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Original investigation

The Experimental Tobacco Marketplace: Demand and Substitutability as a Function of Cigarette Taxes and e-Liquid Subsidies

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Abstract

Introduction: The experimental tobacco marketplace (ETM) approximates real-world situations by estimating the effects of several, concurrently available products and policies on budgeted purchasing. Although the effects of increasing cigarette price on potentially less harmful substitutability are well documented, the effects of other, nuanced pricing policies remain speculative. This study used the ETM as a tool to assess the effects of two pricing policies, conventional cigarette taxation and e-liquid subsidization, on demand and substitutability.

Methods: During sampling periods, participants were provided 2-day samples of 24 mg/mL e-liquid, after which ETM purchase sessions occurred. Across two ETM sessions, conventional cigarettes were taxed or e-liquid was subsidized in combination with increasing cigarette price. The other four available products were always price constant and not taxed or subsidized.

Results: E-liquid functioned as a substitute for conventional cigarettes across all conditions. Increasing cigarette taxation and e-liquid subsidization increased the number of participants for which e-liquid functioned as a substitute. Cigarette taxation decreased cigarette demand, by decreasing demand intensity, and marginally increased the initial intensity of e-liquid substitution, but did not affect the functions' slopes (substitutability). E-liquid subsidization resulted in large increases in the initial intensity of e-liquid substitution, but did not affect e-liquid substitutability nor cigarette demand.

Implications: 24 mg/mL e-cigarette e-liquid was the only product to significantly substitute for cigarettes in at least one condition throughout the experiment; it functioned as a significant substitute throughout all four tax and all four subsidy conditions. Increasing cigarette taxes decreased cigarette demand through decreases in demand intensity but did not affect e-cigarette substitution. Increasing e-liquid subsidies increased e-liquid initial intensity of substitution but did not affect cigarette demand.

Conclusions: This study extended research on the behavioral economics of conventional cigarette demand and e-liquid substitutability in a complex marketplace. The results suggest that the most

efficacious method to decrease conventional cigarette purchasing and increase e-liquid purchasing may involve greatly increasing cigarette taxes while also increasing the value of e-liquid through potentially less harmful product subsidization or differential taxation.

Introduction

Although the ultimate goal of tobacco regulatory science is to reduce all nicotine and tobacco product use, the goal of harm-reduction approaches is to improve public health by reducing cigarette smoking, and/or shifting purchasing to potentially less harmful products.[1–3] One example of these potentially less harmful products is electronic cigarettes (e-cigarettes),[4] which may be used as substitutes for combustible cigarettes and used by smokers to reduce or quit smoking entirely. Achieving this goal requires not only estimating the impact of an array of new, less harmful products on conventional cigarette smoking, but also the impact of different tobacco regulations and pricing policies. Typical methods in tobacco regulatory science include examining the effects of cigarette price, specific product features (eg, packaging), or the introduction of potentially less harmful products on nicotine product purchasing.[5–9] The results of these studies have been promising; notably, the observation that participants are more likely to switch from conventional cigarettes to potentially less harmful products as the price of conventional cigarettes increases. One limitation, however, is that purchasing decisions are typically examined when only two or three products are concurrently available,[7,10–12] which does not reflect the true marketplace of options available to current smokers. Another limitation is that increasing cigarette price may not always be a feasible or desired tobacco policy option. Indeed, theoretical and epidemiological research suggests that relative price manipulations (eg, differential taxation, subsidization) may better serve tobacco regulatory science[13–15]; thus, experimentally examining the effects of relative-pricing policies is key. One method to explore these policies is the application of behavioral economic research procedures.

Behavioral economic studies of tobacco have shown that the type and quantity of products in a marketplace alter a commodity's demand elasticity (ie, sensitivity to price) as well as the switching among those products.[6,7,12,16–18] Thus, achieving the tobacco control goals of reducing purchasing of a particular product and/or shifting preference to another product may each be enhanced or diminished via the economic process of substitution (see Bickel et al.[16] for a review). Substitution refers to the interaction of two products; specifically, it has traditionally been measured as an increase in purchasing of a fixed-price product (eg, e-cigarettes) when the price of an alternative product increases (eg, conventional cigarettes). This may be measured by the slope of the purchasing function,[6,16,19] (but see Green and Freed[20]). However, substitution may also be evident in two other recently developed measures. Substitution can be measured as an increase in purchasing of a commodity at a fixed price, seen at the y-intercept (initial intensity) of the fixed-price function. For example, Pope et al.[21] demonstrated that increasing e-liquid nicotine strength resulted in increases in the slope, and initial intensity, of e-liquid purchasing over cigarette price function. That is, as cigarettes increased in price and cigarette purchases declined, higher e-liquid nicotine strengths produced greater increases in e-cigarette purchasing (slope); moreover, higher e-liquid nicotine strengths produced greater purchasing of e-liquid when cigarettes were freely available (initial intensity). The current complexity of the tobacco marketplace requires an experimental method designed to examine and estimate these inter-product purchasing relations among a broad range of nicotine products.

To address the current complexity of the tobacco marketplace, better understand the substitutability of a broad range of alternate products simultaneously, and help inform tobacco policy, we have developed and tested the experimental tobacco marketplace (ETM).[9,21–23] The ETM is an online, Amazon-like store that displays photos, prices, and information for each of several available nicotine and tobacco products. To date, three laboratory studies using real outcomes in the ETM have consistently illustrated that alternate product substitutability for conventional cigarettes is modifiable depending on consumer characteristics[23] and the number and type of other alternate products available.[9] Furthermore, e-cigarettes or e-liquid generally demonstrate the highest substitutability of all potentially less harmful alternate products tested to date in the ETM.[9,22,23] A recent ETM study identified both the initial intensity and substitutability of e-cigarettes increased dose dependently with e-liquid nicotine strength, where 24 mg/mL e-liquid demonstrated the highest overall substitutability.[21]

The next step is to use the ETM to estimate the effects of other nicotine/tobacco control policies and regulations on purchasing. Two simple and commonly implemented policies to alter product purchasing are taxation and subsidization. Taxes may be implemented as price increases at either the state or federal level (currently, taxes in the United States range from $1.31 to >$5.26 a pack across states[24]) whereas the most likely implementation of subsidies may include manufacturer coupons (eg, "Buy one, get one" offers, discounts). Prior economic studies have shown taxes and subsidies to be effective in increasing and decreasing nicotine purchasing,[13,25–28] whereas no research to the best of our knowledge has experimentally examined these effects in general or across a range of tobacco products.

Before implementation of new tax or subsidy policies, experimental research is needed in order to provide estimates of the policy options that are likely to produce the highest rates of tobacco cessation or substitution of combustible tobacco for potentially less harmful, noncombustible products. These a priori estimates from the ETM may then be used to design more effective policy and avoid possible unanticipated effects.

This study investigated the effects of four conventional cigarette tax rates and four e-liquid subsidization rates (0%, 12.5%, 25%, and 50%) in interaction with the price of conventional cigarettes on cigarette demand and e-liquid substitutability. To account for participants' potential lack of exposure to e-cigarettes, participants were given and taught how to use and refill an e-cigarette device. To ensure that all participants had some e-liquid experience and exposure throughout the study, they were provided training in use of 24 mg/mL e-liquid and a sampling period (2 days) prior to the two ETM purchase sessions. This allowed the examination of cigarette demand and e-liquid substitutability as a function of cigarette taxation and e-liquid subsidization rates within each participant.

Methods

Participants

Participants (n = 29) were recruited from Roanoke, Virginia and surrounding areas and were invited to attend five sessions at the Addiction Recovery Research Center. To meet eligibility criteria, participants (1)

were between the ages of 18 and 65 years, (2) smoked at least 10 cigarettes daily, (3) expressed a willingness to try e-cigarettes, and (4) reported having no unmanaged health conditions. Individuals with immediate intentions to quit smoking and those planning to move away from the area were excluded. In addition, individuals were excluded if they were pregnant, used prescription medication affecting nicotine metabolism, or if they reported regularly using nicotine replacement products (eg, nicotine patch, gum, lozenge). The Virginia Tech Institutional Review Board approved all study protocol and procedures, and all participants provided written informed consent.

Procedures

After an initial screening questionnaire determined eligibility, participants completed five sessions, including two e-liquid sampling sessions (each followed by 2-day sampling periods), two ETM purchase sessions, and one follow-up session (see Appendix). Identical to a recent study by Pope et al.[21] participants were provided with and taught how to use an e-cigarette. Participants also chose their preferred flavor of e-liquid to use throughout the study. In addition, during the two sampling sessions (always 2 days prior to ETM sessions) all participants received 2 mL of 24 mg/mL of their preferred e-liquid flavor[29] to take home to sample over the next 2 days (see Appendix for more details).

Account Balance

Identical to the previous ETM study by Pope et al.,[21] participants were provided with an account balance throughout the ETM purchasing sessions to approximate real-world conditions related to income and budget constraints (see Appendix for more details).

Experimental Tobacco Marketplace Sessions

During the two ETM sessions, participants purchased products on OpenCart, a platform where study products (including brand of cigarettes, taxes, and subsidies) can be manipulated, thereby giving each participant an individualized nicotine purchasing site determined by conventional cigarette preference, preferred e-liquid flavor, current conventional cigarette price condition, and conventional cigarette tax or e-liquid subsidy session. Six products were available to purchase: typical brand of cigarette, preferred e-liquid flavor, winterchill flavor Camel Snus, wintergreen flavor Grizzly dip, white ice mint flavor Nicorette 4-mg nicotine gum, and mint flavor Nicorette 4-mg nicotine lozenges. More information about the products, including nicotine content, can be found in the Appendix.

During both ETM sessions, the participants made purchases among all six available products across five ascending conventional cigarette base prices ($0.12, $0.25, $0.50, $1.00, and $2.00 per cigarette), whereas the base prices for all other products remained fixed. Each session included 20 purchasing trials (with participants able to purchase all six products as conventional cigarette prices increased and as various taxes and subsidies were applied), with one session examining cigarette tax rates and another examining e-liquid subsidy rates. The taxation of conventional cigarettes (≥0%, ≥12.5%, ≥25%, and ≥50% added to the $0.12–$2.00 base prices of cigarettes; order counterbalanced) or subsidization of e-liquid (–0%, –12.5%, –25%, and –50% added to the constant, $0.50 base price of e-liquid; counterbalanced order) was applied in counterbalanced order across the two ETM sessions (see Appendix for further detail).

During both ETM sessions, whether tax or subsidy, participants were asked to purchase enough products to use over the next 5 days, and their account balance started over prior to each cigarette price and tax or subsidy condition combination (ie, 20 conditions during each ETM). At the end of each ETM session, the products purchased at one cigarette price within a tax/subsidy rate purchase trial were randomly chosen to be provided to participants.

Statistical Analysis

Microsoft Excel and GraphPad Prism 7 were used for all data analysis. All statistical tests were considered significant at the $p < .05$ level, and all tests were two tailed. Where applicable, Tukey's multiple comparisons were used to further interpret significant main effects and interactions.

Identical to the ETM study conducted by Pope et al.[21] purchasing data were converted from quantity or number of units purchased to total milligram of nicotine purchased (nicotine yield was unavailable for this variety of e-cigarette and e-liquid). Because the nicotine strength of all products was constant across all conditions of the experiment, analyses converting number of products purchased to milligram of nicotine yielded qualitatively identical results as analysis of raw number of products purchased (see Pope et al.[29] for discussion; see also Supplementary Materials).

Conventional Cigarette Demand

For each participant, conventional cigarette demand was quantified separately across the tax and subsidy sessions. Individual cigarettes purchased in each condition were transformed to the corresponding amount (milligram) of nicotine per cigarette. We applied the exponentiated demand model of Koffarnus et al.,[30] which is appropriate for zero values, to individual participant's conventional cigarette demand across the ETM tax conditions and, separately, to cigarette demand across the ETM subsidy conditions:

where Q is conventional cigarette purchasing (milligram nicotine), P is the price of the cigarette, Q_0 represents initial demand or demand intensity (cigarette purchasing level at zero cost), k corresponds to the range of the function in logarithmic units, and α represents demand elasticity.[31] The parameter k was fitted as a constant common across all price conditions and tax and subsidy ETM sessions ($k = 1.51$). Model-derived values of Q_0 and α served as dependent measures of demand intensity and elasticity, respectively, and were each compared using a repeated measures analysis of variance (RMANOVA).

Alternate Product Substitutability

As in prior ETM studies,[9,23] for each participant, linear regressions were applied to fixed price, alternate product purchasing data as a function of log-transformed cigarette prices to estimate substitutability, represented here by the slopes of the fixed-price alternate purchasing functions, and initial intensity, represented here by the y-intercepts of the fixed-price alternate purchasing functions across the four tax conditions and, separately, across the four subsidy conditions. Product substitution was thus demonstrated if a product function's slope was statistically significantly greater than 0, with higher slopes indicating greater substitutability. To test how conventional cigarette tax rates and e-liquid subsidy rates influenced alternate product purchasing and substitutability, RMANOVAs were applied to individual participants' alternate product slope and y-intercept estimates, separately across the tax and subsidy conditions.

Results

Participant Characteristics

Participants were 64% female, 76% white and 16% African American, were of mean age 43.76 years (SD = 11.36 years), and had

13.08 (SD = 1.55) years of education. Only six of 29 participants (24%) reported using e-cigarettes in the past month (*Mean* = 4 days of use and maximum of 12 days of use). No other participants reported e-cigarette use within the past month. On the basis of the Timeline Followback (TLFB)[32] assessment, participants smoked an average of 17.54 (SD = 7.39) cigarettes/day for the 30 days prior to study onset. Participants had a mean score of 7.2 (SD = 2.08) on the Fagerström Test for Cigarette Dependence.[33]

Effects of Conventional Cigarette Tax Rates

Figure 1A displays mean, obtained conventional cigarette demand across the four cigarette tax rates, with the solid lines drawn through the data representing corresponding predictions from Eq. 1. Supplementary Table 1A contains the mean, Eq.1-derived estimates of Q_0 and α and median goodness-of-fit measures for cigarette demand across the four taxation rates. In general, Eq. 1 provided excellent fits to individual subject cigarette demand across both conditions, accounting for over an average of 92% of the variance across all tax and subsidy conditions. As expected, mean cigarette demand decreased as price increased.

Visual inspection of Figure 1A indicates large decreases in Q_0 as a function of altering cigarette tax rate from 0% to 50%. The RMANOVA applied to individual estimates of Q_0 revealed a significant effect of cigarette tax [F (3, 78) = 5.21, p = .005]. Tukey's post hoc tests revealed Q_0 was lower in the 25% and 50% tax conditions each compared to the 0% tax condition (p = .04; p = .003), but all other comparisons were not significant (all ps > .25). The RMANOVA applied to α estimates across cigarette tax rate was not significant [F (3, 78) = 2.04, p = .16].

Figure 1B illustrates the mean e-liquid substitution functions across the four cigarette taxation rates and Supplementary Table 1B lists the results of the linear regressions applied to individual alternate product purchasing across each cigarette tax rate. Overall, 24 mg/mL e-liquid was the only alternate product to function as a significant substitute for conventional cigarettes and did so across all taxation conditions. Purchasing of anything other than conventional cigarettes and e-liquid across any condition of the experiment was rare, with only one participant purchasing snus and dip and no participants purchasing nicotine gum and lozenges across all tax conditions.

Visual inspection of Figure 1B suggests that cigarette taxes had little effect on the slopes (substitutability) or y-intercepts (initial intensity) of the e-liquid substitution functions. The RMANOVA applied to individual e-liquid slope estimates revealed no significant effect of cigarette tax rate on e-liquid substitutability [F (3, 78) = 1.14, p = .34]. Initial intensity increased nominally as a function of tax rate, but there was also not a significant effect [F (3, 78) = 2.30, p = .10]. Importantly, however, the number of individual participants with e-liquid slopes significantly greater than 0 (ie, e-liquid functioned as a significant substitute) were 10, 9, 13, and 16 across the 0%, 12.5%, 25%, and 50% cigarette tax rates, respectively.

Effects of e-Liquid Subsidy Rates

Figure 2A displays mean, obtained and Eq.-1-predicted cigarette demand across the four e-liquid subsidy rates, whereas Supplementary Table 2A contains the mean estimates of Q_0 and α, and median goodness-of-fit measures. Again, mean cigarette demand decreased as price increased. In contrast to cigarette taxation, visual inspection of Figure 2A indicates little variation in demand intensity (Q_0) and demand elasticity (α) as a function of increasing e-liquid subsidy rate. Indeed, the RMANOVAs applied to individual estimates

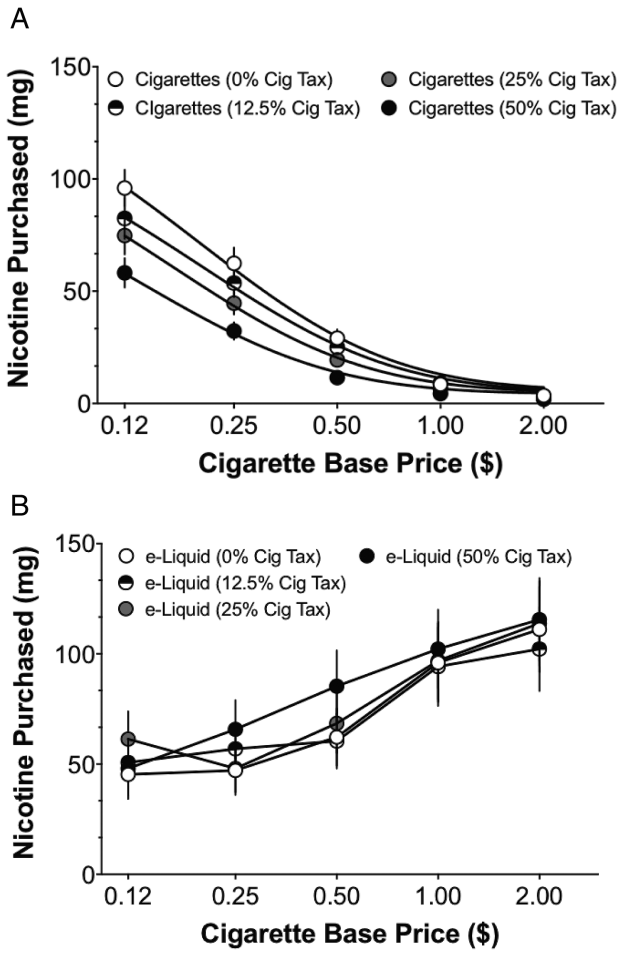

Figure 1. (A) Obtained (circles) and Eq. 1-predicted (lines) conventional cigarette demand as a function of base cigarette price ($\log_{10}$ *x*-axis) and cigarette taxation rate. Cigarette demand decreases as tax rate increases driven by decreases in initial demand. (B) 24 mg/mL e-liquid substitution functions as a function of base cigarette price ($\log_{10}$ *x*-axis) and cigarette taxation rate. Although a significant substitute across all tax rates, e-liquid initial intensity and substitutability levels were unchanged by cigarette tax rate. Error bars represent +/–1 SEM.

of Q_0 and α revealed no significant effect of e-liquid subsidy [F (3, 78) = 0.58, p = .55; F (3, 78) = 1.05, p = .33].

Figure 2B illustrates the mean e-liquid substitution functions across the four e-liquid subsidy rates and Supplementary Table 2B lists the results of the linear regressions applied to individual alternate product purchasing across subsidy rate. The 24 mg/mL e-liquid was again the only alternate product to function as a significant substitute for cigarettes and was a significant substitute across all subsidy conditions. Only three participants purchased any other alternate products (ie, snus, dip, nicotine gum) during subsidy conditions. Visual inspection of Figure 2B indicates that e-liquid subsidy rates had little effect on the substitutability (slope) of the e-liquid substitution functions. However, increasing e-liquid subsidy rate resulted in corresponding increases in the initial intensity (y-intercepts) of the e-liquid substitution functions. Consistent with visual inspection, the RMANOVA applied to individual e-liquid slope estimates revealed no significant effect of e-liquid subsidy rate on e-liquid substitutability [F (3, 78) = 1.20, p = .29]. In contrast, the RMANOVA applied to individual e-liquid y-intercept estimates revealed a

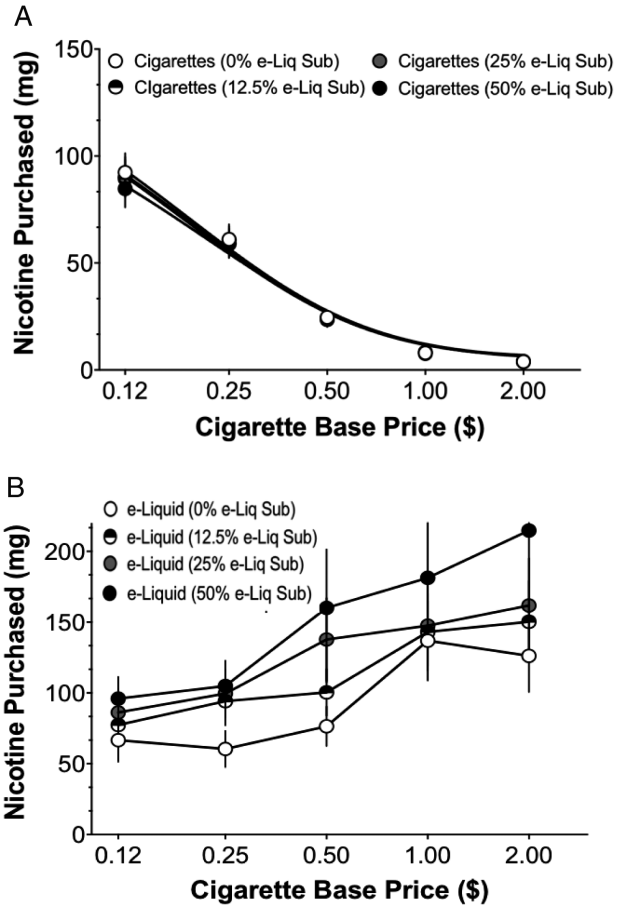

Figure 2. (A) Obtained (circles) and Eq. 1-predicted (lines) conventional cigarette demand as a function of base cigarette price (log_{10} *x*-axis) and e-liquid subsidization rate. Cigarette demand remained unchanged across changes in e-liquid subsidization. (B) 24 mg/mL e-liquid substitution functions as a function of base cigarette price (log_{10} *x*-axis) and e-liquid subsidization rate. 24 mg/mL e-liquid was a significant substitute across all subsidization rates and e-liquid initial intensity increased significantly as a function of increasing subsidization rate. Error bars represent +/–1 SEM.

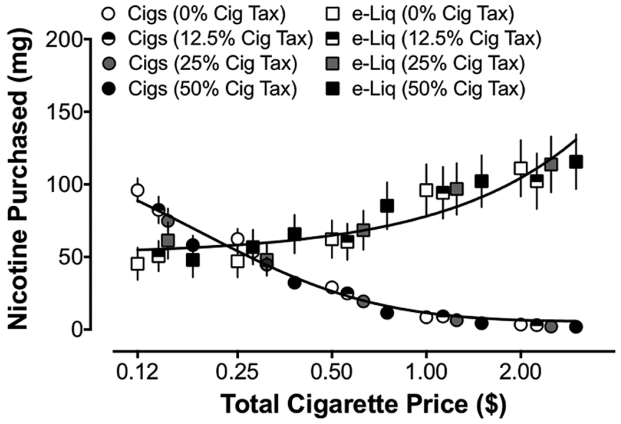

Figure 3. A reanalysis of Figure 1 and the effects of cigarette taxation. Obtained and Eq.1-predicted conventional cigarette demand (circle symbols; descending line) and obtained and linear regression-predicted e-liquid substitution (square symbols; ascending line) are both shown as a function of total cigarette price (base price + tax; log_{10} scale). Cigarette demand and e-liquid substitution at different taxation rates are delineated by the shade of the circle or square symbols. This figure demonstrates that a single function fits cigarette demand and a single function fits all e-liquid substations across all taxation conditions.

significant effect of e-liquid subsidy rate on e-liquid initial intensity [F (3, 78) = 4.92, p = .013]. Post hoc tests indicated the initial intensity of the e-liquid substitution functions in the 25% and 50% conditions were both greater than the initial intensity in the 0% subsidy condition (p = .048; p = .046); no differences in initial intensity were observed across the other condition pairs (all ps > .23). Similar to cigarette taxation, the number of individual participants with e-liquid slopes significantly greater than 0 increased from 12, 15, 18, and 21 across the 0%, 12.5%, 25%, and 50% e-liquid subsidy rates, respectively.

Discussion

This study replicated and extended recent work investigating real purchasing across several different nicotine/tobacco products, while concurrently examining the effects of potential product regulations and policies using the ETM.[9,22,23] Specifically, this study sought to determine whether and how conventional cigarette demand and alternate product substitutability were affected by taxing conventional cigarettes and subsidizing 24 mg/mL e-liquid from rates of 0% to 50%. Conventional cigarette purchasing decreased as cigarette taxation increased, driven by large, significant decreases in demand intensity (ie, estimate of cigarette purchasing when cigarettes were freely available). In contrast, conventional cigarette demand was unaffected by e-liquid subsidization, suggesting that conventional cigarette demand was only sensitive to total cigarette price, not to total price of the alternate product, e-liquid. The lack of a significant effect of e-liquid subsidization on conventional cigarette demand may also indicate that while the two e-liquid sampling periods exposed all participants to 24 mg/mL e-liquid, in essence equating e-liquid experience throughout the duration of the study, this sampling period was not sufficient for e-liquid subsidization to influence conventional cigarette demand. Indeed, similar studies have demonstrated the sensitivity of cigarette demand to the availability of e-cigarette products, but only in users with more e-cigarette experience than the participants in the present study (eg, dual users).[34,35] However, the observation that e-liquid subsidization had no effect on conventional cigarette demand may suggest that cigarette purchasing, although sensitive to own-price manipulation (ie, cigarette taxes), would be relatively insensitive to policy designed to influence the price of noncombustible products such as e-liquid. Similarly, e-liquid subsidization affected only the initial intensity of e-liquid purchasing (y-intercept, or estimate of e-liquid purchasing when cigarettes are freely available), possibly by increasing the overall value of e-liquid irrespective of changes in the value of conventional cigarettes.

Evaluation of the initial intensity and substitutability of the alternate products revealed that, of the four alternate products available in the ETM, only 24 mg/mL e-liquid functioned as a significant substitute for conventional cigarettes within any condition throughout the experiment. Moreover, 24 mg/mL e-liquid functioned as a substitute for conventional cigarettes across all four cigarette tax rates and all four e-liquid subsidy rates (ie, all experimental conditions). Although Pope et al.[21] observed relatively limited purchasing of the other alternate products available, this study observed even greater constriction of purchasing variety across all conditions, with only four participants purchasing other products besides conventional

cigarettes and e-liquid. This extremely restricted range of product purchasing may have resulted from the targeting of cigarette taxation and e-liquid subsidization, combined with sampling of e-cigarettes.

Perhaps the most important result of the study was that while the traditional measure of alternate product substitutability, the slope of the substitution function, was unaffected by both cigarette taxation and e-liquid subsidization, e-liquid initial intensity, represented by the y-intercepts of the substitution functions and providing an estimate of e-liquid purchasing when cigarettes are freely available, increased as a function of both cigarette tax and e-liquid subsidy rates. As might be predicted, increasing e-liquid subsidy rate resulted in larger and significant increases in the initial intensity of the substitution functions compared to the smaller, nominal increases in e-liquid initial intensity observed as a function of increasing cigarette taxation. These increases in the initial intensity represent a change in initial purchasing of e-liquid, which may indicate an increase in the overall value of e-cigarettes, independent of the price of conventional cigarettes and the value of conventional cigarettes. Interestingly, the initial intensity of e-liquid substitution seems to be especially sensitive to many different types of manipulations in the ETM. For example, Pope et al.[21] demonstrated that e-liquid initial intensity increased as a function of increasing e-liquid nicotine strength, although increases in slope (substitutability) were also observed. Similarly, in a hypothetical ETM study,[36] the initial intensity of e-liquid substitution was increased by exposing participants to a particular narrative about the dangers of conventional cigarette smoking and the possible benefits of substituting e-cigarettes. To the extent that the initial purchasing of potentially less harmful products is sensitive to these various policy-type manipulations and is robust, the concept of substitutability should be further developed and explored to incorporate these findings.[34,37] However, we caution that this selective effect of e-liquid subsidies on initial intensity, but not slope, may suggest that e-liquid subsidies would do little to increase the degree of *switching* from combustible products to e-cigarettes, but may instead simply increase rates of dual product use. However, this study was conducted over a relatively short period; additional work is needed to examine the possible long-term effects of taxes and subsidies.

Finally, the taxation condition examined a broader range of prices than the nominal prices used. To the extent that unit price (ie, price per milligram nicotine[38,39]) is operative, we would expect the resulting exploration of all individual prices to converge along a single function. To the extent unit price was determinative of substitution, so should all individual price converge along a single substitution curve. To test if unit price was the operative mechanism, Figure 3 contains a reanalysis of the cigarette taxation data as a function of total cigarette price (base price + taxation). Indeed, the single model fits of Eq. 1 to the cigarette taxation demand data and single linear regression to the e-liquid substitution data provided better fits according to Akaike information criterion than when fitting Eq. 1 and linear regressions separately for each of the four taxation rates (ie, Figure 1). This suggests that the influence of taxes is consistent with relatively straightforward mental calculation, with no effect independent of price. Therefore, the effect of any policy that affects product price, whether tax- or subsidy-based, may be designed with this in mind; that is, the present results suggest that price framing has no incremental influence on cigarette demand or e-liquid purchasing, which may increase the robustness of various policies for impacting purchasing. Ongoing investigations are examining in more detail the implications of the unit price model on cigarette and e-liquid purchasing; thus, stronger conclusions about how unit price determines substitution await further investigation.

Some limitations of this study must be acknowledged. First, a moderating effect of prior e-cigarette use was unable to be explored or detected because of the relatively small, unequal samples sizes of completely naive e-cigarette users and those with some prior experience with e-cigarettes. Second, within the participant sample there was limited heterogeneity, with participants being relatively heavy smokers (~17 cigarettes/day) and the majority being middle-aged (M = 43.76 years) and Caucasian (76%). Third, although e-liquid clearly functioned as a significant substitute for conventional cigarettes across all conditions of the experiment, including an additional cigarette price condition that was sufficiently high to completely suppress cigarette purchasing may have resulted in more robust e-liquid substitution, resulted in elevated substitutability for other alternate products, or greater effects of the taxation and subsidization manipulations. Finally, because a major goal of tobacco control and harm reduction is to maintain potentially less harmful product substitutability over extended periods, future ETM studies may benefit from determining alternate product substitutability and the effects of certain product or policy manipulations over several months or longer, as this study only spanned approximately 2 weeks.

Conclusion

The results of this study suggest that conventional cigarette demand and e-liquid substitutability are differentially affected by specific policies. Conventional cigarette demand was decreased by applying tax rates to cigarettes, with higher tax rates decreasing cigarette demand the greatest, yet cigarette demand was not appreciably affected by subsidizing e-liquid alone. In contrast, the initial intensity of e-liquid purchasing, providing an estimate of e-liquid purchasing when cigarettes are freely available, increased as a function of increasing e-liquid subsidy rates, but taxing cigarettes alone did not alter e-liquid substitutability. Our previous study indicated that both the initial intensity and substitutability (ie, slope) of e-liquid increased as a function of e-liquid nicotine strength.[21] The present results from the ETM have important implication for potential tobacco policy. Specifically, these results suggest that in order to decrease cigarette use and help smokers transition to relatively safer alternatives, both increasing cigarette taxes and potentially less harmful product subsidization, perhaps in combination with higher nicotine strength e-liquids, may be required in order to maximize the harm reduction associated with switching from cigarettes to potentially less harmful products.[40] However, taxing e-liquid while at the same time applying large increases to cigarette taxation to increase the differential between the two may discourage use of any nicotine product while resulting in larger reductions in smoking and increasing incentives to substitute.[13] Future research should examine the benefits and limitations of concurrent taxation and subsidization compared to relative taxation and subsidization in the ETM, as well as the generality of the present results across national and international contexts with varying tobacco prices.[13,14,41] Taken together, the ETM appears to serve as an ideal framework for examining the numerous variables and policies that may influence cigarette demand and potentially less harmful product substitutability.

Supplementary Material

Supplementary data are available at *Nicotine and Tobacco Research* online.

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Declaration of Interests

WKB is a principal in Healthsim, LLC, and NotifiUs, LLC. The other authors report no conflict of interest.

Appendix

Methods

Procedures

Immediately following consent, participants were provided an eGo ONE CT e-cigarette (1100-mAh battery, with 1.0-ohm atomizer head, providing 15-W power), purchased from www.joyetech.com ($54.90 each; Shenzhen Joyetech Co, Ltd, Shenzhen, China). Participants were provided with instructions and learned how to properly use (eg, handling, charging, vaping) and refill the e-cigarette with e-liquid. After, e-liquid flavor preference was assessed, during which participants used the e-cigarette to sample each of three different e-liquid flavors at 0 mg/mL nicotine strength (VaporHQ; Vapor Headquarters, Springfield, OR; "Blueberry Harvest", "American Red" tobacco, "32 Degrees" menthol). All study e-liquid had a ratio of propylene glycol to vegetable glycerin of 50/50. After this process, participants selected their preferred e-liquid flavor to be used for the remainder of study. Thirteen of 29 participants chose blueberry as their preferred flavor, 10 of 29 chose tobacco as their preferred flavor, and six of nine chose menthol.

The sampling sessions were typically held at the beginning of the week, always 2 days prior to the ETM purchase sessions (see Appendix Figure 1). During the two sampling sessions, participants were given 2 mL of their preferred flavor of e-liquid to take home and sample over the next 2 days, with the nicotine strength for all participants being 24 mg/mL. This strength was used because prior research indicated greatest substitutability at 24 mg/mL.[29] Participants were also instructed to return any unused e-liquid from the 2-day sampling period. The average amount of e-liquid returned across the two sampling periods was 0.20 mL (SD = 0.55; range = 0–1.40 mL). Purchase sessions generally occurred later in the week and the follow-up session occurred approximately 1 week after the second and final purchase session. During all sessions, breath carbon monoxide (collected with a hand-held monitor; Bedfont Scientific Ltd, Kent, England) was measured, TLFB data were collected, and a series of questionnaires on the survey platform Qualtrics (Provo, UT) were administered.

After reporting average, weekly nicotine product use over the past 30 days using a modified TLFB, an individualized account balance was determined by multiplying the local market price of each particular nicotine product by the average, reported use of each product. The local market price of each product were as follows: $0.25 per cigarette, $0.50 per mL of e-liquid, $0.20 per dip and snus pouches, $0.80 per piece of nicotine gum, and $0.60 per nicotine lozenge. Calculating the account balance using this method has been shown to result in purchasing that is representative of participants' nicotine and tobacco purchasing prior to the experiment.[42] Participants were alerted of their account balance prior to each ETM session, and reminded any unspent portion of the balance would be disbursed to them.

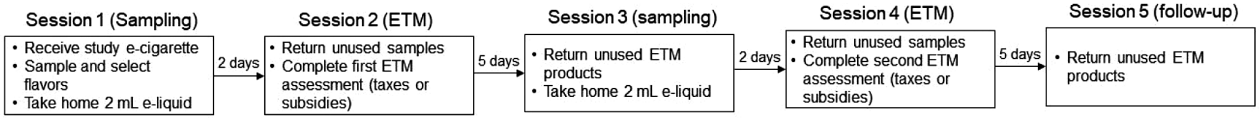
Account Balance

Similar to previous studies using the ETM, participants were given an account balance during ETM purchasing sessions to more appropriately approximate real-world conditions related to income constraints. After reporting nicotine product use over the past 30 days using TLFB, an individualized account balance was calculated by multiplying the local market price of each individual nicotine product by the average, reported use of each product (via TLFB). The local market prices of each product were as follows: $0.25 per cigarette, $0.50 per mL of e-liquid, $0.20 per dip and snus pouches, $0.80 per piece of nicotine gum, and $0.60 per nicotine lozenge. Calculating the account balance using this method produces ETM purchasing that is representative of participants' tobacco purchases prior to the experiment.

Experimental Tobacco Marketplace Sessions

During both ETM sessions, the following six products were available for purchase: their preferred brand of conventional cigarette (individual cigarettes, average nicotine yield varied across brand; average = 1.06 mg/cigarette), their preferred flavor of VaporHQ 24 mg/mL e-liquid (Vapor Headquarters), winterchill flavor Camel Snus (15-pouch tins; R.J. Reynolds, Winston-Salem, NC; 1.85-mg nicotine per pouch), wintergreen flavor Grizzly dip (18-pouch tins; American Snuff Co, LLC, Memphis, TN; 1.97-mg nicotine per pouch), white ice mint flavor Nicorette 4-mg nicotine gum (100-count packages; GlaxoSmithKline Consumer Healthcare, L.P., Moon Township, PA; 4-mg nicotine per piece), and mint flavor Nicorette 4-mg nicotine lozenges (24-count packages, GlaxoSmithKline Consumer Healthcare; 4-mg nicotine per piece). Each product included a product image as well as a detailed description of traditional branding and labeling information, including nicotine content. For the products that had a fixed flavor, either mint or mint-like flavors were chosen due to the general preference of mint products expressed by the majority of tobacco users. Purchases during the ETM session could not go over the allotted account balance. Participants were reminded that any unspent portion of the account balance would be distributed to them. Participants were instructed to purchase enough products to use over the next 5 days, as if they could not purchase any products outside of the study. They were also instructed to return any unused products for reimbursement, and they were reminded that their account balance started over prior to each combination of cigarette price and tax or subsidy condition.

During the cigarette tax ETM session, participants made purchases across the five ascending base cigarette prices and the



Appendix Figure 1. Schematic depicting order and content of experimental sessions. ETM = experimental tobacco marketplace.

application of four conventional cigarette tax rates (≥0%, ≥12.5%, ≥25%, ≥50%; randomized, counterbalanced order) to each of those base prices. Thus, during the tax ETM, participants made purchases among all six products when each of the five base cigarette prices were taxed at each of the four different rates, and the price of all other products was fixed, for a total of 20 purchase trials. During the subsidy ETM session, participants also made purchases across the five ascending base cigarette prices and the application of four e-liquid subsidy rates (–0%, –12.5%, –25%, –50%; randomized, counterbalanced order) to the constant, e-liquid base price ($0.50). That is, during the subsidy session, participants made purchases among all six products when each of the five base cigarette prices were presented and the concurrently available e-liquid was subsidized across the four rates, whereas the price of all other products remained constant, again totaling 20 purchase trials. When participants browsed products in the ETM, the base price (eg, $0.50 per cigarette) was displayed alongside the percentage-based tax or subsidy rate (eg, 12.5%). During the checkout process, participants saw the total price incurred (base price + tax/subsidy). At this stage, participants could either continue to check out of the ETM or return to browse and modify their purchases.

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