Optimal E-Cigarette Policy When Preferences and Internalities are Correlated.*

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Abstract

This paper studies the policy implications of correlation between preferences and internalities in the context of tobacco products. Using novel survey data, I show that cigarette smokers who misperceive the relative health harms of cigarettes and e-cigarettes—and thus for whom internalities associated with imperfect information are potentially large—are also significantly less likely to respond to changes in relative prices. I build this heterogeneity into a model of cigarette and e-cigarette taxation to show that the relationship between the optimal e-cigarette tax and the mean elasticity of substitution is relatively flat. This is policy relevant because evidence of substitution is thought to suggest low (or even negative) e-cigarette taxes. Even at implausibly large degrees of substitution, simulated optimal e-cigarette taxes are positive and large.

JEL Classification: I12; H20

Keywords: Tobacco Control Policy; Behavioral Bias; E-Cigarettes

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1 Introduction

Cigarette regulation has been justified not only by the associated externalities, but also by internalities—uninternalized costs generated by behavioral biases such as present orientation or imperfect information (Cutler et al., 2015; DeCicca et al., 2020). Nascent regulation of electronic nicotine delivery systems (e-cigarettes) has been justified on similar grounds, but the substitutability of cigarettes and e-cigarettes as well as the relative uncertainty regarding the long-run health effects of e-cigarettes generate fascinating challenges for regulators and economists. In an important recent contribution, Allcott & Rafkin (2022) formulate a behavioral public finance model that yields the optimal e-cigarette tax as a function of whether e-cigarettes and cigarettes are substitutes or complements and the *uninternalized* marginal health impacts of each. Yet, as those authors acknowledge, there is significant empirical uncertainty surrounding each of these parameters. For example, a large body of well-identified work finds that e-cigarettes and cigarettes are substitutes (Friedman, 2015; Pesko et al., 2016; Tuchman, 2019; Pesko & Courtemanche, 2020; Saffer et al., 2020; Abouk et al., 2020; Cotti et al., 2021). Yet, other studies find either zero cross-price elasticity or even evidence of complementarity, especially among young adults and teens (Abouk & Adams, 2017; Cotti et al., 2018; Allcott & Rafkin, 2022). Similarly, there is medical consensus that e-cigarettes are significantly less harmful to health than cigarettes, but the variance in beliefs among medical professionals regarding the magnitude of this difference is large (McNeill et al., 2018). Allcott & Rafkin (2022) conclude that the optimal tax on e-cigarettes is likely positive, but a subsidy may be appropriate if significant new evidence of substitution emerges and/or e-cigarettes prove relatively much less harmful to health.

In this paper, I study the extent to which internalities generated by imperfect information relate to the elasticity of substitution between cigarettes and e-cigarettes. It is well-known that tobacco users overstate both the relative and absolute (Viscusi, 2020) health harms of e-cigarettes, particularly after the 2019 EVALI scare, which incorrectly attributed lung injuries caused largely by tainted THC products to e-cigarettes more broadly (Dave et al., 2020; Jin et al., 2022).[1] The key idea of my paper is that beliefs about relative health harms may influence the degree to which changes in relative prices cause changes in behavior. For example, I hypothesize that adult cigarette smokers who claim e-cigarettes are *more* harmful than traditional cigarettes—and thus incorrectly perceive relative health risks—should be less likely to substitute towards e-cigarettes when the relative price of these goods drops (due to an e-cigarette subsidy or a cigarette tax). Evidence in favor of this hypothesis has clear e-cigarette policy implications because the argument for an e-cigarette subsidy hinges on the power of price effects to convince adults with relatively

[1] Viscusi (2016) finds that survey respondents overestimate the absolute harms of e-cigarettes. Huang et al. (2019) show that incorrect beliefs on the relative health harms of e-cigarettes and cigarettes have become more common over time.

large internalities from smoking (i.e., those with incorrect beliefs) to switch to e-cigarettes. To formalize these ideas, I construct a model of e-cigarette and cigarette consumption that includes both habit formation and beliefs regarding health transitions. The model generates the prediction that the price elasticity of demand for e-cigarettes and the cross-price elasticity between e-cigarettes and cigarettes both depend on an individual's assessment of the relative health risks. The framework is flexible and generates a standard representation of the optimal e-cigarette tax as a function of the average marginal distortion (Diamond, 1973) and the average substitution distortion (Allcott et al., 2019; Allcott & Rafkin, 2022). An important difference is that my framework allows for individual-level heterogeneity on the basis of information.

To inform this model, I turn to novel survey data generated specifically for the purpose of gauging heterogeneity in beliefs. I focus on a sample of adult smokers for their policy relevance, since the clear policy goal concerning teens is to discourage tobacco initiation and addiction, which suggests large taxes on both products. Data are from a survey of 1,000 current or recent cigarette-smoking adults in the United States.[2] Of sampled smokers, 56% claimed that e-cigarettes were as or more harmful than traditional cigarettes, a belief at odds with medical research (McNeill et al., 2018). Relative to smokers who correctly perceived relative health risks, these incorrectly informed smokers were statistically much less likely to have experimented or used (or use) e-cigarettes, and they were statistically much less open to substituting towards e-cigarettes in the future.[3] The degree of present orientation, usually considered the first-order behavioral bias with respect to tobacco consumption (Gruber & Koszegi, 2001), was statistically and economically similar (mean $\beta \approx 0.7$) between these groups.

I investigate heterogeneity in the elasticity of substitution in two ways. First, I estimate linear probabilities models for the extent to which a cigarette smoker "has considered" substituting to e-cigarettes exclusively. Those with correct beliefs are 0.239 percentage points (63.4%) more likely to respond yes to this question. Second, in a discrete choice experiment in which the relative price of e-cigarettes was randomly decreased, correctly informed smokers were 16.5 percentage points more likely to state their intention to both reduce cigarette consumption and increase e-cigarette consumption. At mean substitution rates, this suggests that substitution between e-cigarettes and cigarettes is roughly 57.6% larger for correctly informed smokers.

Using the theoretical model and the empirical results, I calibrate the optimal e-cigarette tax and simulate its distribution, allowing for parameter uncertainty. All simulated individuals face identical cigarette and

[2]The survey was conducted via Qualtrics software on the survey research platform Prolific. The survey instrument can be viewed anonymously here.

[3]To complement survey data, I compare evidence on beliefs and behavior to the most recently available Population Assessment of Tobacco and Health (PATH) data.

e-cigarette prices and taxes; they generate identical internalities associated with present orientation; and they generate identical externalities for both goods. However, I assume that incorrectly informed smokers generate additional internalities associated with consumption levels that are optimal under their (incorrect) beliefs. Furthermore, these individuals have a smaller elasticity of substitution, and they consume fewer e-cigarettes.[4] Since the elasticity of substitution varies widely in the literature, I simulate the optimal e-cigarette tax for a range of elasticities, maintaining the gap between individual types. Relative to a simulation without heterogeneity in substitution and internalities, the key result is that this heterogeneity removes any rationale for an e-cigarette subsidy, even at implausibly large degrees of substitution. This is because incorrectly informed cigarette smokers fail to substitute to the healthier alternative when relative prices change, whereas correctly informed cigarette smokers (for whom internalities are smaller) do switch when relative prices change. In the case that cigarettes and e-cigarettes are complements, the optimal e-cigarette tax increases in the degree of complementarity but at a slower rate than under homogeneous types.

Importantly, my simulation results do not hinge on follow-through by smokers with stated preferences; the general intuition follows as long as stated and revealed preferences are positively correlated, and the magnitudes hold as long as differences between stated and revealed preferences are similar between correctly and incorrectly informed smokers. Furthermore, while I find that both those with correct and incorrect beliefs regarding the relative harms of e-cigarettes and cigarettes overstate the absolute harms of both products, perceptions of absolute harms do not matter for the optimal e-cigarette tax. Following the sufficient statistic tradition in behavior public finance (Mullainathan et al., 2012), the optimal e-cigarette and cigarette taxes only depend on perceptions of relative health harms, the elasticity of substitution between products, and the price elasticities of demand. I find that incorporating correlation in the optimal tax model flattens the relationship between the elasticity of substitution and the optimal e-cigarette tax. Within a reasonable range of the elasticity of substitution, the optimal e-cigarette tax ranges between $4/ml and $6/ml. At the Allcott & Rafkin (2022) 95% confidence interval level of substitution, the model without heterogeneity suggests an e-cigarette tax of $2.74/ml whereas the model with heterogeneity implies a tax of $4.67/ml; in the case where cigarettes and e-cigarettes are near perfect substitutes, the model without heterogeneity suggests an e-cigarette *subsidy* of $1.69/ml whereas the model with heterogeneity implies a tax of $3.59/ml.

[4] Chaloupka et al. (2019) offer evidence that behavioral biases such as present orientation and imperfect information are correlated in tobacco users, which suggests that internalities are unlikely to be additive. I posit that, relative to smokers who exhibit present orientation but correct beliefs about relative health harms, internalities are larger in the presence of both present bias and imperfect information.

This paper is similar in spirit to Schmacker & Smed (2023), who study differential responses to corrective "sin" taxes by the degree of self-control an individual has with respect to unhealthy foods. They find larger tax elasticities for those with more self-control. In the context of tobacco, my contribution is to demonstrate that similar heterogeneity (i.e., different elasticities of substitution by information) has important policy implications. This paper also contributes to a large mixed literature on the extent to which information can induce behavioral change. While there is widespread agreement that the 1964 Surgeon General's warning about cigarettes caused a decline in smoking prevalence in the United States, subsequent studies on cigarette warning labels have shown mixed results (DeCicca et al., 2020). A promising avenue has been in personalized sources of information such as a smoker's "lung age" (the age of lungs of a healthy non-smoker). In a randomized controlled trial, Parkes et al. (2008) show that this information causes significant tobacco cessation after one year. On the other hand, Khwaja et al. (2006) establish that only large, own health shocks rather than smoking-related shocks of one's spouse, cause smoking declines, and Darden & Gilleskie (2016) demonstrate that a smoking-related shock to an elder parent does not induce adult smokers to quit. In the event that information shocks alter smoking behavior, consumption prior to the shock was likely greater than optimal, and these internalities should enter benefit-cost analyses of proposed policies.

The paper proceeds with a general theoretical model in Section 2. The theory demonstrates the role of health beliefs in tobacco consumption behavior, and it derives the optimal set of taxes in the case of internalities and externalities. To inform this theory, Section 3 presents novel survey and discrete choice evidence on the correlation between internalities and substitution patterns between e-cigarettes and cigarettes. Section 4 calibrates and simulates the optimal e-cigarette tax for a variety of parameter assumptions, and Section 5 concludes.

2 Theory

I propose a dynamic model of cigarette and e-cigarette consumption in which an individual explicitly forms expectations regarding the health implications of their behavior. As a baseline model, I assume consumers are forward looking; they possess rational expectations regarding the health effects of each tobacco alternative; and they discount future utility in a time-consistent manner. I emphasize that this is a baseline specification to which welfare calculations of different regulations and behavioral biases should be based (Levy et al., 2018). The model makes clear that individual responsiveness to, for example, an increase in the e-cigarette tax should depend on the full price of each alternative, which includes the direct pecuniary costs, the *expected* health implications, and the implications for future addiction. The model is similar to that in AR with the exception that both health and expectations are explicitly modeled. The key innovation is to allow the internalities that result from imperfect information to be correlated with the elasticity of substitution between cigarettes and e-cigarettes. I use the model to generate optimal cigarette and e-cigarette taxes, and, in Section 4, I use parameter estimates from Section 3 to simulate the optimal e-cigarette tax under different assumptions about these correlations.

Consider an infinite-horizon model in which individual-level heterogeneity is indexed by θ.[5] Individuals have preferences over a numeraire good, $q^n_{\theta t}$, traditional cigarettes, $q^c_{\theta t}$, and e-cigarettes, $q^e_{\theta t}$, where the vector $q_{\theta t} = \{q^c_{\theta t}, q^e_{\theta t}\}$ reflects the chosen consumption of each tobacco product and the vector $q_t = \{q^c_t, q^e_t\}$ reflects the choice set. The stock of addictive capital, $S_t = S(S_{t-1}, q_{\theta t-1})$, is a function of the lagged stock and lagged behavior such that $S_{q^j} > 0$ for both $j \in \{c, e\}$. Individuals also face a simple, static budget constraint in which consumption is constrained by exogenous income, $z_{\theta t}$, and government transfers, T_t: $q^n_{\theta t} = z_{\theta t} + T_t - pq_{\theta t}$.[6] Following the realization of utility, the probability of death prior to period $t+1$, $p(\omega_{t+1} = 1|q_t, S_t)$, is a function of S_t and contemporaneous tobacco consumption, q_t. The value of death is normalized to zero.

I assume that utility is quasi-linear in tobacco and composite consumption. At time period $t = 1$, an individual's lifetime utility is given as:

$$U_\theta = \sum_{t=0}^{\infty} \delta^t \Big(1 - p(\omega_t = 1|q_{t-1}, S_{t-1})\Big) \Big[U_\theta(q_t; S_t) + q^n_t\Big], \tag{1}$$

where δ is the fixed rate of time preference and $p(\omega_0 = 1) = 0$. After substituting the static budget constraint, the maximal value of state S_t at time t for an individual of type θ can be expressed with the familiar Bellman equation:

$$V^*_\theta(S_t) = \max_{q_t} \Big[U_\theta(q_t; S_t) - pq_t + z_{\theta t} + T_t + \delta\Big(1 - p(\omega_{t+1} = 1|q_t, S_t)\Big)V^*_\theta(S_{t+1})\Big] \tag{2}$$

Equation 2 makes explicit that, to select q_t optimally, an individual must understand how both cigarettes and e-cigarettes affect the probability of survival, not only through contemporaneous behavior, but also future survival through S_{t+1}. For simplicity, I focus on the direct impact of behavior on survival and define

[5] Where possible, I adopt the notation of AR.

[6] Becker (2007) demonstrates that in a model of a risky good without habit formation but with a complete and fair insurance market, survival expectations associated with consumption do not enter the first-order conditions. I abstract from saving and borrowing, but habit formation plays an important role in the trade-offs between e-cigarettes and cigarettes because both contain nicotine.

the objective marginal impact of tobacco good j on the probability of death at the end of period t to be:

$$\alpha^j_{\theta t} := \frac{\partial p_\theta(\omega_{t+1} = 1 | q_{\theta t}, S_t)}{\partial q^j_\theta}.$$

Furthermore, I define $\tilde{\alpha}^j_{\theta t}$ as an individual of type θ's subjective assessment of this probability. An individual solves for $q_{\theta t}$ by maximizing the perceived value in Equation 2 as defined by $\tilde{\alpha}^j_{\theta t}$. The resulting first-order condition for tobacco good j is:

$$\gamma^j_{\theta t}(p, S_t) = p^j - \underbrace{\Big(\frac{\partial U_\theta(q_{\theta t}, S_t)}{\partial q^j_t} - \delta \tilde{\alpha}^j_{\theta t} V_\theta(S_{t+1}) + \delta\Big(1 - p(\omega = 1 | q_{\theta t}, S_t)\Big)\frac{\partial V_\theta(S_{t+1})}{\partial S_{t+1}}\frac{\partial S_{t+1}}{\partial q^j_t}\Big)}_{\text{Perceived Marginal Utility of Consumption of } j}. \tag{3}$$

The right-hand side of Equation 3 is the difference between the market price of good j and the perceived marginal utility of its consumption, which includes the contemporaneous marginal utility and the perceived marginal impact on future utility. When an individual's subjective assessment of the marginal survival implications equals the objective transition probability (i.e., $\tilde{\alpha}^j_{\theta t} = \alpha^j_{\theta t}$), then $\gamma^j_{\theta t}(p, S_t) = 0$. Generally, $\gamma^j_{\theta t}(p, S_t)$ represents an internality associated with the consumption of good j that deviates from the level of consumption of good j that would occur when $\tilde{\alpha}^j_{\theta t} = \alpha^j_{\theta t}$. The implication of inaccurate beliefs is that individuals either over-assign or under-assign the discounted value of life in state S_{t+1} to the marginal cost of good j. That is, if an individual dies prior to period $t+1$, they forgo the value of life in state S_{t+1}, and incorrect forecasts of the probability of this state imply suboptimal choices. For example, for individuals who overstate the change in the probability of death due to contemporaneous e-cigarette use, $\tilde{\alpha}^j_{\theta t} > \alpha^j_{\theta t}$, this implies that the contribution to the marginal internality from this form of biased risk perceptions is negative.

Subtracting both sides of Equation 3 by γ^j, Equation 3 represents a system of equations for the consumption of cigarettes and e-cigarettes. Taking subjective health assessments as exogenous and fixed, both the price elasticity of demand for good j and the cross-price elasticity of demand will depend on both $\tilde{\alpha}^c_{\theta t}$ and $\tilde{\alpha}^e_{\theta t}$ through the second-order conditions. I allow for this dependence through θ, as defined below.

2.1 Optimal Taxation

The optimal tax is designed to correct behavior associated with the internalities and externalities of tobacco consumption. I define the marginal distortion associated with consumption of good j to be:

$$\varphi^j_\theta := \gamma^j_{\theta t}(p, S_t) + \phi^j_\theta,$$

where $\gamma^j_{\theta t}(p, S_t)$ is the marginal internality and ϕ^j_θ is the marginal externality. To derive the optimal e-cigarette tax, I define the notion of welfare as the sum of the individual utilities:

$$W(\tau) = \sum_\theta s_\theta U_\theta, \tag{4}$$

where s_θ is the type θ share of the population. Assuming the regulator faces a balanced budget constraint such that $T_t = (\tau - \phi_\theta) q_{\theta t}$, the optimal e-cigarette tax is:[7]

$$\tau^{e*} = \frac{\sum_{\theta t} s_\theta \varphi^e_\theta \frac{dq^e_\theta}{d\tau^e}}{\sum_{\theta t} s_\theta \frac{dq^e_\theta}{d\tau^e}} + \frac{\sum_{\theta t} s_\theta \frac{dq^c_{\theta t}}{d\tau^e} (\varphi^c_\theta - \tau^c)}{\sum_{\theta t} s_\theta \frac{dq^e_\theta}{d\tau^e}}. \tag{5}$$

The optimal e-cigarette tax is a function of both the average marginal distortion associated with e-cigarettes (φ^e_θ) and the average uninternalized marginal distortion associated with cigarettes ($\varphi^c_\theta - \tau^c$) that occurs because an e-cigarette tax potentially causes changes in the consumption of cigarettes ($\frac{dq^c_\theta}{d\tau^e}$). To the extent that e-cigarettes and cigarettes have limited substitutability, the distortions associated with cigarettes will have little impact on the optimal e-cigarette tax. Similarly, e-cigarette taxes will only mitigate the marginal distortion of e-cigarettes if individuals are sensitive to e-cigarette prices. The remainder of the paper concerns correlation between product substitution and the internalities of e-cigarettes.

3 Data

A variety of repeated cross-sectional data sources track both cigarette and e-cigarette consumption in the United States, including the Behavioral Risk Factor Surveillance System, the Current Population Survey Tobacco Use Supplement, and the National Health Interview Survey, among others. Similarly, scanner data from Nielsen are particularly valuable in tracking brand-specific purchases within individuals over time. However, these large-scale data sources typically do not ask about perceptions and beliefs regarding tobacco products. As a result, I fielded a novel survey instrument through *Prolific*, an online survey platform in which respondents are paid for survey participation. Researchers post targeted surveys on the *Prolific* platform for participants with certain characteristics (e.g., current cigarette smokers) and participants can undertake the *Prolific* surveys that match their characteristics. My survey posted on the platform on June 1st, 2023, advertising a six-minute survey for current or recent cigarette smokers, and offering an hourly wage of $15. My survey specified a sample size of 1,000 respondents, and data collection was completed

[7] The optimal tax is identical to that in AR, however, internalities (i.e., φ^e_θ) in my paper include costs associated with imperfect information. See the Appendix of AR for a detailed derivation.

within six hours. Of the 1,000 responses, I constructed a final sample of 943 individuals after screening for missing data.[8]

Survey respondents were asked about their beliefs regarding the relative harms of e-cigarettes and cigarettes, ranging from "much more harmful" to "much less harmful". I group together respondents who claimed that e-cigarettes are "much more harmful," "more harmful," or "equally harmful;" 56.3% of this sample hold one of these beliefs, and I label these respondents as holding "incorrect beliefs." Table 1 presents overall sample means plus means (and p-values) by information type (i.e., correct or incorrect). Those with incorrect beliefs are statistically similar with respect to the proportion who claim to smoke daily and the proportion of heavy smoking (i.e., one pack or more per day). On the intensive margin of cigarette smoking, both incorrectly and correctly informed respondents smoke roughly 11.5 cigarettes per day. Respondents were screened prior to the survey for cigarette usage, and roughly 90% of respondents claimed to be current smokers, with the remaining 10% smoking within the last year, and these percentages were not different by information type.[9] Respondents reported paying on average roughly $8 per pack of cigarettes, and both correctly and incorrectly informed respondents were willing to pay considerably more (over $30 per pack). In general, cigarette-smoking behavior was not statistically different by information type; however, with respect to e-cigarettes, incorrectly informed respondents have significantly less experience, both ever and currently, and on the intensive margin. Daily e-cigarette usage was 2.5 times higher among correctly informed respondents, and the mean share of days per month in which a person uses e-cigarettes was 50% higher among correctly informed individuals (0.302 vs. 0.196).

In addition to beliefs regarding relative health harms, respondents were asked to gauge absolute health harms from tobacco products. Relative to a lifelong abstainer from tobacco, respondents were asked to assess the impact of lifetime cigarette use and lifetime e-cigarette use. The mean subjective longevity loss from lifetime cigarette smoking was similar for both types of respondents at roughly 12 years.[10] For lifetime e-cigarette use, the mean subjective longevity loss for incorrectly informed respondents is slightly less than double (11.8 years) that for correctly informed respondents (6.1 years). These results are consistent with the labels applied to each group, but they raise the question of whether the "correctly" informed group also overestimate the health harms of e-cigarettes, especially when McNeill et al. (2018) conclude that e-cigarettes are only 5% as harmful as cigarettes. Indeed, Viscusi (2016) show that survey respondents significantly overestimate the absolute harms of both e-cigarettes and cigarettes.

[8] The survey was built via Qualtrics software.

[9] *Prolific* only offers a filter for current or recent smokers.

[10] For context, the medical consensus, led by Doll et al. (2004), is that lifetime smoking reduces longevity by 10 years. Darden et al. (2018) estimate a model of smoking, morbidity, and mortality simulation that suggests this number is only 4.4 years.

Table 1 also presents evidence on whether respondents had considered quitting traditional cigarettes and exclusively using e-cigarettes instead. The proportion who had considered this change is dramatically different (68% vs. 38%) across the information groups. Controlling for all available demographic, socioeconomic, and tobacco behavioral characteristics available in the tobacco survey, this gap in openness towards substitution remains 0.239 percentage points, or 63.4% at the mean for those with incorrect beliefs.[11]

Respondents were also asked two questions regarding intertemporal trade-offs. The questions concerned the minimum amount a person would be willing to accept to delay a payment of $1,000 by one month and by one year. If the implied discount rate from these two questions is the same, then there is evidence of time-consistent preferences, and the parameter that captures present orientation (denoted β) would be equal to one. Values less than one imply present orientation. Courtemanche et al. (2015) show how to derive β from responses to these questions. For both information types, I find a mean β of roughly 0.7, which suggests time-inconsistent, present-oriented preferences. Present orientation is an important building block of the optimal e-cigarette tax because it represents a behavioral bias that deviates from optimal plans of action and generates internalities. That this parameter is statistically similar across groups implies that differences in internalities across information types are limited (in my simulation exercise) to differences in information. Finally, Table 1 demonstrates relatively similar demographic, socioeconomic, and subjective health profiles of respondents by information type, with the exception of sex and race. Incorrectly informed respondents were statistically more likely to be female and/or Black.

To put the survey statistics in Table 1 in context, Table 2 shows the distribution of beliefs about the relative harms of e-cigarettes for different subgroups (e.g., current e-cigarette users) in both the tobacco survey and the most recent publicly available wave (wave 5, 2021) of the Population Assessment of Tobacco and Health (PATH). PATH data are longitudinal and capture both beliefs and behavior, including relative health risks (Fong et al., 2019). Because tobacco survey respondents are current or recent cigarette smokers, I restrict PATH data to those who currently smoke. Respondents in PATH were able to select "Less Harmful", "About the Same", "More Harmful", or "I don't know", when asked about the relative harms of e-cigarettes to cigarettes. For comparison, I combine the "Much Less Harmful" and "Less Harmful" categories and the "Much More Harmful" and "More Harmful" categories in the tobacco survey. The tobacco survey did not give respondents the option to claim, "I don't know", but the percentage who are unsure in the PATH data is around 1%. Overall, current smokers in the tobacco survey are more likely to hold correct beliefs (43.69% vs. 17.55%). In both data sources, the share with correct beliefs is dramatically increasing in the frequency of e-cigarette use. Furthermore, the share claiming that e-cigarettes are more harmful than cigarettes are

[11] These results are from linear probability models for openness to substitution and are available upon request.

roughly the same across data sources, which implies that the main difference lies in the share claiming that the products are equally harmful. To the extent that the "equal" response is associated with survey respondent inattentiveness (Stantcheva, 2023), the tobacco survey does better than PATH with respect to inattentiveness.

To summarize, the tobacco survey data reveal potentially important correlations between beliefs in the relative health harms of e-cigarettes and cigarettes and e-cigarette behavior, both revealed behavior and openness to future behavior.

3.1 Experimental Variation

To test whether incorrectly informed smokers are more or less likely to respond to changes in relative prices, respondents were directly asked how their cigarette consumption would change if cigarette pack prices increased by a randomized amount, ranging from \$1 to \$4 (roughly 12.5% to 50% at mean prices reported in Table 1). The final two columns of Table 1 show the χ^2 test statistic value and p-value of the test that the shares of each variable are equal across these randomly determined price increases. In all cases, the observable characteristics are statistically balanced across treatment arms. All respondents received some price increase, and the empirical goal was to measure how responsiveness varied by information type. In response to the price increase, respondents could select that their cigarette consumption would "Fall by more than half," "Fall by less than half," "No(t) change," or "Increase." They could also indicate that they would "Completely Quit." Following this question, respondents were asked the following:

> *If you faced the increase in cigarette prices from the last question, how do you think your consumption of e-cigarettes would change?*
>
> - Large Decrease
> - Slight Decrease
> - No Change
> - Slight Increase
> - Large Increase.

To proceed, I define a dependent variable, d_i, for individual i that summarizes responses to both questions, where

- $d_i = 0 \rightarrow$ no change or an increase in cigarette smoking and no change or a decrease in e-cigarette consumption,

- $d_i = 1 \rightarrow$ a decrease in cigarette consumption or an increase in e-cigarette consumption (but not both),
- $d_i = 2 \rightarrow$ both a decrease in cigarette consumption and an increase in e-cigarette consumption.

I label $d_i = 2$ as "pure substitution," and the empirical challenge is to quantify how the share with $d_i = 2$ varies by beliefs and changes in relative prices. To this end, I estimate multinomial logit models of d_i as a function of beliefs, the magnitude of the price increase, and demographic, socioeconomic, and baseline tobacco consumption variables. The estimation equation for is:

$$\begin{aligned} ln\Big[\frac{p(d_i = d)}{p(d_i = 0)}\Big] =& \lambda_{0d} + \sum_{k=2}^{4} \lambda_{k-1d} 1[PriceIncrease_i = k] + \lambda_{4d} 1[Correct_i = 1] + \\ & \sum_{k=2}^{4} \lambda_{k+3d} 1[PriceIncrease_i = k] 1[Correct_i = 1] + X_i \lambda_d. \end{aligned} \tag{6}$$

Here, the probability that a respondent selects cigarette and e-cigarette responses $d \in \{1, 2\}$, relative to $d_i = 0$ are allowed to depend on the randomized price increase (relative to a \$1 cigarette price increase), beliefs, the interaction between price increases and beliefs, and individual observable characteristics X_i.

Table 3 presents the estimated average marginal effects from Equation 6 for having correct beliefs (top panel), as well as all multinomial logit coefficient estimates.[12] Focusing on the last two columns, which capture how covariates affect the probability of pure substitution, the average marginal effect of having correct beliefs is to increase the likelihood of pure substitution by 0.165 percentage points, or 57.6% at the mean proportion of 0.286.[13] Pure substitution is increasing in the size of the price increase and in correct beliefs, but the price effect is not statistically different by correct beliefs. This finding is intuitive to the extent that, as cigarette prices increase, stated substitution occurs for all respondents, regardless of beliefs. The probability of pure substitution is also significantly increasing in full-time employment and current e-cigarette use, and it is significantly decreasing in age, income, and heavy smoking. To demonstrate the results graphically, Figure 1 displays the average marginal effect of having correct beliefs for each response category by the size of the cigarette price increase. The green dashed line shows that correctly informed cigarette smokers are more likely to select pure substitution at all randomized price increases. That is, even when cigarette prices increase by \$4 (or roughly 50% at the mean stated price of one pack of cigarettes), those with correct beliefs are more likely to select pure substitution.[14]

[12] The inclusion of control variables does not change the results.

[13] The average marginal effect is calculated from the full multinomial logit specification, which includes the interaction terms between beliefs and the price increases.

[14] Maximization of Equation 2 implies that e-cigarettes and cigarettes are chosen simultaneously, which is consistent with

Results from the discrete choice experiment above suggest that those with correct beliefs about the relative health harms of e-cigarettes are more likely to substitute towards e-cigarettes when the relative price of e-cigarettes falls. This result implies a stated preference for substitution from correctly informed smokers. A standard critique of stated preferences is that they may not reflect actual behavior, although there is some evidence in health economics that stated preferences do in fact reflect actual willingness-to-pay (Kesternich et al., 2013). In my context, differences between stated and revealed preferences are import if these differences vary by beliefs. That is, as long as this bias is similar between information groups, then predictions regarding heterogeneity in substitution patterns will be policy relevant. Furthermore, in the policy simulations that follow, I simulate the optimal e-cigarette tax for a variety of assumed elasticities of substitution—the key is just that there exists heterogeneity in these parameters by beliefs. I emphasize that few large data sources contain information on both behavior and beliefs, and even large data sources are either under-powered or suffer from pre-trends in standard state by time difference-in-differences analyses (Allcott & Rafkin, 2022). The tobacco survey provides a novel way to investigate heterogeneity in these parameters.

4 Policy

In this section, I use the parameter estimates in Section 3 to inform simulations of the optimal e-cigarette tax in Equation 5. To simplify the optimal tax in Equation 5, I assume that the parameters of the optimal tax are pairwise independent over time and *within* type. I allow the price elasticity of demand for each good $\eta_\theta^j = \frac{\frac{dq_\theta^j}{dp^j}}{\frac{q_\theta^j}{p^j}}$, and the substitution parameter across goods $\sigma_\theta = \frac{\frac{dq_\theta^c}{dp_e}}{\frac{dq_\theta^e}{dp_e}}$ to vary by information type θ. Under these assumptions, the optimal e-cigarette tax simplifies to:

$$\tau^{e*} = \frac{\sum_\theta s_\theta \eta_\theta^e q_\theta^e (\varphi_\theta^e + \sigma_\theta(\varphi_\theta^c - \tau^c))}{\sum_\theta s_\theta \eta_\theta^e q_\theta^e}, \tag{7}$$

where s_θ is the share of the population of type θ; q_θ^e is the mean consumption of e-cigarettes of type θ; η_θ^e is the price elasticity of e-cigarettes of type θ; φ_θ^j is the sum of type θ's mean marginal internality and externality with respect to e-cigarettes; τ^c is the cigarette tax; and σ_θ is the substitution parameter of type θ.

the multinomial logit model in Equation 6. In a robustness check, I also estimate a bivariate probit model of a.) smoking fewer cigarettes and b.) using more e-cigarettes. The results are similar to those above and are available upon request. Importantly, the estimate of ρ, which captures correlation in the unobserved component of the bivariate probit model, is 0.4 and statistically significant. This suggests important individual-level heterogeneity in substitution that is consistent with the rest of the paper.

Positive values of σ_θ imply that the cross-price derivative (i.e., the numerator) is negative, which implies that e-cigarettes and cigarettes are complements. Negative values of σ_θ imply that e-cigarettes and cigarettes are complements. The units of the substitution parameter are cigarette packs per day vaped, which is slightly nonstandard relative to a traditional cross-price elasticity. Nevertheless, the intuition is similar, and it simplifies the presentation of the optimal tax, so I proceed with this definition for comparison to Allcott & Rafkin (2022) (henceforth AR). In Equation 7, if these goods are complements, and if there exist uninternalized distortions with respect to cigarettes ($\varphi^c_\theta - \tau^c$), then the optimal e-cigarette tax should increase. Similarly, if they are substitutes, and if e-cigarettes are less harmful than cigarettes, then the negative value of $\sigma_{\theta t}$ implies that the optimal e-cigarette tax should fall. Equation 7 is close to that in AR, but those authors treat all adults as of the same type. In my case, I define types for incorrectly and correctly informed adult smokers: $\theta \in \{0, 1\}$, where 0 denotes incorrectly informed. Equation 7 shows potentially important heterogeneity in consumption (q^e), marginal distortions (φ^e), own-price elasticity (η^e), and substitution (σ). Thus, I simulate the optimal e-cigarette tax, making similar assumptions as AR with respect to common parameters, but allowing for differences in heterogeneous parameters.

Table 4 presents parameter assumptions for both common and type-specific parameters. A key building block in both AR and my simulation exercises is that distortions and consumption of cigarettes can be converted to e-cigarettes via three parameters. The first parameter is the relative health harm, α. AR present simulation results for both $\alpha = 0.05$ and $\alpha = 0.37$; I assume the mean of these two values such that $\alpha = 0.21$. Second, there needs to be a conversion of nicotine content between a pack of cigarettes, which is the typical unit of analysis in tobacco research, and a milliliter (ml) of vaping liquid. I follow AR in assuming $\Lambda = 0.7$ ml/pack. Finally, to capture roughly equivalent quantities of consumption, based on the mean number of packs per day, I assume $\Gamma = 0.58$ ml/day when vaping.

Recall from Table 1 that present orientation was statistically similar across information types, which suggests that marginal internalities associated with time-inconsistent preferences should be similar. To calculate the common internality associated with cigarettes, I assume that internalities are based on the health care expenditures imposed on oneself (H) under time-inconsistent preferences, as measured by the degree of present orientation β: $\gamma = (1 - \beta)H$ (DeCicca et al., 2020). Here, I use the estimate of health care expenditures per pack of cigarettes from Gruber & Koszegi (2001), inflated to 2023 dollars. When $\beta = 1$, preferences are said to be time consistent, and there are no internalities. The mean present orientation bias in the tobacco survey (Table 1) is 0.706, which is between the 0.6 and 0.9 values assumed in AR. For the marginal externality from cigarettes, I assume the 2023 inflated estimate of externalities per pack of cigarettes from DeCicca et al. (2020). Finally, the Tax Policy Center, 2023 shows the mean federal plus state cigarette tax per pack in 2023 is $3.04.

Next, Table 4 shows parameters that dictate differences by information type. I use the fraction of correctly informed smokers in the tobacco survey ($S_1 = 0.437$), which implies that $S_0 = 0.563$. I define $\omega = 1.576$ as the scaling between the elasticity of substitution for incorrectly and correctly informed smokers. This value comes from the average marginal effect of correct beliefs on pure substitution in Table 3, scaled by their means (i.e., substitution is 57.6% greater for correctly informed smokers.) Specifically, 28.6% of smokers say claim they will substitute when prices of cigarettes increase, and the average marginal effect of correct information is 0.165 percentage points. These statistics suggest that the substitution parameter should be 57.6% smaller (i.e., more substitutable) for those with correct information. In their baseline simulation, AR assume $\sigma = 0.035$, which implies a small degree of complementarity between e-cigarettes and cigarettes, a parameter those authors describe as poorly identified. Rather than take a stand on the mean value of σ in the population, I simulate taxes for values of σ, ranging from -0.5 (perfect substitutes in AR) to 0.5 (strong complements), while maintaining a gap between correctly and incorrectly informed types. Because the focus is on substitution, in simulation I assume a common price elasticity of demand for e-cigarettes of -1.318. In practice, this assumption does not drive the results. When correctly informed individuals are much more price elastic (i.e., $\eta_1^e = -2$) or much less price elastic ($\eta_1^e = -0.5$), my qualitative conclusions are the same.[15] For differences in e-cigarette consumption, I base the quantities of e-cigarette consumption—expressed as the share of days within a month in which a person vapes—off differences in type-specific e-cigarette behavior in Table 1. These values bound the homogeneous quantity in AR of 0.24.

AR assume that present bias represents the only internality from either cigarettes or e-cigarettes. However, as is clear from results in both the tobacco survey and HINTS data, smokers with different beliefs behave differently, and they do so in ways that are consistent with beliefs driving behavior. To the extent that beliefs drive behavior, incorrectly informed smokers smoke more and vape less than would be optimal. The question is then, to what extent does correcting information shift behavior; or equivalently, by how much are smoking and vaping behaviors off because of information? I calibrate this internality from a randomized controlled trial in which information in the form of "lung age" (the age of lungs of a healthy non-smoker) was revealed to smokers. Parkes et al. (2008) show that this information caused a reduction in the mean number of cigarettes smoked per day from 13.7 to 11.7 after one year.[16] Assuming all of this decline comes from those with incorrect information, the scaled reduction in cigarettes per day equals 3.55 cigarettes, which is 17.8% of a 20-cigarette pack. The standard error on the difference in means in their study

[15]These results are available upon request.

[16]In a different context—the causal effect of warning labels—Brewer et al. (2016) found similar gaps.

was 0.85 cigarettes. Thus, using the inflation-adjusted estimate of the internal cost of smoking one pack of cigarettes at h = \$52.03 from Gruber & Koszegi (2001), I assume that the mean information internality, denoted by ι in Table 4, is 0.178*\$52.03. Assuming a normal distribution with standard deviation of 0.85, I draw 1,000,000 values of ι in simulation of the optimal tax. Thus, I generate 1,000,000 e-cigarette taxes, where uncertainty is driven by parameter uncertainty regarding the additional internalities of cigarettes and e-cigarettes. To be clear, the qualitative implications of heterogeneity on the optimal e-cigarette tax do not depend on ι, so long as it is greater than zero.

Figure 2 plots the simulated optimal e-cigarette tax by σ_0, the assumed elasticity of substitution for incorrectly informed smokers. The black solid line shows a baseline scenario in which I ignore the type of heterogeneity as though there were no information issues. As with AR, the optimal e-cigarette tax is increasing in the complementarity between cigarettes and e-cigarettes. At AR's assumed value of $\sigma = 0.035$, the optimal e-cigarette tax is \$5.39/ml, which is within the range of estimates that they report (particularly when α, the relative health harm of e-cigarettes, is larger and β, the degree of present orientation, is smaller). Next, the red dashed line allows for heterogeneous internalities; incorrectly informed smokers have larger internalities but the substitution parameter is common to both types. The red dashed line is steeper, but only marginally, reflecting the larger marginal distortions. Finally, the blue dotted line adds heterogeneity in substitution. The blue dotted line is dramatically flatter, which indicates the optimal e-cigarette tax is less dependent on the elasticity of substitution. If e-cigarettes and cigarettes are substitutes, the black solid and red dashed lines suggest smaller taxes (or even subsidies), but when the internalities are correlated with substitution, even significant mean substitution, suggests the optimal e-cigarette tax is positive and large. For example, when $\sigma_0 = -0.4$, the optimal e-cigarette tax with heterogeneity is \$3.93/ml, whereas the homogenous e-cigarette tax is -\$0.39/ml.

5 Conclusion

This paper demonstrates that smokers who misperceive the relative health harms of e-cigarettes also are less likely to change behavior when relative prices change. The direct policy implication is that e-cigarette taxes should be large and positive even when the mean degree of substitution between e-cigarettes and cigarettes is large. For high mean degrees of complementarity, the e-cigarette tax is lower, but still positive and increasing in the degree of complementarity. The broader point is that future health considerations are important, even to present-oriented, time-inconsistent smokers. For example, Darden (2017) formulates a dynamic stochastic model of lifetime smoking behavior in which health represents the central trade-off to the utility of smoking. A result of that paper is that large, personalized health shocks (but not small shocks) can have informational value in the sense that they do induce cessation, consistent with other studies in the literature (Khwaja et al., 2006). A contribution of this paper is to consider the "why" when thinking about how tobacco regulation affects consumption: some smokers may not substitute towards e-cigarettes because they care about their health and they perceive e-cigarettes to be more harmful.

There is still no consensus on many of the parameters that dictate optimal policy. For example, Figure 2 is constructed assuming that the health implications of e-cigarettes are only 21% of traditional cigarettes, and yet evidence from Table 1 suggests that even correctly informed smokers view the longevity loss from lifelong e-cigarette usage to be about half that of traditional cigarettes (6.11 years vs. 11.803 years). However, repetition of the simulations that generate Figure 2 with $\alpha = 0.52$ simply shifts the curves upwards (i.e., higher e-cigarette taxes). In this case, e-cigarettes are more similar to cigarettes in their health consequences, but the effect of e-cigarette taxes is still driven mainly by the correctly informed types. The value of Figure 2 is to show the importance of heterogeneity for any set of parameters. Furthermore, this paper focuses on adults, as substitution among adults is the only reason for low or negative e-cigarette taxes; incorporating heterogeneity among teens is unlikely to change the call for higher e-cigarette taxes because the first-order consideration with respect to teens is to discourage tobacco initiation. Indeed, Premarket Tobacco Product Applications to FDA for new e-cigarette products must demonstrate that such products encourage adults to substitute away from traditional cigarettes.[17]

In general, this paper calls for more integration of data on information, beliefs, and risk perceptions in tobacco policy evaluation, and it takes a broader perspective of the full price of tobacco products from a smoker's perspective.

6 Conflict of Interest Statement

On behalf of all authors, the corresponding author states that there is no conflict of interest.

[17] Federal Register 86 FR 55300

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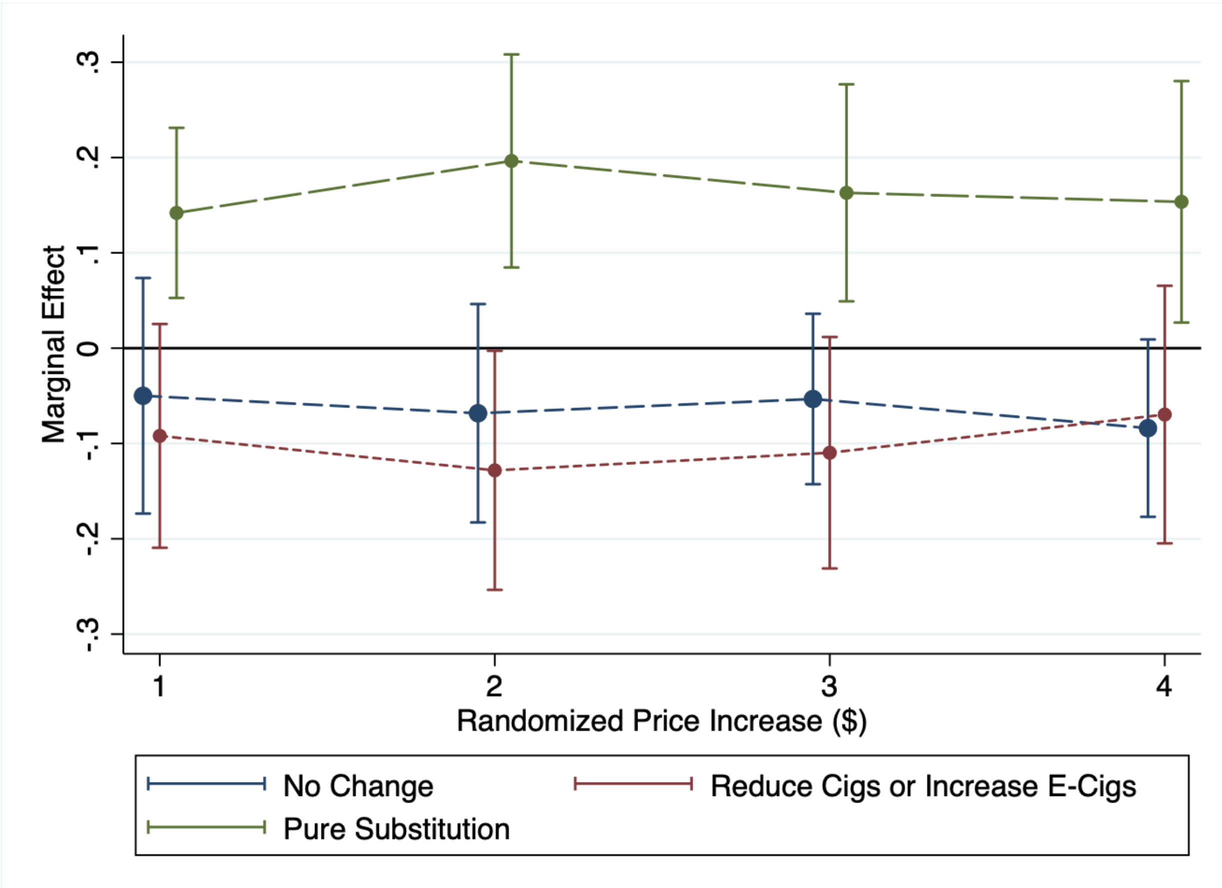
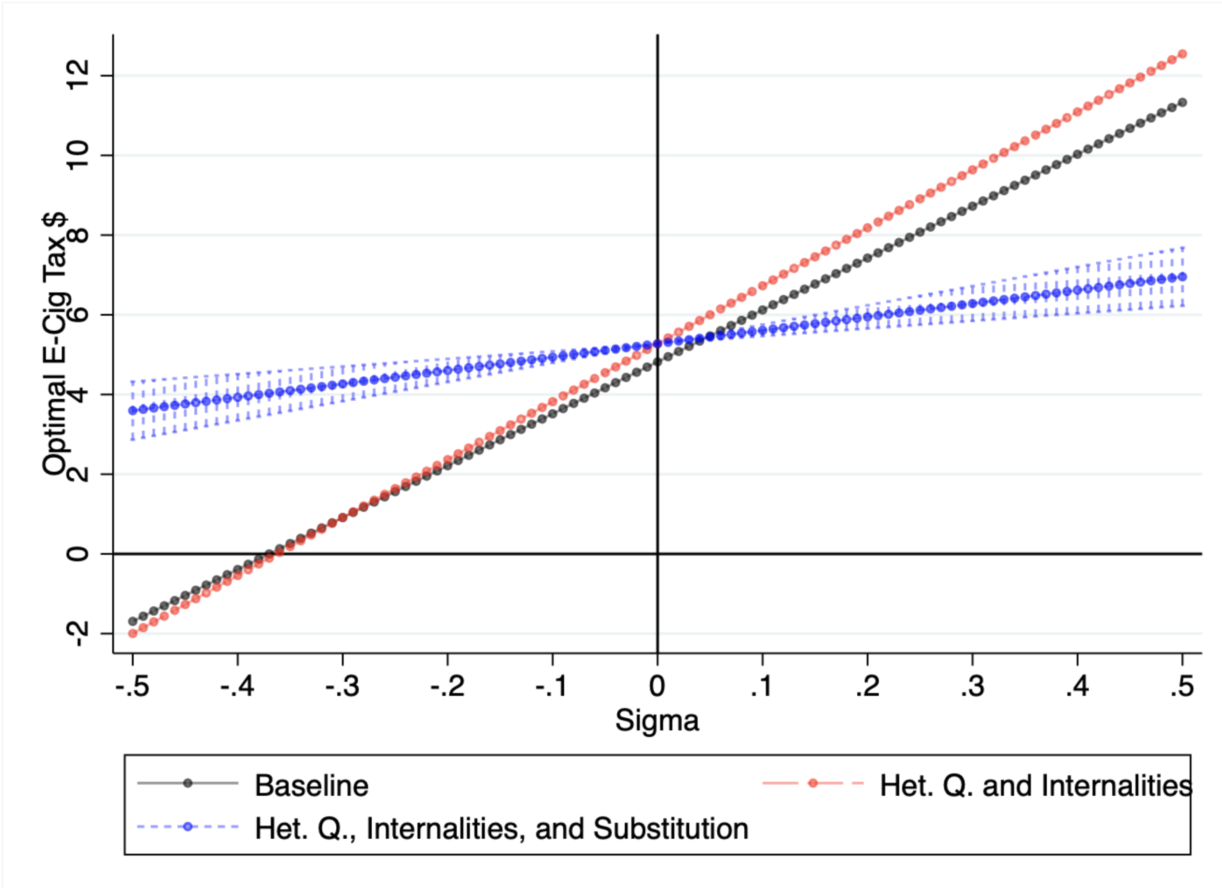
7 Figures and Tables

Figure 1: Average Marginal Effects of Correct Beliefs by Price



Notes: The figure presents the average marginal effects on the probabilities of each behavioral option by the increase in the cigarette price. The marginal effects and their associated 95% confidence intervals are with respect to the "correctly informed" binary variable. All marginal effects are calculated from a multinomial logit model of cigarette and e-cigarette options conditional on the characteristics in Table 1. $n = 943$

Figure 2: Simulated Distribution of E-Cigarette Taxes



Notes: Simulated optimal e-cigarette taxes. The black line assumes that all parameters are homogenous by information type. The red line assumes that q^e and φ^e are heterogeneous by information type. The blue line assumes additional heterogeneity in substitution patterns. Confidence intervals on the blue line come from parameter uncertainty regarding additional internalities associated with imperfect information.

Table 1: Summary Statistics

	Overall	Incorrect Beliefs (56.31%)	Correct Beliefs (43.69%)	p-value	Balance Test χ^2	Balance Test p-value
Cigarette and E-Cigarette Behavior						
Daily Smoker	0.628	0.646	0.604	0.191	6.039	0.110
Cigs. > 19/day	0.216	0.203	0.233	0.274	0.804	0.848
# Cigarettes/Day	11.548	11.574	11.515	0.925	104.729	0.191
Prolific: Current	0.898	0.902	0.893	0.656	1.136	0.768
Price Paid/Pack	8.068	8.119	8.004	0.785	502.700	0.396
Max. Price/Pack	31.371	32.282	30.197	0.395	83.575	0.584
Ever Tried E-Cigs.	0.885	0.861	0.917	0.007	6.850	0.077
Current E-Cig. Use	0.522	0.463	0.597	0.000	6.900	0.075
Daily E-Cig. Use	0.102	0.062	0.153	0.000	6.858	0.077
E-Cig. Share of Days	0.242	0.196	0.302	0.000	26.270	0.196
Years of Longevity Loss from Lifetime:						
Long. Loss Cig.	11.973	12.105	11.803	0.362	51.651	0.770
Long. Loss E-Cig.	9.343	11.849	6.112	0.000	58.342	0.537
Other Preferences						
Open to E-Cig. Subs.	0.509	0.377	0.680	0.000	0.952	0.813
Immediate Preference	0.706	0.698	0.717	0.213	909.785	0.376
Demographic and Socioeconomic Characteristics						
Age in Years	42.411	43.171	41.432	0.030	171.538	0.539
Female	0.460	0.531	0.369	0.000	2.827	0.419
White	0.756	0.727	0.794	0.018	2.285	0.515
Black	0.141	0.177	0.095	0.000	4.038	0.257
Asian	0.031	0.024	0.039	0.206	2.626	0.453
Mixed Race	0.051	0.053	0.049	0.772	1.309	0.727
Other Race	0.021	0.019	0.024	0.566	4.795	0.187
< High School	0.024	0.032	0.015	0.085	1.290	0.731
High School	0.176	0.171	0.182	0.670	1.436	0.697
Some College	0.385	0.395	0.371	0.451	3.476	0.324
College Graduate	0.332	0.326	0.340	0.651	0.435	0.933
Graduate Degree	0.083	0.075	0.092	0.350	1.550	0.671
Employed Full-Time	0.526	0.529	0.522	0.823	3.225	0.358
Annual HH Income	6.459	6.620	6.252	0.220	20.062	0.828
Subjective Health						
Ex. Health	0.049	0.047	0.051	0.784	4.055	0.256
V. Good Health	0.276	0.271	0.282	0.724	0.621	0.892
Good Health	0.423	0.414	0.434	0.535	1.143	0.767
Fair or Poor Health	0.251	0.266	0.233	0.254	5.356	0.148

Notes: The table presents means of baseline characteristics from the tobacco beliefs survey, both overall and by a person's understanding of the health risks of e-cigarettes. Respondents are classified as "Correct" if they responded that e-cigarettes are "less harmful" or "much less harmful" than traditional cigarettes. The first p-value is of the null hypothesis that the means are equal by beliefs. The last two columns report the χ^2 and p-values for the categorical test that the means of each characteristic are equivalent across the four price treatment arms discussed below. n=943.

Table 2: Comparison of Tobacco Survey and PATH Data

			Vaping		
	Overall	Daily Smoker	Ever	Current	Daily
Tobacco Survey	n=943	592	835	492	96
Less Harmful	43.69	42.06	45.27	50.00	65.62
About the Same	46.55	46.96	45.87	42.89	31.25
More Harmful	9.76	10.98	8.86	7.11	3.12
	Overall	Daily	Ever	Current	Daily
PATH Round 5, Current Smokers	n=8,568	6,437	6,780	1,311	512
Less Harmful	17.55	15.8	19.68	39.74	53.32
About the Same	69.23	70.75	68.53	54.77	41.41
More Harmful	12.09	12.16	10.94	5.19	4.88
I don't know	1.12	1.29	0.86	0.31	0.39

Notes: Tobacco survey data are combined to reflect the three main categories in PATH. PATH data are from wave 5, which was collected in 2021. Both data sources reflect current or recent cigarette smokers.

Table 3: Multinomial Logit Coefficients

	d = 1		d = 2	
	Marginal Effect of Correct Beliefs			
	Coef.	S.E.	Coef.	S.E.
Correct Beliefs	-0.101	0.033	0.165	0.029
	Multinomial Logit Coefficients			
Cig. Price Increase				
$2	0.824	0.276	1.250	0.406
$3	1.447	0.295	2.169	0.406
$4	1.480	0.326	2.272	0.433
Correct Beliefs	-0.168	0.315	1.066	0.395
*Price Increase$2	0.126	0.465	0.019	0.553
*Price Increase$3	0.279	0.490	-0.152	0.567
*Price Increase$4	0.662	0.548	0.097	0.621
Age	-0.005	0.008	-0.019	0.009
Female	0.266	0.183	0.319	0.211
White	0.272	0.589	0.102	0.658
Black	0.433	0.622	-0.262	0.708
Asian	1.969	0.876	0.730	0.987
Mixed Race	-0.055	0.689	-0.583	0.778
High School	0.265	0.557	0.187	0.714
Some College	0.394	0.536	0.723	0.691
College Graduate	0.169	0.553	0.050	0.712
Graduate Degress	0.264	0.622	0.692	0.774
Employed Full-Time	0.106	0.184	0.481	0.216
Annual HH Income	-0.072	0.023	-0.095	0.027
Ex. Health	-0.057	0.431	-0.786	0.541
V. Good Health	-0.038	0.246	-0.386	0.286
Good Health	0.033	0.222	-0.008	0.253
Prolific: Current Smoker	-0.032	0.326	-0.286	0.358
Daily Smoker	-0.481	0.228	-0.317	0.255
Cigs. > 19/Day	-0.872	0.317	-0.809	0.371
# Cigarettes/Day	0.027	0.015	0.026	0.017
Ever Tried E-Cigs.	-0.209	0.271	0.903	0.451
Current E-Cig. Use	0.111	0.212	1.141	0.241
Daily E-Cig. Use	-0.117	0.349	0.067	0.342
Price Paid/Pack	0.035	0.023	0.002	0.028
Max. Price/Pack	0.004	0.002	0.006	0.003
Constant	-0.488	0.928	-2.392	1.171
Mean	0.435		0.286	

Notes: Average marignal effects and coefficients correspond to Equation 6. Effects are relative to $d_i = 0$, which implies no change or an increase in cigarette smoking and no change or a decrease in e-cigarette consumption. $d_i = 1$ implies a decrease in cigarette consumption or an increase in e-cigarette consumption (but not both); and $d_i = 2$ implies both a decrease in cigarette consumption and an increase in e-cigarette consumption. $N = 943$

Table 4: Tax Simulation Parameters

Parameter	Description	Value	Source/Notes
Common Parameters			
α	Fraction relative health harms	0.21	Allcott & Rafkin (2022); Mean value
Λ	E-cig nicotine relative to cigs. (ml/pack)	0.7	Prochaska et al. (2022), Willett et al. (2019)
Γ	Avg. ml/day when vaping	0.58	Allcott & Rafkin (2022)
h	Health care internality	$52.03	Gruber & Koszegi (2001)
β	Present orientation	0.706	Table 1
ψ^c	$/pack Externality from cigarettes	0.77	DeCicca et al. (2020)
τ^c	$/pack Cigarette tax	3.04	Tax Policy Center, 2023, U.S. Census Bureau
Type Specific			
s_1	Fraction with correct information	0.437	Table 1
ω	Elasticity of sub. scaling	1.576	Table 3
η^e	Price Elasticity incorrect and correct info.	-1.318	Allcott & Rafkin (2022)
q_0^e	Share of days vaping incorrect info.	0.196	Table 1
q_1^e	Share of days vaping correct info.	0.302	Table 1
ι	Information internality proportion	0.178	Parkes et al. (2008),Brewer et al. (2016)

Notes: Tax simulation parameters