
Original Investigation

The Illegal Experimental Tobacco Marketplace I: Effects of Vaping Product Bans

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Abstract

Objectives: Banning vaping products may have unintended outcomes, such as increased demand for illegal products. This study experimentally examined the effects of a vaping ban and a flavored vaping ban on the probability of purchasing illicit vaping products, and factors affecting purchasing from a hypothetical illegal marketplace.

Methods: A crowdsourced sample of *exclusive* cigarette smokers, *exclusive* e-cigarette users, and *frequent* dual users ($n = 150$) completed hypothetical purchasing trials in an Experimental Tobacco Marketplace under three conditions (no ban, vaping ban, and flavored vaping ban). Participants chose to purchase in a hypothetical legal experimental tobacco marketplace (LETM) or illegal experimental tobacco marketplace (IETM). Vaping products were available in each marketplace depending on the condition. Other tobacco products were always available in the LETM. A hypothetical illicit purchase task with five fine amounts assessed the effect of monetary penalties.

Results: Participants from all groups were more likely to purchase from the IETM when product availability in the LETM was more restricted, with e-cigarette users being most affected. The likelihood of purchasing illegal products was systematically decreased as monetary penalties associated with the IETM increased, with e-cigarette users showing greater persistence in defending their illicit purchases.

Conclusions: Restricting vaping products from the marketplace may shift preference towards purchasing vaping products in the illegal marketplace. Nevertheless, penalties imposed on consumer's behavior might be effective in preventing illicit trade. The IETM is a methodological extension that supports the utility and flexibility of the ETM as a framework for understanding the impact of different tobacco regulatory policies.

Implications: This study suggests that limiting or banning vaping products as a possible strategy to reduce the adverse effects of vaping products could result in some tobacco-users seeking banned products from illegal sources. Monetary fines were shown to reduce illegal purchases. Therefore, policymakers should consider implementing strategies that may mitigate illegal purchases.

Introduction

In 2018, the Food and Drug Administration (FDA) acknowledged the illegal trade in tobacco products as a possible effect of a product standard:

... it is expected that there will still be a subset of consumers uninterested in switching products or in quitting tobacco products altogether, as well as those who believe they are unable to switch or quit. Discerning the reason for their product or brand loyalty is unnecessary for the purposes of this discussion; the result is that these individuals may seek tobacco products from an illicit market after a standard is in place. There is no way to determine with certainty the prevalence and extent to which an illicit market will occur after any particular tobacco product standard is in place, nor how long such a market might be sustainable.^{1,p.13}

Such consumer actions could result in some tobacco-users seeking banned products from illegal sources that, in turn, may undermine the public health benefits of tobacco control. Indeed, considerable evidence shows that illicit trade in tobacco products is ongoing.²⁻⁵ Such products are increasingly available via internet purchase.⁶ Moreover, some of these products contain adulterants not found in commercial products, which may exacerbate health risks.⁷ The tobacco science field has suggested several mitigation strategies,^{8,9} but testing the efficacy of these strategies before policy implementation has not been conducted, in part, because of the absence of appropriate empirical models.

A novel modification and extension of the Experimental Tobacco Marketplace (ETM), The Illegal Tobacco Marketplace (IETM), may fill this scientific gap. The ETM mimics the real-world tobacco marketplace¹⁰ where purchases can be made among various tobacco products differing in prices,^{11,12} flavors, nicotine concentration,¹³⁻¹⁵ and taxes and subsidies.¹⁶ Previous research has shown that purchases are sensitive to contextual situations, such as health or financial narratives.^{17,18} The ETM is a methodology developed to better understand the consequences of regulatory policies on consumer behaviors before policy implementation. The IETM, as employed here, is an alternative concurrent marketplace to the ETM. In the IETM, products not available in the ETM can be purchased. This methodological development expands the ETM by examining the conditions under which illicit purchases are more likely. Modeling and testing illegal marketplace features, even within a hypothetical context, may shed insight on unintended policy effects and offer the opportunity to evaluate ways to mitigate them.

One tobacco policy that has received considerable attention is limiting access to vaping products. Many countries around the world and an increasing number of states and localities in the United States have banned certain types of vaping products as a way to deter their use, especially by youth, where vaping rates have soared in recent years.¹⁹ An outbreak of vaping-associated lung disease in the fall of 2019²⁰ was traced to the use of illicit vaping products with tetrahydrocannabinol (THC) and vitamin E acetate. This motivated some cities (eg, New York, San Francisco) and states (eg, Massachusetts, Michigan, New York, and Rhode Island) to ban access to vaping products.^{21,22} Certain categories of vaping products have also been restricted under federal tobacco control policy.²³ In January 2020, the FDA banned the sales of flavors, with the exception of menthol, in pod-based e-cigarettes such as JUUL products.²⁴ This was in part due to the surge in youth using these products.²⁵ However, at the federal level, flavors are still available in disposables and tank-based systems.

According to a recent study that examined the prevalence of e-cigarette use among different ages from a nationally

representative sample, e-cigarette use increased in most young adult subgroups, including never smokers from 2014 to 2018.²⁶ Another study found that flavor (menthol, mint, clove, spice, candy, fruit, chocolate, alcohol, or other sweets) was a primary reason for using tobacco products among 80% of youth, 73% of young adults, and 29% of older adults.²⁷ When asked if they would continue using their preferred tobacco product if the flavor (menthol/mint, candy, fruit, coffee, alcohol, spice, or other) was removed, 75% of youth and young adults said they would no longer use the product.²⁸ These findings suggest that the prevalence of tobacco use, including e-cigarettes, would be reduced if flavors additives were prohibited. However, what addicted cigarette smokers/e-cigarette users might actually do when faced with a flavors prohibition remains unclear, because preferred tobacco products may be accessed through illicit channels.²⁹

Banning vaping or flavored vaping products may have unintended outcomes, such as e-cigarette users seeking alternative means of obtaining their preferred products.³⁰ For example, a recent study reported that smokers who learned about a potential issuance of a low nicotine content product standard were more likely to be interested in illicit cigarette purchases.³¹ Increasing demand for contraband or nonconforming vaping products as a result of a ban might increase the prevalence of harmful health effects. Illicitly produced tobacco products are not subject to accepted commercial manufacturing practices that can ensure some level of quality control, and thus may expose consumers to unknown health risks.^{1,7} Therefore, understanding consumer's behavior in situations where vaping product availability is restricted is an important policy and public health consideration.

The present experiment used a between-within repeated measures (mixed experimental) design to examine:

- the effects of implementing a vaping ban and a flavored vaping ban on the probability of purchasing vaping products in a hypothetical IETM;
- the effects of increasing prices for conventional cigarettes in a Legal ETM (LETM) on purchasing from the hypothetical IETM;
- how the chance of a monetary penalty affects the likelihood of purchasing from an illegal market;
- the rationale of participants for purchasing from the hypothetical LETM or IETM; and,
- how different tobacco-user types (exclusive cigarette smokers, exclusive e-cigarettes users, and *frequent* dual users) respond to the above aims.

We hypothesize that (1) product availability and cigarette price in the LETM would affect participants' likelihood to purchase in the IETM, with e-cigarette users being most affected by product availability, *given that the bans restricted their preferred product availability*; and cigarette users and dual users showing greater sensitivity to cigarette price compared to e-cigarette users, given that cigarettes are their preferred or one of their preferred products; and (2) the increasing magnitude of monetary penalties for purchasing their preferred product in the illegal market would suppress illegal purchases *because these penalties would functionally increase the costs associated with illegal purchases*.

Methods

Participants

Participants were recruited into the study between October and November 2019 from Amazon Mechanical Turk (Mturk), a crowdsourcing platform in which employers post tasks to be

completed in exchange for monetary compensation.³² Before enrollment, participants completed a screening questionnaire to determine eligibility. More information about the use of Mturk, compensation, and the screening procedure can be found in the supplementary material. Participants were considered: (a) exclusive cigarette smokers ($n = 50$) if they reported smoking five or more cigarettes per day and not using e-cigarettes in the past month, (b) *frequent* dual users ($n = 50$), if they reported smoking five or more cigarettes per day and using e-cigarettes every day or almost every day in the past month, and (c) exclusive e-cigarette users ($n = 50$) if they reported using e-cigarettes every day or almost every day and not smoking cigarettes in the past month. Individuals who did not report smoking cigarettes or using e-cigarettes did not qualify.

Participants provided electronic informed consent before beginning the study, which was approved by an Institutional Review Board at Virginia Polytechnic Institute and State University.

Procedure

Participants completed an online survey administered through Qualtrics survey software.³³ The median completion time of the survey was 29 minutes. The survey contained demographic questions, the Fagerstrom Test for Cigarette Dependence (FTCD³⁴;) and/or the Fagerstrom Test for E-cigarette Dependence (FTED; adapted), when appropriate, a Timeline Followback to report nicotine product use in the previous week (TLFB³⁵); and questions related to other substance use and illicit purchase history. The survey also included hypothetical tobacco purchases in the LETM or the IETM, an illicit purchase task with different magnitudes of monetary penalty, questions about their preferred product value, and open-ended questions about the reasons for LETM or the IETM purchases, detailed below.

Experimental Tobacco Marketplace

Participants were provided a hypothetical account balance to purchase tobacco products for seven days. To simulate the individual budget spent per week with tobacco products, the account balance was calculated by multiplying: the self-reported average number of cigarettes smoked per day during the past month by the average unit price for exclusive cigarette smokers; the reported frequency of e-cigarette use on a typical day by the average number of puffs per use by the average e-cigarette price per puff for exclusive e-cigarette users, and the sum of both for *frequent* dual users. The prices of the tobacco products to calculate the budget were based on prior studies.^{15,17,18} This calculation mimics the income constraints faced by participants in real-world conditions.^{10,36}

The ETM included three scenarios, each consisting of six price trials. At the beginning of every scenario, participants were presented with an imagined regulation (ie, no ban, vaping ban, and flavored vaping ban) after which they engaged in six price trials related to that scenario. In every price trial, participants first chose in which marketplace they would like to purchase tobacco products: the LETM or the IETM. Then, they were directed to the chosen marketplace to complete a hypothetical purchase.

Scenario

Participants were exposed to three conditions in a randomized order: no ban, vaping ban, and flavored vaping ban. For every condition, participants were asked to imagine that they were in a specific situation, told they would be presented with several opportunities to choose from which marketplace they would like to

purchase, and shown a list of available products in each marketplace. The specific language regarding each situation is available in [Table S1](#).

Marketplace Choice

Before every trial, participants were provided with a list of available products and their respective prices in each marketplace and presented with the option to purchase tobacco products from the LETM or the IETM.

Hypothetical Purchases

After choosing the marketplace, participants completed a hypothetical purchase in that marketplace. Each marketplace displayed pictures, information (eg, nicotine dose and flavor), and prices for several tobacco products. A range of tobacco products (conventional cigarettes, chewing tobacco (dip), snus, nicotine gum, and nicotine lozenges) was always available in the LETM. Disposable e-cigarettes, e-liquids, pods, and cartridges were available in each marketplace according to specific restrictions:

- (1) No ban: vaping products, in any flavor, were available in both LETM and IETM.
- (2) Vaping ban: vaping products were only available in the IETM.
- (3) Flavored vaping ban: tobacco flavored vaping products were only available in the LETM, and any other flavor of vaping products were available in the IETM.

The price of conventional cigarettes available in the LETM increased across six trials in a logarithmic scale (\$0.13, \$0.25, \$0.50, \$1.00, \$2.00, and \$4.00). All the other product prices in the LETM and in the IETM remained constant across all six price trials. The prices for each product were as follows: \$0.20 per pinch of dip and snus pouches, \$0.80 per piece of nicotine gum and nicotine lozenge, \$9.99 per disposable e-cigarette, \$0.89 per mL of e-liquid, and \$3.50 per unit of e-cigarette pods and cartridges.

Reasons to Choose the LETM or the IETM

Two open-ended questions were presented after ETM completion: When you were deciding from which marketplace to purchase, what are the things that made you choose the LETM/IETM?

Illegal Market Risk-Taking

Hypothetical Illicit Purchase Task

Based on previous behavioral economic work utilizing purchase tasks,^{37,38} we created a novel illicit purchase task to model the likelihood of purchasing as a function of different monetary penalties. Participants were asked to imagine they could no longer buy their product legally and rate how likely they would purchase from an illegal market on a range from 0 (“not all likely”) to 100 (“extremely likely”). Five monetary penalty amounts, with a 10% chance of receiving the penalty, were presented in a randomized order: \$10, \$30, \$100, \$300, and \$1000.

Preferred Product Value: Miles, Dollars, Hours

Participants answered questions about the maximum travel distance, the maximum fine, and the maximum hours of community service they were willing to spend to purchase illegal products. Additional analysis on preferred product value is available in the supplementary material.

Statistical Analysis

Participant Characteristics

Demographic characteristics (eg, age, race, and income) were compared among the three groups (exclusive cigarette smokers, *frequent* dual users, and exclusive e-cigarette users) using analysis of variance (ANOVA), Chi-square tests, and Fisher's exact test, where appropriate. Cigarettes per day and FTCD were compared between cigarette smokers and dual users, and e-cigarettes per day and FTED were compared between e-cigarette users and dual users using a *t*-test. Alternative substance use and prior illegal purchasing were compared among the three groups using Chi-square tests or Fisher's exact tests, where appropriate. See [Table S1](#) for all measures.

Marketplace Choice

This study used a between-within repeated measures (mixed experimental) design to test the effect of three product bans (within-subject) across three smoking preference groups (between-subject). Marketplace preference was estimated using a mixed-effects logistic regression to assess differences between choosing the IETM or the LETM across different ban scenarios and cigarette prices (ie, a group-condition interaction). Specifically, marketplace preference was modeled by cigarette price, group, condition, the interaction between cigarette price and group, and the interaction between condition and group. Random effects corresponded to participants, thereby accounting for the dependence among responses in the repeated measure design.

Reasons to Choose the LETM or the IETM

Answers to the two open-ended questions were reviewed and coded by two independent observers according to categories created to group similar reasons to choose a marketplace. The data sheets were compared to determine the agreement percentage (agreements/agreements+disagreements \times 100). The inter-rater agreement was 97.33%.

Illegal Market Risk-Taking

A total of 149 (one missing due to a software coding error) illegal market risk-taking demand tasks were evaluated for systematic response per three criteria: trend (ie, increasing likelihood of purchasing in the illegal market over increasing monetary penalties), bounce (ie, greater than 25% increase in the likelihood of purchasing in the illegal market compared to the likelihood at the lowest monetary penalty), and reversal from zero (ie, zero likelihood of purchasing in the illegal market at any monetary penalty amount and subsequent higher likelihood at a greater amount)³⁹ that could indicate a misunderstanding of the task. In total, 29 individuals failed at least one check and the demand parameters could not be estimated for 14 individuals due to always indicating a 0% likelihood of purchasing from the illegal marketplace. Data from these participants were removed from the analysis. The final dataset consisted of demand tasks from 34 exclusive cigarette users, 38 *frequent* dual users, and 35 exclusive e-cigarette users. These data were subsequently analyzed by fitting an exponentiated function⁴⁰ based on the exponential demand equation⁴¹ using the *bezdemand* package in R.⁴²

$$\text{Equation : } Q = Q_0 * 10^{k(e^{-\alpha Q_0 C} - 1)}$$

where Q represents the likelihood of purchasing in the illegal market, Q_0 is the estimated likelihood of purchasing in the illegal market when there are no monetary penalties (ie, intensity; a measure of amplitude), k is a weighting parameter signifying the

range of likelihood in logarithmic units, α is the rate of change in elasticity across the entire curve (a measure of persistence), and C is the monetary penalty amount. For all participants, we used a value of 0.97 for k (calculated as a shared parameter across all groups).⁴³ Individual demand-derived parameters (Q_0 and α) were natural log-transformed to more closely approximate a normal distribution amenable to parametric analyses. An ANOVA followed by Tukey's *post hoc* test for multiple comparisons was used for group comparisons of $\log(Q_0)$ and $\log(\alpha)$.

R software Version 3.5.1 was used for all data analyses.⁴⁴ All statistical tests were considered significant at an alpha of 0.05 level.

Results

Participant Characteristics

Characteristics of the recruited sample are displayed in [Table 1](#). Differences in the characteristics of each tobacco-user type were generally consistent with what is reported in other studies.²⁶ Exclusive e-cigarette users were slightly younger ($p = .003$) and better educated ($p = .026$) compared to exclusive cigarette smokers and *frequent* dual users. Smoking-related measures between dual users and e-cigarette users were significantly different with e-cigarette users reporting greater use of e-cigarettes per day ($p=0.001$) and showing higher FTED scores ($p < .001$), a measure of e-cigarette dependence. No statistically significant differences in the number of cigarettes per day ($p = .740$) and FTCD ($p = .865$) were observed between dual users and cigarette smokers.

Marketplace Preference

Marketplace preference, ie, the choice to purchase from the LETM or the IETM, was modeled using a mixed-effects logistic regression ([Figure 1](#)). A significant effect of condition was observed ($X^2(2) = 43.09$; $p < .001$). Participants from all three groups were more likely to purchase from the IETM if product availability in the LETM was restricted, ie, under product bans. Specifically, participants were more likely to choose the IETM under a complete ban on vaping products (OR = 6.93; $p < .001$; [Figure 2](#)) and a partial ban restricting flavored vaping products (OR = 2.83; $p < .001$) compared to the no ban condition. A significant effect of trial was observed ($X^2(1) = 24.42$; $p < .001$). That is, as the price of cigarettes increased, participants were more likely to purchase from the IETM. No significant main effect of condition was identified ($X^2(2) = 5.56$; $p = .062$).

A significant interaction between condition and group was identified ($X^2(4) = 88.34$; $p < .001$). In particular, exclusive e-cigarette users showed the greatest likelihood to purchase from the IETM in response to policies restricting access to all vaping products (OR = 256.20; $p < .001$) and flavored vaping products (OR = 33.52; $p < .001$) when compared to exclusive smokers. No significant increases in the likelihood for *frequent* dual users to purchase from the IETM in response to the ban on all vaping products or flavored vaping products compared to cigarette users were observed.

A significant interaction between group and trial was identified ($X^2(2) = 10.84$; $p = .004$). E-cigarette users were less price-sensitive compared to exclusive cigarette smokers (OR = 0.60; $p = .003$). That is, cigarette smokers were more likely to buy vaping products in the IETM as the price of cigarettes in the LETM increased. This finding suggests that increasing cigarette prices would result in cigarette smokers switching from their usual product to vaping products and *frequent* dual users increasing consumption of vaping products,

Table 1. Demographic Characteristics, Smoking-Related Measures, and Illegal Activity by Group

		Exclusive cigarette smokers (<i>n</i> = 50)	Dual users (<i>n</i> = 50)	Exclusive E-cigarette users (<i>n</i> = 50)	<i>p</i> -value
Demographics	Age (mean [SD])	39.90 (11.10)	33.52 (7.13)	35.38 (9.63)	0.003 ^a **
	Yearly income (mean [SD])	49,285.24 (33,145.74)	52,417.38 (31,380.16)	48,533.28 (28,589.38)	0.803 ^a
	Gender = male (%)	23 (46.0)	29 (58.0)	30 (60.0)	0.315 ^b
	Race = White/Caucasian (%)	43 (86.0)	44 (88.0)	42 (84.0)	0.051 ^c
	Hispanic = Not Hispanic or Latino (%)	48 (96.0)	47 (94.0)	45 (90.0)	0.606 ^c
	Education (%)				0.026 ^a *
	Less than high school	3 (6.0)	0 (0.0)	0 (0.0)	
	High school/GED	8 (16.0)	2 (4.0)	11 (22.0)	
	Some college	12(24.0)	14(28.0)	12 (24.0)	
	Professional degree (MD, JD, DDS, DVM, PsyD)	0 (0.0)	0 (0.0)	3 (6.0)	
	2-year college degree (associates)	6 (12.0)	8 (16.0)	6 (12.0)	
	4-year college degree (BA, BS)	18 (36.0)	21 (42.0)	18 (36.0)	
	Master's degree	3(6.0)	5 (10.0)	0 (0.0)	
	Employment = employed (%)	40(80.0)	46(92.0)	41(82.0)	0.063 ^c
Smoking-related measures	Cigs per day (mean [SD])	14.74 (8.93)	13.96 (13.93)	NA	0.740 ^d
	ECig per day (mean [SD])	NA	13.90 (12.33)	37.72 (49.43)	0.002 ^d **
	FTCD (mean [SD])	4.14 (2.44)	4.06 (2.24)	NA	0.865 ^d
	FTED (mean [SD])	NA	2.62 (1.96)	4.02 (1.65)	<0.001 ^d ***
Alternative substance use (previous week)	Cigars or little cigarillos (%)	2 (4.0)	10 (20.0)	4 (8.0)	0.058 ^c
	Snus (%)	0 (0.0)	3 (6.0)	0 (0.0)	0.109 ^c
	Dip (eg, chewing tobacco (%)	1 (2.0)	4 (8.0)	0 (0.0)	0.125 ^c
	Nicotine replacement therapy (eg, nicotine lozenge, nicotine gum, nicotine patch) (%)	2 (4.0)	4 (8.0)	2 (4.0)	0.749 ^c
	Marijuana (%) (more than once per month)	21 (42.0)	31 (62.0)	17 (34.0)	0.104 ^b
Illegal activity	Previous illicit purchase (%)				0.301 ^c
	0 times	13(26.0)	10(20.0)	19(38.8)	
	1–2 times	13(26.0)	11(22.0)	6(12.2)	
	3–5 times	6 (12.0)	5(10.0)	5(10.2)	
	6–10 times	4 (8.0)	2(4.0)	5(10.2)	
	More than 10 times	14 (28.0)	22(44.0)	14(28.6)	
	Previous illicit tobacco/nicotine product purchase (%) ^e				0.021 ^c *
	0 times	26(70.3)	14(35.0)	19(63.3)	
	1–2 times	5(13.5)	12(30.0)	3(10.0)	
	3–5 times	2(5.4)	3(7.5)	5(16.7)	
6–10 times	1(2.7)	1(2.5)	0(0.0)		
More than 10 times	3(8.1)	10(25.0)	3(10.0)		

^aIndicates an ANOVA.

^bIndicates chi-square test.

^cIndicates fisher's exact test.

^dIndicates *t*-test.

^eOnly 37 cigarette users, 40 dual users, and 31 e-cigarette users reported previously purchasing tobacco products from an illicit source and were included in the analysis of this question.

**p* < .05.

***p* < .01.

****p* < .001.

even if vaping products were only available illegally. Additionally, all groups purchased higher quantities of tobacco products in the IETM under the two ban conditions compared to the no ban condition (Tables S2A–S4C).

Reasons to Choose the IETM

Reasons for choosing the IETM (Table 2) were more frequently related to product price in the legal marketplace for exclusive cigarette smokers (48%) and frequent dual users (48%), suggesting that switching was

price sensitive. Exclusive e-cigarette users reported reasons related to product and flavor availability (34% and 30%, respectively), suggesting they were more focused on product. Interestingly, exclusive e-cigarette users and frequent dual users identified the lack of substitutes in the LETM (56% and 36%, respectively), as the reason for purchasing in the IETM, either indicating they would not pay a high price for a cigarette or that they would not switch from vaping products to any of the alternative products available in the LETM. Reported reasons for choosing the LETM are shown in Table S5.

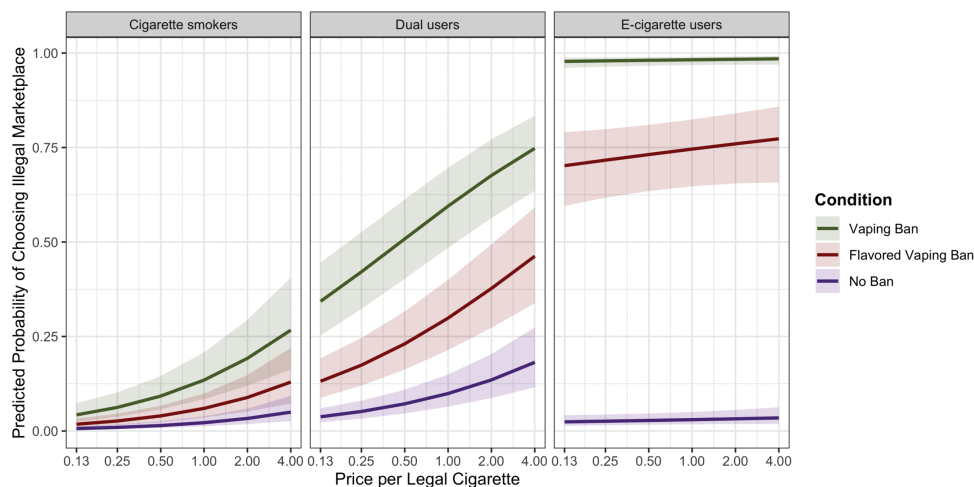


Figure 1. Model estimated probability of choosing the illegal marketplace with 95% confidence intervals in three different scenarios: Vaping Ban, Flavored Vaping Ban, and No Ban, as the price of conventional cigarettes increased in the legal marketplace, for exclusive cigarette smokers, frequent dual users, and exclusive e-cigarette users.

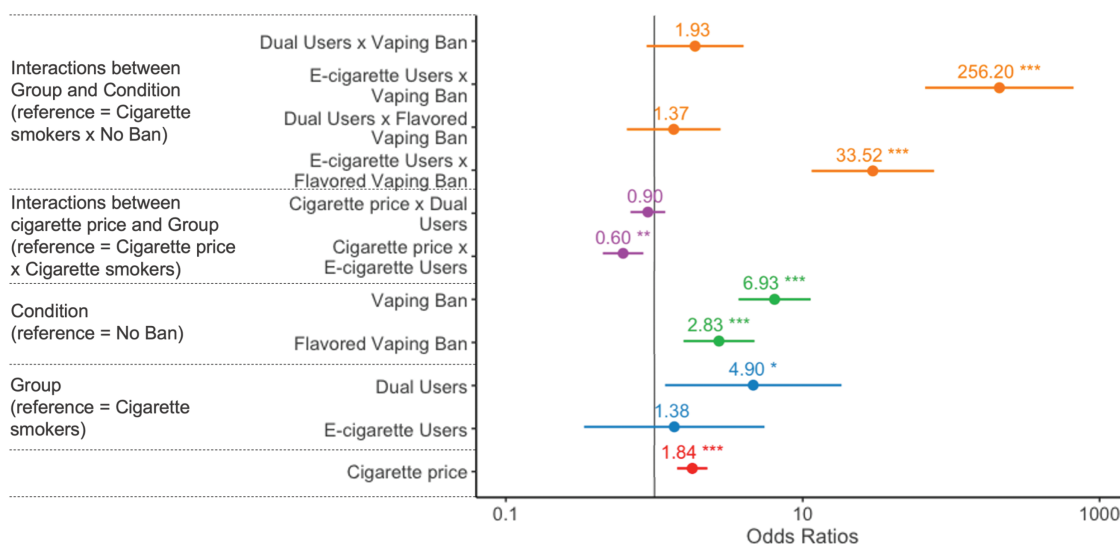


Figure 2. Conditional Odds Ratios (ORs) of purchasing in the illegal tobacco marketplace using estimates from the full model (each variable is compared to its reference).

Illegal Market Risk-Taking

Hypothetical Illicit Purchase Task

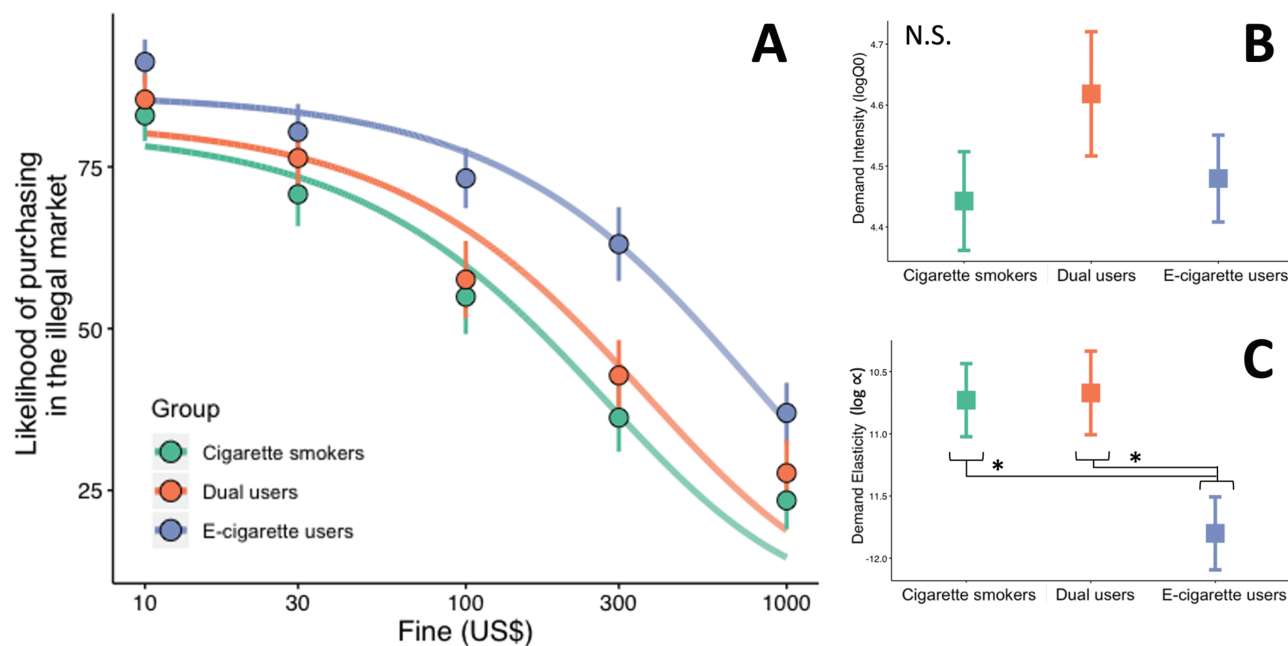
Illegal market risk-taking was assessed using a hypothetical purchase task where consumption was framed as a probability of a single purchase³⁷ in the illegal marketplace under five different monetary penalty scenarios. The likelihood of purchasing in the illegal market was systematically affected by fine increases for the majority of the participants (68% of exclusive cigarette users, 76% of frequent dual users, and 71.4% of exclusive e-cigarette users). Figure 3 depicts the fitted group demand curves for illicit purchases of tobacco products, individual estimates of demand intensity [$\log(Q_0)$], and individual estimates of change in demand elasticity [$\log(\alpha)$], both of which are aggregated into means.^{45,46} When considering only those participants

who indicated a likelihood of purchasing from the illegal marketplace, model fits of group means resulted likelihood of purchasing in the illegal marketplace were well described by Equation (1), with R^2 values of 0.945, 0.925, and 0.963 for exclusive cigarette smokers, frequent dual users, and exclusive e-cigarette users, respectively (Figure 3A).

No significant differences in $\log(Q_0)$ (Figure 3B) were observed among the groups ($F(2,104) = 1.167, p = .315$), meaning that the likelihood of illicit purchases when no penalties are applied was not significantly different across groups when the preferred tobacco product was not legally available. In contrast, significant differences in $\log(\alpha)$ (Figure 3C) were observed among all groups ($F(2,104) = 4.164, p = .018$). Tukey's post hoc comparisons indicated

Table 2. Text Analysis of the Reported Reasons to Choose the Illegal Experimental Tobacco Marketplace. Number of Endorsements (percentages) Are Included

	Cigarette smokers	Dual users	E-cigarette users	Total
Lack of substitutes in the legal marketplace (%)	10 (20.0)	18 (36.0)	28 (56.0)	56 (37.33)
Product price in the legal marketplace (%)	24 (48.0)	24 (48.0)	5 (10.0)	53 (35.33)
Product availability (%)	4 (8.0)	11 (22.0)	17 (34.0)	32 (21.33)
Flavor availability (%)	2 (4.0)	8 (16.0)	15 (30.0)	25 (16.66)
Product safety/quality (%)	1 (2.0)	0 (0.0)	1 (2.0)	2 (1.33)
Not applicable (never chose) (%)	15 (30.0)	4 (8.0)	4 (8.0)	23 (15.33)

**Figure 3.** (Panel A) Likelihood of purchasing in the illegal market given 10% chance of receiving \$10, \$30, \$100, \$300, \$1000 fines in log space on the x-axis. (Panel B) Demand intensity [$\log(Q_0)$] and (Panel C) demand elasticity [$\log(\alpha)$] from demand equation fitted to individual data points. N.S.: not significant; *: $p < .05$.

significantly lower $\log(\alpha)$ values for exclusive e-cigarette users compared to *frequent* dual users ($p = .029$) and exclusive cigarette smokers ($p = .048$). Additionally, at the group level, we identified the monetary penalty amounts at which participants were indifferent (ie, 50% likely) between purchasing from the two marketplaces: \$166.48 for exclusive cigarette smokers, \$233.11 for *frequent* dual users, and \$553.27 for exclusive e-cigarette users. That is, higher fines would result in participants being less likely to purchase from an illegal marketplace. These results indicate different sensitivities of illicit purchases to fine increases.

Discussion

The present study examined an experimental model of an illegal tobacco marketplace. Specifically, in three tobacco-user types (exclusive cigarette smokers, *frequent* dual users, exclusive e-cigarette users), the probability of illegal purchasing was examined as a function of increasing conventional cigarette price under a vaping ban and a flavored vaping ban. The five primary results of the present study are: (1) the two bans increased the likelihood of purchasing from the IETM in all users, with the largest effect predicted among exclusive e-cigarette users; (2) increasing cigarette price resulted in the increased likelihood of purchasing from the IETM in exclusive cigarette smokers and *frequent* dual users, (3) a vaping ban resulted

in higher odds of purchasing from the IETM compared to a flavored vaping ban; (4) the most frequently cited reasons for illegal purchases were the lack of substitutes in the LETM by e-cigarette users and dual users, product price in the LETM by cigarette smokers and dual users, and product availability in the IETM by e-cigarette users and; (5) the likelihood of purchasing from the illegal marketplace was suppressed by the magnitude of the monetary penalty imposed, with exclusive e-cigarette users being the most resistant to such penalties. We address the implications of these findings below.

Consistent with our first hypothesis, our findings suggest that limiting or banning vaping products from the marketplace or increasing the price of cigarettes may shift preference towards purchasing illegal vaping products. Banning vaping products increased illicit purchases to the greatest extent among exclusive e-cigarette users compared to exclusive cigarette smokers and dual-users. When asked why they purchased from the illegal market, participants supported these observations. Further, exclusive e-cigarette users referred to the lack of substitutes available in the legal marketplace, suggesting they are willing to accept fewer substitutes in the tobacco marketplace than exclusive cigarette smokers and *frequent* dual users. Similarly, a previous study showed that a potential issuance of a low nicotine content product standard (banning regular cigarettes from the legal market) changed smokers' interest towards purchasing

regular content cigarettes from illicit sources compared to controls.³¹ Together, these findings suggest that restrictive policies may stimulate interest in and shifts towards illegal marketplaces.

Exclusive cigarette smokers and *frequent* dual users' interest in illicit vaping products increased as cigarette costs in the LETM became prohibitive. Vaping products have been reported to act as partial substitutes for cigarettes for these groups of tobacco users.^{12,47-49} Our findings suggest that high cigarette prices could lead to substitution with vaping products even when they are only available in the illegal market for exclusive cigarette smokers and *frequent* dual users.

When flavored vaping products were no longer available in the LETM, purchasing from the IETM increased, but to a lesser degree compared to when all vaping products were banned. This finding suggests that product availability might be more important than flavor availability in maintaining legal tobacco purchasing. A previous study investigating flavor availability indicated that overall 25% of flavored e-cigarette users would switch to nonflavored vaping products if flavors were prohibited, and 75% of those users would no longer use vaping products.²⁸ However, this study did not consider purchasing from illicit sources. Our results suggest flavor restriction would stimulate searching for other flavored vaping products in a portion of e-cigarette users and dual users. This is consistent with self-reported changes in tobacco use after a flavor ban instituted in San Francisco, where users were still purchasing vaping products.⁵⁰

Also consistent with our second hypothesis, illegal purchases were suppressed by increasing monetary penalties in all groups. Interestingly, exclusive e-cigarette users were more likely to purchase from an illegal market compared to exclusive cigarette smokers and *frequent* dual users at a given monetary penalty. If the main reason for illegal purchasing was the lack of legal substitutes, exclusive e-cigarette users may be more resistant to the effect of sanctions. These findings suggest that a more multi-pronged approach may be necessary to decrease the likelihood of illegal market purchases.^{8,9}

Some limitations of this study must be acknowledged. First, the budget calculation for e-cigarettes was based on the self-reported number of puffs taken per day using a representative average of price per puff for varied products, including e-liquid, disposable, and pods/cartridges. Therefore, the calculation did not consider individual characteristics such as puff topography and the type of device used. Future studies can ask participants to self-report on the appropriateness of the budget provided or may develop additional procedures to calculate the e-cigarette budget. Second, participants were not able to choose more than one marketplace in the same trial, which might have restricted their real-world options and impacted their choice. However, to mitigate "sampling" among the marketplaces, participants were provided detailed instructions on what products were available in each marketplace. Third, no consequences were presented contingent on purchasing in the IETM. Whereas this may have affected participants' responses, we sought to isolate marketplace choice to the various vaping bans. Fourth, this study was constrained by the hypothetical nature of the tasks, which may represent a threat to external validity. Nevertheless, previous studies using the ETM found that hypothetical purchasing and substitution are correlated with real-world use.^{51,52} Fifth, this online convenience sample of exclusive cigarette smokers, *frequent* dual users, and exclusive e-cigarette users may not be completely representative of larger epidemiological outcomes. Previous researchers have indicated the potential generality of behavioral effects observed on MTurk to laboratory-based studies,^{53,54} including tobacco users.⁵⁵

However, MTurk samples are exclusively internet users, differing in age, education, and employment compared to the general population.⁵³ Future investigations may recruit more representative samples to examine the generality of the findings.²⁶ *Lastly, future studies should explore the product bans in a between-subject design to ensure no carryover effects persist among the bans.*

In future studies, the ETM framework can be extended to estimate the effects of different population-level strategies, such as the application of taxes and subsidies to vaping products; or a partial flavor ban, excluding menthol-flavored vaping products, on patterns of illicit purchasing. Furthermore, the examination of different combinations to prevent and reduce illicit trade (eg, flavor ban and law enforcement) before implementation might also be useful to inform tobacco control policymaking and help prevent the seeking out of illegal tobacco marketplaces. The availability of legal alternatives on the supply side and the acceptability of these alternatives on the demand side have been raised as important factors that could influence the development of the illegal market.⁸ As such, research on the degree to which other tobacco products substitute for vaping products would be valuable information to help guide vaping regulation.

In conclusion, this study shows the utility of experimental preparations, such as the ETM, to model the legal and the illegal tobacco marketplace.⁵⁶ This methodological development provides the opportunity to experimentally and systematically explore factors that may promote or inhibit illegal purchasing. Here we found that product bans and price increased illicit purchases. Whether other products engender illicit purchases and whether this is or will be consistent with real-world choice await additional research. Finally, this extension supports the continued utility and flexibility of the ETM in tobacco regulatory science.

Supplementary Material

A Contributorship Form detailing each author's specific involvement with this content, as well as any supplementary data, are available online at <https://academic.oup.com/ntr>.

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Declaration of Interests

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