner data and careful econometric methods found a price elasticity for cigarettes of -0.39 (Cotti et al., 2022), in line with the consensus estimate.

summarized the extant results on the price elasticity of demand for ENDS with the range of −0.78 and −2.1.[a] A meta-analysis from a few years ago found a median elasticity estimate for e-cigarettes of -1.8 (Jawad et al., 2018). The table below shows all the available econometric estimates of the price elasticity of demand for ENDS that could be found. A few studies using individual data from youths only are excluded, as are purely experimental (stated preference or non-market transaction) studies apart from the oft-cited discrete choice experiment of Pesko et al. (2016).[b] The summary figures mentioned above, along with the figures in the table from individual studies, imply that the price elasticity of demand for ENDS is much higher than for cigarettes.

[a] Yurekli et al. (2020), summarizing results from Huang et al. (2014), Pesko et al. (2016, 2020), Stoklosa et al. (2016), Zheng et al. (2017), and a previous version of Cotti et al. (2022)

[b] For example, Cantrell et al. (2020) study the behavior of a sample aged 15-21 years. They found some evidence of substitution between rechargeable ENDS and cigarettes but their estimated own-price effect for ENDS was not statistically significant. Including Pesko et al. (2016) among the studies in the table to follow does not expand the range of the elasticity estimates in the literature reviewed; their own-price elasticity of demand is on the high end but smaller than that of Zheng et al. (2017). Most other experimental studies of demand for ENDS are not performed by economists.

TABLE 1: STUDIES CONTAINING ESTIMATES OF OWN-PRICE ELASTICITY OF DEMAND FOR ENDS

Study	Data	Unit of observation	Elasticity estimates	Notes
Huang et al. (2014)	Retail scanner data from food and drug stores, mass merchandisers, and convenience stores. US states.	Aggregated to store type in a retail market. Separate product categories: disposable and reusable ENDS. Quarterly.	Around -1.2 (disposable e-cigarettes). Around -1.9 (reusable e-cigarettes)	Log-log demand equation. Treats prices as exogenous.
Pesko et al. (2016)	Survey data from a discrete choice experiment.	An individual.	-1.8 for disposable ENDS.	Logit model. Data are from stated preferences and do not represent actual market transactions.
Stoklosa et al. (2016)	Retail scanner data from supermarkets, convenience stores, and gas stations. Six EU countries.	Aggregated to product type (e-cigarettes and cigarettes) in a country.	Baseline results: -0.79 to -0.83. Myopic addiction model: -0.26 to -0.27 for short-run elasticity; -1.13 to -1.18 for long-run elasticity	Does not include refills for ENDS (liquids or cartridges). Log-log demand equation. Possibly less relevant since data are not from the US
Zheng et al. (2017)	Retail scanner data from convenience stores and gas stations. United States.	Aggregated to product type in a retail market. Separate product categories: cigarettes, e-cigarettes, four	Conditional on total tobacco expenditure: -2.05 Unconditional: -2.05 Single-equation estimate: -2.82	Two-level Almost Ideal Demand System for six tobacco products. Treats prices as exogenous.

		other tobacco categories. Four-week periods.		
Yao et al. (2020)	Retail scanner data from food, drug, and convenience stores and mass merchandisers. California.	Aggregated to store type in a retail market. Separate product categories: disposable and reusable ENDS. Quarterly.	Disposable e-cigarettes: -0.37 Reusable e-cigarettes: -0.20	Log-log demand equations. Treats prices as exogenous.
Cotti et al. (2022)	Retail scanner data from food, drug, and convenience stores and mass merchandisers. United States.	Locality (state or county) and quarter by product (cigarettes, e-cigarettes, and three other tobacco products.	All e-cigarettes: -2.1 to -2.25 Tobacco-flavored e-cigarettes: -1.46 Menthol/mint flavored e-cigarettes: -1.07 Other flavored e-cigarettes: -3.44	Linear-linear IV model, using taxes as instruments for prices. Excludes ENDS without nicotine. Refill cartridges are analyzed separately from devices and kits. ENDS are separated by flavor: tobacco flavor, mint and menthol, and other.
Allcott & Rafkin (2021)	Retail scanner data from food, drug, and convenience stores and mass merchandisers. US.	Locality (states and 2 counties) and quarter by individual product UPC.	Baseline estimation: -1.32 Six other estimates: -1.67 to -1.09, with median -1.30.	Log-log IV model, using taxes as instruments for prices.

It is important to note that except for two cases *all* of the price elasticities are greater in magnitude than the consensus figure of -0.4 for cigarettes.[a] A reasonable pair of estimates for the price elasticity of ENDS demand to use for illustrative purposes in the main text would appear to be **-1.3** and **-2.3**. The former estimate is from Allcott and Rafkin (2021). The latter estimate, from Cotti et al. (2022), was produced from the most recent and carefully designed econometric study. Between these two estimates lie the consensus figure from the meta-analysis of Jawad et al. (2018) and most of the other estimates found in the literature. The only major results less elastic than -1.3 are those of Stoklosa et al. (2016), but those are not from consumers in the US

3. Cross-product substitution

While cigarettes and ENDS could theoretically be either complements or substitutes, the consensus of the empirical literature appears to be that the two types of products are substitutes. The meta-analysis by Jawad et al. (2018) found that he median cross-price elasticity of demand for ENDS with respect to price changes for cigarettes was 1.2, or that a 1% increase in the price of cigarettes leads to 1.2% more quantity demanded of e-cigarettes. Results from individual studies reporting econometric estimates of cross-price elasticities are in the table below. Note that positive cross-price elasticities imply that the two products are substitutes, while negative cross-price elasticities would imply that they are complements. In the table, notation $\varepsilon_{ENDS,cig}$ means the elasticity of demand for ENDS with respect to changes in the price of cigarettes and $\varepsilon_{cig,ENDS}$ means the elasticity of demand for cigarettes with respect to changes in the price of ENDS.

[a] The two exceptions, both from Stoklosa et al. (2016), are short-run elasticities from a dynamic model. For policy purposes involving tobacco-related health harms the long-run elasticities are more relevant (since many of the potential health harms from smoking or vaping would not appear immediately), and the long-run elasticities from that model are much larger.

TABLE 2: STUDIES CONTAINING ESTIMATES OF CROSS-PRICE ELASTICITY OF DEMAND FOR ENDS AND CIGARETTES

Study	Data	Unit of observation	Elasticity estimates	Notes
Huang et al. (2014)	See previous table	See previous table	$\varepsilon_{ENDS,cig}$ = 0.54 for disposable ENDS.	Estimate of $\varepsilon_{ENDS,cig}$ is statistically significant at the 10% level only. Estimate of $\varepsilon_{ENDS,cig}$ for reusables is positive but not statistically significant. See also notes in previous table.
Pesko et al. (2016)				
Stoklosa et al. (2016)	See previous table	See previous table	Baseline model: $\varepsilon_{ENDS,cig}$ = 3.60 to 4.55 Myopic addiction model: $\varepsilon_{ENDS,cig}$ = 1.5 for short-run elasticity; about 6.5 for long-run elasticity.	One of the two long-run elasticities reported is significant at the 10% level only; all other estimates are significant at the 1% or 5% levels. See also notes in previous table.

Zheng et al. (2017)	See previous table	See previous table	Conditional on total tobacco expenditure: $\varepsilon_{ENDS,cig}$ = 1.86, $\varepsilon_{cig,ENDS}$ = 0.004 Unconditional: $\varepsilon_{ENDS,cig}$ = 1.81, $\varepsilon_{cig,ENDS}$ = 0.004 Single-equation estimate: $\varepsilon_{ENDS,cig}$ = 1.86	The single-equation estimate of $\varepsilon_{cig,ENDS}$ was not significant. See also notes in previous table.
Yao et al. (2020)	See previous table	See previous table	$\varepsilon_{ENDS,cig}$ = 1.74 for reusable ENDS.	Estimate of $\varepsilon_{ENDS,cig}$ for disposables is positive but not statistically significant. Estimates of $\varepsilon_{cig,ENDS}$ are near zero and not significant for both types of ENDS.
Saffer et al. (2020)	Individual survey data for adults (CPS-Tobacco Use		Participation elasticity for smoking (with respect to changes in price of ENDS): 0.13	Participation elasticity is for the extensive margin only and mainly reflects impacts on cessation and relapse. Estimate is an arc elasticity

	Supplement). Minnesota.			for a discrete change observed in the data. Authors state estimate is a lower bound.
Cotti et al. (2022)	See previous table	See previous table	ENDS as a group: $\varepsilon_{ENDS,cig}$ = 1.14, $\varepsilon_{cig,ENDS}$ =0.46 Tobacco-flavored e-cigarettes: $\varepsilon_{ENDS,cig}$ = 0.85 Menthol/mint flavored e-cigarettes: $\varepsilon_{ENDS,cig}$ = 0.66 Other flavored e-cigarettes: $\varepsilon_{ENDS,cig}$ =1.81 Non-flavored cigarettes: $\varepsilon_{cig,ENDS}$ = 0.53 Menthol cigarettes: $\varepsilon_{cig,ENDS}$ = 0.29	

Allcott & Rafkin (2021)	See previous table		$\varepsilon_{ENDS,cig}$ = 0.22 to 0.84 $\varepsilon_{cig,ENDS}$ = 0.75 to 1.72	All elasticity estimates for ENDS (7 each for $\varepsilon_{ENDS,cig}$ and $\varepsilon_{cig,ENDS}$) are positive but statistically insignificant. The range given for $\varepsilon_{cig,ENDS}$ includes only the three estimates that are apparently significant at the 5% level (the authors report standard errors but not significant stars). Two of the insignificant estimates are negative.

Some of the estimates in the table require comment. The participation elasticity from Saffer et al. (2020) can be converted to the more-usual quantity elasticity (to make it comparable to the other estimates in the table) if the fraction of the total elasticity coming from the extensive margin is known. For cigarettes, the conventional wisdom holds that about half of the price elasticity stems from the participation elasticity. For e-cigarettes, less is known about these margins, but if the same division of total elasticity into its margins holds for ENDS as for cigarettes, Saffer et al.'s (2020) participation elasticity estimate of 0.13 can be converted to a cross-price elasticity ($\varepsilon_{cig,ENDS}$) of roughly 0.26. These authors also discuss why their estimate is only a lower bound on the true elasticity.

Allcott and Rafkin's (2021) estimates are noteworthy because their methodology leads to results that both less certain and outside the range of the other estimates in the literature. None of their estimates of $\varepsilon_{ENDS,cig}$ are statistically significant, which means that they cannot reject the null hypotheses that demands for ENDS and cigarettes are independent (which would strain credulity and is not claimed to be the case by the authors). However, the lack of significance found in their study results from large standard errors (i.e., imprecision in their estimates) rather than a precise finding of independent demand. That is, their results appear to reflect a lack of statistical power[a] more than a confident statement that the null hypothesis is actually true. Furthermore, their estimate of $\varepsilon_{ENDS,cig}$ = 0.22, which is lower than all the other estimates in the table, is produced by a model that includes state-specific linear time trends. As discussed in Cotti et al. (2022, footnote 4), including such trends may obscure the causal cross-price effects. Allcott and Rafkin's (2021) estimates for $\varepsilon_{cig,ENDS}$ are,

[a] In statistics, *power* is defined as one minus the probability of Type II error, where the latter is the acceptance of the null hypothesis when it is actually false.

on the other hand, much larger than all the other estimates in the table. Due to the outlying nature of these cross-elasticities and the other issues discussed here, coupled with the fact that the study has not undergone peer review yet,[a] they are not adopted here for the computations in the main text.

The estimates of cross-price elasticity across the various studies display significant variation. Setting aside the low, insignificant estimate of Allcott and Rafkin (2021), the estimates for $\varepsilon_{ENDS,cig}$ range from 0.54 on the low end to 6.5 on the high end, although the different types of products (e.g., disposables vs. reusables), elasticities (short-run, long-run), and modeling approaches (static, dynamic, differing functional forms, etc.) make direct comparison of estimates problematic. Ignoring possible noncomparability for the moment, the high end for a reasonable range of estimates for $\varepsilon_{ENDS,cig}$ appears to be 1.8, implying that a 1% increase in cigarette prices increases demand for e-cigarettes by 1.8%, showing that the two products are highly substitutable. The lower estimates from the careful study of Cotti et al. (2022), $\varepsilon_{ENDS,cig}$ = 1.1 are also of interest, given the high-quality empirical methods and recent data used. Thus for purposes of the computations in the text a reasonable range for $\varepsilon_{ENDS,cig}$ will be taken to be **1.1** to **1.8**. There are fewer estimates of the converse elasticity, $\varepsilon_{cig,ENDS}$, and they have a broad range from almost **0** to **1.7**.

4. Income elasticity of demand

In contrast with estimates of price elasticity, there is little to no consensus on the income elasticity of demand for cigarettes. Until recently, the only point of agreement was that the income elasticity was not negative (IARC, 2011). Estimates typically lay between zero and

[a] Note that this is also true of Cotti et al. (2022) however.

one, indicating that cigarettes are a *normal good* but not a *luxury good*. The meta-analysis of Andrews and Franke (1991) found that the mean income elasticity from 37 studies performed through 1990 was 0.36. However, evidence since then suggests that the income elasticity of demand for cigarettes has declined over time in the US (IARC, 2011, p.350). One very recent study found that the income elasticity has even turned mildly negative in high income countries (Nargis, et al., 2020), although this is estimated with highly aggregated data. An income elasticity of **0.1** appears to be a reasonable choice, based on studies published since 1990 (see the review in IARC, 2011). However, it is also defensible to view an income elasticity of zero as a reasonable approximation, given that the estimates are often small and, in many studies, the estimated income elasticity does not differ significantly from zero (in the statistical sense).

For ENDS, no estimates of income elasticity were found in the literature. However, the results for the conditional expenditure elasticities from Hovhannisyan et al. (2020, not yet peer reviewed), which are 0.895 for cigarettes and 2.533 for e-cigarettes, imply that the income elasticity of ENDS is 2.8 times the income elasticity of cigarettes.[a] Thus if the income elasticity of cigarettes is 0.1, the income elasticity of ENDS would be around **0.3**.

B. Mathematical results for optimal tax rates

1. Rationale #1 (minimizing deadweight loss)

The equation on page 9 for the optimal tax rates under the criterion of maximizing social surplus (traditionally defined) is derived here, following Auerbach (1985). Although the

[a] In principle, the income elasticities could be computed from the Almost Ideal Demand System estimated by Hovhannisyan et al. (2020), but they report only second-stage expenditure elasticities and not the first-stage elasticity of the budget share devoted tobacco goods.

Ramsey Rule has been derived for many sets of assumptions in the literature, it is most common to use compensated elasticities in the formulas. Given the need to match any optimal tax formula to published estimates of the relevant elasticities, which are universally computed for unconditional demand functions, I (re)derive the Ramsey Rule here using uncompensated elasticities.

Consider a representative consumer with indirect utility function $V(p,I)$, where p is the vector of tax-included (i.e., consumer) prices and I is the consumer's income. Define x as the vector of Marshallian demand for the set of goods; since demand depends on prices and income, x is a function: $x(p,I)$. Let T be the desired total tax revenue that must be created. Let the vector of unit taxes be t and the pre-tax cost of goods (i.e., the producer prices) be q. As elsewhere in the text it is assumed that q is constant and that the goods are competitively supplied, so there are no excess profits to consider. As usual in such mathematical approaches, there is a numeraire good 0 with unit tax normalized to be zero (thus, zero is the "outside good"—here, representing purchases other than ENDS and cigarettes).

The social planner's goal is to minimize deadweight loss (or, equivalently, to maximize V) subject to meeting the goal for tax revenue. The revenue constraint is:

$$T = t \cdot x = (p - q) \cdot x$$

The Lagrangian for the constrained maximization problem is:

$$\mathcal{L} = V(q + t, I) - \lambda[T - t \cdot x]$$

After noting that derivatives with respect to taxes are the same as derivatives with respect to prices, since a dollar of extra tax increases consumer prices by a dollar, the first-order condition for a maximum can be written:

$$\frac{\partial \mathcal{L}}{\partial t_i} = \frac{\partial V(p, I)}{\partial p_i} + \lambda \sum_{j=1,2} t_j \frac{\partial x_j}{\partial p_i} = 0 \;\; \text{for } i = 1,2$$

Roy's identity from microeconomic theory implies that $x_i = -\,(\partial V/\partial p_i)/\mu$, where μ is the marginal utility of income $\partial V/\partial I$. Thus $\partial V/\partial p_i = -\mu x_i$, and substituting this into the expression above and suppressing the arguments of the functions yields:

$$-x_i(\mu - \lambda) + \lambda \sum_j t_j \frac{\partial x_j}{\partial p_i} = 0 \;\; \text{for } \; i = 1,2$$

Add and rearrange some terms:

$$\sum_j t_j \left(\frac{\partial x_j}{\partial p_i}\frac{p_i}{x_j}\right)\frac{x_j}{p_i x_i} = \frac{\mu - \lambda}{\lambda} \;\; \text{for } i = 1,2$$

By definition of the cross-price elasticity,

$$\varepsilon_{ji} = \frac{\partial x_j}{\partial p_i}\frac{p_i}{x_j}$$

and so we have

$$\sum_j t_j \varepsilon_{ji} \frac{x_j}{R_i} = \frac{\mu - \lambda}{\lambda} \;\; \text{for } i = 1,2$$

where $R_i = p_i x_i$ is the expenditure on (equivalently, tax-inclusive revenue from) good *i*.

Since the right side of the equation is the same regardless of *i*, we can expand the sums and set the left sides for *i* = 1,2 equal to each other:

$$\tau_1 \varepsilon_1 + \tau_2 \varepsilon_{21} \frac{R_2}{R_1} = \tau_2 \varepsilon_2 + \tau_1 \varepsilon_{12} \frac{R_1}{R_2} \qquad \text{(A-1)}$$

where as in the text $\tau_i = t_i / p_i$ and $\varepsilon_i = \varepsilon_{ii}$.

If there are no cross-price effects, then this equation simplifies to the simple Ramsey Rule given in section III.A in the main text. If the demands are not independent, then the rule can be expressed in terms of price and income elasticities as follows. First, note that the relationship between the cross-price Marshallian (uncompensated) elasticities is:

$$\varepsilon_{ij} = \varepsilon_{ji} \frac{R_j}{R_i} + \left(\varepsilon_j^I - \varepsilon_i^I\right) S_j \qquad \text{(A-2)}$$

where the *I* superscript denotes an income elasticity and $S_i = R_i / I$ is the share of total income spent on good *i*.[a] Using this relationship in the optimal tax formula given in equation (A-1) leads to:

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[a] To show this result, begin with the Slutsky equation relating the compensated and uncompensated demand functions:

$$\frac{\partial x_i}{\partial p_j} = \frac{\partial h_j}{\partial p_i} - \frac{\partial x_i}{\partial I} x_j$$

where *X* is Marshallian demand and *h* is the Hicksian compensated demand function. Multiplying both sides by $^{p_j}/_{x_i}$ and using the symmetry of the cross-partial derivatives of Hicksian demand, we have:

$$\frac{\partial x_i}{\partial p_j} \frac{p_j}{x_i} = \left(\frac{\partial h_j}{\partial p_i} \frac{p_i}{x_j} \right) \frac{p_j x_j}{p_i x_i} - \left(\frac{\partial x_i}{\partial I} \frac{I}{x_i} \right) \frac{p_j x_j}{I}$$

or

$$\varepsilon_{ij}^U = \varepsilon_{ji}^C \frac{R_j}{R_i} - \varepsilon_i^I \frac{R_j}{I} \qquad \text{(w-1)}$$

where the *U* and *C* superscripts are for uncompensated and compensated elasticities, respectively. Note that due to the symmetry of the cross-partial derivatives of the compensated demand functions, the relationship between the compensated elasticities is:

$$\frac{\tau_1}{\tau_2} = \frac{\varepsilon_2 - \varepsilon_{12} + (\varepsilon_2^I - \varepsilon_1^I)S_2}{\varepsilon_1 - \varepsilon_{21} + (\varepsilon_1^I - \varepsilon_2^I)S_1} \qquad \text{(A-3)}$$

Which is the expanded Ramsey Rule stated in the main text on page 9.

2. Implied specific tax rates from the Ramsey Rule

The relative tax rates computed by the Ramsey Rule are stated in terms of the unit tax rate as a fraction of the tax-inclusive price. What does this efficient-taxation rule imply for the specific (i.e., unit) taxes on the commodities themselves? The median state ($1.80) specific tax on cigarettes is in Nevada, which with the federal tax of $1.01 leads to a total tax of $2.81 per pack (CfTFK, 2021). Cigarette prices in Nevada average about $6.80 per pack.[a] Thus τ_{cig} = 2.81 ÷ 6.8 = 0.44. If the optimal ratio of the tax rates is 4.5, the midpoint of the two multiples above, then τ_{ENDS} = 0.098. This latter tax rate corresponds to a tax of about $0.108 on a (pre-tax) dollar's worth of e-cigarettes.[b] To see that this tax level is indeed much lower for ENDS than for cigarettes, note that if, in the absence of taxes, an e-cigarette product cost the same as cigarettes, then the total tax for the e-cigarette product would be only $0.40 (compared to the $2.81 tax on the pack of cigarettes).[c]

$$\varepsilon_{ij}^C = \varepsilon_{ji}^C \frac{R_j}{R_i} \qquad \text{(w-2)}$$

Equations (w-1) and (w-2) imply that

$$\varepsilon_{ij}^U = \varepsilon_{ij}^C - \varepsilon_i^I \frac{R_j}{I} \qquad \text{(w-3)}$$

Rearranging the terms in equation (w-1) and then switching *i* and *j* subscripts yields:

$$\varepsilon_{ij}^C = \varepsilon_{ji}^U \frac{R_j}{R_i} + \varepsilon_j^I \frac{R_j}{I} \qquad \text{(w-4)}$$

Substitute equation (w-4) into equation (w-3) to arrive at equation (A-2) in the text.

[a] See CDC's *The Tax Burden on Tobacco*, cited in the text.
[b] To check this, see that if the specific tax on ENDS is $0.1084, where the units of ENDS are normalized so that before taxes one unit costs $1, then τ_{ENDS} is 0.1084 ÷ (1 + 0.1084) = 0.098, the desired relative tax rate.
[c] To check this, see that if the pre-tax ENDS price is the same as the pre-tax cigarette price ($3.99 in the median state), then τ_{ENDS} is 0.4035 ÷ (3.99 + 0.4035) = 0.0918, τ_{cig} is 2.81 ÷ 6.80 = 0.4132, the ratio of these optimal taxes is indeed 0.4132 ÷ 0.0918 = 4.5.

3. Relaxing the assumption of constant marginal cost

The formulas derived above assume constant marginal cost. Note that relaxing the assumption of constant marginal cost is unlikely to change the relative comparison of the tax rates. With linear nonconstant supply functions ENDS would have a higher ad valorem tax rate than cigarettes if, in addition to having more elastic demand, ENDS also has a more elastic supply curve (Yang and Stitt, 1995). There are no direct estimates of supply elasticities available for cigarette and ENDS manufacturing, but the former is highly likely to be smaller than the latter. The mature technology used to manufacture cigarettes is likely to result in economies of scale (see Bain's (1954) classic study of American industry for evidence from the mid-20th century) and relatively flat industry supply curves (and hence low supply elasticity). On the other hand, in a newer market like ENDS with a great multiplicity of heterogeneous products, a variety of production processes with varying costs are undoubtedly employed, leading to a more elastic supply curve.

4. The terms involving the budget shares in the expanded Ramsey Rule are likely very small

It is mentioned in the text that the terms involving the product of the difference in the income elasticities and the budget shares can be ignored in equation (A-3). The reason follows. First, the difference in the income elasticities is only around 0.2 in magnitude at best guess, and may be lower, given the estimates discussed above. Second, the income elasticities are multiplied in the equation by the share of the budget spent on cigarettes or ENDS. These budget shares are very small in the US (about 1.2% for cigarettes and 0.004% for ENDS on average, which is the appropriate measure for optimal taxes computed for the representative consumer). These figures are computed from the data presented in Zheng et al. (2017) and are for years 2009-2014.[a] These two considerations imply that the terms involving the income elasticities can safely be ignored.

5. Rationale #3 (public health)

The equation on page **Error! Bookmark not defined.** for the optimal tax rates under the public health criterion is derived here. With the same set-up for the representative consumer as for rationale #1, let $H(x)$ be the total public health harm created when amounts x of the goods are consumed. These harms include both private and external harms. It is assumed that the outside good involves no health harms.

The social planner's goal is to minimize deadweight loss (or, equivalently, to maximize V) subject to meeting a fixed goal of health improvement. The goal is:

$$H\big(x(p,I)\big) - H(p_0,I) = \Delta$$

where p_0 is the initial price before the new taxes are chosen. The health constraint can be written:

$$H\big(x(q+t,I)\big) - H(q,I) = \Delta$$

The Lagrangian for the constrained maximization problem is:

$$\mathcal{L} = V(q+t,I) - \lambda\big[\Delta - H\big(x(q+t,I)\big) + H(q,I)\big]$$

The first-order condition for a maximum can be written:

[a] The budget share for ENDS may be higher today, but it is still much smaller than the budget share for cigarettes for the average consumers since in 2020 total expenditure on cigarettes was still ten times expenditure on ENDS in the US (per Euromonitor's Passport database).

$$\frac{\partial \mathcal{L}}{\partial t_i} = \frac{\partial V(p,I)}{\partial p_i} + \lambda\left(\sum_j \frac{\partial H\big(x(p,I)\big)}{\partial x_j}\frac{\partial x_j(p,I)}{\partial p_i}\right) = 0 \text{ for all } i$$

Application of Roy's identity to the expression above yields:

$$-\mu x_i + \lambda\left(\sum_j \frac{\partial H}{\partial x_j}\frac{\partial x_j}{\partial p_i}\right) = 0 \text{ for all } i$$

Dividing both sides by x_i and restating in terms of elasticities, we have:

$$\left(\sum_j \frac{\partial H}{\partial x_j}\varepsilon_{ji}\frac{x_j}{R_i}\right) = \frac{\mu}{\lambda} \text{ for all } i$$

where $R_i = p_i x_i$ as above. For economy of notation, denote the marginal harm from x_i to be H_i. Since the right side of the equation is constant across *i*, we have for goods 1 and 2:

$$H_1\varepsilon_1\frac{x_1}{R_1} + H_2\varepsilon_{21}\frac{x_2}{R_1} = H_1\varepsilon_{12}\frac{x_1}{R_2} + H_2\varepsilon_2\frac{x_2}{R_2}$$

Manipulate the terms:

$$\frac{H_1}{p_1}\varepsilon_1 + \frac{H_2}{p_2}\varepsilon_{21}\frac{R_2}{R_1} = \frac{H_1}{p_1}\varepsilon_{12}\frac{R_1}{R_2} + \frac{H_2}{p_2}\varepsilon_2$$

so that

$$\frac{H_1}{p_1}\left(\varepsilon_1 - \varepsilon_{12}\frac{R_1}{R_2}\right) = \frac{H_2}{p_2}\left(\varepsilon_2 - \varepsilon_{21}\frac{R_2}{R_1}\right)$$

or

$$\frac{H_1/p_1}{H_2/p_2} = \frac{\varepsilon_2 - \varepsilon_{21}\frac{R_2}{R_1}}{\varepsilon_1 - \varepsilon_{12}\frac{R_1}{R_2}} \qquad \text{(A-4)}$$

If there are no cross-price effects, then this equation simplifies to the one given on page **Error! Bookmark not defined.** in the main text. If the demands are not independent, then the rule can be expressed in terms of price and income elasticities as follows. Using relationship (A-2), the optimal tax formula in equation (A-4) leads to:

$$\frac{H_1/p_1}{H_2/p_2} = \frac{\varepsilon_2 - \varepsilon_{12} + (\varepsilon_2^I - \varepsilon_1^I)S_2}{\varepsilon_1 - \varepsilon_{21} + (\varepsilon_1^I - \varepsilon_2^I)S_1} \qquad \text{(A-5)}$$

Substituting $p_i = t_i + q_i$, the optimal tax condition (A-5) can be written as:

$$t_1 = \left(q_2\frac{H_1}{EH_2} - q_1\right) + \frac{H_1}{EH_2}t_2 \qquad \text{(A-6)}$$

where E is the modified elasticity ratio:

$$E = \frac{\varepsilon_2 - \varepsilon_{12} + (\varepsilon_2^I - \varepsilon_1^I)S_2}{\varepsilon_1 - \varepsilon_{21} + (\varepsilon_1^I - \varepsilon_2^I)S_1}$$

that appears on the right side of equations (A-3) and (A-5).

Based on equation (A-6), the unit tax on good 1 is larger than the unit tax on good 2 if:

$$\left(q_2\frac{H_1}{EH_2} - q_1\right) + \frac{H_1}{EH_2}t_2 > t_2$$

or

$$t_2\left(1 - \frac{H_1}{EH_2}\right) < \left(q_2\frac{H_1}{EH_2} - q_1\right)$$

To allow direct comparability of the unit taxes, set the units of the two goods to be a (pre-tax) dollar's worth of output. Then the inequality simplifies to

$$t_2\left(1-\frac{H_1}{EH_2}\right) < -\left(1-\frac{H_1}{EH_2}\right)$$

which (assuming positive tax rates) holds if and only if the expression in the parentheses is negative. Thus we have:

$$t_1 > t_2 \iff \frac{H_1}{H_2} > E$$

For the case with no income effects or cross-elasticities, then cigarettes are taxed at a relatively higher rate if

$$\frac{H_{cig}}{H_{ENDS}} > \frac{\varepsilon_{ENDS}}{\varepsilon_{cig}}$$

C. Other reduced-harm tobacco products

By and large, the same conclusions found for the relative tax rates for ENDS and cigarettes also hold for heated tobacco and snus as well. However, the conclusions must necessarily be more tentative since these alternative products are less studied. As with the analysis for ENDS and cigarettes, the conclusion that other reduced-risk products should be taxed at lower rates than cigarettes depends (to varying degrees depending on the rationale for the taxation) on their harm to health, promotion of cessation, substitution in demand, and externalities created by consumption, all relative to smoking.

1. Harm

While not harm-free, snus is “clearly less harmful” (Foulds et al., 2003) and “associated with substantially fewer health hazards” (Rutqvist et al., 2011) than smoking cigarettes. One study found that switching from cigarettes to Swedish snus has nearly the same impact on life expectancy as cessation (Gartner et al., 2007). Snus has much lower levels of tobacco-specific nitrosamines (TSNAs) than cigarettes. Expert consensus is that low-TSNA smokeless tobacco such as snus has no more than 10% of the health risk of smoking (Levy et al., 2004), although it must be noted that some North American brands of snus have more TSNAs than Swedish snus (Lawler et al., 2020).

Less is known about the relative risks of heated tobacco products, and they are not risk-free. The evidence, however, indicates that they to expose users to fewer harmful constituents than smoking cigarettes (Jankowski, et al., 2018; McNeill et al., 2018), a level of exposure that one study termed “substantially lower” than for cigarettes (Simonavicius et al., 2019). The FDA has approved a few snus and heated tobacco products for marketing as “modified risk” products that offer significantly less exposure to harmful chemicals than cigarettes. The FDA rulings allow various IQOS heated tobacco products manufactured by Philip Morris International to be marketed with the claim that they “significantly reduce the production of harmful and potentially harmful chemicals” and that “scientific studies have shown that switching completely from conventional cigarettes to the IQOS system significantly reduces your body’s exposure to harmful or potentially harmful chemicals.”[a] In contrast, the FDA

[a] See https://www.fda.gov/media/139797/download. The rulings also conclude that the products are “appropriate for the protection of public health” but, somewhat paradoxically, stop short of allowing PMI to claim that the products “significantly reduce harm and the risk of tobacco-related disease to individual tobacco users.”

allows the General brand smokeless tobacco products from Swedish Match to claim that "using General Snus instead of cigarettes puts you at a lower risk of mouth cancer, heart disease, lung cancer, stroke, emphysema, and chronic bronchitis".[a]

2. Cessation from smoking

In Sweden, where snus originated and is widely used among former smokers, the product appears to have contributed to the country's low smoking rate by preventing initiation and facilitating cessation (Ramstrom & Foulds, 2008). A systematic review of clinical trials found that snus indeed increases cessation from smoking, including in the US (Rutqvist et al., 2013). There is no scientific evidence yet regarding the effect of heated tobacco use on cessation (Tattan-Birch et al., 2022), although one-fifth of users in Korea report being ex-smokers (Kim et al., 2021).

3. Substitution with cigarettes

There is no consensus in the literature as to whether smokeless tobacco is a substitute, complement, or neither to cigarettes, with several studies arriving at each conclusion, and no econometric literature at all yet regarding that question for heated tobacco products. Regardless of whether these products are economic substitutes with cigarettes, demand for all of them decreases at higher prices, and so higher taxes discourage their use.

4. Demand elasticity

Less is known about the elasticity of demand for other reduced-harm tobacco products. Shang et al. (2020) find that demand for heated tobacco products is "highly responsive to

[a] See https://www.fda.gov/news-events/press-announcements/fda-grants-first-ever-modified-risk-orders-eight-smokeless-tobacco-products.

price changes”. Efficient taxes would therefore be lower on such products than on cigarettes, as with ENDS. Demand elasticity for snus and nicotine gum has also been found to be higher than for cigarettes (Stein et al., 2017), although other studies conclude that the price elasticity of demand for smokeless tobacco is the same as or lower than for cigarettes (Huang et al., 2018).[a] Under this rationale, then, the tax rate on heated tobacco products would also be lower than the tax on cigarettes, but it is unclear how the optimal tax on smokeless tobacco would compare to the optimal cigarette tax.

5. Externalities

Smokeless tobacco products entail no secondhand exposure at all. Heated tobacco products do create passive exposure to particulates, but only a quarter or less of the amount that cigarettes release and for a much shorter duration (McNeill et al., 2018; Protano et al., 2016). Since any public-finance externalities would be no larger with these alternative products than from smoking, and would probably be much lower, optimal Pigouvian taxes on smokeless products and heated tobacco would also be lower than on cigarettes.

6. Internalities

How would taxes on other reduced-harm products compare with those on cigarettes under rational 4? The epidemiologically correct perception that smokeless tobacco products are less risky than cigarettes was held by a majority of respondents in only 18% of studies on the subject (Czoli et al., 2017). Less than a quarter of current and recent smokers in one survey agreed with the statement that “heated tobacco products are less harmful than

[a] However, of the studies cited in Huang et al. (2018) finding that elasticity is lower for smokeless tobacco than for cigarettes, only one is both from the past decade and for the US market, and it estimates tax elasticities instead of direct price elasticities.

regular cigarettes" (Fung et al., 2020). Data from the PATH study show that 62.7% [61.9, 63.5] of adults believe that snus is about as harmful as smoking, and 29.9% [29.1, 30.7] believe that snus is more harmful.[a] The survey question did not distinguish between Swedish snus, for which these beliefs are nearly certainly incorrect, and American smokeless tobacco, not all of which is low-TSNA (as mentioned above).

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[a] Statistics computed by the author from data collected mainly in 2019. See footnote 19 in the main text.

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